

A CLINICAL APPLICATION GUIDE TO STANDARDIZED WHEELCHAIR SEATING MEASURES OF THE BODY AND SEATING SUPPORT SURFACES Revised Edition



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Assistive Technology Partners

SCHOOL OF MEDICINE

UNIVERSITY OF COLORADO **ANSCHUTZ MEDICAL CAMPUS**

A CLINICAL APPLICATION GUIDE TO STANDARDIZED WHEELCHAIR SEATING MEASURES OF THE BODY AND SEATING SUPPORT SURFACES

Revised Edition

August 2013

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Author's note on revised edition: Shortly after the initial publication of this manual in February 2013, a fundamental change to the coordinate axis system (upon which many of the measures in this guide are based) was voted upon at a committee meeting of ISO TC173/SC1, Working Group 11 on Wheelchair Seating, in San Francisco June 2013. Therefore, this revised edition reflects the change made to a right hand rule convention for labeling the coordinate axes, as well as a change to the right hand grip rule for determining positive direction of rotation for absolute angle measures.

ACKNOWLEDGMENTS

Completion of this clinical guide represents the culmination of many years of work, involving not only the project consultants listed previously, but also several colleagues in other countries. Initial draft work on a clinical guide to the ISO 16840-1: 2006 standard began in 2005, even before the standard was published. Those of us who were involved in the development of the ISO standard recognized that a clinical guide would be needed in order to support its adoption and use. Therefore, early drafting of this guide was undertaken by an ISO task group, headed by myself, and including U.S. members Dr. Barbara Crane, Dr. Douglas Hobson, and Jean Minkel. Additionally, the following three colleagues should be credited for their contributions to early drafts and discussions of the guide: Barend ter Haar from England, Lloyd Walker from Australia, and Hirose Hideyuki from Japan.

Unfortunately, work progressed slowly during those early years of 2006 – 2010 as this was a purely volunteer, collaborative effort of ISO committee members from several countries. With progress stalling in 2010, we realized that this work required funding if it was ever to be finished. Therefore, we owe much gratitude to the Paralyzed Veterans of America (PVA) Education Foundation, for recognizing the value of this project, and for providing the critical funding that allowed the guide to be completed.

Of the early contributors to this work, I would especially like to thank Barend ter Haar, of BES Rehab Ltd. Barend was involved in the development of the ISO 16840-1: 2006 standard from its beginning in 1998, and his passion for accuracy and intellectual debate spurred countless hours of discussion which ultimately expanded our perspectives and depth of knowledge. For that I am grateful. Barend was also an early and passionate advocate for the development of a clinical guide to the standard, and therefore was instrumental in launching this work. While he was not part of the PVA funded project team beginning in 2011, he authored and edited initial rough drafts of several chapters of this guide, prior to 2010.

The illustrations in this guide are critical to its understanding and success. I would like to acknowledge and thank Chuck Rowles, and his employer Pride Mobility Products Corporation, for providing initial drawings. When Chuck could no longer work on the project, I reached out to the industry for help and Marni McKay of Sunrise Medical connected me with our skilled illustrator, Rick Morris. Rick contributed countless hours developing nearly all of the 242 figures for this guide, continuing to work and finish edits even after funds had been exhausted. His skill in interpreting my rough sketches, and turning them into simple but professional illustrations, was remarkable. I would also like to acknowledge and thank Sunrise Medical for providing access to their conference line for all of our calls back and forth regarding the development of these illustrations.

It is difficult to express the depth of gratitude I owe to my project team, who dedicated countless hours on this project above and beyond what could have ever been expected. Barbara Crane, Susan Johnson Taylor, Susan Cwertnia and Kim Davis all contributed unique skill sets and perspectives, in addition to their broad depth and breadth of clinical expertise, to this collaborative work effort. They reviewed and edited drafts many times, over and over again. During numerous conference calls they provided invaluable feedback as I presented issues needing resolution, and as we struggled with how to translate the ISO terms into clinically relevant measures and simple methodologies. I valued their opinions tremendously, and counted on their expertise and unique perspectives to guide all decisions regarding content, style, wording and what to include or not include in the clinical considerations for each measure. We spent many hours together at conferences, ISO meetings and during conference calls, and have become close friends. Mostly I thank these amazing women for tolerating my perfectionism, supporting me emotionally, and pulling me back from the brink of panic when I realized that all our drafts had to be re-written to comply with the changes decided upon at the infamous May ISO meeting in Pittsburgh.

Finally, I would like to thank my colleague at Assistive Technology Partners, Elizabeth Woodruff, for her quality work compiling and formatting all the chapters and figures of this guide into the final product. Beth spent many hours organizing and labeling all the electronic files for the illustrations, and was able to do last minute edits to figures using Adobe Illustrator, for which I was extremely grateful. Her eye for detail, high standards and extreme organization was invaluable to the completion of this guide.

Kelly Waugh

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PREFACE

This manual is the initial product of a two year project funded by the Paralyzed Veterans of America (PVA) Education Foundation. The overall goal of this project is to support and advance clinical practice and fundamental research in wheelchair seating. This project focused on increasing the adoption of standardized measures and terminology related to wheelchair seated posture and seating equipment parameters. The primary purpose of this clinical guide was to translate a highly technical international standard into a format and language that is easier to understand and clinically useful. This standard, titled ISO 16840 (2006): *Wheelchair seating -- Part 1: Vocabulary, reference axis convention and measures for body segments, posture and postural support surfaces* [1], was published in 2006. Unfortunately, it has yet to be adopted in clinical practice.

This preface includes a review of the history behind this work, as well as an overview of the content, scope and intended use of the manual.

1 Background

The development of wheelchair seating as a sub-specialty of rehabilitation services has been happening over the last several decades. This practice involves the selection and provision of wheelchair seating products that provide improved body support, movement control, and injury prevention for the wheelchair user. Inherent in this selection process is the measurement and communication of the postural measures of the seated person, as well as the orientation, location and linear measures of the person's seating support surfaces.

A significant impediment to further development in this field has been the existence of tremendous variation in the use of terminology related to both the postural measures of a seated individual, as well as, measures of seating support surfaces. Standard terms and definitions have been lacking for communication of critical postural information and support surface parameters in a way that is useful to therapists, suppliers, researchers and manufacturers providing wheelchair seating devices and services. There is also a clinical need to be able to quantify the change in posture of an individual which occurs after seating technology intervention, or which may occur over an extended time during use of the device. This needs to be done in a way that is consistent and reproducible with time, and by techniques that are commonly used in different clinics so that the information gathered is communicated in an unambiguous fashion.

In 1998 a task group of experienced clinicians and engineers initiated a collaborative work effort of the International Organization of Standardization (ISO) and the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) to develop terminology standards related to measures of the seated person and their seating supports. During its development process, the draft concepts were frequently shared with researchers and clinicians in Europe, Australia, Japan and North America in an attempt to ensure that the final product was clinically relevant. After an eight year effort, ISO published the following standard: ISO 16840-1:2006 *Wheelchair seating -- Part 1: Vocabulary, reference axis convention and measures for body segments, posture and postural support surfaces* [1].

The ISO 16840-1:2006 standard is a complex document that specifies

1. A global coordinate system for measurement,
2. Standard terms and definitions for describing the angular orientation and linear dimensions of a person seated in a wheelchair, and
3. Standard terms and definitions for describing the angular orientation, linear dimensions, and coordinate locations of seating support surfaces.

It is important to note that the ISO 16840-1:2006 standard does not prescribe a specific clinical methodology for taking these measurements, but only *defines the term and the convention* for determining the value of a measure. Additionally, it does not re-define terms for dynamic physiological movements (such as flexion or extension) which are already commonly used medical terms, but rather provides an alternative vocabulary for describing the static posture of a wheelchair seated individual that is more clinically useful for our field.

Although the completion of the ISO 16840-1:2006 standard was a significant achievement, there has been minimal adoption of the terms and measures included in the standard to date by practitioners. It is difficult for individual clinicians and other stakeholders to access this document and apply the information into their practice because standards documents are highly technical by necessity, difficult to understand, and costly to purchase. The purpose of this clinical guide is to extract the terminology and principles contained in the ISO 16840-1:2006 standard and present them in a format and language that is comprehensible, clinically useful and accessible to those who are involved in wheelchair seating evaluation, product selection and provision, and research. It is our hope that this guide will ultimately facilitate incorporation of these standardized seating terms and measures into common clinical practice, as well as promote collaborative research in the field of wheelchair seating.

All international standards are “living documents” because they are routinely reviewed and revised as needed. In a May 2011 ISO committee meeting, concurrent with the development of this clinical guide, some of the foundational principles of the original ISO 16840-1:2006 standard were identified as needing revision. Because the development of this guide has provided insight into the revisions needed, it was decided that revisions to the standard would commence following completion of this guide. The content of this clinical guide is based on the anticipated revision to ISO 16840-1:2006, which is in progress as of June 2013.

The American National Standards Institute (ANSI) supports a process where ISO standards relevant to wheelchairs are reviewed and adopted as U.S. national standards, and published through RESNA. The ANSI/RESNA version of the ISO 16840-1:2006 standard has not yet been published. While this clinical guide is based primarily on the content of ISO 16840-1:2006 and its anticipated revisions, we have also integrated correct terminology and principles where appropriate from the following additional standards: ISO 7176-7 (1998): *Wheelchairs-- Part 7: Measurement of seating and wheel dimensions* [2] and RESNA WC-1: 2009, Section 26: *Vocabulary* [3]. The ISO 16840-1:2006 standard is simply referred to as “the standard” throughout this guide.

2 Content and Scope

This clinical guide is divided into five chapters with five appendices. The first chapter is an introduction, which includes an explanation of the concepts that provide a foundation for understanding the measures included in this manual. Chapters 2 through 5 include a comprehensive selection of the measures defined in the standard, categorized as either a body measure or a support surface measure.

Body Measures: The standard defines two types of body measures - angular and linear. The angular measures are used to describe and define a seated person’s body posture and orientation, and include primarily *absolute body segment angles*, and a small set of *relative body segment angles*. The linear measures include dimensions of the body, such as *lower leg length*, used to help specify and properly fit seating support surfaces.

Support Surface Measures: The standard defines three types of seating support surface measures - angular measures, linear size measures and location measures. Similar to the body, the angular measures include primarily *absolute support surface angles*, and a small set of *relative support surface angles*. The linear size measures will be familiar to those in the field, and include such commonly used measures as *seat depth* and *seat width*. The support surface location measures defined in the ISO standard have not been included in this

version of the guide, as they are clinically difficult to apply. (These location measures allow one to specify the precise X, Y, Z coordinate location of a support surface within the body support system.) A general description of these location measures as defined in the ISO standard is included in Appendix D. As an alternative to these location measures, some common linear placement measures have been included with the size dimensions covered in Chapter 5.

For each measure defined in this guide, there is a description of the measurement accompanied by one or more figures. For most measures, the following information is included:

- Correct term for the measure
- Purpose
- Clinical relevance
- Accurate definition
- Sample measurement procedures
- Typical values
- Clinical considerations

Additionally, a summary of the key information needed to define the measure is highlighted separately in a box format for quick review.

Levels of Complexity: In recognition that the majority of wheelchair seated individuals have less complex postural support requirements, the measures described in chapters two, three and four are listed in a table and separated into two levels of complexity. The "Level I" measures are the most commonly used or baseline measurements needed for clinical application of the standard. The Level II measures can be used for individuals with more complex postural characteristics, such as joint deformity and asymmetric postures, or for those who need a more complex seating system due to impairments of sitting balance or abnormalities of muscle tone. ***This categorization of measures is not intended to be prescriptive*** since the choice of measurements used in any one service delivery process will depend not only on the clinical presentation of the individual, but also the characteristics of the wheelchair, the goals of the measurement process and the availability of measurement tools. For example, clinicians and scientists who are taking measurements in a research setting, and who have access to more sophisticated measurement tools, may choose to take a greater number of measurements than a practitioner in the field working with clients with simple postural support needs.

Finally, there are several attached appendices to this guide which provide additional clarifying information and/or charts which can be used as a reference for greater understanding of the included measures.

3 Intended Use

This clinical guide should be used as a resource manual. It is not intended to be read in its entirety, beginning to end, and all terms/measures "memorized". We recommend reading Chapter 1 first, and then any of the subsequent chapters can be read individually, in no particular order. Once the reader understands the principles used to label angular and linear measures, and how certain categories of measures are defined, continued reading of an entire chapter (including all Level 2 measures) becomes redundant. Therefore, once the principles are grasped, the guide can be used as a resource to "look up" a particular term or measure of interest when needed.

Finally, we anticipate that there will be future revisions to this manual, as the ISO and RESNA standards are revised and updated.

4 References

1. ISO 16840 (2006): *Wheelchair Seating, Section 1 - Vocabulary, reference axis convention and measures for body posture and postural support surfaces*, International Organization for Standardization, TC-173, SC-1, WG-11.
2. ISO 7176-7 (1998): *Wheelchairs-- Part 7: Measurement of seating and wheel dimensions*, International Organization for Standardization, Geneva, Switzerland, May 1998.
3. RESNA WC-1: 2009, Section 26: *Vocabulary*. Rehabilitation Engineering and Assistive Technology Society of North America.

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1 Conventions for Labeling the Body and Seating Support Surfaces

1.1 Body segment terminology

Seating support components in a wheelchair are designed to contact and support specific areas of the body, referred to as *body segments*. Dividing the body into segments is useful because it helps to define and label the seating support components in a wheelchair by the part of the body that the support is intended to contact. Additionally, observing and measuring the orientation of different segments of the body provides a useful way to both describe a seated person's body posture, and also relate this to the orientation of the corresponding seating support surface. Therefore, the standard divides the body into the following segments: head, neck, trunk (comprised of upper trunk and pelvis), thigh, lower leg, foot, upper arm, forearm and hand (Fig. 1.1). The name of each segment is used to label the specific postural support device that is designed to contact and support that segment of the body. Additionally, the orientation of each individual segment then becomes the foundation for the angular measures which can be used to define seated posture.

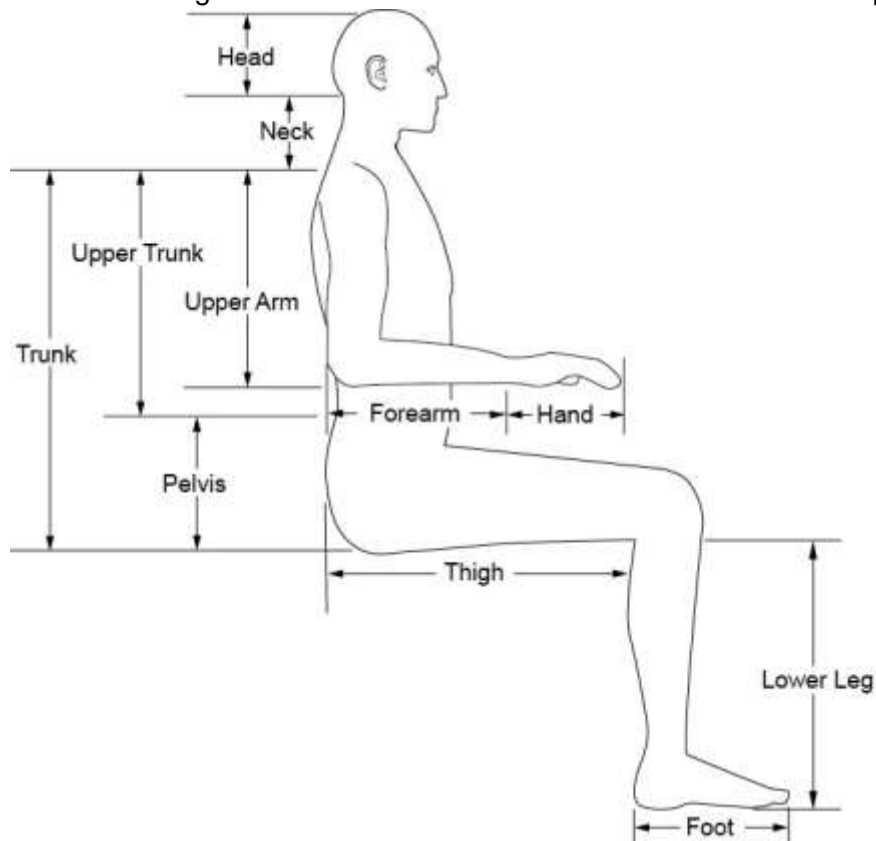


Fig. 1.1: Body segmentation scheme

1.2 Seating support terminology

1.2.1 Labeling convention for postural support devices

The terms used in this guide to label postural support devices are based on *RESNA WC-1: 2009, Section 26: Vocabulary* [1]. In this RESNA standard, the labeling of seating supports is done according to the following general principles:

- (1) Surfaces in a wheelchair intended to contact the user's body are called "supports" as opposed to a "rest" or "pad". For example, the correct term is a foot support, not a footrest; and a lateral trunk support, not a lateral trunk pad.
- (2) A support surface in a wheelchair seating system is labeled by the body segment it is intended to contact and the side of that segment where it is typically placed. For example, a pad placed on the lateral side of the thigh would be called a "lateral thigh support". By contrast, supports should not be labeled based on their intended purpose, because the purpose of the support is unique to the person and how it is applied. For example, it is not correct to label a lateral thigh support surface an "adductor".
- (3) The following directional reference terms are used to indicate which side of the body segment the surface is intended to contact: "anterior" (in front), "posterior" (behind), "superior" (above), "inferior" (below), "medial" (on the inside) and "lateral" (on the outside).
- (4) If a postural support device is intended to contact a body segment on its primary weight bearing side, the directional term does not need to be used because it is implied. For example, instead of saying "inferior foot support", the term "foot support" is used to indicate the primary support for the foot, which is assumed to be on the inferior surface. However, if an additional support surface is added to the foot support, use of the directional reference is required for clarification. For example, a surface intended to contact the medial side of the person's foot would be called a "medial foot support".
- (5) If a support is intended to contact only a small section of a body segment, then a term for a more specific area of the body may be used. For example, if a support surface is intended to contact just the pelvic area of the thigh segment, it can be called a "lateral pelvic support", to differentiate it from a longer lateral thigh support. Similarly, a "lateral knee support" is intended to contact only the very end of the thigh segment at the knee joint.

Following are some current exceptions to the above rules for labeling seating supports, because the terms for these supports are so common in the field:

- The term "seat" is used instead of "inferior buttock/thigh support", even though a seat cushion is intended to contact the inferior surface of the buttock/thigh segment.
- The term "back support" is used instead of "posterior trunk support", even though it is intended to contact the posterior side of the trunk.
- The term "arm support" is used instead of "inferior forearm support", even though it is intended to contact the inferior surface of the forearm.

1.2.3 Other terms used in guide

For clarification, the following general terms are also used in this guide when discussing wheelchair seating products and components [1]:

Body support system: The "body support system" refers to all those parts of the wheelchair which are intended to directly contact the user's body, including the seat, back support, arm support, foot support and head support. A body support system is comprised of "postural support devices" and their attaching hardware.

Postural support device: A "postural support device" is a structure, attached to the body support system or wheelchair, which has a surface intended to contact the occupant's body or extremities. Examples of postural support devices are the back support, seat cushion, or lateral trunk support. A postural support device is usually comprised of a contact surface on one side (sometimes called a "contact face") and a noncontact

surface on the other side. A postural support device often has some type of padding or other conforming material on the contact surface side, interfaced with a more rigid structure on the non-contact surface side. The rigid structure allows the device to be interfaced either directly or indirectly (via hardware) with the wheelchair or other postural support device components. The term “postural support device” refers only to the support component, and does not include the attaching hardware.

Postural support device assembly: A “postural support device assembly” refers to the postural support device and its attachment hardware, as a unit. For example the term “back support assembly” would describe a pre-contoured back support with its attaching hardware.

Support surface: A “support surface” is the part of the postural support device which is intended to contact the user’s body. For additional clarification, we may also use the term *contact surface* to describe the support surface on this side.

Pre-contoured: This term refers to a type of postural support device that has a generically shaped or curved contact surface when it is not loaded or being used.

1.3 Categorizing postural support devices

Since postural support devices are labeled based on the side of the body segment they are intended to contact, this can be used as a way to categorize postural support devices in a body support system. “Posterior supports” include all of the postural support devices that contact the posterior side of a body segment in the sitting position, and include the head support, back support and lower leg support. “Inferior supports” include all of the supports that contact the inferior side of a body segment in the sitting position, and include the seat, arm support and foot support. These posterior and inferior supports are typically the primary weight bearing support surfaces in a wheelchair body support system. Secondary support surfaces are typically used in more complex seating configurations, and can include lateral, medial, anterior and superior supports. Examples of “lateral supports” include lateral trunk supports and lateral head supports. “Superior supports” are rare, but may include such things as a flexible superior thigh support.

It can be useful to categorize seating support surfaces in the manner described above, because support surfaces in a specific category are often measured similarly. For example, the orientation in space of all inferior support surfaces is defined and measured the same, whether the inferior support surface is part of a seat cushion, arm support or foot support. This is described in more detail in chapter three.

2 Describing Wheelchair Seated Posture

One of the aims of this work has been to standardize the way we describe and measure the posture of a wheelchair-seated person. Traditional methods have not been adequate, and the standard offers additional vocabulary and measures to address this need.

2.1 Describing wheelchair seated posture using terms for joint motion

Traditionally, clinicians in our field have used conventional medical terminology to describe a person’s static seated posture by describing the position of specific joints using joint motion terminology (e.g. the amount of flexion, extension, rotation, etc. present in the joint when in the seated position). For example, a clinician may describe a wheelchair-seated posture this way: “Mr. Jones sits with a left pelvic obliquity and right pelvic rotation, trunk laterally flexed to the right, with hips extended and left leg abducted 15 degrees.” While this method of describing wheelchair seated posture is appropriate *if terms are used accurately*, it has not adequately or completely met our industry’s need for clinical term standardization.

As a method of describing and measuring wheelchair seated posture, the use of conventional joint motion terminology has been inadequate for the following reasons:

(1) Inaccurate use

Joint motion terms are often used inaccurately for the description of wheelchair seated posture by clinicians in this field. For example, in the above statement, saying the hips are extended is technically incorrect, because if the person is flexed at all at the hips, they are still in a *position* of hip flexion, not extension. Similarly, clinicians frequently use the term "hip abduction" to describe a thigh that is angled outward on the seat; however this term is frequently used inaccurately. The term "hip abduction" is defined as movement of the femur *relative to the pelvis*, and therefore a seated person's thigh could be angled outward relative to the midline of the seat and still not be in a position of hip abduction if the pelvis is also rotated.

(2) Does not provide a measure of orientation in space

While medical terminology for joint motion *does* provide a measure that describes the relationship between two adjacent anatomical segments (for example movement of the femur relative to the pelvis), it does *not* provide a measure of the absolute orientation of a single body segment in space, relative to gravity or to a neutral sitting reference. Note that in the examples above, the position of the person's thigh was being described relative to a neutral 90-90-90 sitting position (e.g. describing the thigh as 'extended' because it is angled down relative to the horizontal, and describing it as 'abducted' because it is angled outward relative to the midline of the seat). Relating the orientation of a person's body segment relative to a neutral sitting position is clinically intuitive and useful in our field, however using conventional terms for joint motion to do this is inaccurate. Being able to define and measure how the body is oriented in relationship to the force of gravity is also clinically useful in our field; however terms for joint motion do not provide this critical information. Therefore, another set of terms and measures is required in our field to address this need. The absolute body segment angles defined in the standard provide this additional set of terms.

(3) Does not help with prescription of seating support surface angles

Clinical terms for goniometric measurement of joint range of motion are based on conventions that relate to the standing person. This has created confusion in many measures of seated persons, especially measures of hip joint position and the corresponding seat to back support angle. This is because values for joint ranges of motion are based on a standing zero reference position and therefore do not easily translate into measures of seating support surfaces for prescription purposes. For example, if you desire to seat a person in 80 degrees of hip flexion, you would want to set up the seat to back support angle at 100 degrees, not 80 degrees.

2.2 Describing wheelchair seated posture using body segment angles

As an alternative to describing seated posture using joint range of motion terminology, the standard uses *angular measures of body segments* to quantify a static seated posture. By measuring the spatial orientation of individual body segments - either relative to an adjacent segment (relative angles) or relative to an outside reference (absolute angles), one can define the static seated posture of an individual. These angular measures are called **Body Segment Angles**. The standard defines these Body Segment Angles in a manner which allows easy translation into the equivalent body support system parameters wherever possible, helping with prescription. The corresponding angles of the body support system are thus called **Support Surface Angles**. The standard intentionally applies the same conventions for assigning a numerical value to angular measures of the body and the seating support surfaces. Therefore, if a body segment is parallel to its supporting surface, then the body segment angle will be the same as the support surface angle.

It is important to note that this new nomenclature is not intended to replace conventional joint range of motion terminology, but rather provides an auxiliary set of terms and measures useful for the field of wheelchair seating. This allows the clinician to choose the term which most accurately reflects what they are observing and need to measure. For example, a person has a fixed windswept posture of the lower extremities

in sitting and a description of the position is needed. To describe and measure the position of outward rotation of the thigh on the seat, use the term “transverse thigh angle” as defined in this guide (see Chapter 2), which describes the angle of the thigh relative to the midline of the wheelchair seat. This may be useful to help specify the angle adjustment of a lateral thigh support necessary to align with the angle of the thigh. However, the transverse thigh angle does not give you any information on the position of hip abduction that the person is in. If you want to describe an angle which reflects the *position of the hip joint*, then you would measure the angle of the femur relative to the pelvis according to the standardized methodology for measuring hip range of motion, and use the term “hip abduction”. This full set of terms allows us to describe and measure posture and orientation in a manner which is accurate, clinically useful and practical for seating prescription.

3 Foundational Concepts

3.1 Coordinate axis system convention

In order to accurately and consistently define all the measurements in the standard, a coordinate axis system needs to be established, with three axes labeled X, Y and Z. The axis system is “orthogonal”, which means these three axes are at 90 degrees to each other. Of course, the three axes could be arranged in any orientation in space, and with the axes labeled in any order. However, the ISO committee elected an axis orientation system, called a “convention”, that follows both the “right hand rule” and “right hand grip rule” (see section 4.3.3). In this convention, when one uses the right hand and holds the thumb, first finger, and middle finger at right angles to each other and with the palm facing upwards (Fig. 1.2), the index (first) finger of the right hand

points forward along the +X axis, the middle finger points upwards along the +Y axis, and the thumb points sideways and to the right along the +Z axis.¹

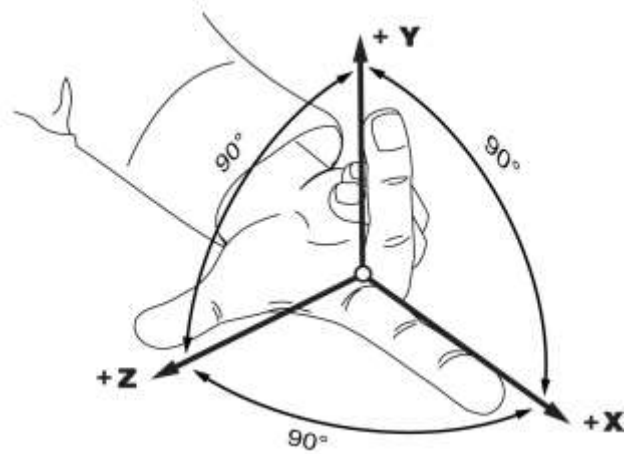


Figure 1.3 below shows this coordinate axis system superimposed on a seating system and on a seated person's body.

¹ This convention was adopted at an ISO meeting in June of 2013. This differs from the current ISO 16840-1: 2006 standard as well as the original version of this clinical guide, and is one of the planned revisions to the ISO standard. The decision to change to a right hand rule with the assignment of the X, Y and Z axes as shown was made to align with International Society of Biomechanics (ISB) recommendations.

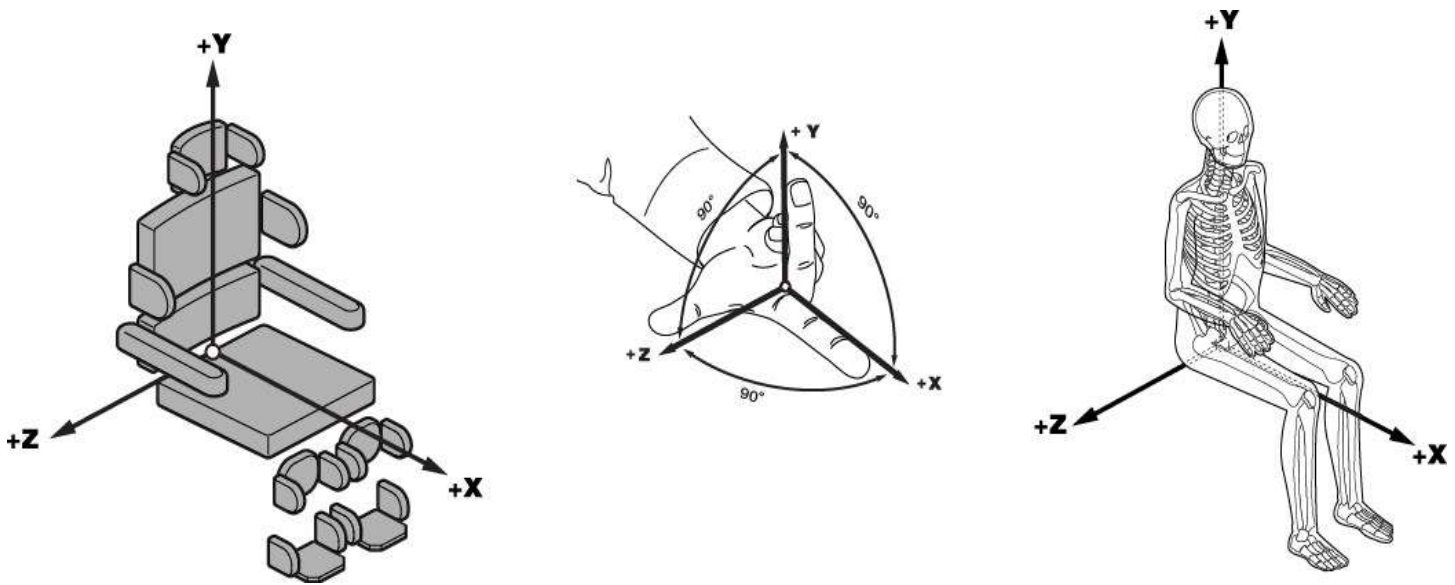


Fig. 1.3: Coordinate axis system superimposed on seat and person

3.2 The three reference planes

Joint motions of the human body have typically been defined by the *body plane* in which the movement occurs, with the person in a standing reference position (Fig. 1.4a). A *body plane* is an imaginary flat, twodimensional surface that is used in the medical field to define either a particular area of anatomy or a joint motion. The “transverse plane” is a horizontal plane that divides the body or any of its parts into upper and lower (or superior and inferior) parts. Most movements that occur along this plane involve rotation. For example, pelvic, trunk and neck rotation are defined as motions occurring in the transverse plane, best viewed from above. The “frontal plane” (sometimes called *coronal*) is a vertical plane running from side to side that divides the body into anterior and posterior parts. The primary movements in the frontal plane (in standing) are abduction and adduction, as well as lateral flexion. Lateral trunk flexion, lateral neck flexion, and hip abduction/adduction are defined as joint motions occurring in the frontal plane, best viewed from the front. The “sagittal plane” is a vertical plane running from front to back that divides the body or any of its parts into left and right sides. The two basic movements in the sagittal plane are flexion and extension. Hip flexion/extension, knee flexion/extension, and elbow flexion/extension are defined as motions occurring in the sagittal plane, best viewed from the side.

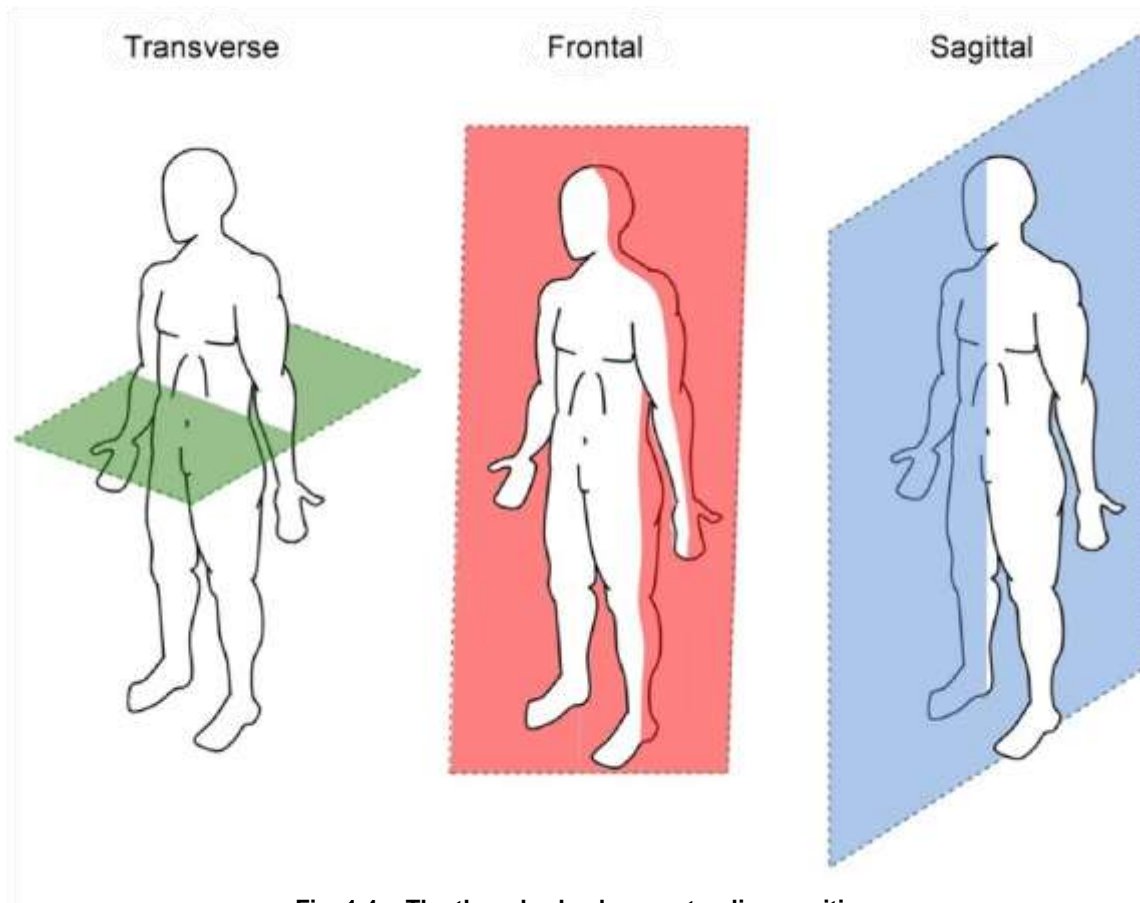


Fig. 1.4a: The three body planes, standing position

3.2.1 Axis of rotation

When a body segment is moving in one of these planes, it is rotating about an axis which is perpendicular to the plane of movement. This axis is called the “axis of rotation”. The axis of rotation is an imaginary straight line running through the joint center of rotation, around which a body segment rotates. Figure 1.4b shows the axis of rotation for motion in each of the three planes. Motions in the transverse plane occur about a vertical, superior/inferior axis; motions in the frontal plane occur about a horizontal, anterior/posterior axis; and motions in the sagittal plane occur about a horizontal, medial/lateral axis. The axis of rotation is always perpendicular to the plane in which the movement is occurring. For a more detailed example of this concept applied to pelvic movement, see Appendix A: Pelvic Motion in the Three Reference Planes.

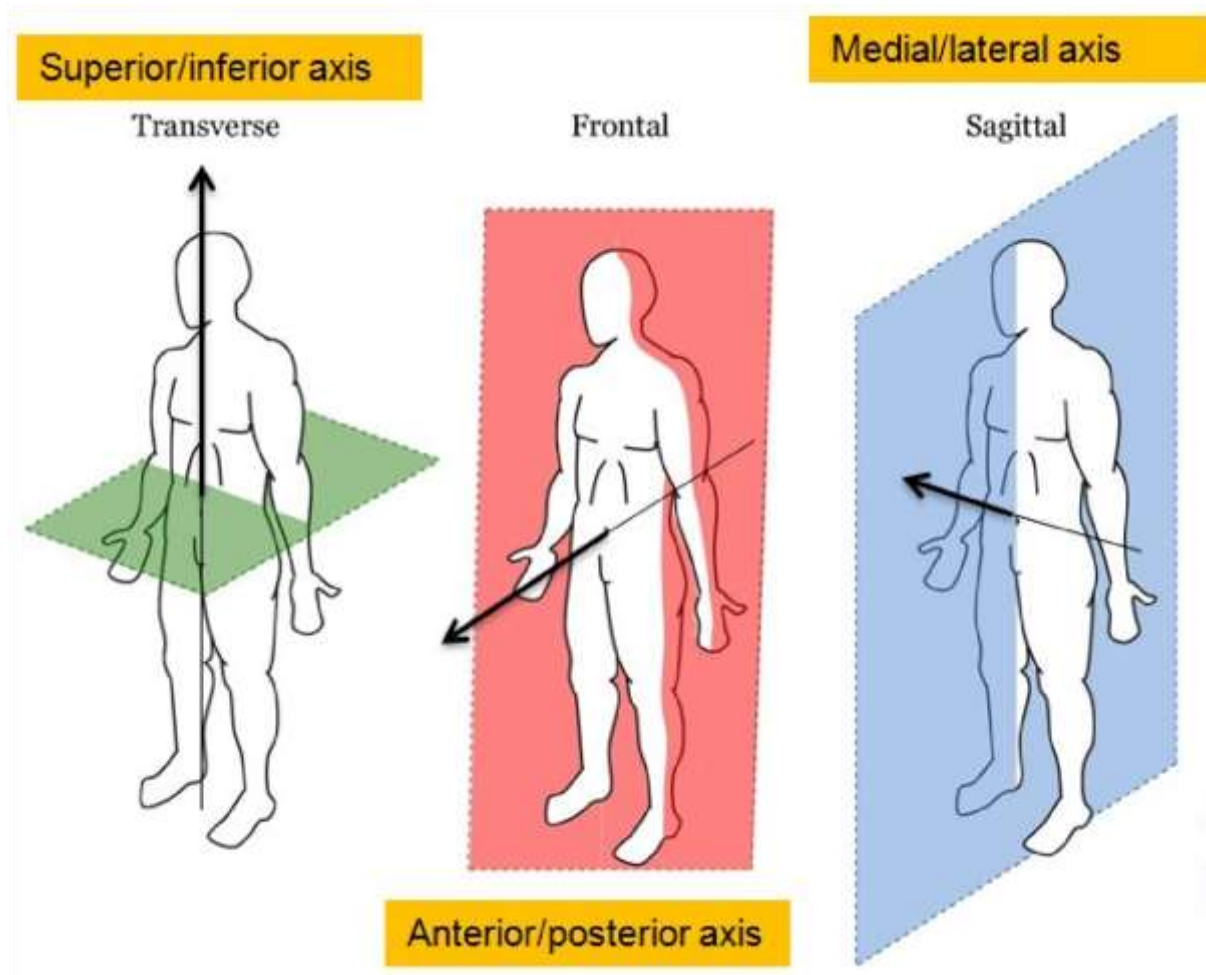


Fig. 1.4b: Axis of rotation for movement in three planes

3.2.2 Seated posture deviations in the three planes

Similarly, when describing the static posture or orientation of human body segments *in the sitting position*, clinicians typically use a side view, front view, and occasionally a top view (Fig. 1.5). The side view allows us to observe postural deviations that occur in the sagittal plane, the front view allows observation of postural deviations in the frontal plane, and the top view allows us to see the postural deviations in the transverse plane. Examples of postural deviations occurring in the sagittal plane in the seated person are a posterior pelvic tilt, spinal kyphosis and neck hyperextension. Examples of postural deviations in the frontal plane are pelvic obliquity, lateral trunk lean, and windswept lower legs. Examples of postural deviations in the transverse plane are pelvic rotation, trunk rotation and windswept thighs. Using just the pelvis as an example, viewed from the side shows the amount of anterior or posterior pelvic tilt (sagittal plane deviations); viewed from the front shows the amount of pelvic obliquity (frontal plane deviation); and from above shows the amount of pelvic rotation (transverse plane deviation).

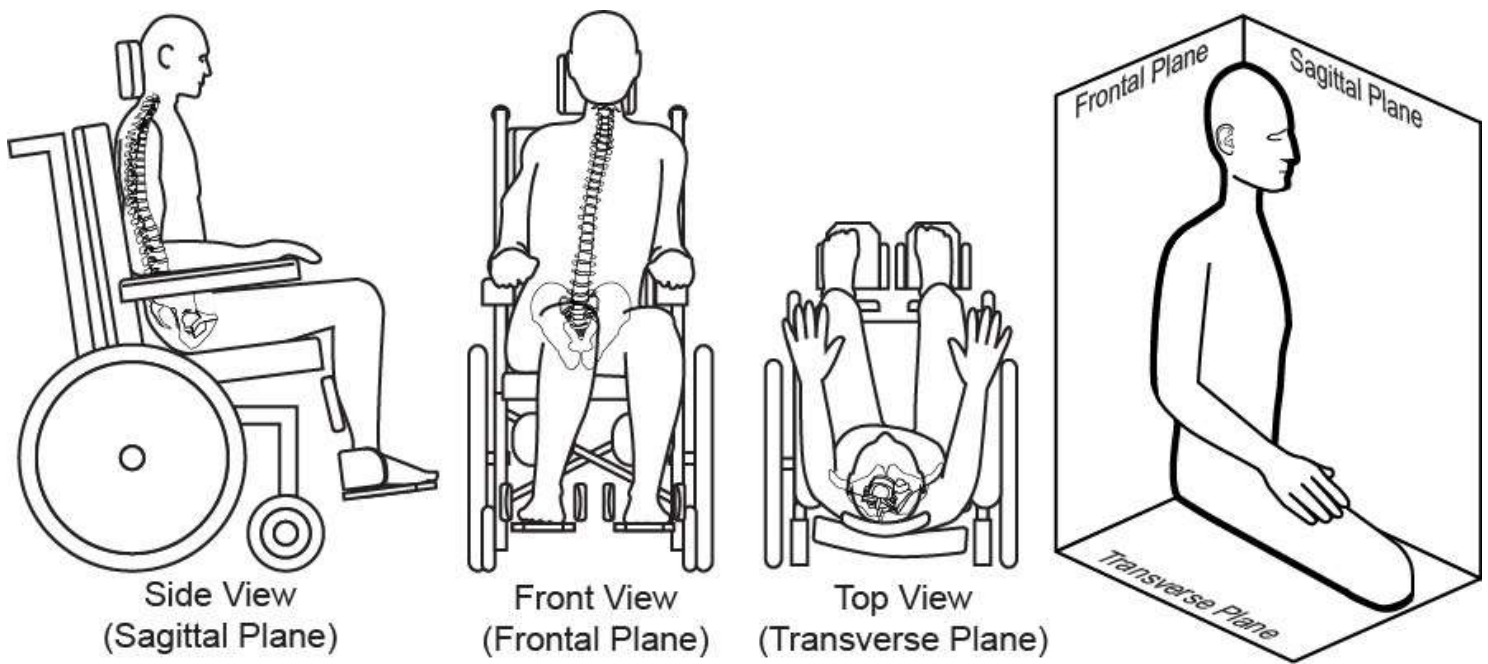


Fig. 1.5: Describing postural deviations in three planes

3.2.3 Relating the reference planes to the coordinate axis system for measurement

Each of these three reference planes is defined by two of the axes in the coordinate axis system. Therefore, the X, Y and Z axes define the sagittal, frontal, transverse reference planes, which are at 90 degrees to each other (Fig. 1.6). These reference planes can be thought of as the surface upon which angles are projected for measurement. As shown in Fig. 1.6, the **sagittal plane** is defined by the XY axes and is viewed by looking at the seated person from the side. The **frontal plane** is defined by the YZ axes and is viewed by looking at the front of the person, and the **transverse plane** is defined by the XZ axes and is viewed by looking down at the person from above.

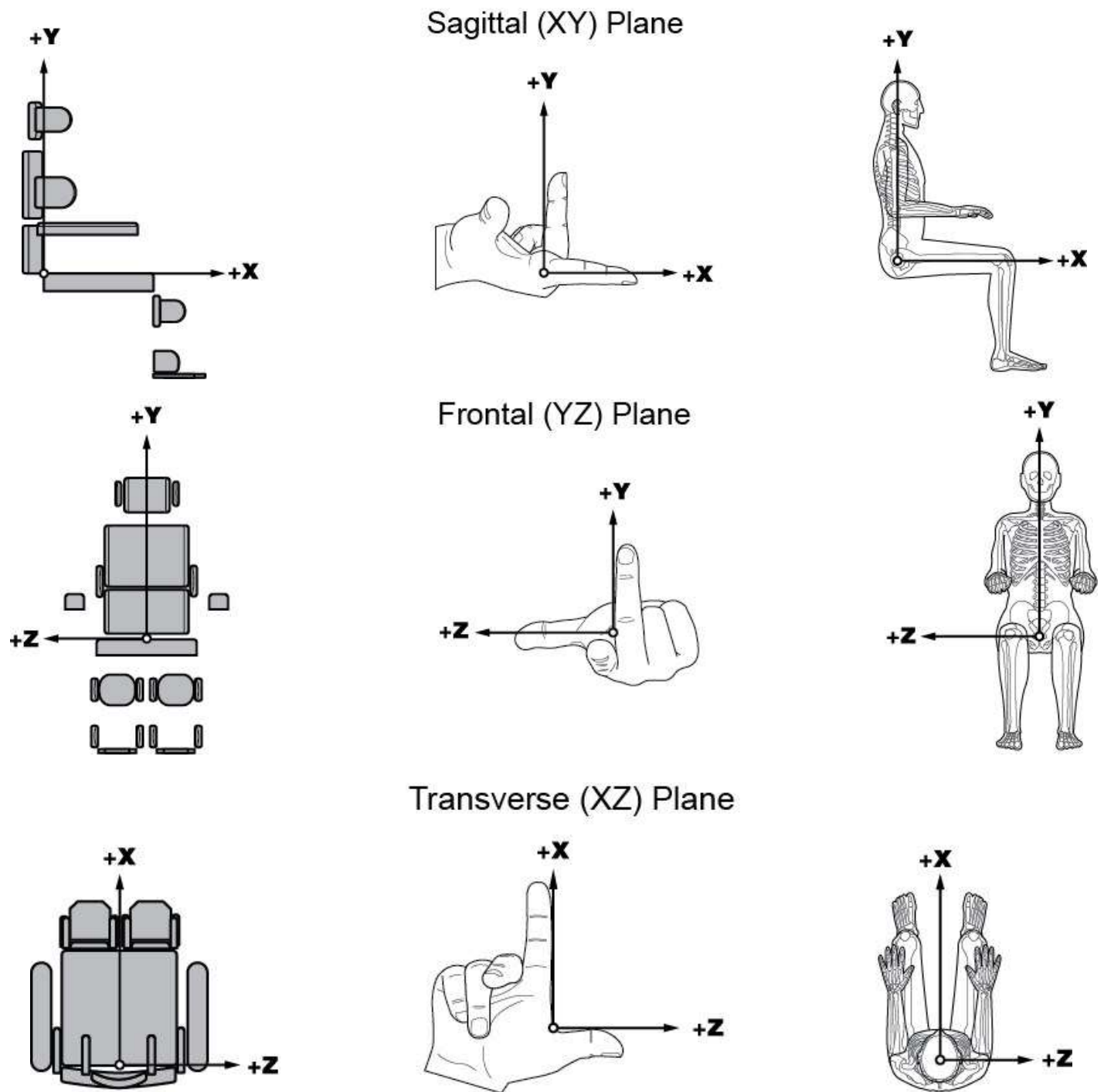


Fig. 1.6: Reference planes defined by axes

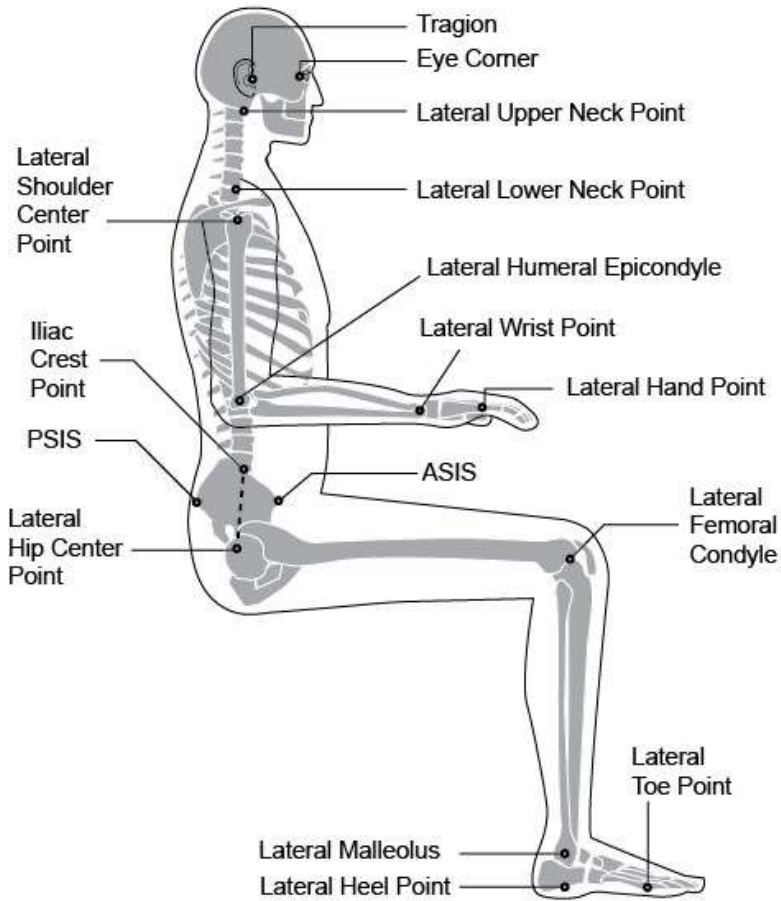
3.3 Body segment lines and landmarks

In order to be able to **measure** the orientation of a body segment, one must be able to locate a line on that segment from which to determine its orientation and measure an angle. Therefore, anatomical landmarks were identified on each body segment, in each view, that could be used to locate the end points of a line. Figure 1.7 shows examples of the body landmarks used in each of the three views. Lines which join these body landmarks are called *body segment lines*, and they can be located in each of the three views. Defining body segment lines, which join the body landmarks, enable the orientation of body segments to be measured.

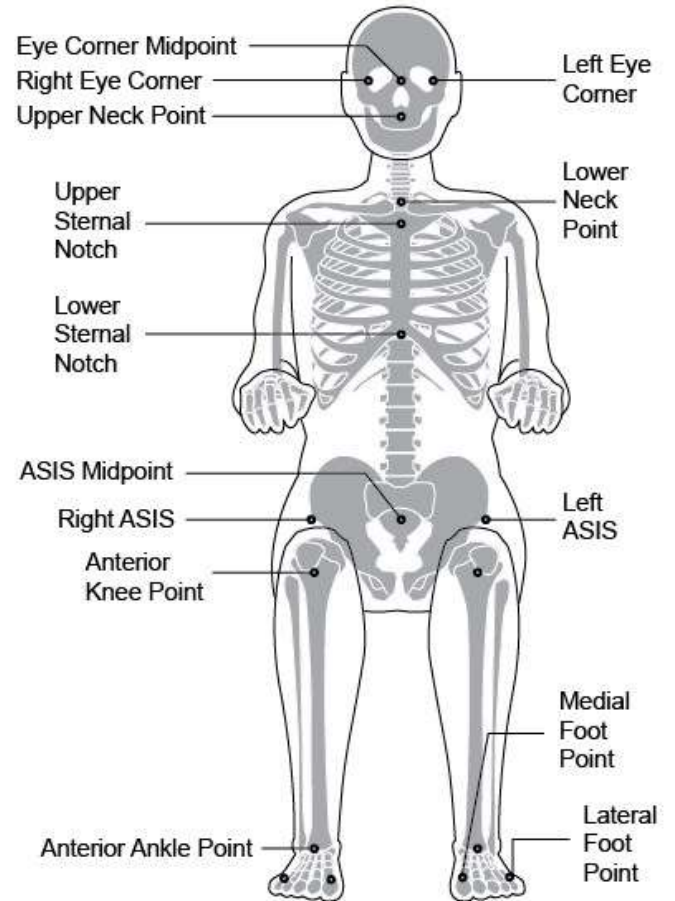
Figure 1.8 shows examples of some of the defined body segment lines in each of the three views. Appendix B includes several tables and figures which define and describe all of the body segment lines and body landmarks in each of the three views.

Since one of the intended goals is to be able to quantify a change in posture before and after seating intervention, clinicians need to be able to measure selected body segment angles while the individual is seated in their wheelchair. Therefore, body landmarks should be palpable when the client is seated against a back support and seat. This is challenging in the trunk and pelvis segments, as the most easily palpable bony landmarks are those of the spine and posterior pelvis, which are often not accessible when seated in a wheelchair. Therefore, landmarks on the side of the trunk and pelvis were chosen whenever possible. It is important to also note that palpation of anatomical landmarks can be a challenge when there is a large amount of soft tissue present over the bony landmark. The latter situation will give rise to lower levels of accuracy.

Examples of Body Landmarks (Sagittal View)



Examples of Body Landmarks (Frontal View)



Examples of Body Landmarks (Transverse View)

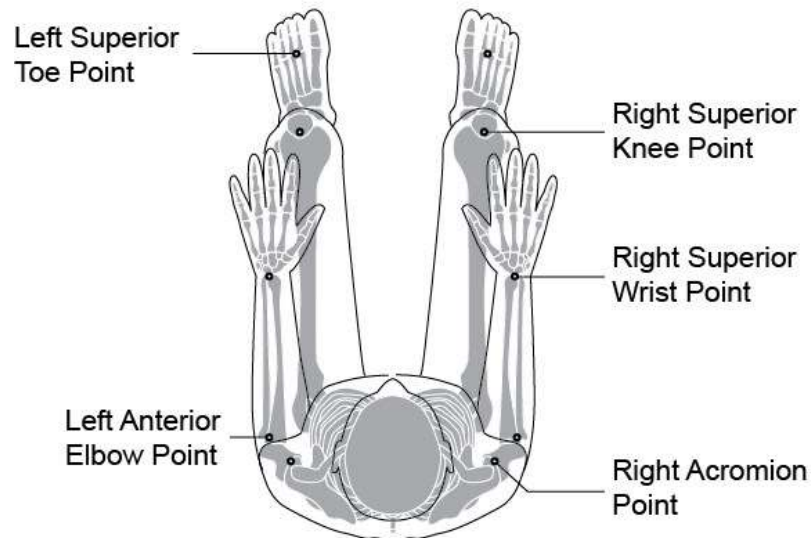


Fig. 1.7: Examples of body landmarks in three views

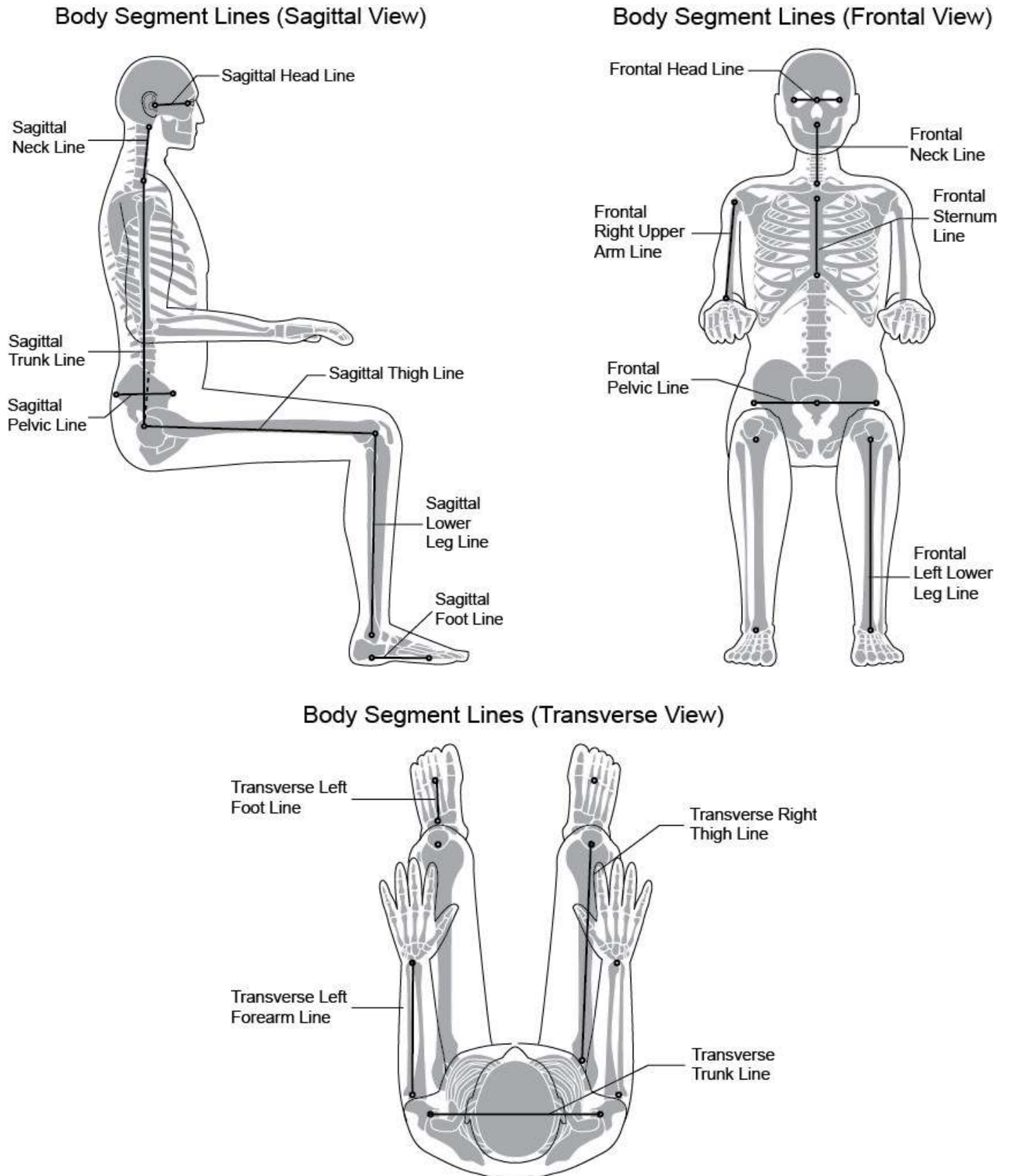


Fig. 1.8: Examples of body segment lines in each plane

3.3.1 Palpable vs. computed body landmarks

Most landmarks used to define the body segment lines are known bony anatomical protuberances that can be readily located from palpation of the body surface. These landmarks not only identify the end points for the body segment lines, but also, in most cases, simulate the joint center of rotation between two adjacent body segments for determination of relative angles in the sagittal plane. However, there are four key centers of rotation that cannot be readily located from palpation of the body surface, and these are the hip joint center, the shoulder joint center, and the upper and lower neck joints. For these four centers of rotation, it is necessary to use simple calculations or approximations to accurately identify the end point of the segment lines. These "computed landmarks" are called the lateral hip center point, the lateral shoulder center point, the lateral upper neck point and the lateral lower neck point (Fig. 1.7). Calculation of these joint centers is explained in an annex of the ISO 16840-1:2006 standard [2], but is not included in this guide. To simplify measurement in a clinic setting, we have indicated alternate surface landmarks which can be used as approximations for these computed joint centers in the sample procedure section of relevant measures. For example, the greater trochanter can be used as an approximation of the lateral hip center point.

3.3.2 Body segment lines are used to measure angular orientation not linear dimensions

The body landmarks used to define body segment lines for determination of body segment angles *are not the same* landmarks used to define linear body measures. Linear measures of the body are defined using external surface landmarks rather than internal bony landmarks because the lengths of body segment lines are not relevant to the specification of support surface linear dimensions in most cases. For example, one would not measure the distance from the lateral hip center point to the lateral femoral condyle (length of sagittal thigh line) to determine an appropriate seat depth because there is more soft tissue to consider (Fig. 1.9).

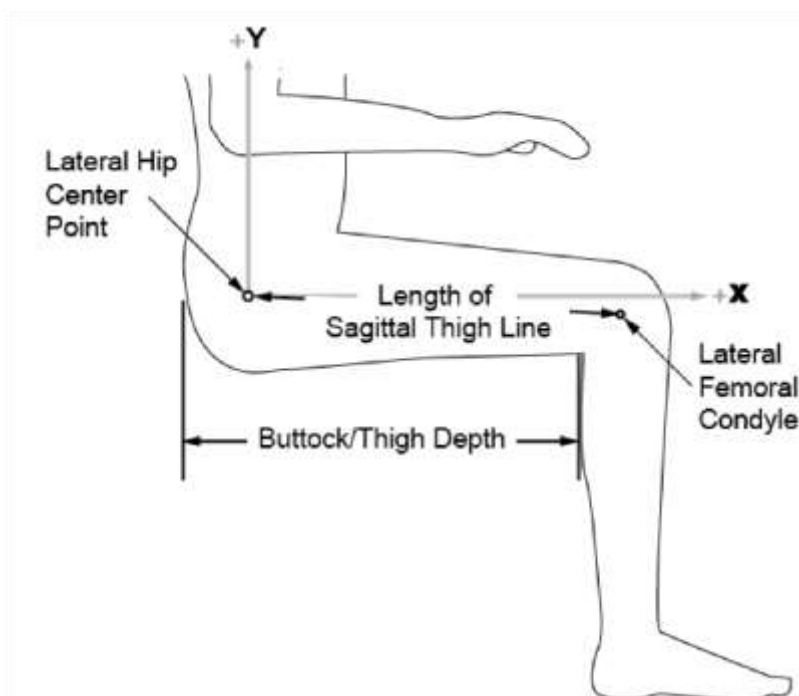


Fig. 1.9: Sagittal thigh line vs. buttock/thigh depth

3.4 Support surface reference planes, geometric centers and reference lines

Similar to body segment lines, in order to be able to **measure** the orientation of a seating support surface, one must be able to locate a line on the contact surface from which to determine its orientation and measure an

angle. This is done by first identifying the *support surface reference plane*, and then locating a line which lies on that plane to represent its orientation. Because not all seating surfaces are flat, this requires use of another concept - the *support surface geometric center* – to define the support surface reference planes of contoured surfaces.

3.4.1 Support surface reference planes A support surface reference plane is an imaginary plane that lies along the contact surface of a postural support device used to represent the orientation of that support surface for measurement purposes.

Visualizing the support surface reference plane of a flat surface is easy. Figure 1.10 shows the support surface reference planes of some simple flat seating support surfaces. Note that the reference planes lie on the **contact surface side** of the postural support devices.

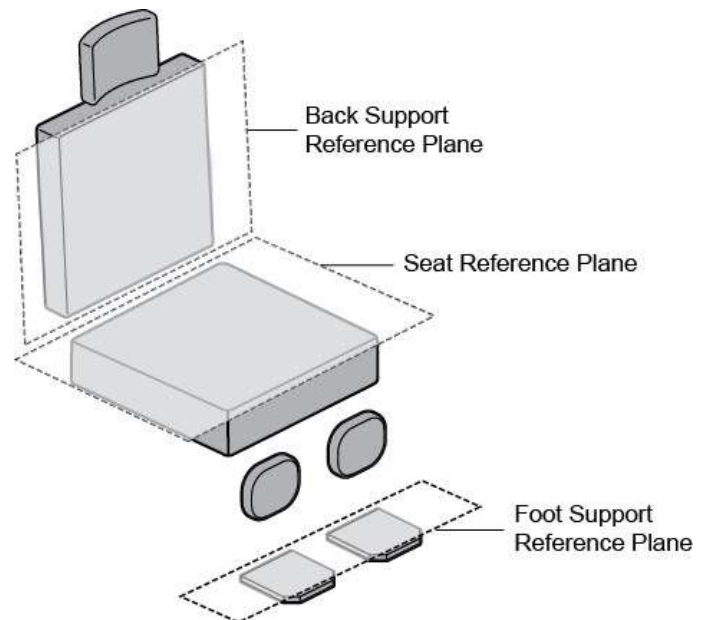


Fig. 1.10: Support surface reference plane

3.4.2 Support Surface Geometric Center

Reference planes are easy to identify when the contact surface is flat, but more difficult if the contact surface is pre-contoured or custom contoured. How do you define the reference plane of a support surface which is contoured? The standard uses the concept of a **support surface geometric center** in order to provide a definition of support surface reference planes that works for both flat and contoured surfaces.

In the standard, the **support surface geometric center (SSGC)** is defined as "the point of intersection of two or more lines joining the furthest points from the edges of a contact surface, measured along the surface" [2]. Basically, it is the geometric center of the contact surface side of a postural support device, easily identified on a symmetrical surface which is rectangular, more difficult on a surface which is asymmetrical and/or contoured (Fig. 1.11).

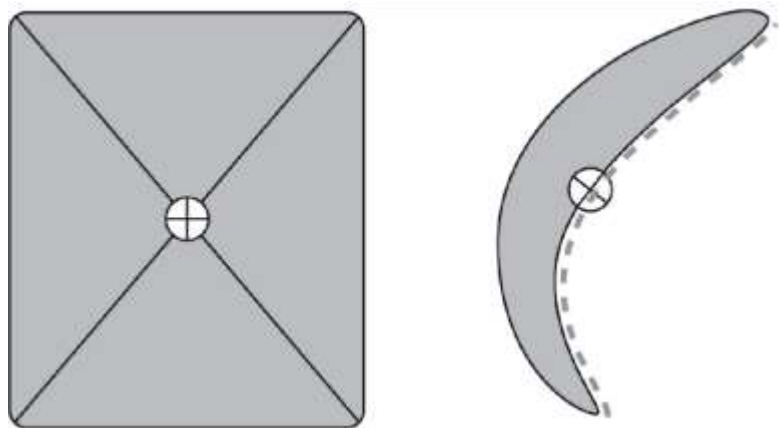


Fig. 1.11: Support surface geometric center

The standard uses the concept of the SSGC in its definition of a support surface reference plane, so that the definition works for contoured as well as flat surfaces, as follows: "A support surface reference plane is the plane passing through the SSGC tangential to the surface curvature at the SSGC radius at the point of the SSGC." [2] In other words, the support surface reference plane is perpendicular to the radius of the surface curve at the geometric center of the support. Given that a non-planar seating support may be made up of

multiple curved surfaces, the standard simply chooses to define the reference plane based on the curvature at the geometric center of the support surface.

While this sounds complicated, **you don't need to understand this concept thoroughly in order to implement the measures in this guide.** To simplify the measurement of a seating support surface which is contoured, you can approximate the contact surface reference plane by using the flat rigid backing on the non-contact surface side of the postural support device. More detailed instructions for identifying the support surface reference planes of contoured postural support devices is included in the introduction of Chapter 3, Section 1.5.

3.4.3 Support surface reference lines

So how do you identify a line on the support surface reference plane from which to measure an angle of orientation? Support surfaces do not have landmarks like a body segment does. You could draw an imaginary line on the contact surface of a support which is symmetrical by connecting the midpoint of the back edge to the midpoint of the front edge. However, if the support is not symmetrical, the line may be angled and would not necessarily represent the orientation of that surface accurately. The standard solves this problem by assigning a **local axis system** to the support surface, with its origin at the SSGC. This is explained in the next Section 3.5.

3.5 Global vs. local axis systems

In order to define all the measurements in the standard, two types of coordinate systems, each with three axes and defining three planes are specified. All of the axis systems are “orthogonal” which means the axes are at 90 degrees to each other, and labeled X, Y, Z according to the right hand rule convention explained in Section 3.1 of this chapter. The two types of axis systems are “global axis systems” and “local axis systems”. A global axis system is an absolute system, meaning it is fixed in space and does not change its orientation; therefore it can be used as an external reference system. A local axis system is not fixed, and can move or rotate in space. This allows the orientation of a local axis system to be compared to a global axis system for measurement of angular deviations.

The global axis systems defined in the ISO 16840-1: 2006 standard include the Wheelchair Axis System (WAS), the Support Surface Axis System (SSAS), and the Seated Anatomical Axis System (SAAS).[2] We have only included an explanation of the Wheelchair Axis System in this chapter, because it is the external reference system used to define angular measures in this guide. The other two global axis systems defined in the standard are not needed to apply the measures included in this guide. See Appendix C for a description of the SSAS and SAAS and their purpose.

3.5.1 The Wheelchair Axis System (WAS)

The global coordinate system used as the external reference for the measurement of absolute body and support surface angles is called the “Wheelchair Axis System”, or WAS. The WAS is external to both the person and the body support system. It is used as the fixed zero reference when measuring all absolute angles of body segments or support surfaces. In the WAS, the Y axis is aligned with gravitational vertical (perpendicular to the ground), the Z axis is perpendicular to Y and aligned with the drive wheel axles of the wheelchair, and the X axis projects forward perpendicular to both the Y axis and the Z axis (Fig. 1.12). In the sagittal plane (side view), the X axis represents the horizontal, and the Y axis is gravitational vertical. In the frontal plane (front view), the Z axis represents the horizontal, as it is also perpendicular to the vertical Y axis. In the transverse plane (top view), both X and Z axes lie in the horizontal plane, and their location within that plane is defined by the rear wheel axles of the wheelchair. The WAS can also be called a “gravitational” axis system.

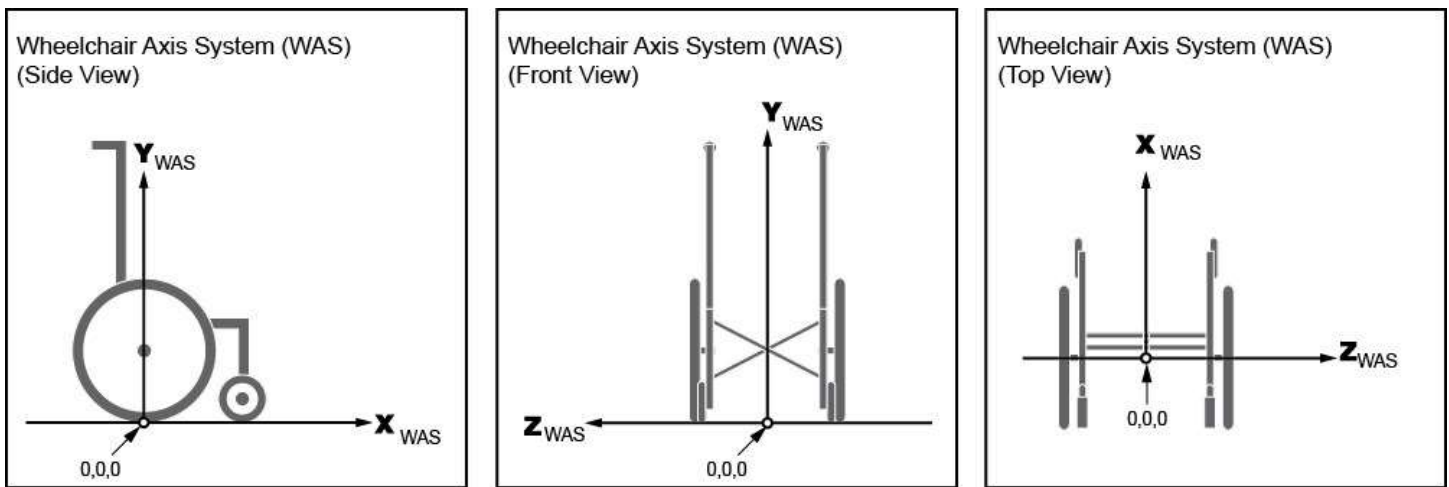


Fig. 1.12: Wheelchair Axis System (WAS)

Though not critical for the measurement of angles defined in this guide, any axis system must have a defined origin (0, 0, 0) in order to use it as a reference for measuring linear displacements along the three axes. The origin of the WAS is located on the floor directly below the midpoint of the line passing through the axes of the drive wheels on the wheelchair frame.

3.5.2 Local axis systems of support surfaces

Each postural support device has its own local axis system, which will rotate with changes in orientation of the support surface (Fig. 1.13). This allows comparison of the orientation of the support's local axis system to the fixed Wheelchair Axis System (WAS) to determine angular rotation of the support surface.

The **origin** of a local axis system is important to identify only if one wants to determine the linear location or displacement of a single postural support device relative to the WAS origin. In order to standardize location measures of seating supports (see Appendix D), the standard specifies the origin of a support surface's local axis system to be at the Support Surface Geometric Center (SSGC). Two of the three axes of the local axis system therefore lie on the support surface reference plane

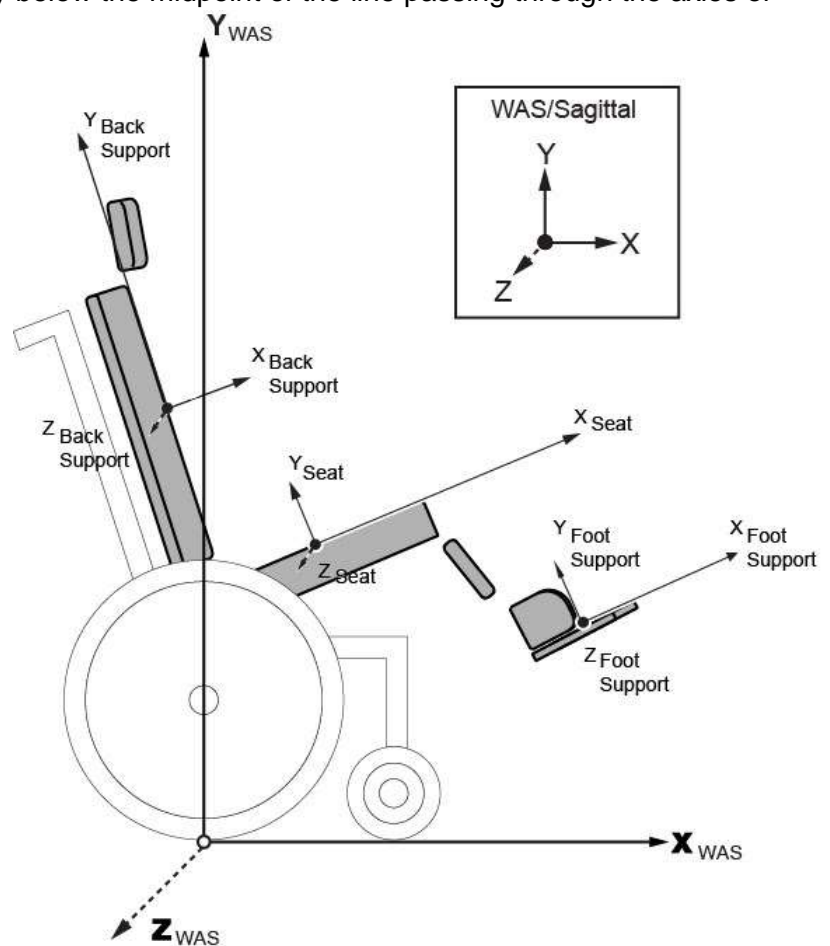


Fig. 1.13: Local axis systems of support surfaces

plane. The individual axes of the local axis system thus become the reference lines on the support surface reference plane that you can use to measure the support surface angle. Determining the

absolute angle of a support surface thus involves comparing the orientation of one of the three local axes (the support surface “reference axis”) to the corresponding axis of the Wheelchair Axis System, and finding the angular difference. This will be explained in greater detail in section 4 of this chapter, Angular Measures.

3.5.3 Local axis systems of body segments

Similar to the support surfaces, each body segment can also be viewed as having a local axis system which will rotate with changes in orientation of the body segment (Fig. 1.14). This allows comparison of the orientation of the body segment’s local axis system to the fixed Wheelchair Axis System (WAS) to determine angular rotation of the body segment.

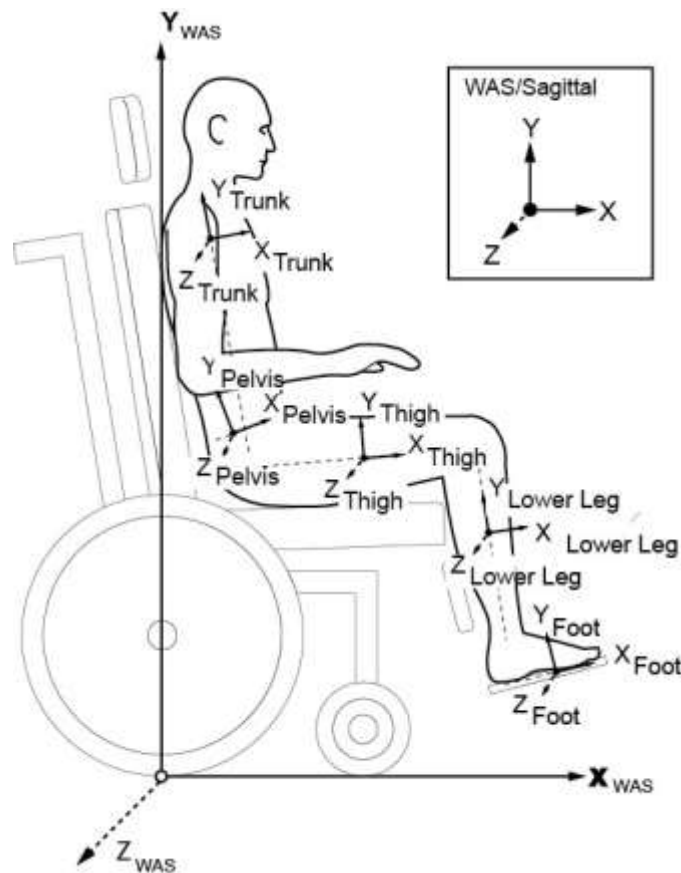


Fig. 1.14: Local axis systems of body segments

As mentioned previously, the **origin** of a local axis system is important to identify only if one wants to determine the linear location or displacement of a single body segment or support surface relative to the WAS origin. Because the standard does not define terms for the linear location or displacement of *body segments* relative to the WAS origin, the origin of a body segment’s local coordinate system has not been specified. However, a body segment’s local axis system may be placed anywhere along the body segment line in order to determine angular measures. **The body segment line then corresponds to one of the local axes.** Determining the absolute angle of a body segment thus involves comparing the orientation of one of the three local axes – represented by the body segment line - to the corresponding axis of the Wheelchair Axis System, and finding the angular difference. This will be explained in greater detail in section 4 of this chapter, Angular Measures.

3.6 Seated reference position

The zero reference position used to define joint range of motion in standard medical practice is the standing position (usually just referred to as the “Standard Anatomical Position”). However, this reference position is

not very useful when describing a seated person's angular dimensions and relating them to angular dimensions of the body support system of a wheelchair. For this reason, the use of a *seated reference position* is introduced in the standard to help define the measures most relevant to the seated posture. The Seated Reference Position (SRP) is a specified hypothetical position with the body segments in a seated position, rather than a standing one, where the body segments are at 90 degrees to one another (Fig. 1.15).

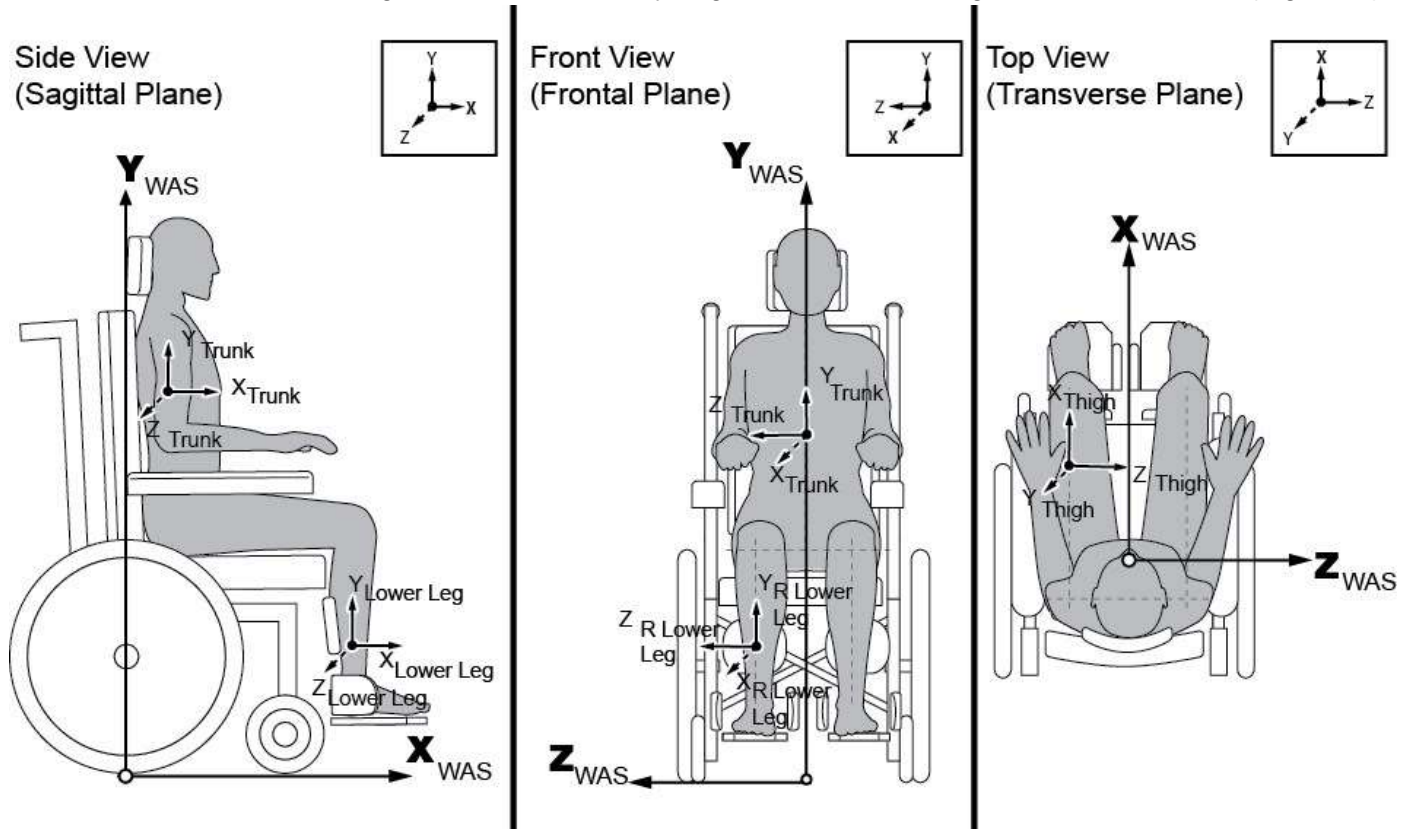


Fig. 1.15: Seated Reference Position (SRP)

When the body is in the SRP, the axes of the local axis system for each body segment align with (i.e. point in the same direction) and are parallel to the axes of the Wheelchair Axis System. In other words, when the body is in the SRP all the local Y axes are parallel to the vertical, the local X axes are parallel to the X axis of the WAS, and the local Z axes are parallel to the Z axis of the WAS. This makes all absolute body segment angles “0 degrees” in this position. Therefore, the Seated Reference Position can also be described as the “zero reference position” to which angular deviations can be compared and measured. **Please note that this is not intended to be a desired seated posture, but a reference position** much as the standing anatomical position is the zero reference for measuring physiological joint motions.

3.7 The support surface reference position

Similar to the Seated Reference Position, the Support Surface Reference Position (SSRP) is a hypothetical position of the body support system components where the support surface reference planes are at 90 degrees to one another (Fig. 1.16).

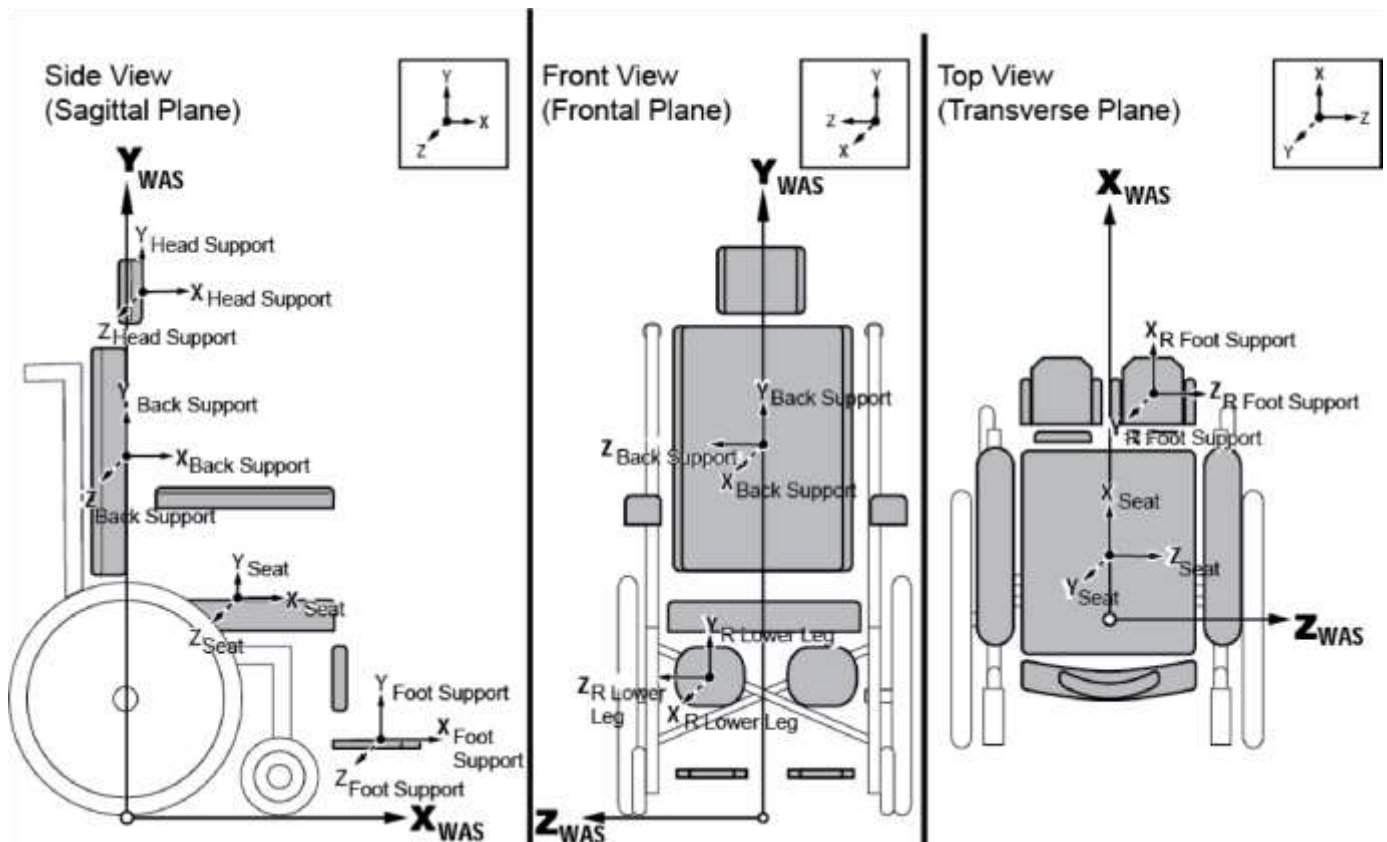


Fig. 1.16: Support Surface Reference Position (SSRP)

When the support surfaces are in the SSRP, the axes of each postural support device's local axis system align with (i.e. point in the same direction) and are parallel to the axes of the Wheelchair Axis System. In other words, when components are aligned in the SSRP, all the local Y axes are parallel to the vertical, the local X axes are parallel to the X axis of the WAS, and the local Z axes are parallel to the Z axis of the WAS. This makes all absolute support surface angles "0 degrees" in this position. The SSRP is therefore defined as the zero reference position for the seating support surfaces, to which angular deviations can be compared and measured. **Please note that this is not intended to represent a desired or ideal orientation of the support surfaces in a body support system**, but a zero reference position much as the standing anatomical position is the zero reference for measuring physiological joint motions.

4 Angular Measures

4.1 Absolute vs. relative angles

It is important to be able to define angular measures in two ways, and therefore the standard defines and differentiates between "relative angles" and "absolute angles". Relative angles define the angular relationship of two adjacent body segments or support surfaces; whereas absolute angles define the spatial orientation of a single body segment or support surface with respect to an external reference axis of the Wheelchair Axis System (such as gravitational vertical or horizontal). Examples of relative body segment angles are the Thigh to Trunk Angle, the Thigh to Lower Leg Angle, and the Lower Leg to Foot Angle (Fig. 1.17). These relative angles describe the relationship of these four body segments to each other in the sagittal plane, as represented by the angles formed by their sagittal body segment lines.

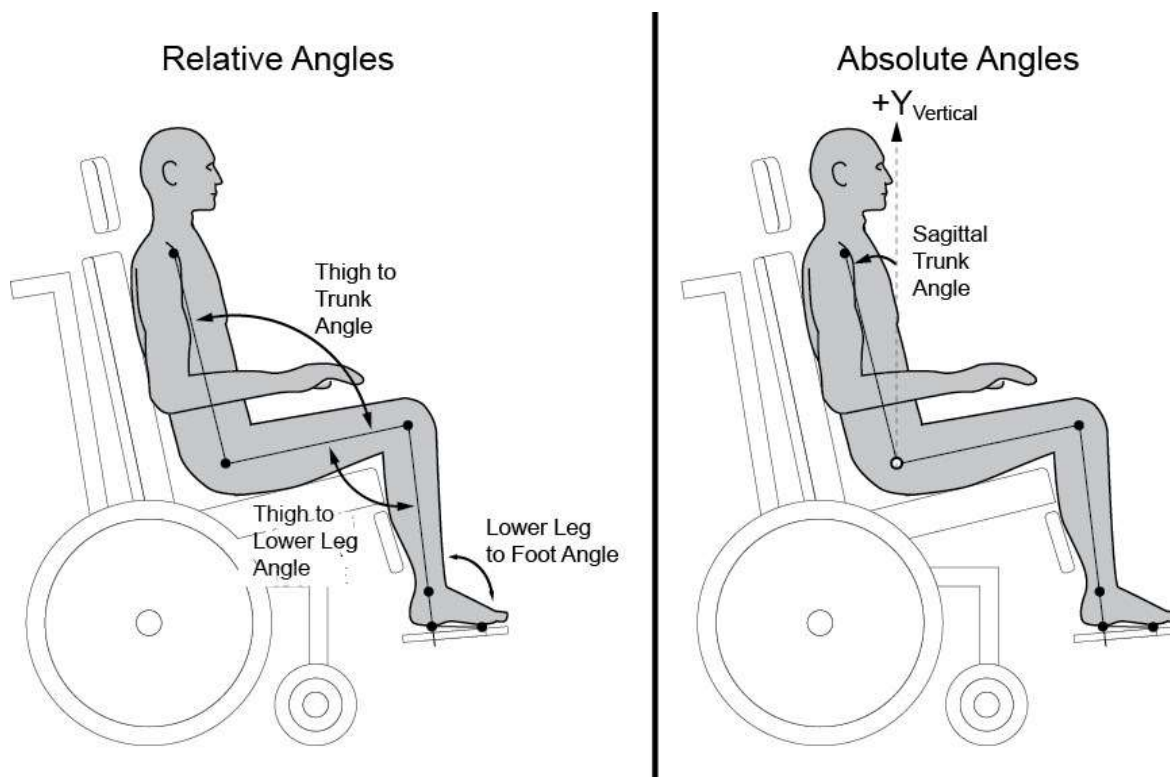


Fig. 1.17: Relative vs. absolute body segment angles

Alternatively, one can also look at the orientation of each of these segments individually relative to the horizontal or vertical. For example, the orientation of the trunk in the sagittal plane relative to the vertical is an absolute angle called the “sagittal trunk angle”. This is clinically relevant because it reflects how the force of gravity is acting on the person’s torso, and will affect the distribution of weight on the back support surface and seat. However, this absolute angle gives no information about the degree of hip flexion the seated person is in, which would be represented by the relative angle between either the trunk and thigh, or more specifically the pelvis and thigh segments.

Similar to the body, the standard defines both relative and absolute *support surface* angles (Fig. 1.18). Relative angles measure the angle between two adjacent support surfaces, and absolute support surface angles measure a support surface’s orientation with respect to an external reference axis of the Wheelchair Axis System (WAS). An example of a relative support surface angle is the Seat to Back Support Angle, which represents the angle between the seat and back support, as represented by their support surface reference planes. The orientation of the back support with respect to the vertical is represented by the Back Support Sagittal Angle, which is an absolute angle.

4.2 Relative angles

The standard defines a small set of terms for relative angles in the sagittal plane only. The three primary relative support surface angles in the sagittal plane shown in Fig. 1.18 are commonly specified in seating prescription, as they can have a significant impact on the user’s posture, comfort, health and function. Therefore, it is necessary to be able to define the relative body segment angles which correspond to these primary seating angles in a manner which aids prescription. Conversely, relative angles of support surfaces in the frontal and transverse planes are rarely used or needed in practice. Therefore, it is not critical to be able to define relative angles of the body in these two planes in a manner which allows translation into prescriptive relative angles of support surfaces. For these reasons, only a small set of relative angle measures are included in the standard and in this version of the guide. However, these will be the most commonly used measures in most clinical situations.

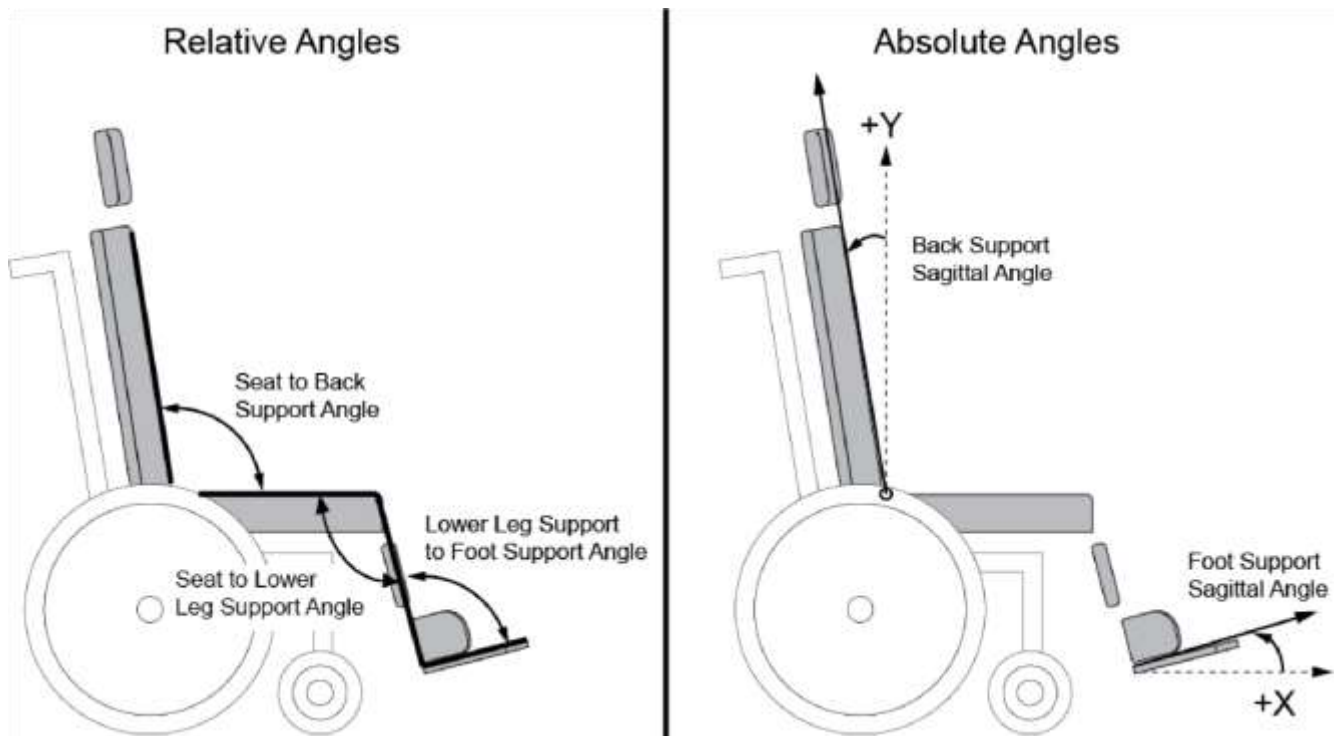


Fig. 1.18: Relative vs. absolute support surface angles

4.2.1 Determining the value of relative angle measures

The intersection of two adjacent body segment lines or support surface reference planes forms an angle which can be measured using a goniometer. However, a challenge remains in assigning the value to a relative angle because any angle has two sides that can be measured - one side is less than 180 degrees, and the other side is greater than 180 degrees. The correct side of the angle to measure and record is specified in this guide for each relative body segment or support surface angle. Decisions regarding this were based on clinical intuitiveness and harmonization with ISO 7176-7 [3]. In general, the “flexion” side of the joint which is at the intersection of the segments is the side which is measured for the relative body segment angles. The corresponding relative support surface angle is then measured similarly so that the values correspond. Examples of some relative body segment angles and their values are shown in Fig. 1.19.

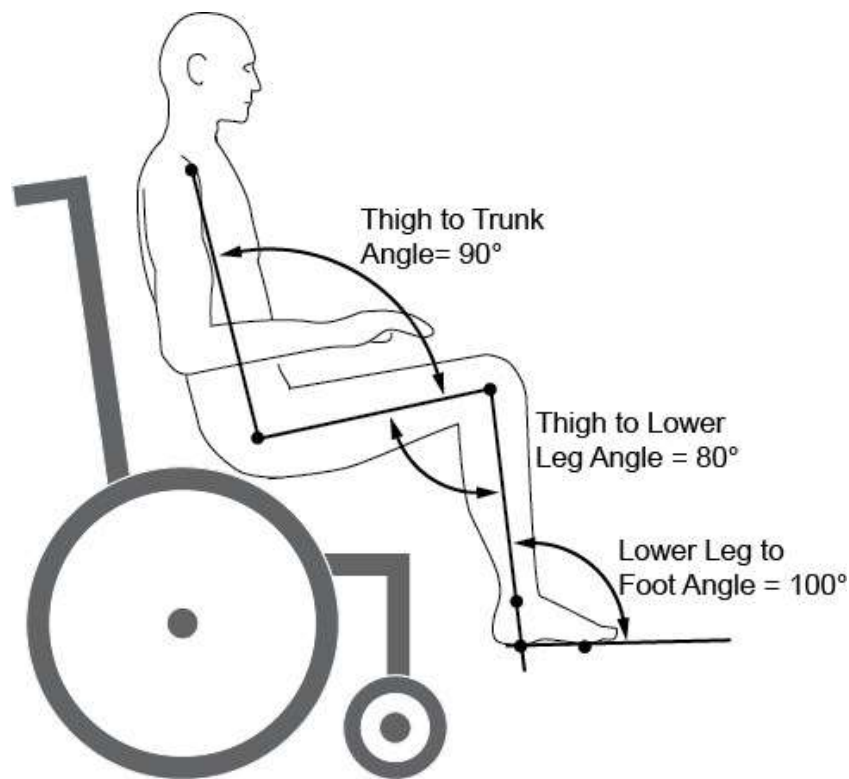


Fig. 1.19: Examples of relative body segment angles and their values

4.3 Absolute angles

Absolute angles define the spatial orientation of a single body segment or support surface with respect to an external reference axis of the Wheelchair Axis System (such as gravitational vertical or horizontal). The standard uses what we call a ‘projected angles approach’ to measuring the absolute angles of body segments, instead of the approach familiar to biomechanists or clinicians using 3D Motion Capture systems. This is to simplify the description of angular orientation into two dimensions instead of three dimensions, so that they can be taken in a clinical setting using inexpensive tools. This is necessary so that two dimensional angular measures can be taken even if a body segment is deviated in more than one plane. In this method, deviations of a body segment (as represented by the body segment line) are “projected” onto one of the three reference planes for measurement. Similarly, deviations of a support surface (as represented by its reference axis) are “projected” onto one of the three reference planes for measurement.

Absolute angles can then be defined in all three planes for each body segment and each support surface. Therefore, the words sagittal, frontal and transverse are used in the term for the angle to differentiate measures in these three planes. Postural deviations of a body segment in the sagittal plane are called “sagittal angles”. An example of a sagittal body segment angle is the sagittal trunk angle, shown previously in Fig. 1.17. Similarly, the angular orientation of a support surface in the sagittal plane is also called a sagittal angle, for example the “Back support sagittal angle”, shown in Fig. 1.18. Postural deviations of a body segment in the frontal plane are called “frontal angles”. An example of a frontal body segment angle is the “frontal head angle”. Similarly, the angular orientation of a support surface in the frontal plane is also called a frontal angle, for example “Head support frontal angle”. Finally, postural deviations of a body segment in the transverse plane are called “transverse angles”. An example of a transverse body segment angle is the “transverse thigh angle”. Similarly, the angular orientation of a support surface in the transverse plane is also called a transverse angle, for example “lateral knee support transverse angle”.

4.3.1 Determining the value of an absolute body segment angle

When body segments deviate from the Seated Reference Position (which is common), the absolute body segment angle is the angle of rotation between the specified reference axis of the Wheelchair Axis System (WAS) and the corresponding axis of the body segment's local axis system, as represented by its body segment line, projected onto the appropriate plane. This can be visualized by superimposing the X, Y, and Z axes of the WAS onto the body segment's local X, Y, Z axes, and then measuring the degree to which the local axes have rotated away from the WAS axes.

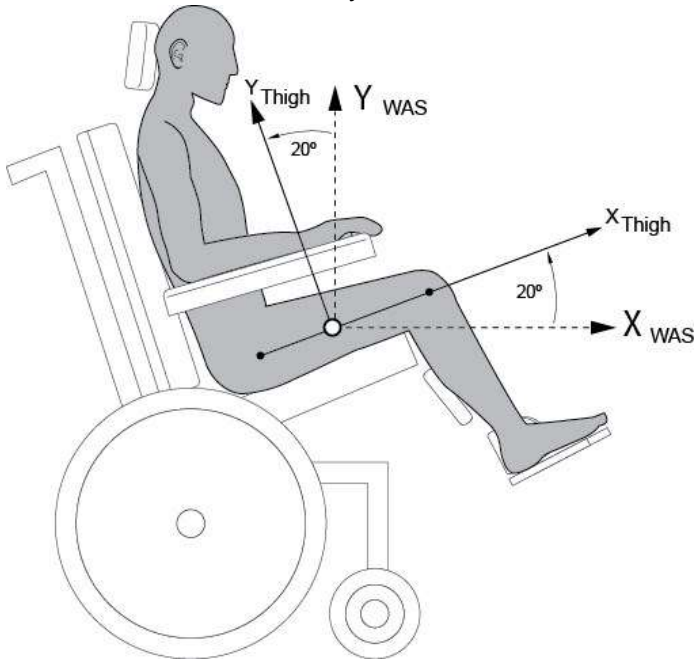


Fig. 1.20a: Sagittal thigh angle - Comparing local and global axes

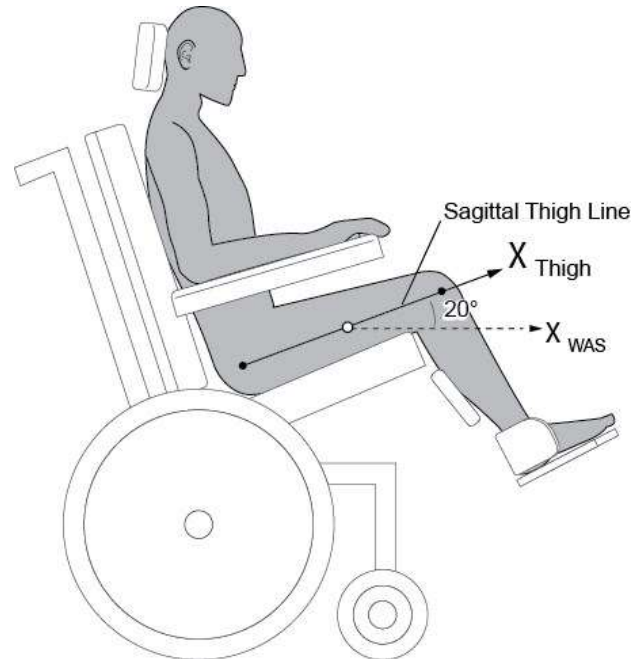


Fig. 1.20b: Sagittal thigh angle - Using body segment line

For example, Figs. 1.20a and 1.20b show the **sagittal thigh angle**, which is a measure of the angle of the thigh relative to the horizontal (X axis of the WAS), viewed from the side. Both the Y and X axes lie in the sagittal plane, so those are the axes you see in Fig. 1.20a. (The Z axis is projecting towards you as you view the person from the side.) It does not matter which of the two axes (X or Y) one compares, as the degree of rotation will be the same for the two axes lying on the plane. This is because the axes are all orthogonal, meaning at 90 degrees to each other, and we are measuring angles projected onto the relevant planes. As shown in Fig. 1.20a, if the X axis of the thigh segment's local axis system is rotated in the sagittal plane 20 degrees relative to the X axis of the WAS (which is the horizontal), then the local Y axis will also be rotated 20 degrees compared to the WAS Y axis (which is the vertical). Therefore, to determine the sagittal thigh angle, you can either measure the angle between the thigh segment local X axis and the horizontal, or the segment's local Y axis and the vertical – it does not matter as the value will be the same. Locating the axes of the body segment is easy because one of the axes always lies on the body segment line (see 3.5.3). Since the *sagittal thigh line* represents the local X axis of the thigh segment (Fig. 1.20b), it is easiest to measure the angle between the horizontal (X_{WAS}) and the sagittal thigh line (X_{THIGH}). Therefore, the sagittal thigh angle is simply the angle between the horizontal and the sagittal thigh line.

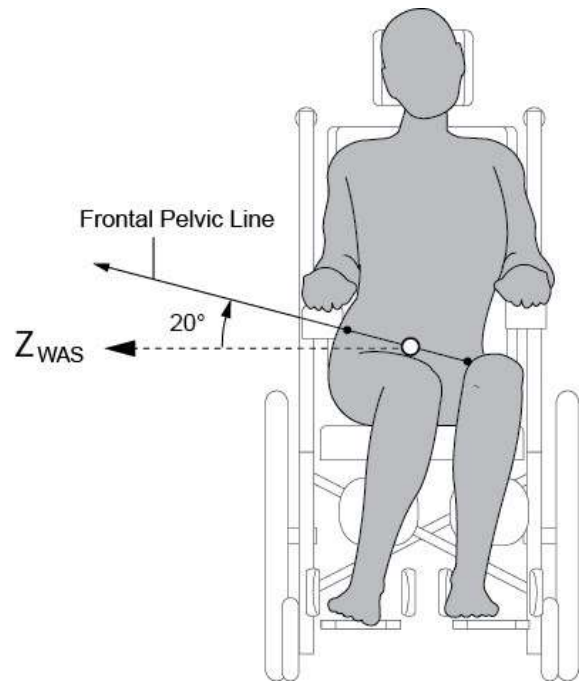
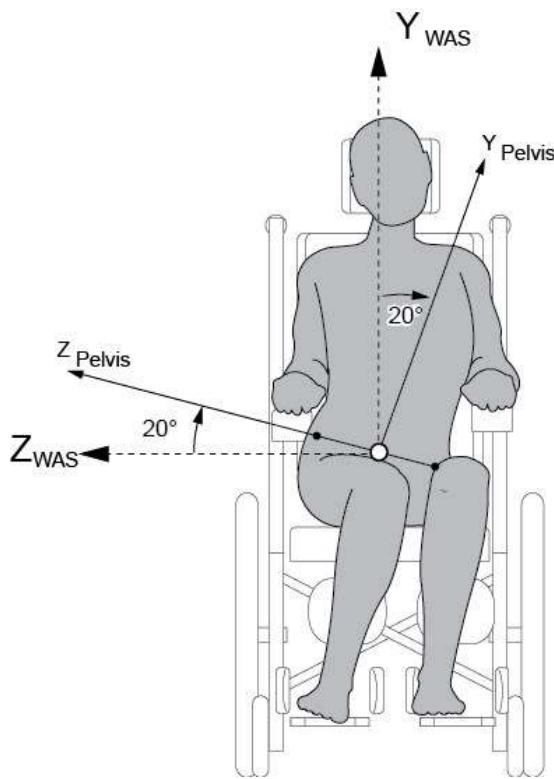


Fig. 1.21a: Frontal pelvic angle - Comparing local and global axes

Fig. 1.21b: Frontal pelvic angle - Using body segment lines

Figures 1.21a and 1.21b show the **frontal pelvic angle**, which is a measure of the angle of the pelvis with respect to the horizontal, viewed from the front.

The Y and Z axes lie in the frontal plane, so those are the axes you see in Fig. 1.21a. (The X axis is projecting towards you as you view the person from the front.) Figure 1.21a shows the Frontal Pelvic Angle as the degree of rotation of either the local Y or Z axes of the pelvic segment away from the Y or Z axes of the WAS. It doesn't matter which of the two axes one compares, as the value will be the same. Since the local Z axis of the pelvic segment is represented by the *frontal pelvic line* (Fig. 1.21b), it is easiest to measure the angle between the horizontal (Z_{WAS}) and the frontal pelvic line (Z_{PELVIS}). Therefore, the frontal pelvic angle is simply the angle between the horizontal and the frontal pelvic line.

To review, the orientation and location of each body segment's local axis system was chosen so that one of the axes is aligned with the body segment line in the Seated Reference Position. (This gives the body segment line a direction, like a vector.) **Therefore, the body segment line represents one of the local axes.** This means that you can compare the orientation of the body segment line to the corresponding axis of the WAS to determine the angle value. Therefore, one does not need to actually visualize the local X, Y and Z axes to measure absolute body segment angles, one need only to identify the body segment line, and then the guide will indicate which of the three WAS axes is easiest to use as the external reference line for each angular measure. Appendix B includes a listing of all the body segment lines and their defining body landmarks.

4.3.2 Determining the value of an absolute support surface angle

Absolute angular orientations of seating support surfaces are measured in accordance with the same conventions used for body segment angles. In order to determine the value of an absolute support surface angle, the orientation of the support surface's local axis system is compared to the orientation of the Wheelchair Axis System (WAS), and the angular difference between the axes of these two systems is measured (Fig. 1.22).

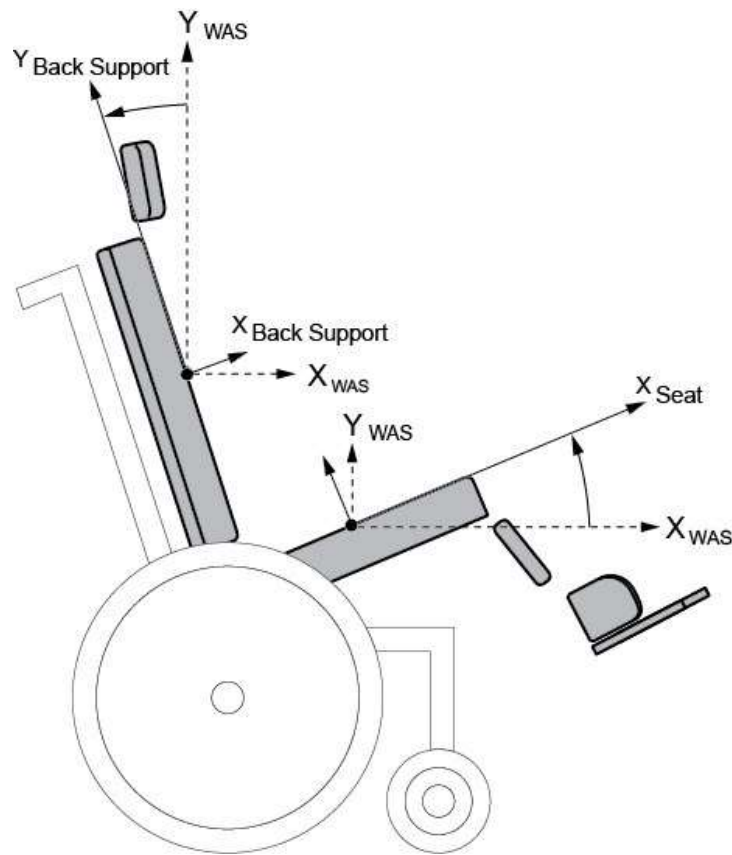


Fig. 1.22: Determining value of an absolute support surface angle

Similar to the body, the orientation of a support surface's local axis system is specified so that it is aligned with the Wheelchair Axis System in the Support Surface Reference Position (SSRP). Therefore, when a support surface is in the SSRP, the absolute angle value is zero. When a support surface deviates from the SSRP, one of the support surface local axes – the X, Y or Z axis - is compared to the corresponding axis of the WAS system to determine the angle value. For each absolute angular measure of a support surface, you can choose either of two axes which lie in the relevant plane to compare to the corresponding axes of the WAS, because the axes are orthogonal. For example, to measure the **back support sagittal angle** (Fig. 1.22), you can either measure the angle between the back support's Y axis and the vertical, or the back support's X axis and the horizontal – the value will be the same. This guide will indicate which local axis to use for a reference line, whichever is easiest and most intuitive. As a general rule, we will use one of the two axes that lies on the support surface reference plane, instead of the axis which projects perpendicular to the reference plane. In cases where there are two local axes lying in the support surface reference plane that could be used for measurement, we will describe a methodology for using one of those axes, however you can always choose the other axis if desired.

4.3.3 Determining direction of deviation for all absolute angles

In addition to determining the *value* of an absolute angle, it is necessary to indicate the direction of rotation away from the zero reference. For example, when the thigh is horizontal as in the Seated Reference Position (SRP), the sagittal thigh angle is zero. If the thigh deviates away from the horizontal position by 10 degrees, the sagittal thigh angle will be 10 degrees. However, the thigh could be angled *upward* 10 degrees, or *downward* 10 degrees, and these two positions need to be distinguished somehow. Similarly, when the seat is horizontal as in the Support Surface Reference Position (SSRP), the seat sagittal angle is zero. However, the seat could be angled upward 5 degrees, or downward 5 degrees, and saying that the seat sagittal angle is 5 degrees does not distinguish between these two very different positions.

The direction of rotation of a body segment or postural support device away from its zero reference position must be differentiated in some way. The standard does this by assigning a positive or negative sign to the angle value reported. The convention used to determine which direction of rotation is positive and which is negative is based on an engineering principle called the “right hand grip rule”, which aligns with the right hand rule convention explained in Section 3.1.

To understand the right hand grip rule, you need to be able to visualize the axis of rotation for angular deviations in each of the three planes, as explained in section 3.2.1 of this chapter. The axis of rotation for absolute angles in the sagittal plane (side view) is the Z axis, for angles in the frontal plane (front view) it is the X axis and for angles in the transverse plane (top view) it is the vertical Y axis (see Fig. 1.23). Using the right hand grip rule, the positive direction of rotation is indicated by the direction that your fingers curl when you point your thumb along the axis of rotation for angular deviations in that plane. Therefore, to determine the positive direction of rotation, point the thumb of your right hand along the positive direction of the specified axis of rotation (X, Y or Z) for deviations in that plane. Your thumb now represents the axis of rotation. The positive direction of rotation is indicated by how your fingers ‘wrap’ around this axis as you curl your fingers (Fig. 1.23).

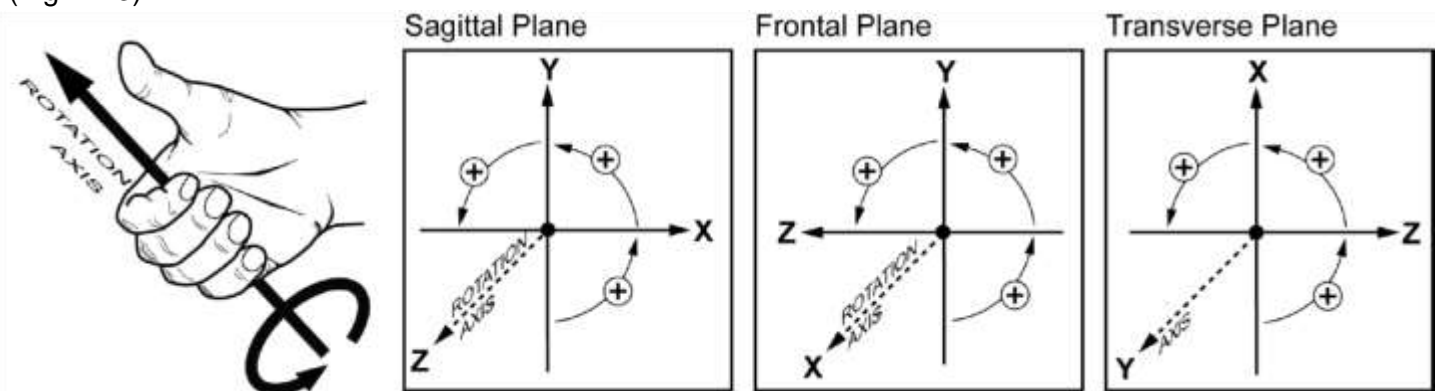
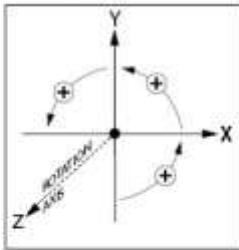


Fig. 1.23: Right hand grip rule specifies positive direction of rotation

For example, sagittal absolute angles represent rotations of a body segment or support surface in the sagittal (XY) plane, about the Z axis (see Fig. 1.24a). Remember, the +Z axis points towards the person's right side. So, to determine the positive direction of rotation for body segment angles in the sagittal plane, point your right thumb towards the person's right side (or towards yourself as you look at the right side of the person being measured). Now, curl your fingers into your palm. This shows that positive rotation occurs in a counter clockwise direction from your perspective when looking at the person from the right side. Therefore, backward leaning of the head, trunk or pelvis away from the zero reference position would be noted as a positive value, and forward leaning or rotation would be negative. Figure 1.24a shows the direction of positive and negative rotations for absolute body segment angles in the sagittal plane.

Frontal absolute angles represent rotations of a body segment or support surface in the frontal (YZ) plane, about the X axis (Fig. 1.24b). Remember, the +X axis points anteriorly towards the front of the person or wheelchair. So, to determine the positive direction of rotation for body segment angles in the frontal plane, point your right thumb towards the front of the seated person or wheelchair (or towards yourself as you look at the person from the front). Now, curl your fingers into your palm. This shows that positive rotation occurs in a counter clockwise direction from your perspective when looking at the person from the front. Therefore, lateral leaning of the trunk to the right would be noted as a positive value, and a tilt to the left would be negative. Figure 1.24b shows the direction of positive and negative rotations for absolute body segment angles in the frontal plane.

Sagittal Plane



Frontal Plane

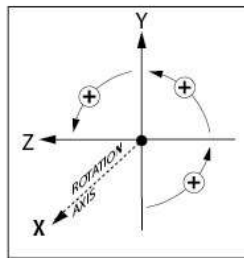


Fig. 1.24a: Determining positive and negative values of absolute body segment angles in sagittal plane

Transverse Plane

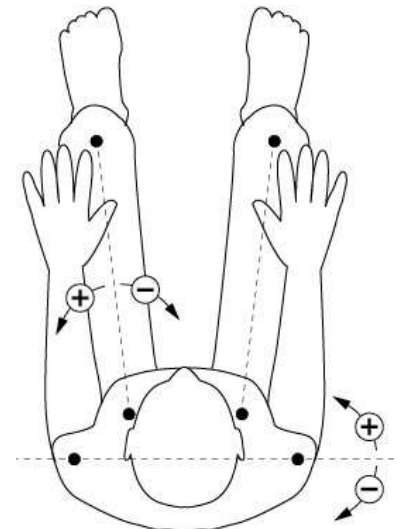
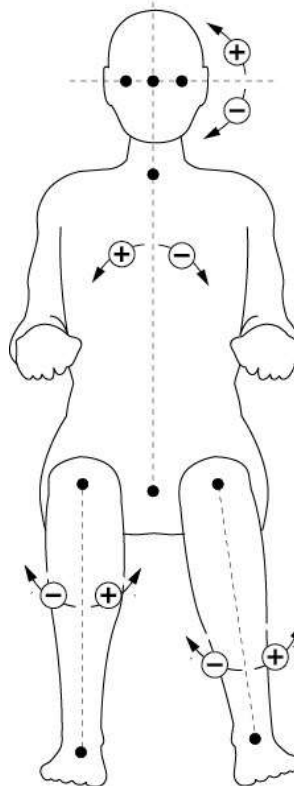
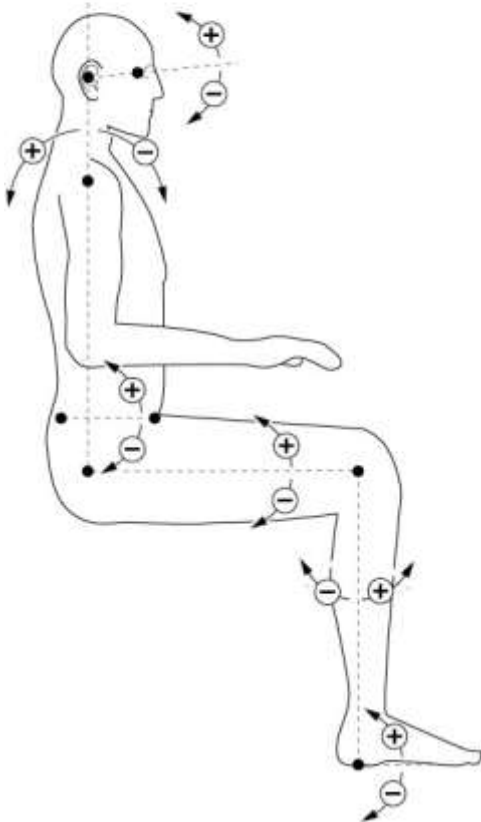
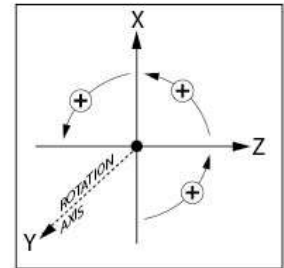


Fig. 1.24c: Determining positive and negative values of absolute body segment angles in transverse plane

Transverse absolute angles represent rotations of a body segment or support surface in the transverse (XZ) plane, about the Y axis (Fig. 1.24c). Remember, the +Y axis points upwards in line with the vertical. So, to determine the positive direction of rotation for body segment angles in the transverse plane, point your right

thumb upwards along the vertical (or towards yourself as you look down at the person from above). Now, curl your fingers into your palm. This shows that positive rotation occurs in a counter clockwise direction from your perspective when looking at the person from above. Therefore, rotation of the thigh towards the left would represent a positive deviation of the thigh away from the wheelchair X axis and would be measured as a positive number of degrees. Rotation of the thigh towards the right would be negative. Fig. 1.24c shows the direction of positive and negative rotations for absolute body segment angles in the transverse plane.

To simplify the right hand grip rule in a manner which may be easier to remember, you can use the following rule: When viewing the person from the right side, from the front or from above, counter-clockwise rotations are positive, and clockwise rotations are negative. This “counter-clockwise is positive” rule works as long as you remember to view sagittal plane deviations from the **right side** of the person, frontal plane deviations from the **front** of the person, and transverse plane deviations from **above** the person. This is natural for frontal and transverse angles, because one generally stands in front of the wheelchair seated person to view frontal plane deviations, and one generally looks down from above the wheelchair seated person to view transverse, rotational deviations. However, to view sagittal plane deviations, you may need to stand on both the right and left sides of the person or wheelchair, depending on whether you are measuring a right or left extremity or support surface. To use the “counter-clockwise is positive” rule, you must imagine that you are viewing the person from the right side. *If you view sagittal plane deviations from the left side, clockwise rotations are positive, and counterclockwise rotations are negative.*

Another way to help remember the “counter-clockwise is positive” rule is to raise your right hand and point the thumb of your right hand towards you. The direction that your fingers curl is the positive direction of rotation, which is counterclockwise from your viewpoint.

The same right hand grip rule convention is used to determine the positive and negative direction of deviation for support surfaces, shown in Fig. 1.25.

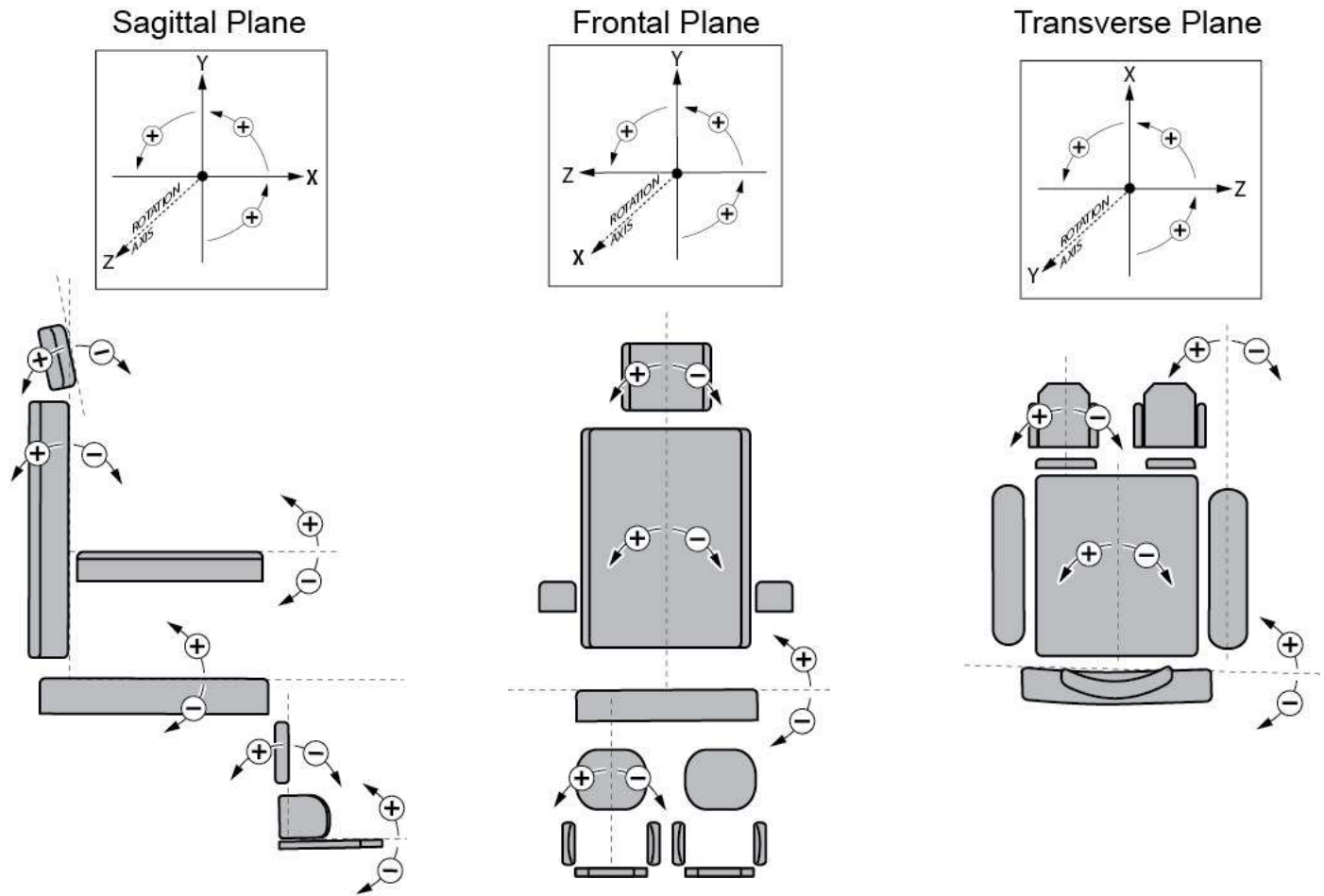


Fig. 1.25: Determining positive and negative values of absolute angles in each plane/support surface

It is acknowledged that using positive and negative numbers may not be intuitive; however it is the most accurate way to differentiate the direction that a body segment or support surface has rotated away from the zero reference position. As an alternative, one could indicate the direction of rotation through the addition of a descriptive word to the absolute number value. For example, one could say “sagittal angle 10 degrees forward” or “sagittal angle 10 degrees back”, or use terms such as “up”, “down”, “anterior”, “posterior”, “left”, “right” etc. However, this introduces the necessity of defining another set of terms to indicate direction, and may cause confusion especially when communicating internationally. In this guide we have given suggestions for directional terms which can be used in place of positive/negative notations to indicate the direction of deviation away from the reference position for specific angular measures. However, we advocate use of a purely number based system of recording values, using positive and negative notations, as this eliminates ambiguity and will be the easiest system to automate. Ultimately, the notation method chosen may depend on the tools available or personal preference. However when using positive and negative numbers, care must be taken to be sure the sign indicating the direction of rotation is clearly indicated. In this guide, we will use the notation of positive (+) and negative (-) numbers.

4.4 Relating body segment angles to support surface angles

Because one of the uses of the angular body measures is to help determine and prescribe the appropriate wheelchair seating angles, each support surface’s local coordinate system is oriented in a manner consistent with the corresponding body segment coordinate system. Consequently, if a seated person’s body segments (or more precisely their body segment lines) are parallel to the segment’s supporting surface (or more precisely the relevant support surface reference axis), the absolute and relative angles of the body and the

corresponding support surfaces should be the same. This not only assists with easily translating the desired body segment angles into seating support surface angles, but it also helps the clinician recognize potential postural misalignment when the two measures are intended to be the same, but are not.

For example, if a seated person's trunk is parallel to the back support, and their thigh is parallel to the seat, then the person's Thigh to Trunk Angle will be the same as the Seat to Back Support Angle. By employing the same method of measurement for the body and the supporting equipment surfaces, it becomes easier to translate desired body alignment into prescriptive angles of the seating system.

It is important to note that while the measurement methodology is the same, there are separate terms for angular measures of the body versus angular measures of support surfaces, emphasizing the importance of differentiating between the two. For example, an individual may be sitting in their wheelchair with a Thigh to Trunk Angle of 105 degrees, even though their Seat to Back Support Angle is 95 degrees. All too often in the past, practitioners have made the mistake of assuming that the seated person's body angles are the same as the equipment angles. Having separate terms for each prompts clinicians to observe and measure a person's body angles separate from the support surface angles during assessment, fittings or follow-up.

5 Linear Measures of the Body and Support Surfaces

In addition to angular measures, the standard also defines the terms used to measure linear dimensions of a person's body in the sitting position, as well as the linear dimensions of the support surfaces. Linear measures of the body are used to specify appropriate support surface linear dimensions and placement. It is important to note that there are separate terms for linear *body* measures and linear *support surface* measures, emphasizing the importance of differentiating between the two. For example, while a person's buttock/thigh depth should be used to specify the desired seat cushion depth, these values are not usually the same, and thus require separate terms. This differentiation supports clinician/supplier judgment in the specification of seating parameters depending on user need.

5.1 Terminology conventions for linear measures

To improve consistency and standardize terminology, the standard establishes the following rule for labeling linear measures of support surfaces: all linear measures taken parallel to the support surface reference plane in the direction of the Y axis are termed **length (l)**, in the direction of the Z axis are termed **width (w)**, and measures taken in the direction of the X axis are termed **depth (d)**. Additionally, the term **thickness (t)** is used to describe a linear support surface measure taken perpendicular to the support surface reference plane. Figure 1.26 shows examples of linear length, width, depth and thickness measures.

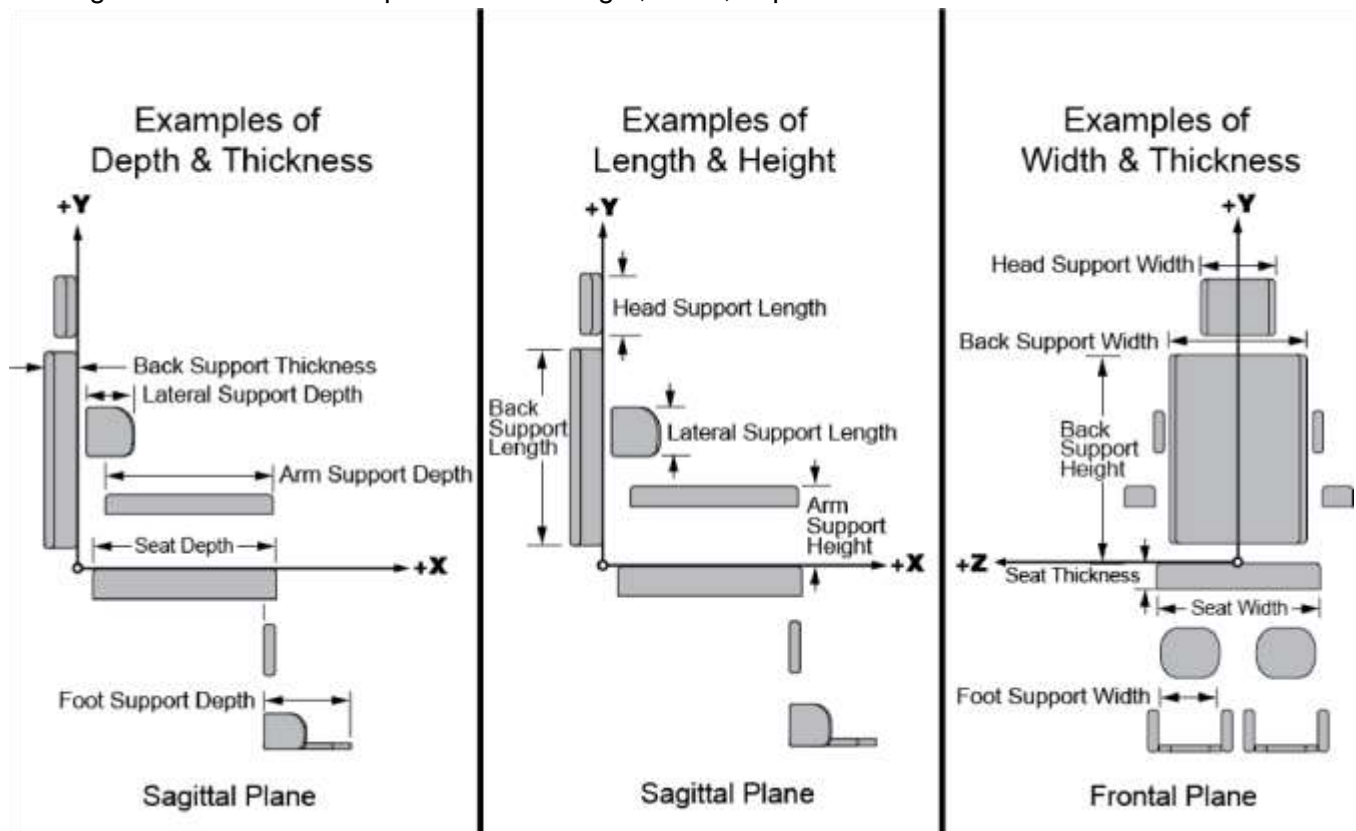


Fig. 1.26: Examples of support surface linear measures

This same convention for the terms length, width and depth is followed for linear measures of the body for consistency. For example, the terms “buttock/thigh depth” and “foot depth” are used instead of buttock/thigh length and foot length, since these terms describe dimensions taken in the direction of the body segment's local X-axis.

5.1.1 Height versus length

It is important to note the confusion surrounding the term “height”. Whereas the terms length, depth, width and thickness are linear *size* dimensions, the term height is a *placement* dimension referring to the location of a point on the body or support surface relative to an *external* point. When applied to the seated person, the term “height” is used when taking a measurement from a reference point external to the body to a point on the body. For example, elbow height is a measure of the linear distance from the loaded sitting surface to the elbow, and shoulder height is a measure of the linear distance from the loaded sitting surface to the top of the shoulder in sitting.

When applied to a support surface the term height should be used to define the location of a support along the vertical Y axis, measured from an external reference point to a point on the support component. Typically, height dimensions of support surfaces are those dimensions that are adjustable. The term height should not be used to describe the actual linear size dimension of the support component along that axis. For example, ISO 7176-7 (1998): *Wheelchairs-- Part 7: Measurement of seating and wheel dimensions* [3] defines back support height as the distance from the seat to the top of the back support, which may not be the same as the distance from the bottom of the back support component to the top of the back support, as shown in Fig. 1.25. According to the terminology convention established in the 16840-1:2006 standard, that linear dimension of the back support component is called “length”, to differentiate it from “height” [2]. Back support height is an important location measure, as it determines the placement of the back support vertically on the back canes.

The ISO 16840-1:2006 standard proposes a very different method and set of terms for defining the placement or location of postural support devices in a body support system; therefore the term “height” is not defined in the ISO standard [2]. As mentioned previously in the preface to this guide, these “support surface location measures” as defined in the standard have not been included in this version of the guide, because they are clinically difficult to apply. However, a general description of these location measures as defined in the ISO standard is included in Appendix D. As an alternative, we have chosen to include in Chapter 5 of this guide six of the most common height measures used in wheelchair seating prescription, based on the definitions in ISO 7176-7 (1998): *Wheelchairs-- Part 7: Measurement of seating and wheel dimensions* [3].

6 Use of Generic Category Labels in the ISO Standard

As explained in Section 1.2 of this chapter, all seating support surfaces can be categorized as either a posterior, anterior, inferior, superior, lateral or medial support, based on which side of the person's body segment the surface is intended to contact in the Seated Reference Position (SRP). In the ISO 16840-1:2006 standard, these generic terms are used instead of specific postural support device labels (such as head support or foot support) to define support surface angles and dimensions. Therefore, in the ISO16840-1:2006 standard you will not see the term “seat to back support angle”, but rather “inferior support to posterior support angle”, because the definition and determination of this angle is the same whether the inferior support is a seat or foot support, and whether the posterior support is a back support or lower leg support [2]. This was done to reduce redundancy in the definitions in the ISO standard; however in this clinical guide we use the actual label for the postural support device in the term defining the measure, using the now standardized terms for specific postural support devices from RESNA WC-1: 2009, Section 26: Vocabulary [1]. For example, in this guide we use the ISO definition of “posterior support sagittal angle” from the standard to define the terms “back support sagittal angle”, “head support sagittal angle” and “lower leg support sagittal angle”.

Similar to the angular support surface measures, the standard uses these same generic labels when defining support surface linear measures such as length, depth and width. Therefore, there is no definition for “seat depth” in the ISO standard, but rather a definition for “inferior support depth”. As with angles, this guide

applies the generic definitions to common support surfaces, using terms from *RESNA WC-1: 2009, Section 26: Vocabulary* [1] to define the size dimensions of all common postural support devices.

7 Tools for Measurement

The sample measurement procedures described in this clinical guide may all be performed using basic tools commonly available in service delivery settings. For example, therapists typically employ goniometers to measure joint motion. While we will be measuring static body segment angles, rather than joint motion, a goniometer can still be used. Sagittal and frontal absolute angle measures can be determined using a goniometer with a bubble level, or an inclinometer, as they rely on a gravitational reference axis. All linear dimensions can be determined using a metal tape measure or caliper (M-L Stick).

7.1 Tools used to measure relative angles

All relative angles of the body and support surfaces can be measured using a goniometer. Some angles will be easier to measure with a 180 degree goniometer that does not have a large dial in the center (Fig. 1.27), whereas other angles can be easily measured with a larger 360 degree goniometer such as the one pictured in Fig. 1.28. For relative angles each arm of the goniometer is aligned with one of the two adjacent body segment lines, or adjacent support surface reference planes.

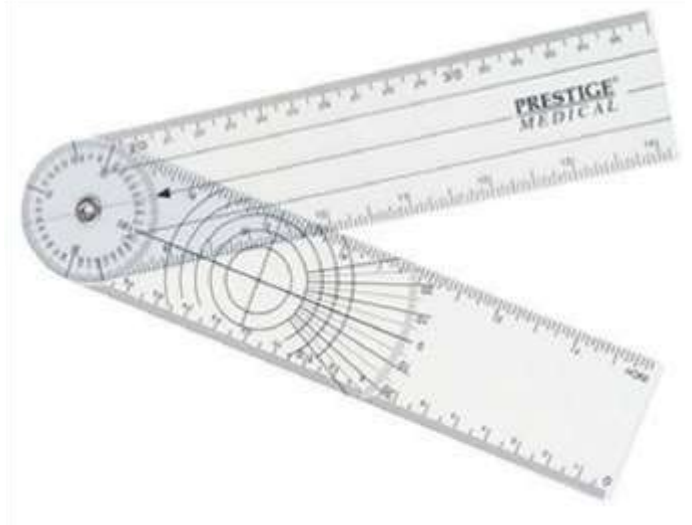
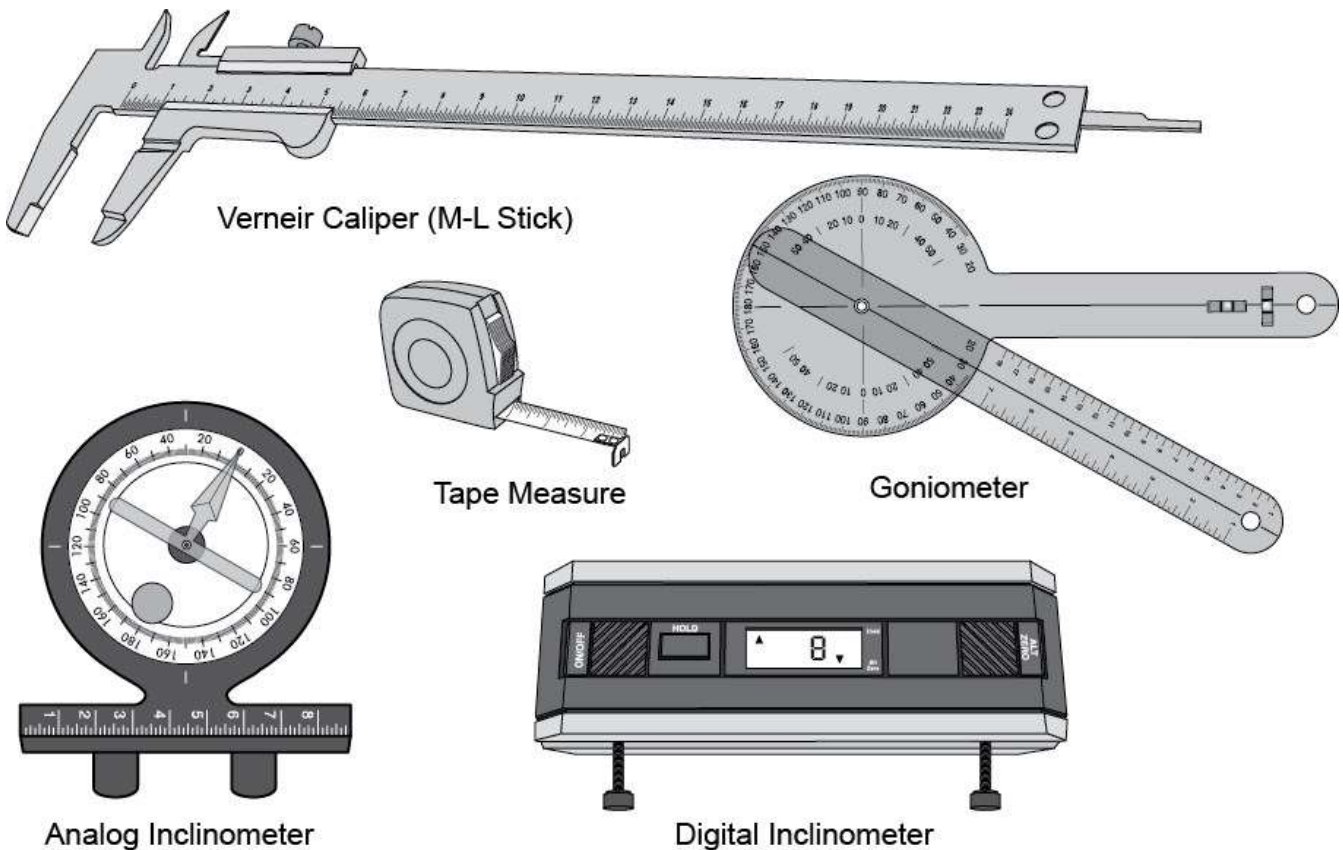


Fig. 1.27: 180 degree goniometer



7.2 Tools used to measure absolute angles

All absolute angles can be measured using either a 360 degree goniometer with a bubble level, or an inclinometer (digital or analog). Since absolute angles are determined by comparing a line on the body segment or support surface to an external reference line – it becomes necessary to identify the external reference line. For angles in the sagittal plane (side view) and frontal plane (front view), the orientation of the body segment or support surface is compared to either the vertical or horizontal; therefore the measurement device must be able to identify the gravitational horizontal and/or vertical. An inclinometer (sometimes called an “angle finder”) automatically measures degrees off of either the horizontal or vertical, and therefore this will be the most straightforward tool to use for sagittal and frontal angles. It is helpful if the inclinometer has two straight edges perpendicular to one another, as this makes it easier to align the edge to either a vertical or horizontal reference. Digital inclinometers are easier to read and will indicate positive and negative values, however they are more expensive than analog inclinometers. However, an inexpensive goniometer can also be used for sagittal and frontal angles by mounting a bubble level horizontally and vertically on the fixed arm (bubble level extensions for goniometers are commercially available). The bubble level allows you to align that arm of the goniometer with the horizontal or vertical, and then the other arm can be aligned with the body segment or support surface.

Inclinometers cannot be used to measure absolute angles in the transverse plane because these angles are not referenced to the horizontal or vertical. Absolute angles in the transverse plane are referenced to the wheelchair, specifically either the X or Z axis of the Wheelchair Axis System; therefore, for these measures it will be necessary to locate a line along or parallel to these axes. The wheelchair Z axis is parallel to a line running through the axles of the rear wheels, and the wheelchair X-axis projects forward perpendicular to this Z axis and parallel to the seat rails. Locating these two axes can be done by lining up the wheelchair over two perpendicular pieces of tape placed on the floor, so that the tape represents the wheelchair X and Z axes. You can then sight down to the lines of tape to align one arm of the goniometer with the desired reference axis. This is explained again in the introduction sections of Chapters 2 and 3.

There are two new tools developed in Japan which can be used to measure absolute body segment angles in order to quantify seated posture according to the ISO 16840-1:2006 standard. These are the Horizon tool [4] and Rysis software [5,6]. The Horizon is a device which is similar to a digital inclinometer, however it can measure absolute angles in the transverse plane as well as angles in the sagittal and frontal plane. The Horizon tool is not yet available in the United States; however, plans to sell the product in the U.S. are underway. (The Horizon tool can also be purchased directly from the vendor YU-KI Trading Co., Ltd). The Rysis software was also developed in Japan, and is available to download at no cost [7]. In this methodology, clinicians mark body landmarks of interest using ½” diameter adhesive markers and then capture a digital image. This digital image is then analyzed using computer based image analysis software, resulting in a report of absolute body segment angle values which describe the person’s posture.

7.3 Tools used to measure linear dimensions

Linear measurement tools may include tape measures, and caliper systems or “M-L Sticks” (instruments that orthotists and prosthetists use to measure width of body segments). If using a tape measure, it is preferable to use a ½” metal tape measure as opposed to a cloth tape measure to improve accuracy. For some linear measures of the body, it is helpful to use firm, flat surfaces to hold against the soft tissue of the body. This can be performed using a clipboard, book, small board, or another item with similar characteristics.

7.4 Other tools

Measurement of an individual's *desired* posture during assessment may also be facilitated by use of a seating simulator or posture measurement frame (a simplified type of seat simulator). These tools provide a certain degree of adjustability in various seating parameters, allowing the clinician to provide firm surfaces set at specific angles and dimensions to help support the individual in the desired seated posture. Measurements are then taken with the client in the simulated desired posture and orientation for accuracy. Simulation of desired posture may also be done using a wheelchair, standard chair, or on a mat-table or plinth, however this can be difficult with clients who have poor sitting balance.

Specialty manual tools have also been developed, including a hip centre location tool. These simple tools are useful in determining the location of computed landmarks which represent joint centers used for measurement of certain angles specified in the standard, if greater precision is desired.

More precise measures of posture may be obtained through use of research based tools, such as 3dimensional motion analysis systems. It is important to note that the three dimensional angles calculated from use of these systems will differ from those measured using projections onto the planes, particularly if the body segments or support surfaces are deviated in more than one plane.

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1 Introduction

The terms defined in this chapter are measures of a static position rather than goniometric measures of joint range of motion. The methodology for measuring joint range of motion is well established in the medical field, and it is not the intention of the standard or this guide to re-define these measures, but rather to define terms which both describe a static seated posture and also provide measures which more easily translate into corresponding support surface angles for prescription purposes.

The angular orientation of a person's body segments in sitting can have a significant impact on their posture, comfort, health and function. These angular terms and measures can be used to either (1) document the person's **existing** posture during assessment and then follow-up, to document postural change with seating intervention, and/or (2) specify the **desired** posture of specific body segments to assist with prescription of new seating supports designed to support that desired posture.

Table 1 lists the angular body measures which are defined and explained in this chapter. They have been identified as either a Level I or Level II measure, to suggest a selection of measures to take based on complexity of client need. This is not intended to be prescriptive since the choice of measurements used in any one assessment process will depend not only on the clinical presentation of the individual, but also the complexity of their postural support needs, the goals of the measurement process and the availability of measurement tools. For example, clinicians and scientists who are taking measurements in a research setting, and who have access to more sophisticated measurement tools, may choose to take a greater number of measurements than a practitioner in the field working with clients with simple postural support needs. *In most clinical situations, it will be useful to measure the three Level I relative angles, and perhaps a few absolute angles of interest if there are postural deviations.*

Table 1: Suggested angular body measures based on complexity of client need

	Level I	Level II
Relative Angles	Thigh to trunk angle Thigh to lower leg angle Lower leg to foot angle	Thigh to pelvis angle
Absolute Angles SAGITTAL PLANE	Sagittal pelvic angle Sagittal trunk angle Sagittal thigh angle	Sagittal head angle Sagittal upper trunk angle Sagittal sternal angle Sagittal abdominal angle Sagittal lower leg angle Sagittal foot angle
Absolute angles FRONTAL PLANE	Frontal pelvic angle Frontal sternal angle Frontal trunk angle	Frontal head angle Frontal lower leg angle Frontal foot angle
Absolute angles TRANSVERSE PLANE	Transverse pelvic angle Transverse trunk angle	Transverse head angle Transverse thigh angle Transverse foot angle

This chapter does not include all of the body angles defined in the standard. For example, absolute angles of the following body segments are not included: neck, upper arm, forearm and hand. Measures identified as being the most useful for the description of seated posture and for

wheelchair seating prescription were selected for inclusion. These measures also serve to illustrate the application of the principles encompassed within the standard. Once these principles have been grasped, extrapolation to more complex or less common measures which are not included in this guide is relatively simple.

Relative angle measures are defined first, and then absolute angles. The absolute angle measures are organized by plane, with absolute angles in the sagittal plane listed first, then frontal plane angles and then transverse plane angles. A review of general principles and instructions specific to measuring angles in that plane is included at the beginning of each section.

2 Relative Body Segment Angles

2.1 General instructions

Relative body segment angles are defined in the sagittal plane only; therefore adding the word “sagittal” to the term is not necessary. They are measured by aligning a goniometer along the two sagittal body segment lines of the adjacent body segments being measured. As any angle can be measured on one of two sides (Fig. 2.1), the side of the angle to be measured is defined in the summary box. For consistency and clinical intuitiveness, the flexion side of the joint was chosen. In most situations, this will result in a number less than 180 degrees.

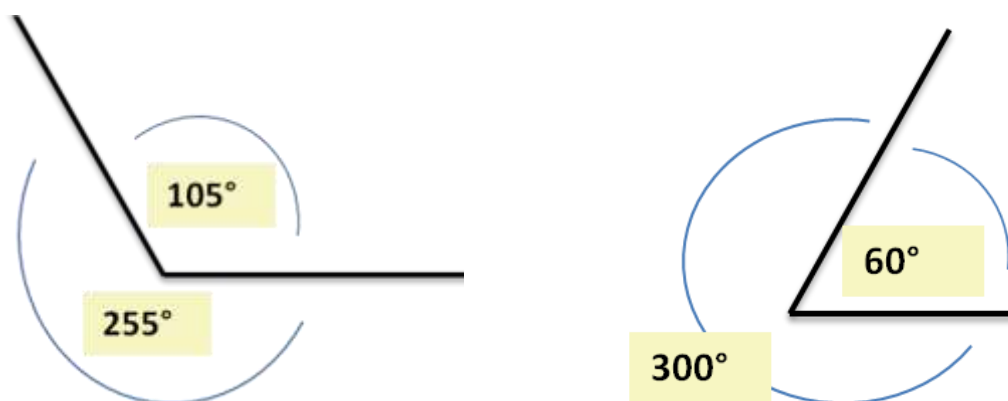


Fig. 2.1: An angle has two sides

These relative body segment angles are clinically relevant because they correspond to the primary seating angles of the body support system, called the *relative support surface angles* (see Chapter 3, Section 2). Because the relative body segment angles are defined the same way as the relative support surface angles, it is easy to assess discrepancies during assessment, as well as use the desired body angles to prescribe the corresponding seating angles.

It is important to understand how these relative body segment angles relate to, but are not the same as, measures of hip flexion/extension, knee flexion/extension and ankle dorsiflexion/plantarflexion. These physiological joint motions are defined as rotations away from the zero reference standing position, and therefore the values do not equate to the values obtained when measuring the static relative body segment angles. The value of a relative body segment angle is often the *supplementary* angle to the corresponding angle of joint motion. Supplementary angles add up to 180 degrees (Fig. 2.2). For example, if the person is seated in a position of 75 degrees of hip flexion, their corresponding thigh to trunk angle is 105 degrees. These relationships are explained in more detail in the considerations section of each relative angle measure.

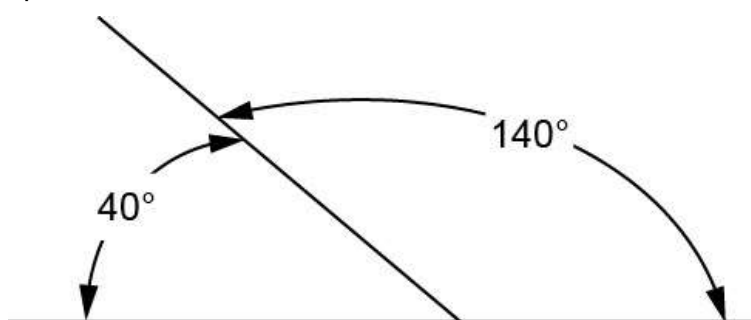


Fig 2.2: Supplementary angles

THIGH TO TRUNK ANGLE

Type of Measurement: Relative body segment angle, right and left

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Description: The angle between the thigh and the trunk, viewed from the side.

Landmarks used:

- Lateral hip center point (center of rotation)
- Lateral femoral condyle
- Lateral lower neck point

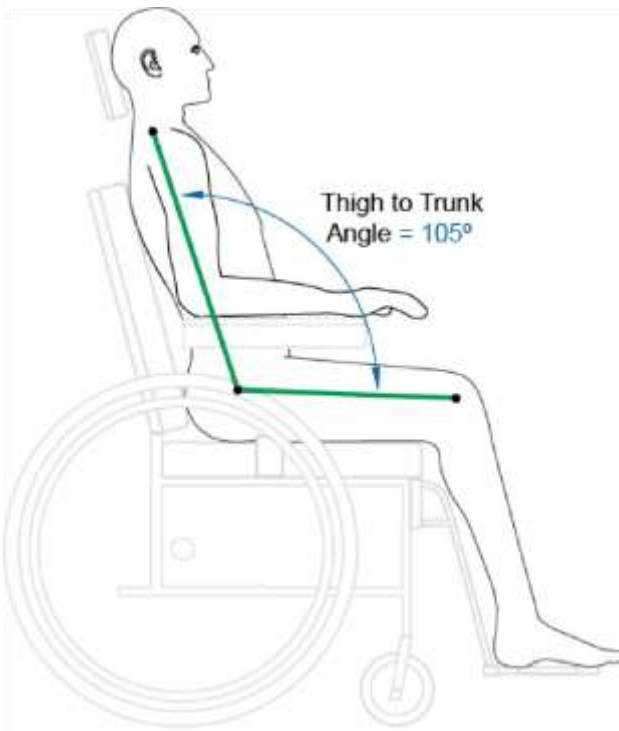
Body segment lines used to form angle:

- Sagittal trunk line
- Sagittal thigh line

Angle measured: The anterior side of the angle formed between the sagittal trunk line and the sagittal thigh line.

SRP Value: 90 degrees

Typical Values: 90 – 120



2.2 Thigh to trunk angle

Purpose:

To document the existing or desired angular position of the trunk relative to the thigh

Clinical Relevance:

The thigh to trunk angle is a reflection of the position of hip flexion, and it can be used to help determine the desired seat to back support angle in the case of a single angle (straight) back support.

Fig. 2.3: Thigh to trunk angle

Sample procedure:

1. Locate body landmarks and body segment lines

- Locate the lateral hip center point, lateral femoral condyle and lateral lower neck point (or their approximations). The sagittal trunk and thigh lines connect these points.
 - *Lateral hip center point* – approximated by the most anterior point on the lateral surface of the greater trochanter.
 - *Lateral femoral condyle* - point at most lateral aspect of the lateral femoral condyle.
 - *Lateral lower neck point* – location can be approximated by:
 - o The most anterior point on the acromion process if shoulder complex is well aligned with the trunk, or
 - o The center point of a line between the C7 spinous process and the upper sternal notch.
 - *Sagittal thigh line* - the line passing through the lateral hip center point and the lateral femoral condyle
 - *Sagittal trunk line* - the line passing through the lateral lower neck point and the lateral hip center point.

2.

Measure the angle (using a goniometer)

- Place the goniometer center over the greater trochanter, or approximate lateral hip center point.
- Align the stationary arm along the sagittal trunk line, pointing towards the acromion. Align the moveable arm along the sagittal thigh line, pointing towards the lateral femoral condyle.
- Read the value representing the anterior side of the angle, on the front side of the hip.

Typical Values:

Values could fall between 60 degrees and 180 degrees, but for a seated individual are typically 90 to 120 degrees. The thigh to trunk angle is 90 degrees in the Seated Reference Position (SRP).

Considerations:

- Since the trunk is viewed as a whole body segment (encompassing the pelvis and all spinal segments), this angle represents a gross orientation of the upper body relative to the thigh. It does not represent or describe the posture of the spine, whether flexed, extended, kyphotic or lordotic.
- While the thigh to trunk angle reflects the seated person's angle of gross hip flexion, these two measures are supplementary angles and therefore have a different value. For example, if a person is sitting in a position of 75 degrees of gross hip flexion, the thigh to trunk angle is 105 degrees (Fig. 2.4).
- It is also important to understand that this angle is a reflection of gross hip flexion not true acetabular hip flexion. True acetabular hip flexion is a measure of the relationship between the thigh and the *pelvis*, while gross hip flexion is a measure of the relationship between the thigh and the *trunk*. The thigh to pelvis angle corresponds to a true hip flexion angle.
- The support surface angle which corresponds to the thigh to trunk angle is the seat to back support angle.

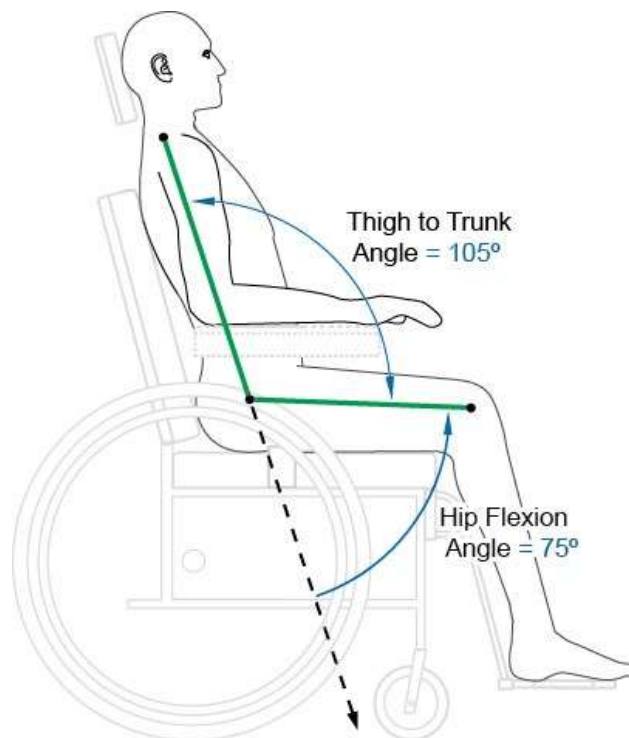


Fig. 2.4: Thigh to trunk angle vs. hip flexion angle

THIGH TO /2:(5/(*ANGLE

Type of Measurement: Relative body segment angle, right and left

Description: The angle between the thigh and the lower leg, viewed from the side.

Landmarks used:

- Lateral femoral condyle (center of rotation)
- Lateral hip center point
- Lateral malleolus

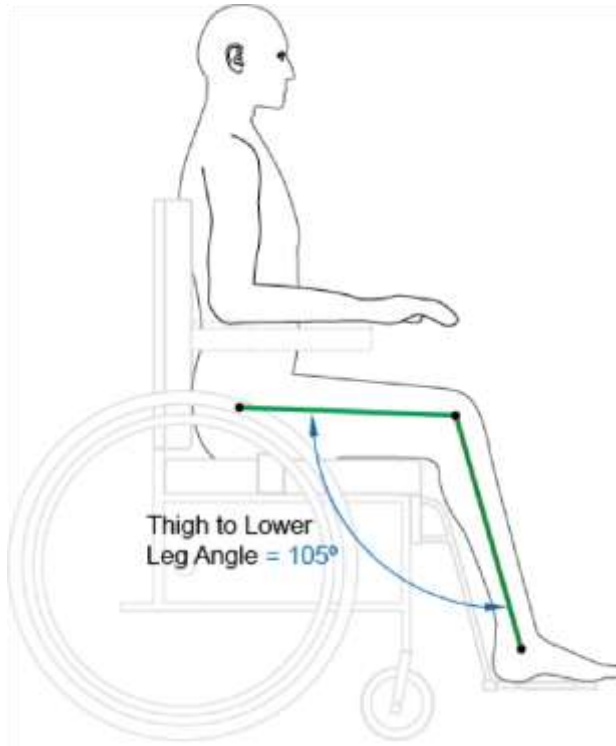
Body segment lines used to form angle:

- Sagittal thigh line
- Sagittal lower leg line

Angle measured: The posterior side of the angle formed between the sagittal thigh line and the sagittal lower leg line.

SRP Value: 90 degrees

Typical Values: 80 – 120



2.3 Thigh to lower leg angle

Purpose:

To document the existing or desired angular position of the lower leg relative to the thigh

Clinical Relevance:

The thigh to lower leg angle reflects the position of knee flexion, and is used to help determine the desired seat to lower leg support angle. The seat to lower leg support angle can then be used to help in the selection of the wheelchair's lower leg support assembly.

Fig. 2.5: Thigh to lower leg angle

Sample procedure:

1. Locate landmarks and body segment lines

- a) Identify the lateral femoral condyle, the lateral hip center point and the lateral malleolus. The sagittal thigh and lower leg lines connect these points.
 - *Lateral femoral condyle* - point at most lateral aspect of the lateral femoral condyle.
 - *Lateral hip center point* - approximated by the greater trochanter.
 - *Lateral malleolus* - point at most lateral aspect of lateral malleolus.
 - *Sagittal thigh line* - the line passing through the lateral hip center point and the lateral femoral condyle.
 - *Sagittal lower leg line* - the line passing through the lateral femoral condyle and the lateral malleolus.

Measure the angle (using a goniometer)

- a) Place the goniometer center over the lateral femoral condyle.
- b) Align the stationary arm along the sagittal thigh line, pointing towards the greater trochanter. Align the moveable arm along the sagittal lower leg line, pointing towards the lateral malleolus.

2.

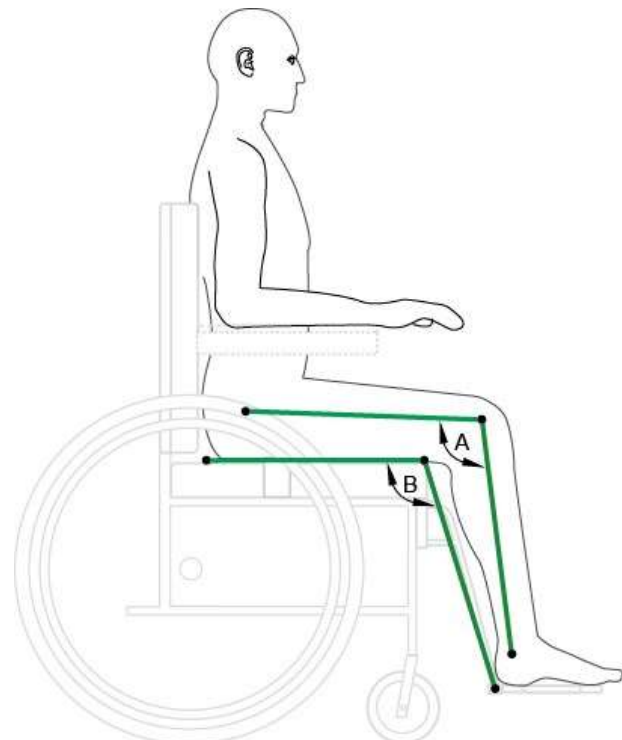
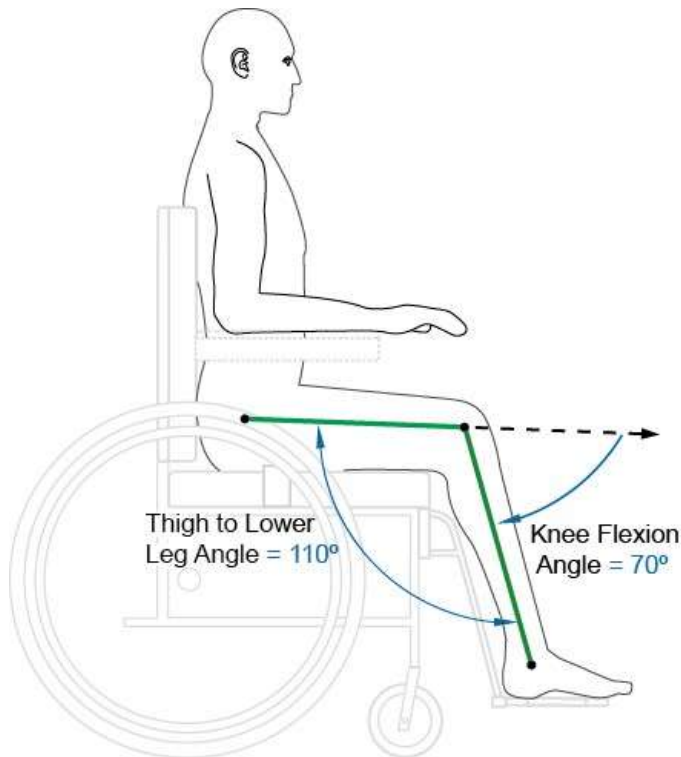
c) Read the value representing the posterior side of the angle.

Typical values:

Values can fall between 45 and 180 degrees (knee completely straight) but for a seated person are typically 80 to 120 degrees. The thigh to lower leg angle is 90 degrees in the Seated Reference Position (SRP).

Considerations:

- The thigh to lower leg angle is a reflection of the position of knee flexion, however these two measures are supplementary angles and therefore have different values. For example, if a person is sitting in a position of 70 degrees of knee flexion, the thigh to lower leg angle would be 110 degrees (Fig. 2.6).
- The support surface angle which corresponds to the thigh to lower leg angle is the seat to lower leg support angle.
- However, the thigh to lower leg angle is unlikely to be exactly the same as the corresponding seat to lower leg support angle, because the knee joint is always located anterior to the front edge of the seat (Fig. 2.7).



A – Thigh to Lower Leg Angle = 95°

B – Seat to Lower Leg Support = 105°

Fig. 2.6: Thigh to lower leg vs. knee flexion angle

Fig. 2.7: Thigh to lower leg angle vs. seat to lower leg support angle

2.4 Lower leg to foot angle**Purpose:**

To document the existing or desired angular position of the foot relative to the lower leg

Clinical Relevance:

LOWER LEG TO FOOT ANGLE

Type of Measurement: Relative body segment angle, right and left

Description: The angle between the lower leg and the foot, viewed from the side. Right and left measures may differ.

Landmarks used:

- Lateral femoral condyle
- Lateral malleolus
- Lateral heel point (center of rotation)
- Lateral toe point

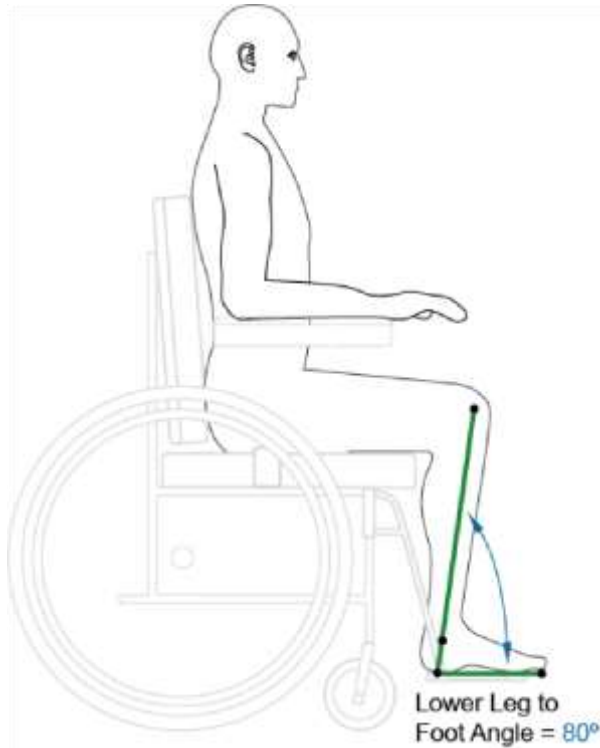
Body segment lines used to form angle:

- Sagittal lower leg line
- Sagittal foot line

Angle measured: The anterior side of the angle formed between the sagittal lower leg line and the sagittal foot line.

SRP Value: 90 degrees

Typical Values: 80 – 110



desired lower leg support to foot support angle.

The lower leg to foot angle reflects the position of ankle dorsi/plantarflexion, and is used to help determine the

Fig. 2.8: Lower leg to foot angle

Sample procedure:

1. Locate landmarks and body segment lines

- Identify the lateral femoral condyle and the lateral malleolus. The line passing through these points is the sagittal lower leg line.
- Then locate the lateral heel point by projecting the sagittal leg line down to the bottom surface of the foot. Locate the lateral toe point. The line connecting the lateral heel point and the lateral toe point is the sagittal foot line.
 - *Lateral femoral condyle* - point at most lateral aspect of the lateral femoral condyle.
 - *Lateral malleolus* - point at most lateral aspect of lateral malleolus.
 - *Lateral heel point* - the intersection of the sagittal lower leg line and the plantar surface (bottom) of the foot.
 - *Lateral toe point* - the lateral distal protuberance of the fifth metatarsal.
 - *Sagittal lower leg line* - the line passing through the lateral femoral condyle and the lateral malleolus.
 - *Sagittal foot line* - the line passing through the lateral heel and toe points.

Measure angle (using a goniometer)

- Place the goniometer pivot center over the lateral heel point.
- Align the stationary arm along the sagittal lower leg line, pointing up towards the lateral femoral condyle. Align the moveable arm along the sagittal foot line, pointing towards the lateral toe point.

2.

c) Read the value representing the anterior (front) side of the angle.

Typical values:

Values can fall between 60 degrees and 150 degrees, but for a seated individual are typically 80 to 110 degrees. The lower leg to foot angle is 90 degrees in the Seated Reference Position (SRP).

Considerations:

- If significant inversion, eversion or other deformities are present in the ankle or forefoot, this could affect the position of the heel point and/or toe point, and will require approximation.
- The lower leg to foot angle is a reflection of the position of ankle dorsiflexion, however these two measures have different values. A position of 0 degrees of dorsiflexion or plantar flexion is equal to a lower leg to foot angle of 90 degrees, as in the Seated Reference Position. If a person's ankle is in a position of 10 degrees of ankle dorsiflexion, their lower leg to foot angle would be 80 degree (Fig. 2.9). A 10 degree plantar flexion contracture would result in a lower leg to foot angle of 100 degrees.

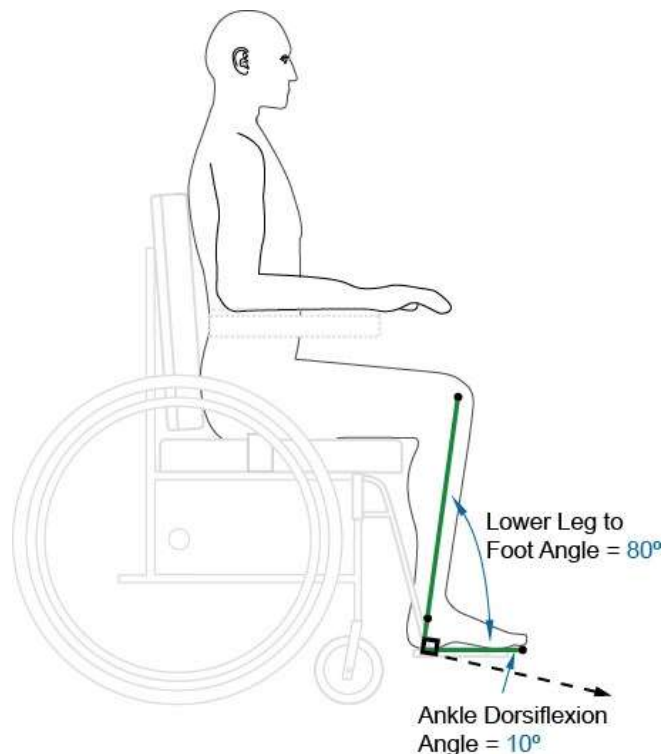


Fig. 2.9: Lower leg to foot angle vs. dorsiflexion angle

2.5 Thigh to pelvis angle

Purpose:

To document the existing or desired angular position of the pelvis relative to the thigh

Clinical Relevance:

The thigh to pelvis angle reflects the position of “true” acetabular hip flexion, and can be used to help determine the desired angle between the seat and the lower portion of a two – section back support.

THIGH TO PELVIS ANGLE

Type of Measurement: Relative body segment angle, right and left

Description: The angle between the pelvis and the thigh, viewed from the side. **Landmarks used:**

- ASIS
- PSIS
- Lateral hip center point (center of rotation)
- Lateral femoral condyle

Body segment lines used to form angle:

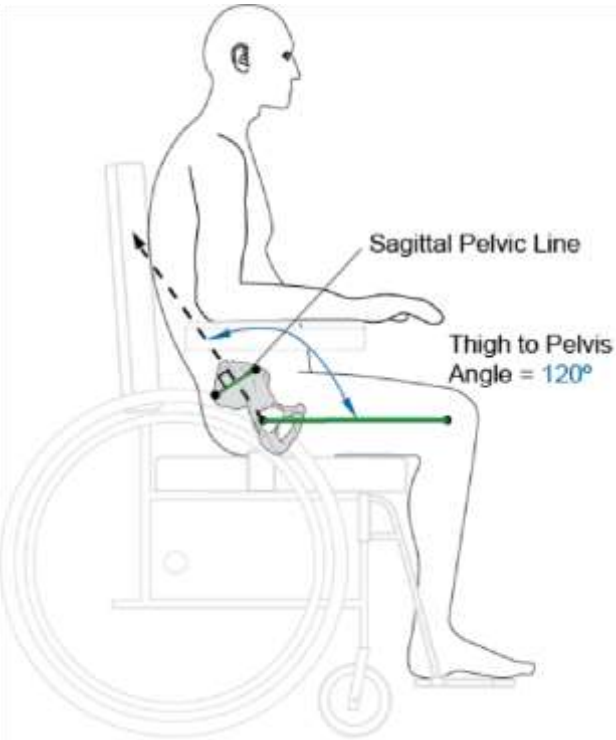
- Sagittal pelvic line
- Sagittal thigh line

Angle measured: The anterior side of the angle formed between the perpendicular to the sagittal pelvic line and the sagittal thigh line.

SRP Value: 90 degrees

Typical Values: 80 – 110

Additionally, this angle is clinically relevant because changes in the degree of “true” hip flexion that a person is sitting in can have a significant effect on posture, health and function and therefore a clinician may wish to measure this



to document seating intervention outcomes relative to posture.

Fig. 2.10: Thigh to pelvis angle

Sample Procedure:

1. Locate the perpendicular to the sagittal pelvic line

- Palpate the ASIS and PSIS and locate the line between these points, which is the sagittal pelvic line.
- Locate the greater trochanter and then project a line perpendicular to the sagittal pelvic line down to the greater trochanter.
 - *ASIS* – most anterior inferior prominence of the ASIS.
 - *PSIS* - lowest point on the posterior surface of the PSIS.
 - *Sagittal pelvic line* - the line passing through the ASIS and PSIS on same side.
 - *Lateral hip center point* - approximated by the greater trochanter.

2. Locate remaining landmarks and sagittal thigh line

- Identify the lateral femoral condyle at the knee. The line passing through the lateral hip center point and the lateral femoral condyle is the sagittal thigh line.
 - *Lateral femoral condyle* - point at most lateral aspect of the lateral femoral condyle.

- *Sagittal thigh line* – the line passing through the lateral hip center point and the lateral femoral condyle.

3. Measure angle (using a goniometer)

- Place the goniometer pivot center over the lateral hip center point (or approximation).
- Align the stationary arm perpendicular to the sagittal pelvic line, pointing towards the iliac crest. Align the moveable arm along the sagittal thigh line, pointing towards the lateral condyle of the knee.
- Read the value representing the anterior side of the angle.

Typical values:

Values can fall between 60 to 130 degrees, but for a seated individual are typically between 80 to 110 degrees. The thigh to pelvis angle is 90 degrees in the Seated Reference Position (SRP).

Considerations:

- While the thigh to pelvis angle reflects the seated person's angle of "true" hip flexion, these two measures are supplementary angles and therefore have different values. For example, if a person is sitting in a position of 60 degrees of "true" hip flexion, their thigh to pelvis angle would be 120 degrees (Fig. 2.11).
- If the thigh remains horizontal, then changes in this angle will reflect varying degrees of anterior or posterior pelvic tilt.
- There may be right and left measures if the person's thighs are not parallel to each other.

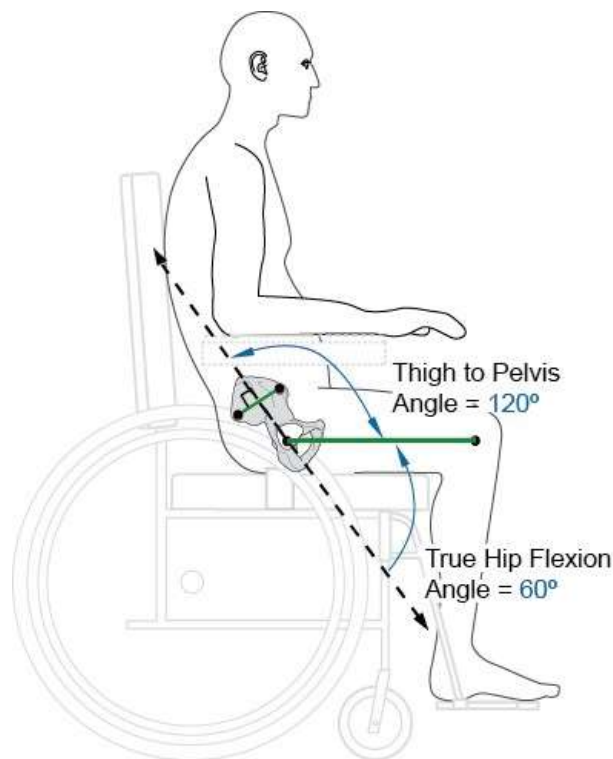
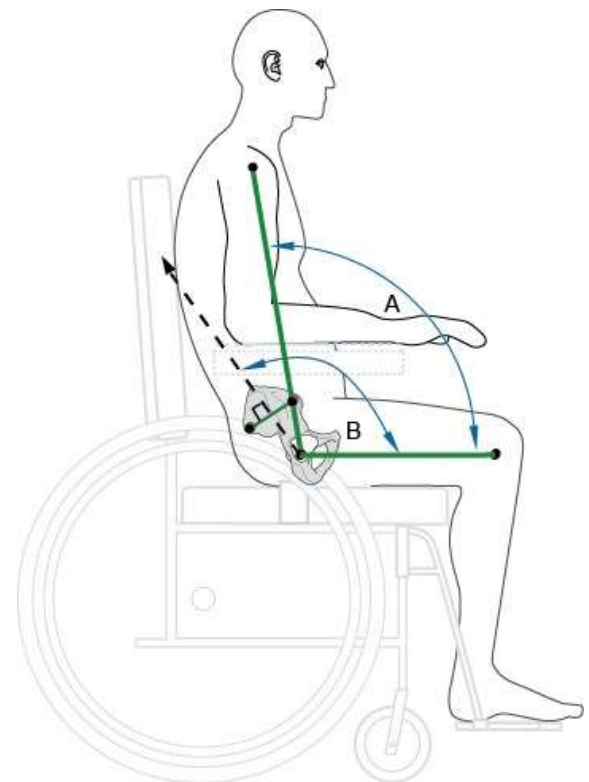


Fig. 2.11: Thigh to pelvic angle vs. hip flexion angle

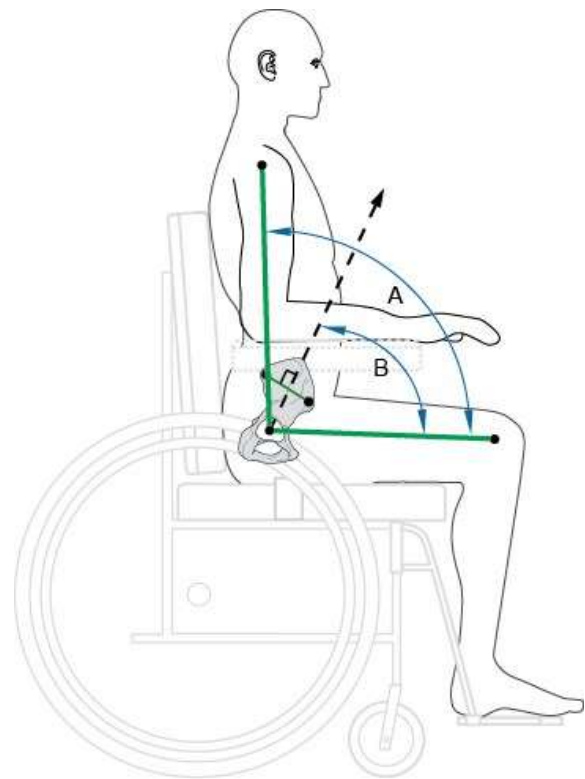
- The difference between the thigh to trunk angle and the thigh to pelvis angle can provide insight into the posture of the trunk, whether tending to be kyphotic or lordotic. If the thigh to pelvis angle is greater than the thigh to trunk angle, then the person would most likely be sitting with a posteriorly tilted pelvis and kyphotic trunk (Fig. 2.12).
- Conversely, if the thigh to pelvis angle is less than the thigh to trunk angle, then the person is most likely sitting with a more lordotic posture (Fig. 2.13).
- The support surface angle which corresponds to the thigh to pelvis angle is the seat to lower back support angle.



A – Thigh to Trunk Angle = 100°

B – Thigh to Pelvis Angle = 120°

Fig. 2.12: Thigh/pelvis greater than thigh/trunk indicates kyphotic posture



A – Thigh to Trunk Angle = 90°

B – Thigh to Pelvis Angle = 70°

Fig. 2.13: Thigh/pelvis less than thigh/trunk indicates lordotic posture

3 Absolute Body Segment Angles in Sagittal Plane

3.1 General instructions

All absolute, sagittal body segment angles are determined by viewing the subject from the side, as these angles reflect rotations of a single body segment in the sagittal (XY) plane. The value of an absolute angle is the degree of rotation of the body segment line away from its zero reference position as defined in the Seated Reference Position (SRP). By definition, all sagittal body segment lines align with either the vertical or horizontal in the SRP. **Therefore, all absolute sagittal body segment angles are determined by measuring the angle between the sagittal body segment line and either the vertical or horizontal reference.** If the body segment line is aligned with the horizontal in the SRP, then the zero reference line is the horizontal. If the body segment line is aligned with the vertical in the SRP, then the zero reference line is the vertical. One can always take a perpendicular to the body segment line and compare it to the alternate reference, as the value will be the same. Remember that when a body segment is deviated in more than one plane at the same time, its segment line is projected to the sagittal plane for measurement of the sagittal body segment angle.

3.1.1 Determining whether sagittal angles are positive or negative according to the right hand rule convention (see Chapter 1, Section 4.3.3)

When a body segment deviates from the Seated Reference Position in the sagittal plane, this represents a rotation of that segment in the sagittal plane about the Z-axis. To determine whether the angle is positive or negative, curl the fingers of your right hand in the direction of rotation that the body segment has deviated from the neutral Seated Reference Position. If your thumb is pointing to the right side of the person in line with the positive +Z-axis, the sagittal angle is positive. If your thumb is pointing towards the left side of the person (opposite direction from the +Z-axis, in line with the negative –Z-axis) the sagittal angle is negative.

Using the “counter clockwise is positive rule”, ***if you are viewing the person from the right side***, rotations in a counter clockwise direction are positive, and rotations in a clockwise direction are negative. (If you are viewing the person from the left side, rotations in a clockwise direction will be positive, and counterclockwise will be negative.) Regardless of the view, backward/posterior rotation of a body segment above the hips (pelvis, trunk, head) is positive, and forward/anterior rotation of a body segment above the hips is negative. For body segments below the hips (thigh, lower leg, foot), upward rotation of the segment is positive, and downward/backward rotation from the SRP is negative.

3.1.2 Relationship between absolute and relative angles in the sagittal plane

It is important to understand the relationship between absolute and relative body segment angles in the sagittal plane. Absolute angles can change with or without changes in the relative angles, so they may or may not reflect changes in joint position. For example, Figs. 2.14a and 2.14b show two figures sitting with the same sagittal lower leg angle, but with different thigh to lower leg angles. In Fig. 2.14a, the + 40 degree sagittal lower leg angle resulted from elevation of the lower leg segment, such as might occur with an elevating leg support.

In Fig. 2.14b, the + 40 degree sagittal lower leg angle resulted from tilt of the entire seating system. Compared to the SRP, the first figure experienced a change in the thigh to lower leg angle, whereas in the second the thigh to lower leg angle is unchanged.

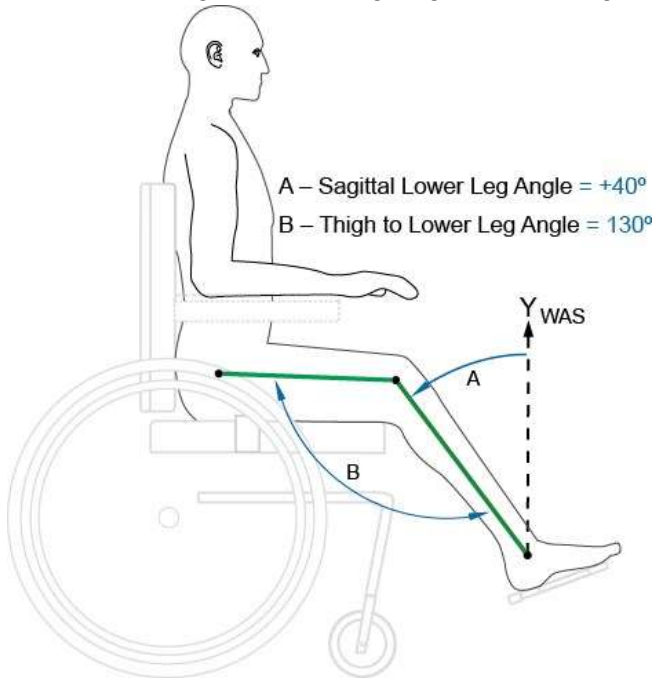


Fig. 2.14a: Sagittal lower leg angle = +40° via increase to lower leg angle posterior tilt in space

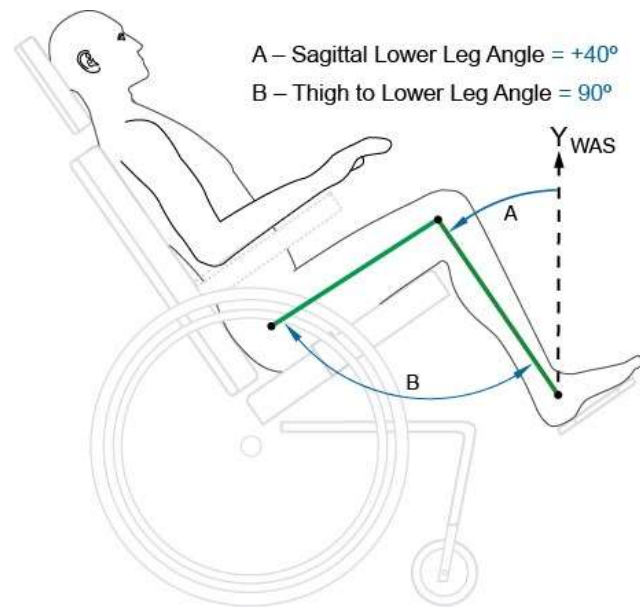


Fig. 2.14b: Sagittal lower leg angle = +40° via in thigh

3.2 Locating the gravitational vertical or horizontal reference line

If you are using an inclinometer or angle finder, these tools automatically align their zero reference with either the vertical or horizontal. If you are using a goniometer, this can be done by sighting along a line which you know is vertical or horizontal, or by using a goniometer with a bubble level attached to the stationary arm.

3.3 Special measurement protocol for sagittal absolute angles

All absolute angles of the body in the sagittal plane will be affected by changes in the orientation in space of the wheelchair's body support system. Therefore, when measuring sagittal absolute angles of a person sitting in an adjustable tilt seating system, adjust the seating system so that the seat support is horizontal, or note the baseline orientation of the body support system during measurement by recording the seat sagittal angle.

3.4 Sagittal pelvic angle

Purpose:

To document the existing or desired orientation of the pelvis in the sagittal plane

Clinical Relevance:

This angular measure is used to quantify what is also referred to as "pelvic tilt". This measure can be used to document changes in pelvic orientation in this plane, which can have a significant effect on the user's overall seated posture and function.

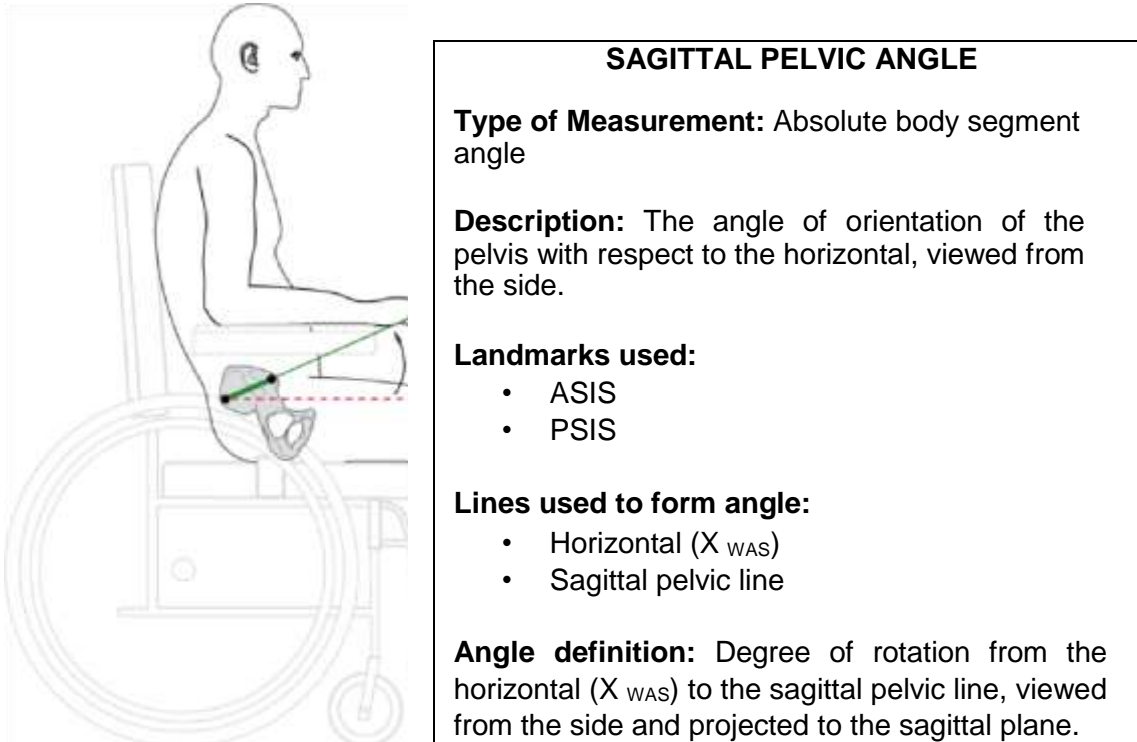


Fig. 2.15: Sagittal pelvic angle

Sample Procedure:

1. Locate landmarks and sagittal pelvic line

- a) Palpate the ASIS and PSIS and locate the line between the ASIS and PSIS by sliding your finger from the PSIS directly outward to the side of the body. The line passing through the ASIS and PSIS projected to the side of the body is the *sagittal pelvic line*.
 - *ASIS* – most anterior inferior prominence of the ASIS.
 - *PSIS* - lowest point on the posterior surface of the PSIS.

2. Measure the angle

a) Using an inclinometer or angle finder:

- i. Place the horizontal straight edge of the inclinometer or angle finder along or parallel to the sagittal pelvic line, and read the angle value.

b) Using a goniometer:

- i. Place the goniometer pivot center over the approximate location of the PSIS, projected laterally to the side of the person.
- ii. Align the stationary arm with the horizontal.

- iii. Align the movable arm along the sagittal pelvic line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the ASIS is higher than the PSIS, signifying a posterior rotation of the pelvis, the value is positive.
- If the ASIS is lower than the PSIS, signifying an anterior rotation of the pelvis from the horizontal, the value is negative.

Typical values:

When the ASIS-PSIS line is aligned with the horizontal, the value of the sagittal pelvic angle will be 0 degrees, as in the Seated Reference Position. Values from 0 to +45 degrees would indicate a posterior pelvic tilt, and values from 0 to -45 degrees would indicate an anterior pelvic tilt.

Considerations:

- While the terms anterior pelvic tilt, neutral pelvic tilt and posterior pelvic tilt have traditionally been used to describe the orientation of the pelvis in the sagittal plane in the standing position, these terms have not been well defined or quantified, and this has led to their misuse in the field of wheelchair seating. This measure provides a standardized method of quantifying the degree of anterior or posterior pelvic tilt in a wheelchair seated person which is consistent with other measures in the standard.
- Note that the sagittal pelvic angle is an absolute angle (referenced to the horizontal) and thus describes the orientation of the pelvis in space, and not relative to the femur or the lumbar spine. Therefore, this measure alone cannot describe the degree of hip flexion or the degree of spinal flexion/extension of the person.
- The sagittal pelvic angle may also be used to help determine the desired orientation of the lower back support (lower back support sagittal angle), however due to significant variation in the soft tissue bulk and shape of the buttocks, these two measures may not correlate well.

3.5 Sagittal trunk angle

Purpose:

To document the existing or desired orientation of the trunk in the sagittal plane

Clinical Relevance:

This angular measure is used to quantify what has been commonly referred to as "recline" of the upper body, and it can be used to help prescribe the desired orientation of the back support (back support sagittal angle) relative to the vertical reference. The orientation in space of a seated person's upper body can have numerous effects on muscle tone, posture, functional movement, visual regard, swallowing and/or breathing, and therefore it can be an important measure and document.



Fig. 2.16: Sagittal trunk angle

SAGITTAL TRUNK ANGLE

Type of Measurement: Absolute body segment angle

Description: The angle of orientation of the trunk with respect to the vertical, viewed from the side.

Landmarks used:

- Lateral lower neck point
- Lateral hip center point

Lines used to form angle:

- Vertical (Y_{WAS})
- Sagittal trunk line

Angle definition: Degree of rotation from the vertical (Y_{WAS}) to the sagittal trunk line, viewed from the side and projected to the sagittal plane.

Sample Procedure:

1. Locate landmarks and sagittal trunk line

- a) Identify the lateral lower neck point and the lateral hip center point (or their approximations). The line passing through these points is the *sagittal trunk line*.
 - *Lateral lower neck point*– location can be approximated by:
 - o The most anterior point on the acromion process if shoulder complex is well aligned with the trunk, or
 - o The center point of a line between the C7 spinous process and the upper sternal notch.
 - *Lateral hip center point* – approximated by the most anterior point on the lateral surface of the greater trochanter.

2. Measure angle

a) Using an inclinometer or angle finder

- i. Align the vertical straight edge of the inclinometer or angle finder with the sagittal trunk line, and read the angle value.

b) Using a goniometer

- i. Place the goniometer pivot center over the lateral hip center point (or greater trochanter).
- ii. Align the stationary arm with gravitational vertical.
- iii. Align the moveable arm along the sagittal trunk line previously located. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the vertical reference line

- If the trunk is 'reclined' from the vertical (leaning back), signifying a posterior rotation of the trunk segment from the vertical, the value is positive.
- If the trunk is 'proclined' from the vertical (leaning forward), signifying an anterior rotation of the trunk segment relative to the vertical, the value is negative.

Typical values:

When the person's trunk is fully upright and the sagittal trunk line is aligned with the vertical, this angle will be 0 degrees, as in the Seated Reference Position. Positive values from 0 to +50 degrees would indicate trunk recline (shoulders behind hips), and negative values from 0 to -20 degrees would indicate trunk procline (shoulders in front of hips). Values may range from +50 to -20 degrees if the person is seated in a wheelchair with adjustable recline or tilt, but for a seated individual in a fixed system are typically +30 to 0 degrees.

Considerations:

- Note that the sagittal trunk angle is an absolute angle and thus describes the orientation of the trunk in space, referenced to the vertical, and not relative to the thigh. Therefore, this measure does not reflect the degree of hip flexion of the user.
- Because the trunk segment includes the pelvis and upper torso, this is a gross measure of the overall orientation of the upper body as a whole, from hip to shoulder. As such, it does not describe the posture of the spine at all. However, a comparison of the sagittal pelvic angle with the sagittal trunk angle would indicate whether the person's spinal posture is either grossly flexed or grossly extended.
- For example, if the sagittal pelvic angle and the sagittal trunk angle are the same, then this means that they are "in line" with each other and the spine is grossly in a neutral position. However, if the sagittal trunk angle is zero (in line with vertical), and the sagittal pelvic angle is +20 degrees, then the person's spine will be flexed. If the sagittal trunk angle is zero, and the sagittal pelvic angle is -10 degrees, then the spine must be extended.

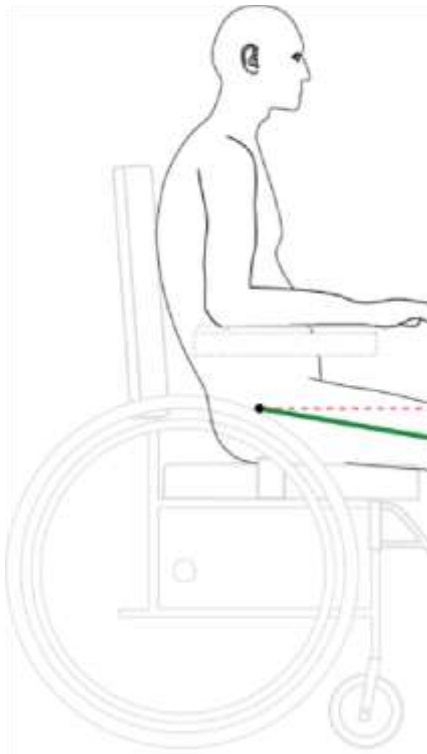
3.6 Sagittal thigh angle

Purpose:

To document the existing or desired orientation of the thigh in the sagittal plane

Clinical Relevance:

This angle can be used to quantify the orientation of the thigh as an individual segment, as an alternative to documenting the relative angles of thigh to trunk or thigh to lower leg. This measure reflects the degree of incline or decline of the thigh, and can also be used to determine the desired orientation of the seat (seat sagittal angle). This is clinically relevant because when the sagittal thigh angle and the seat sagittal angle are not the same (meaning they are not parallel), this may indicate an inadequate fit between person and equipment.



SAGITTAL THIGH ANGLE

Type of Measurement: Absolute body segment angle, right and left

Description: The angle of orientation of the thigh in the sagittal plane, with respect to the horizontal.

Landmarks used:

- Lateral hip center point
- Lateral femoral condyle

Lines used to form angle:

- Horizontal (X_{WAS})
- Sagittal thigh line

Angle defined: Degree of rotation from the horizontal (X_{WAS}) to the sagittal thigh line, viewed from the side and projected to the sagittal plane.

Fig. 2.17: Sagittal thigh angle

Sample Procedure:

1. Locate landmarks and sagittal thigh line

- a) Identify the lateral hip center point and the lateral femoral condyle. The line passing through these points is the *sagittal thigh line*.
 - *Lateral hip center point* – approximated by the most anterior point on the lateral surface of the greater trochanter.
 - *Lateral femoral condyle* - point at most lateral aspect of the lateral femoral condyle.

2. Measure angle

- a) Using inclinometer or angle finder
 - i. Align the horizontal straight edge of the inclinometer or angle finder along or parallel to the sagittal thigh line, and read the angle value.
- b) Using a goniometer
 - i. Place the goniometer pivot center over the lateral hip center point (or greater trochanter).
 - ii. Align the stationary arm with the horizontal reference line.
 - iii. Align the moveable arm along the sagittal thigh line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the thigh is 'inclined' from the horizontal (angling upward), the value is positive.
- If the thigh is 'declined' from the horizontal (angling downward), the value is negative.

Typical values:

When the sagittal thigh line is parallel to the horizontal, as in the Seated Reference Position, the value of the sagittal thigh angle would be 0 degrees. Values may range from positive 30 to negative 20 degrees, however for a seated person are typically +20 to -10 degrees.

Considerations:

- In order to align the thigh parallel to the seat, the contour of the seat surface must accommodate the unique shape of the person's buttock/thigh. A mismatch between the person's shape and the seat contour can result in a difference between the sagittal thigh angle and the seat sagittal angle.
- Note that this is an absolute angle, and thus does not give information about the relative angles at the hip and knee (as measured by the thigh to trunk angle and thigh to lower leg angle).

3.7 Sagittal head angle

Purpose:

To document the existing or desired orientation of the head in the sagittal plane

Clinical Relevance:

This angular measure is used to quantify what may be referred to as either "recline" or "incline" of the head. The orientation in space of a seated person's head can affect functional head movement, visual regard, swallowing and eating; therefore it can be an important angle to measure and document.



SAGITTAL HEAD ANGLE

Type of Angle: Absolute body segment angle

Description: The angle of orientation of the head in the sagittal plane with respect to the horizontal, viewed from the side.

Landmarks used:

- Tragion
- Eye corner

Lines used to form angle:

- Horizontal (X_{WAS})
- Sagittal head line

Angle definition: The degree of rotation from the horizontal (X_{WAS}) to the sagittal head line, viewed from the side and projected to the sagittal plane.

Fig. 2.18: Sagittal head angle

Sample Procedure:

1. Locate landmarks and sagittal head line

- a) Identify the tragion of the ear and eye corner on the same side. The line passing through these points is the *sagittal head line*.
 - *Tragion* – the most anterior superior notch of the ear, located at the upper edge of the external auditory meatus.
 - *Eye corner* – lateral corner of the eye formed by the meeting of the upper and lower eyelids.

2. Measure angle

- a) Using inclinometer or angle finder
 - i. Align the horizontal straight edge of the inclinometer or angle finder along or parallel to the sagittal head line, and read the angle value.
- b) Using goniometer

- i. Place the goniometer pivot center over the trignon.
- ii. Align the stationary arm with the horizontal reference line. jj. Align the moveable arm along the sagittal head line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the head is 'inclined' from the horizontal (tilted up or back), signifying a posterior rotation of the head, the value is positive.
- If the head is 'declined' from the horizontal (tilted down or forward), signifying an anterior rotation of the head, the value is negative.

Typical values:

Values for the sagittal head angle may range between positive 30 and negative 30 degrees, but for a seated person will typically be + 20 to -20. A value of 0 degrees would indicate that the head is in neutral, with the eye gaze horizontal. Positive values indicate that the head is tilted posteriorly, and negative values indicate that the head is tilted anteriorly.

Considerations:

- Note that the sagittal head angle is an absolute angle and thus describes the orientation of the head with respect to the horizontal, and not relative to the cervical spine or trunk. Therefore, this measure does not necessarily reflect the degree of neck flexion or extension. For example, reclining the entire upper body would result in a change in the sagittal head angle without necessarily an increase in neck extension (Figs. 2.19a, 2.19b)
- This angle can be used to help specify the head support sagittal angle.

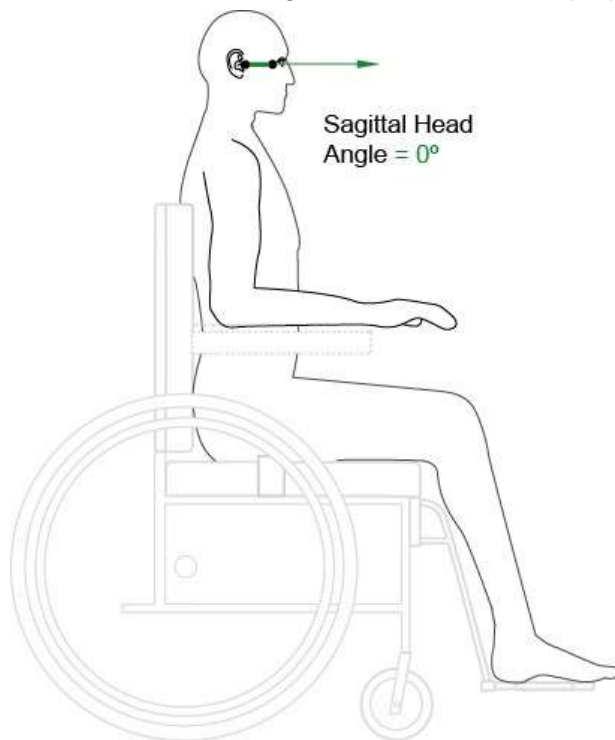


Fig. 2.19a: Sagittal head angle = 0°

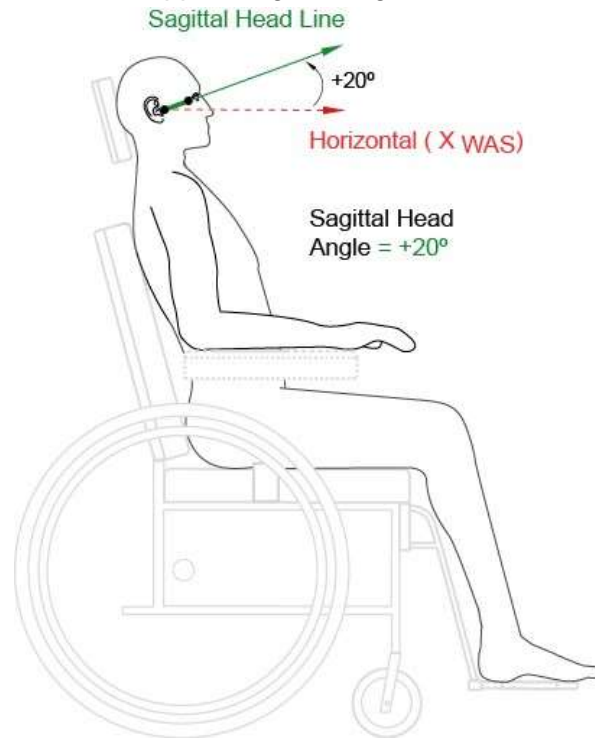


Fig. 2.19b: Sagittal head angle = +20°, no change in neck posture

3.8 Sagittal upper trunk angle

Purpose:

To document the existing or desired orientation of the upper trunk in the sagittal plane

Clinical Relevance:

This angular measure is used to quantify the orientation of the upper part of the trunk (above the pelvis) with respect to a vertical reference line. This is very similar to the sagittal trunk angle; however it does not reflect the trunk as a whole (from hip to shoulder) but only the upper torso above the pelvic area. As such, independent changes in this angle may reflect changes in spinal extension or flexion if assessed relative to the sagittal pelvic angle. This measure can also help determine the desired orientation of an upper back support as specified by the upper back support sagittal angle, in cases where there is a split back support (such as a bi-angular back support).

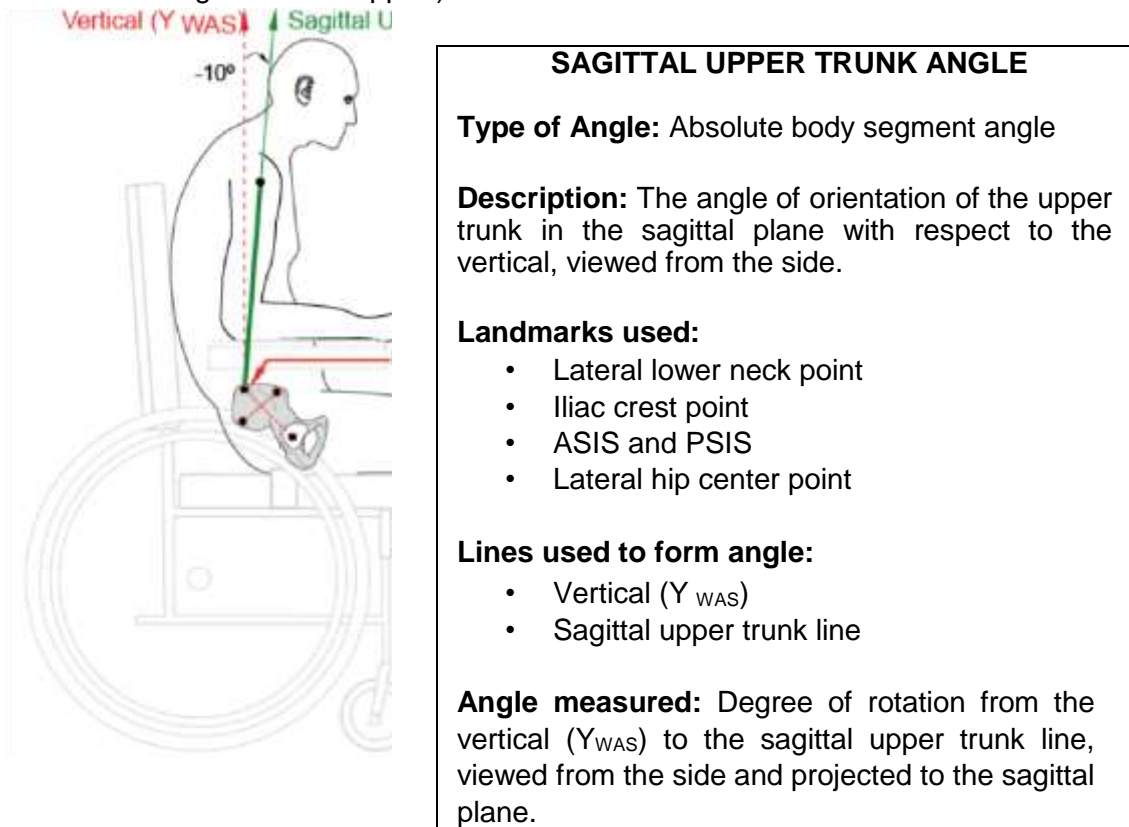


Fig. 2.20: Sagittal upper trunk angle

Sample Procedure:

1. Locate landmarks and sagittal upper trunk line

- a) Locate the lateral lower neck point.
 - *Lateral lower neck point* – location can be approximated by:
 - o The most anterior point on the acromion process if shoulder complex is well aligned with the trunk, or
 - o The center point of a line between the C7 spinous process and the upper sternal notch.
- b) Locate the Iliac crest point, which is the point where a perpendicular to the sagittal pelvic line crosses the iliac crest. To identify the iliac crest point:

- i. Locate the ASIS, PSIS and lateral hip center point. These anatomical landmarks are used to determine the iliac crest point.
- ii. Locate the sagittal pelvic line, which is the line passing through the ASIS and PSIS on the same side.
- iii. Locate the lateral hip center point – approximated by the greater trochanter.
- iv. Extend a line upward from the lateral hip center point so that it is perpendicular to the sagittal pelvic line. The point where this perpendicular line crosses the iliac crest is the iliac crest point.

Hint: Use a cross-shaped object (e.g. two sticks perpendicular to each other). Align one stick with sagittal pelvic line and then align the bottom of perpendicular stick with the lateral hip center point. The iliac crest point is located where the top of this stick crosses the iliac crest.

- c) Locate the *sagittal upper trunk line*, which is the line passing from the iliac crest point through the lateral lower neck point.

2. Measure angle

a) Using inclinometer or angle finder:

- i. Align the vertical straight edge of the inclinometer or angle finder along or parallel to the sagittal upper trunk line, and read the angle value.

b) Using a goniometer:

- i. Place the goniometer pivot center over the iliac crest point.
- ii. Align the stationary arm with the vertical reference line.
- iii. Align the moveable arm along the sagittal upper trunk line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the vertical reference line

- a) If the upper trunk is 'reclined' from the vertical (leaning back), signifying a posterior rotation of the upper trunk segment from the vertical, the value is positive.
- b) If the upper trunk is 'proclined' from the vertical (leaning forward), signifying an anterior rotation of the trunk segment relative to the vertical, the value is negative.

Typical values:

Values may range from positive 50 to negative 20 degrees, but for a seated individual are typically +20 to -10 degrees. When the person's upper trunk is fully upright and the sagittal upper trunk line is aligned with the vertical, this angle will be 0 degrees, as in the Seated Reference Position. Positive values would indicate upper trunk recline (shoulders behind pelvis), and negative values would indicate upper trunk procline (shoulders in front of pelvis).

Considerations:

- It is very difficult to reliably locate the iliac crest point, and therefore this measure may not be repeatable. The sagittal sternal angle has been shown in one study by Hirose [1] to be a reliable representation of the angle of the thoracic spine, and that measure can be used instead of this angle if desired.
- Note that this is an absolute angle, and therefore it does not give information about the degree of spinal extension or flexion or kyphosis/lordosis posture. However, by comparing the sagittal pelvic angle to the sagittal upper trunk angle, one can identify grossly extended or flexed spinal postures.

- For example, if the sagittal pelvic angle and sagittal upper trunk angle are the same, one could assume that the upper trunk is in line with the pelvis and the spine is in neutral alignment in the sagittal plane. Conversely, if the sagittal pelvic angle is +20 degrees, and the sagittal upper trunk angle is -10 degrees, the spine must be flexed.

3.9 Sagittal sternal angle

Purpose:

To provide an alternative method for documenting the existing or desired orientation of the upper trunk in the sagittal plane

Clinical Relevance:

This angular measure can be used to reflect the inclination of the thoracic spine in the sagittal plane. This is clinically relevant because deviations of the spine in this plane can have a significant effect on the seated user's posture, health and function and therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture.

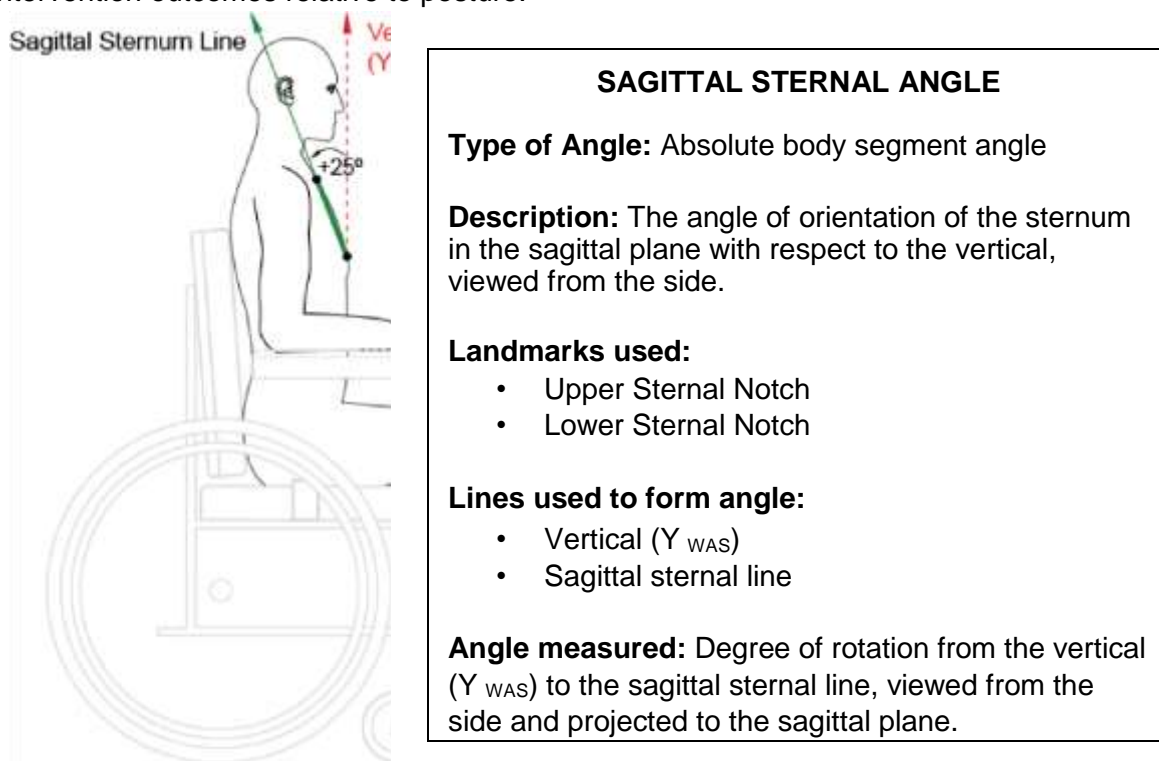


Fig. 2.21: Sagittal sternal angle

Sample Procedure:

1. Locate the landmarks and sagittal sternal line

- Identify the upper and lower sternal notches. The line passing through these points is the *sagittal sternal line*.
 - Upper sternal notch* - midpoint of the anterior surface at the top of the sternum (suprasternal notch).
 - Lower sternal notch* - midpoint of the anterior surface of the lower end of the sternum at the level of the base of the rib cage.

2. Measure angle

a) Using inclinometer or angle finder:

- i. Align the vertical straight edge of the inclinometer or angle finder along the sternum parallel to the sagittal sternal line, and read the angle.

b) Using goniometer:

- i. Place the goniometer pivot center over the lower sternal notch.
- ii. Align the stationary arm with the vertical.
- iii. Align the moveable arm parallel to the sagittal sternal line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the vertical reference line

- If the sternum is 'reclined' from the vertical (leaning back), signifying a posterior rotation of the sternum from the vertical, the value is positive.
- If the sternum is 'proclined' from the vertical (leaning forward), signifying an anterior rotation of the sternum relative to the vertical, the value is negative.

Typical values:

Values may range from positive 30 to negative 20 degrees. If the sternum is vertical, the value of this measure will be 0 degrees; however, due to the normal shape of the rib cage it is likely that the sagittal sternal angle is not zero in the Seated Reference Position, but rather a positive value. Positive values would indicate a 'recline' of the sternum and negative values would reflect a 'procline' of the sternum.

Considerations:

- This measure provides another method for describing the orientation of the upper trunk, similar to the sagittal upper trunk angle but perhaps easier to measure.
- Note that this is an absolute angle, and therefore it does not give information about the degree of spinal extension or flexion, kyphosis or lordosis. However, by comparing the sagittal sternal angle to the sagittal abdominal angle, one can identify grossly extended or flexed spinal postures. Research done in Japan by Hirose has indicated that the sagittal sternal angle correlates well to the inclination of the thoracic spine

[1].

- Due to the anatomy of the rib cage, if the sagittal sternal angle and sagittal abdominal angle are the same, one could assume that the spine is in some degree of flexion.

3.10 Sagittal abdominal angle

Purpose:

To document the inclination of the abdominal segment in the sagittal plane, as a reflection of lumbar spine posture

Clinical Relevance:

This angular measure is difficult to measure in the clinic; however it is included here because with more advanced measurement tools it may eventually allow measurement of the degree of kyphotic or lordotic postures without x-rays. This is clinically relevant because deviations of the spine in this plane can have a significant effect on the seated user's posture, health and function and therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture.



SAGITTAL ABDOMINAL ANGLE

Type of Angle: Absolute body segment angle

Description: The angle of orientation of the abdominal segment in the sagittal plane with respect to the vertical, viewed from the side.

Landmarks used:

- Lower Sternal Notch
- ASIS Midpoint

Lines used to form angle:

- Vertical (Y_{WAS})
- Sagittal abdominal line

Angle definition: Degree of rotation from the vertical (Y_{WAS}) to the sagittal abdominal line, viewed from the side and projected to the sagittal plane.

Fig. 2.22: Sagittal abdominal angle

Sample Procedure:

1. Locate the landmarks and sagittal abdominal line

- a) Identify the lower sternal notch and the midpoint between the right and left ASIS's, called the ASIS midpoint. The line from the ASIS midpoint passing up through the lower sternal notch is the *sagittal abdominal line*.
 - *Lower sternal notch* - midpoint of the anterior surface of the lower end of the sternum at the level of the base of the rib cage.
 - *ASIS midpoint* – midpoint of the line between the right ASIS and the left ASIS.
 - o This point is difficult to locate without software which allows calculation of the location from the right and left ASIS, because this point often lies inside the soft tissue of the body.

2. Measure angle

a) Using inclinometer or angle finder:

- i. Align the vertical straight edge of the inclinometer or angle finder along or parallel to the sagittal abdominal line, and read the angle.

b) Using goniometer:

- i. Place the goniometer pivot center over an approximation of the ASIS midpoint.
- ii. Align the stationary arm with gravitational vertical.
- iii. Align the moveable arm parallel to the sagittal abdominal line, pointing toward the lower sternal notch. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the vertical reference line

- If the abdominal line is 'reclined' from the vertical (leaning back), signifying a posterior rotation of the abdominal segment from the vertical, the value is positive.
- If the abdominal line is 'proclined' from the vertical (leaning forward), signifying an anterior rotation of the abdominal relative to the vertical, the value is negative.

Typical values:

Values may range from positive 10 to negative 40 degrees. If the sagittal abdominal line is vertical, the value of this measure will be 0 degrees; however, due to the normal shape of the rib cage it is likely that the sagittal abdominal angle is not zero in the Seated Reference Position, but rather a negative value. Negative values would indicate a more forward oriented abdominal/lumbar segment, and positive values would indicate a more reclined or posteriorly oriented abdominal/lumbar segment.

Considerations:

- This measure provides a way of characterizing the inclination of the lumbar spine while measuring from the front of the person.
- Note that this is an absolute angle, and therefore by itself it does not give information about the degree of spinal extension/flexion or kyphosis/lordosis. However, by comparing the sagittal abdominal angle to the sagittal sternal angle, one can identify grossly extended or flexed spinal postures.
- Due to the anatomy of the rib cage, if the sagittal sternal angle and sagittal abdominal angle are the same, one could assume that the spine is in some degree of flexion.

3.11 Sagittal lower leg angle

Purpose:

To document the existing or desired orientation of the lower leg in the sagittal plane

Clinical Relevance:

This angle can be used to quantify the orientation of the lower leg as an individual segment, as an alternative to documenting the relative angles of thigh to lower leg or lower leg to foot. This angle can also be used to help determine the location of the foot support and/or the sagittal lower leg support angle.



SAGITTAL LOWER LEG ANGLE

Type of Measurement: Absolute body segment angle, left and right

Description: The angle of orientation of the lower leg in the sagittal plane with respect to the vertical, viewed from the side.

Landmarks used:

- Lateral femoral condyle
- Lateral malleolus

Lines used to form angle:

- Vertical (Y_{WAS})
- Sagittal lower leg line

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the sagittal lower leg line, viewed from the side and projected to the sagittal plane.

Fig. 2.23: Sagittal lower leg angle

Sample Procedure:

1. Locate the body landmarks and segment line

- a) Identify the lateral femoral condyle and lateral malleolus. The line passing through these two points is the *sagittal lower leg line*.
 - *Lateral femoral condyle* - point at most lateral aspect of the lateral femoral condyle.
 - *Lateral malleolus* - point at most lateral aspect of lateral malleolus.
 - *Sagittal lower leg line* – the line passing through the lateral femoral condyle and the lateral maleollus.

2. Measure angle

- a) Using a goniometer
 - i. Place the goniometer pivot center over the lateral malleolus.
 - ii. Align the stationary arm with gravitational vertical.
 - iii. Align the moveable arm along the sagittal lower leg line. Read the angle value.

Alternatively, you can place the goniometer center at the knee and point the arms of the goniometer downward towards the ankle. The resulting angle value will be the same.

- b) Using inclinometer or angle finder

- i. Align the vertical straight edge of the inclinometer or angle finder along or parallel to the sagittal lower leg line, and read the angle.

3. Determine positive or negative value based on the direction of rotation from the vertical reference line

- If the distal end of the lower leg is forward (ankle more anterior than knee), the value is positive.
- If the distal end of the lower leg is rearward (ankle more posterior than knee), the value is negative.

Typical values:

If the lower leg is perpendicular to the ground, or in line with the vertical, as in the Seated Reference Position, the sagittal lower leg angle value is 0. Values may range from positive 90 (lower leg is horizontal) to negative 30 degrees, but for a seated person in a non-tilting wheelchair typical values are +30 to -10 degrees.

Considerations:

- This angle will be affected by, but may not be the same as, the lower leg support sagittal angle.
- Note that this is an absolute angle, and thus does not give information about the relative angles at the knee and ankle joint (as measured by the thigh to lower leg angle and lower leg to foot angle). The sagittal lower leg angle can change with or without a change in the thigh to lower leg angle (see Figs.

2.14a and 2.14b).

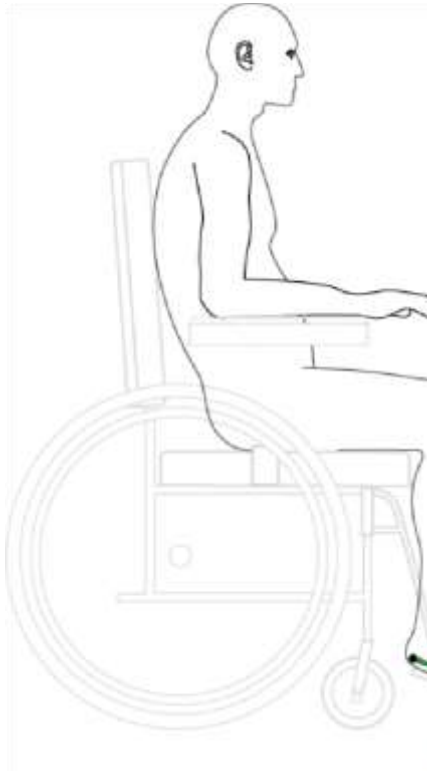
3.12 Sagittal foot angle

Purpose:

To document the existing or desired orientation of the foot in the sagittal plane

Clinical Relevance:

This angle can be used to quantify the orientation of the foot as an individual segment, as an alternative to documenting the relative lower leg to foot angle. This angle can also be used to help determine the desired orientation of the foot support.



SAGITTAL FOOT ANGLE

Type of Measurement: Absolute body segment angle, left and right

Description: The angle of orientation of the foot in the sagittal plane with respect to the horizontal, viewed from the side.

Landmarks used:

- Lateral heel point
- Lateral toe point

Lines used to form angle:

- Horizontal (X_{WAS})
- Sagittal foot line

Angle definition: The degree of rotation from the horizontal (X_{WAS}) to the sagittal foot line, viewed from the side and projected to the sagittal plane.

Fig. 2.24: Sagittal foot angle

Sample Procedure:

1. Locate the landmarks and sagittal foot line

- a) Identify the lateral heel point and the lateral toe point. The line passing through these two points is the *sagittal foot line*.
 - *Lateral heel point* - intersection of sagittal lower leg line and plantar surface of the foot.
 - o To locate the lateral heel point, extend the sagittal lower leg line (line from lateral femoral condyle at knee to lateral malleolus at ankle) down to the bottom of the foot.
 - *Lateral toe point* - the lateral distal protuberance of the fifth metatarsal.

2. Measure angle

- a) Using inclinometer or angle finder
 - i. Align the horizontal straight edge of the inclinometer or angle finder along or parallel to the sagittal foot line, and read the angle value.
- b) Using goniometer
 - i. Place the goniometer pivot center over the lateral heel point.
 - ii. Align the stationary arm with the horizontal.
 - iii. Align the moveable arm along or parallel to the sagittal foot line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the foot is 'inclined' from the horizontal (angling upward), the value is positive.
- If the foot is 'declined' from the horizontal (angling downward), the value is negative.

Typical values:

If the foot is parallel to the ground, as in the Seated Reference Position, the angle is 0 degrees. Values may range from positive 90 (lower leg is horizontal, foot is vertical) to negative 30 degrees, but for a seated person in a non-tilting wheelchair typical values are + 30 to - 10 degrees.

Considerations:

- Note that this is an absolute angle, and thus does not necessarily give information about the degree of ankle dorsiflexion or plantarflexion, as represented by the lower leg to foot angle. For example, elevating the whole lower leg (changing the sagittal lower leg angle) will result in a change in the sagittal foot angle as well, without a change in lower leg to foot angle.
- If the lower leg is perpendicular to the ground (sagittal lower leg angle zero degrees), a negative sagittal foot angle would indicate that the ankle is plantarflexed, and a positive sagittal foot angle would indicate that the ankle is dorsiflexed.
- This angle will be affected by, but may not be the same as, the foot support sagittal angle.

4 Absolute Body Segment Angles in Frontal Plane

4.1 General instructions

All absolute, frontal body segment angles are determined by viewing the subject from the front, as these angles reflect rotations of a single body segment around the X-axis in the frontal (YZ) plane. The value of an absolute angle is the degree of rotation of the local body segment line away from its zero reference position as defined in the Seated Reference position (SRP). By definition, all frontal body segment lines align with either the vertical or horizontal in the SRP. **Therefore, all absolute frontal body segment angles are determined by measuring the angle between either the horizontal or vertical and the frontal body segment line.** When the body is in the SRP, all frontal absolute angles are zero. If the frontal body segment line is aligned with the *horizontal* in the SRP, then the zero reference line is the horizontal. If the frontal body segment line is aligned with the *vertical* in the SRP, then the zero reference line is the vertical. One can always take a perpendicular to the body segment line and compare it to the alternate reference, as the value will be the same. Remember that when a body segment is deviated in more than one plane at the same time, its segment line is projected to the frontal plane for measurement of the frontal body segment angle.

4.1.1 Determining whether frontal angles are positive or negative using the right hand rule convention (see Chapter 1, Section 4.3.3)

When a body segment deviates from the Seated Reference Position in the frontal plane, this represents a rotation of that segment in the frontal plane about the X-axis. To determine whether the angle is positive or negative, curl the fingers of your right hand in the direction of rotation that the body segment has deviated from the neutral Seated Reference Position. If your thumb is pointing forward in line with the positive +X-axis, the frontal angle is positive. If your thumb is pointing towards the rear of the person (opposite direction from the +X-axis, in line with the negative -X-axis) the frontal angle is negative. If you are standing in front of the person to view deviations in the frontal plane, rotations in a counter clockwise direction from this view will always be positive, and rotations in a clockwise direction are negative. This means that a tilt or rotation of a body segment above the hips to the person's right is positive, and a tilt to the person's left is negative. This is reversed for body segments below the hips (lower leg and foot); for example, a rotation of the lower leg to the right would be negative, and to the left would be positive.

4.2 Locating the gravitational vertical or horizontal reference line

If you are using an inclinometer or angle finder, these tools automatically align their zero reference with either the vertical or horizontal. If you are using a goniometer, this can be done by sighting along a line which you know is vertical or horizontal, or by using a goniometer with a bubble level attached to the stationary arm.

4.3 Frontal pelvic angle

Purpose:

To document the existing or desired orientation of the pelvis in the frontal plane

Clinical Relevance:

This angular measure is used to quantify what is also referred to as a "pelvic obliquity". This measure is important clinically because asymmetries of the pelvis in this plane can have a significant affect on a seated

person's upper body posture, comfort and function as well as risk of skin breakdown from differential loading of the ischials, buttocks and thighs.



FRONTAL PELVIC ANGLE

Type of Angle: Absolute body segment angle

Description: The angle of orientation of the pelvis with respect to the horizontal, viewed from the front.

Landmarks used:

- Right ASIS
- Left ASIS

Lines used to form angle:

- Horizontal (Z_{WAS})
- Frontal pelvic line

Angle definition: Degree of rotation from the horizontal (Z_{WAS}) to the frontal pelvic line, viewed from the front and projected to the frontal plane.

Fig. 2.25: Frontal pelvic angle

Sample Procedure:

1. Locate the landmarks and frontal pelvic line

- a) Palpate the right and left ASIS's, and locate the line between them which is the *frontal pelvic line*.
 - *Right ASIS* - the most anterior inferior prominence of the right anterior superior iliac spine projected to the anterior surface of the body.
 - *Left ASIS* - the most anterior inferior prominence of the left anterior superior iliac spine projected to the anterior surface of the body.

2. Measure angle

a) Using an inclinometer or angle finder

- i. Place the horizontal straight edge of the inclinometer or angle finder along or parallel to the frontal pelvic line, and read the angle value.

b) Using a goniometer

- i. Standing in front of person, place the goniometer pivot center over the left ASIS.
- ii. Align the stationary arm with the horizontal pointing towards the person's right side.
- iii. Align the moveable arm along or parallel to the frontal pelvic line. Read the angle value.

Note: You can also place the goniometer pivot center over the right ASIS and point the arms of the goniometer to the person's left side. The angle value will be the same.

3. Determine positive or negative value based on the direction of rotation away from the horizontal reference line

- If the right ASIS is lower than the left ASIS, indicating a counterclockwise rotation as viewed from the front, the value is positive.
- If the right ASIS is higher than the left ASIS, indicating a clockwise rotation as viewed from the front of the person, the value is negative.

Typical values:

If the pelvis is "level" in the frontal plane the value of this measure will be 0 degrees because the frontal pelvic line will be aligned with the horizontal, as in the Seated Reference Position. Positive values reflect what is commonly known as a right pelvic obliquity (right ASIS lower than the left as in Fig. 2.26) and negative values reflect what is commonly known as a left pelvic obliquity (left ASIS lower than the left, as in Fig. 2.25).

Considerations:

- If the frontal pelvic angle is not 0 degrees, this indicates an asymmetry of the pelvis in this plane, and this measure is an indication of the magnitude of the asymmetry. This information can help in the appropriate prescription of a seat support surface which is intended to accommodate the asymmetry.
- This measure is also important in that it provides an indicator of the differential loading likely to be occurring through the ischial tuberosities, buttocks and thighs.
- When taken both before and after seating intervention, this measure could provide an objective measure of postural change.
- This measure will be affected by any change in the seat support frontal angle, such as that which may occur in a wheelchair with a lateral tilt adjustment.

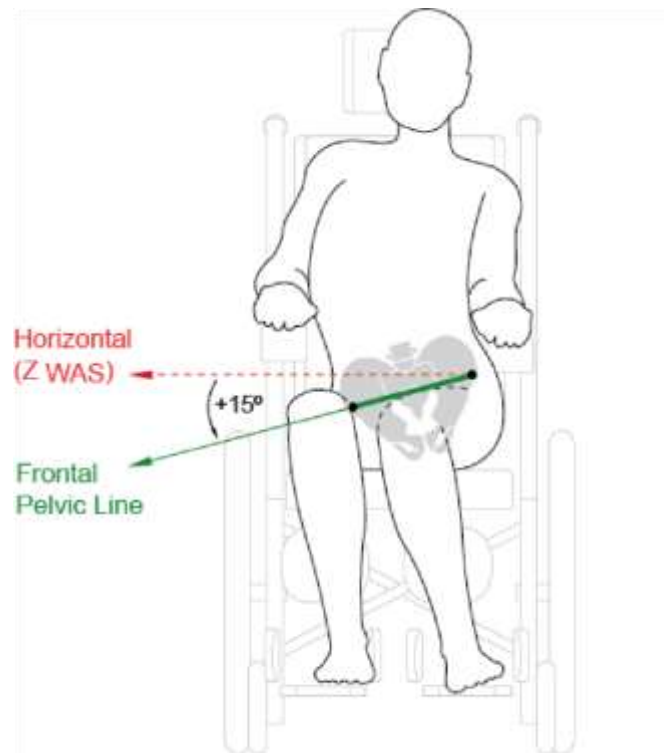


Fig. 2.26: Frontal pelvic angle, positive

4.4 Frontal sternal angle

Purpose:

To document the existing or desired orientation of the upper trunk in the frontal plane

Clinical Relevance:

This angular measure is used to quantify the degree of lateral tilt or lean of the upper trunk in the frontal plane, which is often a reflection of an underlying scoliosis. A deviation of the upper trunk in this plane can have a significant effect on the seated user's posture, health and function and therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture.



FRONTAL STERNAL ANGLE

Type of Angle: Absolute body segment angle

Description: The angle of orientation of the upper trunk with respect to the vertical, viewed from the front.

Landmarks used:

- Upper sternal notch
- Lower sternal notch

Lines used to form angle:

- Vertical (Y_{WAS})
- Frontal sternal line

Angle definition: Degree of rotation from the vertical (Y_{WAS}) to the frontal sternum line, viewed from the front and projected to the frontal plane.

Fig. 2.27: Frontal sternal angle

Sample Procedure:

1. Locate landmarks and the frontal sternal line

- Palpate the upper and lower boundaries of the sternum to identify the upper and lower sternal notches. The line passing through these two points is the *frontal sternal line* (parallel to the sternum itself).
 - *Upper sternal notch* - midpoint of the anterior surface at the top of the sternum (suprasternal notch).
 - *Lower sternal notch* - midpoint of the anterior surface of the lower end of the sternum at the level of the base of the rib cage.

2. Measure angle

- Using an inclinometer or angle finder

b) Using a goniometer

- i.
- i. Place the vertical straight edge of the inclinometer or angle finder along or parallel to the frontal sternal line, and read the angle value.
Place the goniometer pivot center over the lower sternal notch (lowest portion of the sternum).
- ii. Align the stationary arm with the vertical. iii. Align the moveable arm along or parallel to the frontal sternal line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation away from the vertical reference line

- If the top of the sternum is tilted to the person's right, indicating a counterclockwise rotation as viewed from the front, the value is positive.
- If the top of the sternum is tilted to the person's left, indicating a clockwise rotation as viewed from the front of the person, the value is negative.

Typical values:

If a person's upper trunk (as reflected by the sternum) is in line with gravitational vertical, this measure will be 0 degrees, as in the Seated Reference Position. A positive angle would indicate a lateral upper trunk lean to the person's right side and a negative angle would indicate a lateral upper trunk lean to the person's left side.

Considerations:

- The orientation of the sternum in the frontal plane will approximate the orientation of the upper torso or thoracic spine in the frontal plane, unless there are gross deformities of the sternum and/or rib cage.
- This measure is done using the frontal sternum line because it would be difficult to measure the orientation of the trunk along the thoracic spine of a person seated in a wheelchair.
- Note that the frontal sternal angle is an absolute angle and thus describes the orientation of the upper trunk with respect to the vertical and not relative to the pelvis or lower trunk segment. Therefore, this measure does not necessarily reflect the degree of lateral trunk flexion or spinal curve, unless one compares the frontal pelvic angle to the frontal sternal angle.
- This angle may be affected by a seat that is not level in the frontal plane.
- This measure may also be used to help determine and justify back support characteristics and the need for secondary supports to either prevent or accommodate an asymmetry.

4.5 Frontal trunk angle

Purpose:

To document the existing or desired orientation of the whole trunk in the frontal plane

Clinical Relevance:

This angular measure can be used to quantify the degree of lateral tilt or lean of the whole trunk relative to the location of the pelvis, in the frontal plane. A deviation of the trunk in this plane can have a significant effect on the seated user's posture, health and function and therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture.

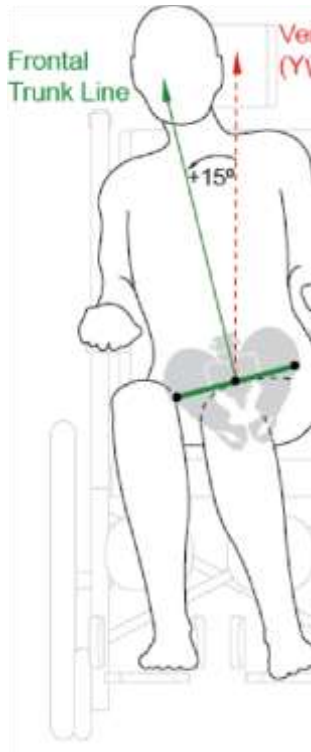


Fig. 2.28: Frontal trunk angle

FRONTAL TRUNK ANGLE

Type of Angle: Absolute body segment angle

Description: The angle of orientation of the whole trunk with respect to the vertical, viewed from the front.

Landmarks used:

- Upper sternal notch
- ASIS midpoint

Lines used to form angle:

- Vertical (Y_{WAS})
- Frontal trunk line

Angle definition: Degree of rotation from the vertical (Y_{WAS}) to the frontal trunk line, viewed from the front and projected to the frontal plane.

Sample Procedure:

1. Locate the landmarks and frontal trunk line

- a) Identify the upper sternal notch and ASIS midpoint. The line connecting the ASIS midpoint to the upper sternal notch is the *frontal trunk line*.
 - *ASIS Midpoint* - midpoint of the line between the right ASIS and left ASIS.
 - *Upper sternal notch* - midpoint of the anterior surface at the top of the sternum (suprasternal notch).

2. Measure angle

a) Using an inclinometer or angle finder

- i. Place the vertical straight edge of the inclinometer or angle finder along or parallel to the frontal trunk line, and read the angle value.

Place the goniometer pivot center over the ASIS midpoint.

- ii. Align the stationary arm with the vertical.
- iii. Align the moveable arm along or parallel to the frontal trunk line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation away from the vertical reference line

- If the top of the sternum is located to the person's right relative to the ASIS midpoint (as in Fig. 2.28), indicating a counter clockwise rotation as viewed from the front of the person, the value is positive.

b) Using a goniometer

- i.
 - If the top of the sternum is located to the person's left relative to the ASIS midpoint, indicating a clockwise rotation as viewed from the front, the value is negative.

Typical values:

If the frontal trunk line is in line with gravitational vertical, this measure will be 0 degrees, as in the Seated Reference Position. A positive angle would indicate an overall trunk lean or shift to the person's right side and a negative angle would indicate an overall trunk lean to the person's left side.

Considerations:

- Note that the frontal trunk angle is an absolute angle and thus describes the orientation of the whole trunk with respect to the vertical. Therefore, this measure does not necessarily reflect the degree of lateral trunk flexion or spinal curve, unless one compares the frontal pelvic angle to the frontal trunk angle.
- This angle may be affected by a seat that is not level in the frontal plane.
- Because the ASIS midpoint grossly represents the center of the buttocks, and the upper sternal notch grossly represents the center of the upper trunk, this measure can provide an indication of functional balance in the frontal plane. If the frontal trunk angle is not zero, this can indicate that the person's trunk is shifted to the right or left of their buttocks. Alternatively, Fig. 2.29 shows an individual who presents with a scoliosis, however the frontal trunk angle is zero, indicating a functionally balanced posture.
- This measure may also be used to help determine and justify back support characteristics and the need for secondary supports to either prevent or accommodate an asymmetry or position of imbalance.

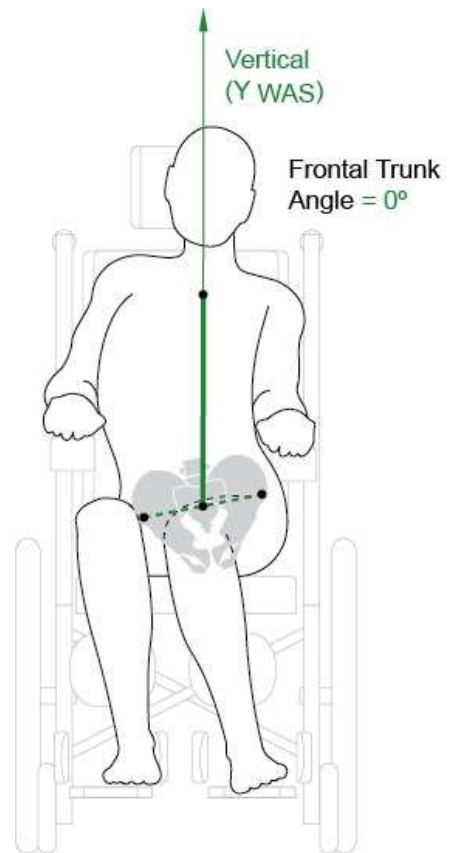


Fig. 2.29: Frontal trunk angle = 0, with scoliosis

4.6 Frontal head angle

Purpose:

To document the existing or desired orientation of the head in the frontal plane

Clinical Relevance:

This angular measure is used to quantify a deviation of the head posture in the frontal plane, which may be a reflection of an underlying fixed cervical spinal curve. This is clinically relevant because fixed deviations of the head in this plane can have a significant effect on the seated user's posture, health and function and

therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture. This angle could also help determine the orientation of the head support in the frontal plane when significant fixed deviations are present.

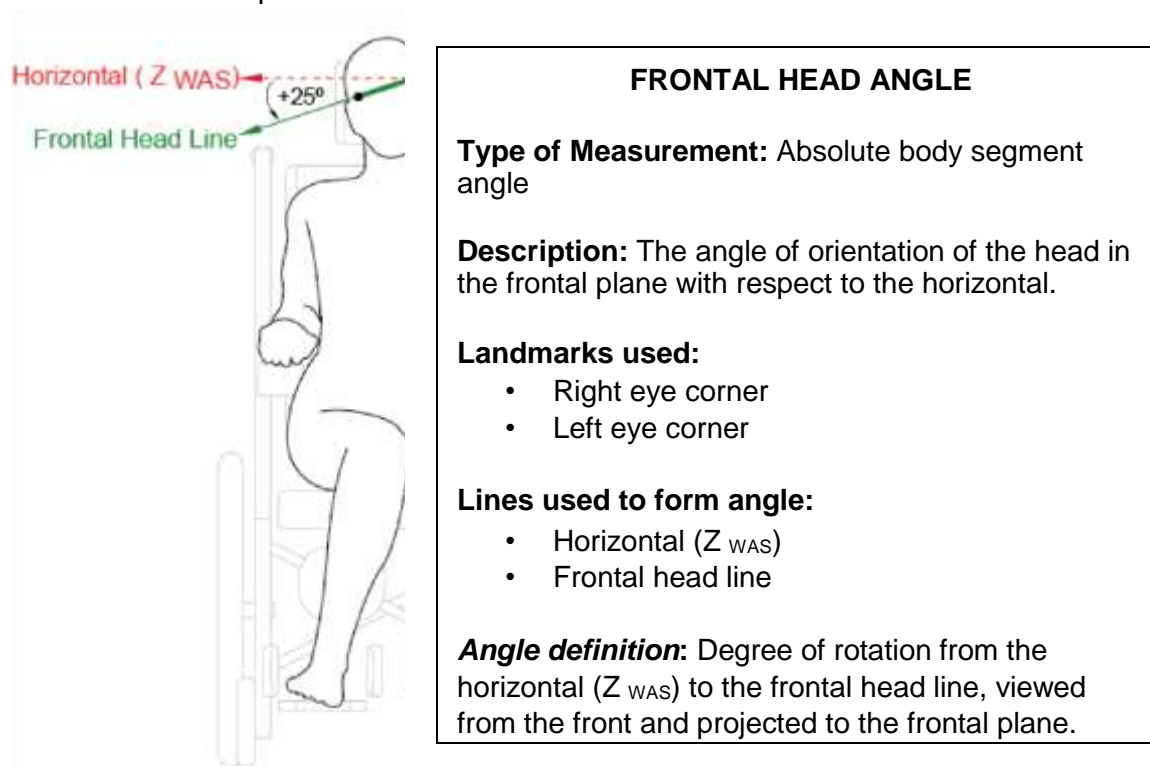


Fig. 2.30: Frontal head angle

Sample Procedure:

1. Locate the landmarks and frontal head line

- a) Locate the right and left eye corners. The line connecting these two points is the *frontal head line*.
 - *Right eye corner* - lateral corner of the right eye formed by the meeting of the upper and lower eyelids.
 - *Left eye corner* - lateral corner of the left eye formed by the meeting of the upper and lower eyelids.

2. Measure angle

- a) Using an inclinometer or angle finder
 - i. Place the horizontal straight edge of the inclinometer or angle finder along or parallel to the frontal head line, and read the angle value.

Using a goniometer

- i.
- b.
 - Place the goniometer pivot center over the left eye corner, or at the left end of the frontal head line.
 - ii. Align the stationary arm with the horizontal, pointing to the right side of the person.
 - iii. Align the moveable arm along or parallel to the frontal head line. Read the angle value.

3. Determine positive or negative value based on the direction of rotation away from the horizontal reference line

- If the head is tilted to the right (right eye lower than left), indicating a counterclockwise rotation as viewed from the front, the value is positive.
- If the head is tilted to the left (left eye lower than right), indicating a clockwise rotation as viewed from the front, the value is negative.

Typical values:

If the frontal head line is 'level', or horizontal, the frontal head angle is 0 degrees as in the Seated Reference Position. Positive values indicate that the head is tilted to the person's right, and negative values indicate that the head is tilted to the person's left.

Considerations:

- The frontal head angle is a measure of the orientation of the head relative to the horizontal, and not a measure of the orientation of the head relative to the neck or trunk which reflects lateral neck flexion.

Therefore, a change in the frontal head angle may occur with or without lateral neck flexion.

- For example, if the trunk is tilted the same degree as the head in this plane relative to the horizontal (frontal trunk and head angles are the same) then one can assume that there is no lateral neck flexion – even if the frontal head angle is not zero.

4.7 Frontal lower leg angle**Purpose:**

To document the existing or desired orientation of the lower leg in the frontal plane

Clinical Relevance:

This measure is clinically relevant because deviations of the lower leg in this plane may indicate a position of abnormal rotation in the hip. This measure can also be used to help determine the location and orientation of the foot supports.

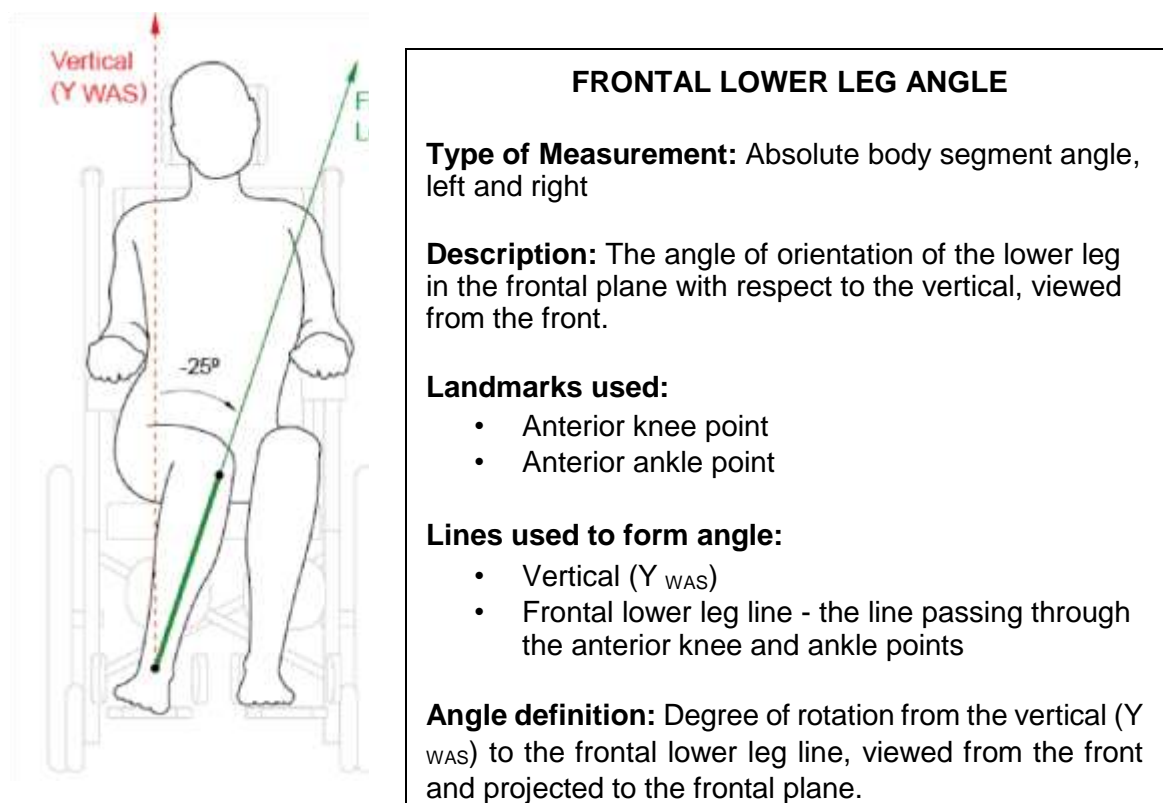


Fig. 2.31: Frontal lower leg angle

Sample Procedure:

1. Locate the body landmarks and frontal lower leg line

- Identify the anterior knee point and the anterior ankle point. *The frontal lower leg line is the line connecting these two center points.*
 - *Anterior knee point* - the midpoint between the medial and lateral femoral condyles, projected to the anterior surface of the knee (approximately the mid patella).
 - *Anterior ankle point* - the midpoint between the medial and lateral malleoli projected to the anterior surface of the ankle.

2. Measure angle

a) Using an inclinometer or angle finder

- Place the vertical straight edge of the inclinometer or angle finder along or parallel to the frontal lower leg line and read the angle value.

b) Using a goniometer

- Place the goniometer pivot center over the anterior ankle point.
- Align the stationary arm with the vertical projecting upwards.
- Align the moveable arm along or parallel to the frontal lower leg line, projecting upwards. Read the angle value.

Alternatively, you can place the goniometer center at the knee and point the arms of the goniometer downward. The resulting angle value will be the same.

3. Determine positive or negative value based on the direction of rotation away from the vertical reference line:

- If the foot is positioned to the left of the knee, indicating a counterclockwise rotation as viewed from the front, the value is positive.
- If the foot is positioned to the right of the knee, indicating a clockwise rotation as viewed from the front of the person, the value is negative.

Typical values:

If the lower leg is perpendicular to the ground, as in the Seated Reference Position, the frontal lower leg angle is 0 degrees because the frontal lower leg line is aligned with the vertical. Positive values indicate that the lower leg is rotated to the person's left, and negative values indicate that the lower leg is rotated to the person's right.

Considerations:

- Note that this is an absolute angle, and therefore by itself is not an accurate indication of the degree of internal/external hip rotation. For example, if the pelvis is angled in the frontal plane an equal degree, there may be no hip rotation even though the lower leg is rotated with respect to the vertical.
- However, if the pelvis is level (frontal pelvic angle of 0 degrees), a *negative* frontal lower leg angle would indicate external rotation of the left hip and internal rotation of the right hip (Fig. 2.32).
- If the pelvis is level (frontal pelvic angle of 0 degrees), a *positive* frontal lower leg angle would indicate internal rotation of the left hip and external rotation of the right hip (Fig. 2.33).

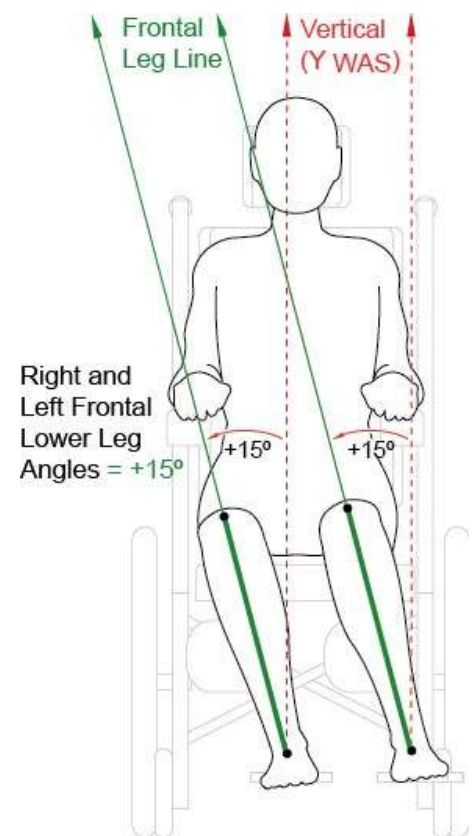
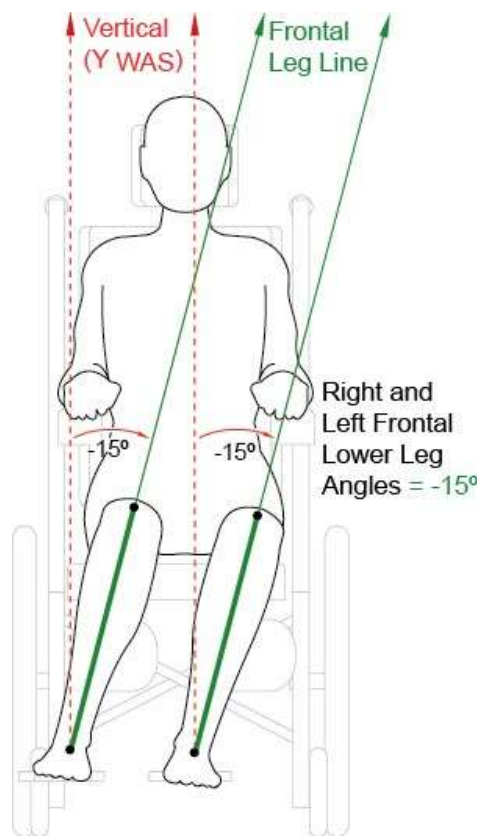


Fig. 2.32: Lower legs windswept to right

Fig. 2.33 Lower legs windswept to left

4.8 Frontal foot angle

Purpose:

To document the existing or desired orientation of the foot in the frontal plane

Clinical Relevance:

This measure is clinically relevant because deviations of the foot in this plane may indicate either a deformity of the ankle joint, or an asymmetrical orientation of the lower leg. This measure can also be used to help determine the orientation of the foot support in the frontal plane (foot support frontal angle).

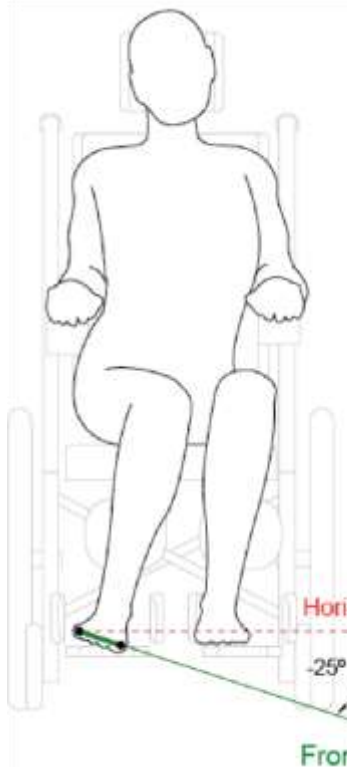


Fig. 2.34: Frontal foot angle

FRONTAL FOOT ANGLE

Type of Measurement: Absolute body segment angle, left and right

Description: The angle of orientation of the foot in the frontal plane with respect to the horizontal, viewed from the front.

Landmarks used:

- Medial foot point
- Lateral foot point

Lines used to form angle:

- Horizontal (Z_{WAS})
- Frontal foot line

Angle measured: Degree of rotation from the horizontal (Z_{WAS}) to the frontal foot line, viewed from the front and projected to the frontal plane.

Sample Procedure:

1. Locate the body landmarks and frontal foot line

- Locate the medial and lateral foot points. The line passing through these points (on bottom surface of foot) is the *frontal foot line*.
 - *Medial foot point* - the inferior border of the distal head of the first metatarsal.
 - *Lateral foot point* - the inferior border of the distal head of the fifth metatarsal.
 - *The frontal foot line can be simulated by placing a firm flat surface under the foot which is parallel to the line connecting the medial and lateral foot points.*

2. Measure angle

a) Using an inclinometer or angle finder

- Place the horizontal straight edge of the inclinometer or angle finder along the surface under the foot or parallel to the frontal foot line and read the angle value.

b) Using a goniometer

- i. Place the goniometer pivot center over the midpoint of the frontal foot line, or at the left side of the surface under the foot.
- ii. Align the stationary arm with the horizontal reference, pointing to the right side of the person.
- iii. Align the moveable arm along or parallel to the frontal foot line, projecting to the right. Read the angle value.

3. Determine positive or negative value based on the direction of rotation away from the vertical reference line

- If the inferior surface of the foot is tilted down on the right, indicating a counterclockwise rotation as viewed from the front, the value is positive.
- If the inferior surface of the foot is tilted down on the left side, indicating a clockwise rotation as viewed from the front of the person, the value is negative.

Typical values:

If the plantar surface of the foot is parallel to the ground, as in the Seated Reference Position, the frontal foot angle is 0 degrees.

Considerations:

- Note that this is an absolute angle, and therefore by itself is not an accurate indication of the degree of ankle inversion/eversion or hip internal/external rotation.
- This angle will be affected by the frontal lower leg angle. If the frontal lower leg angle changes, this will result in an equal change in the frontal foot angle if the ankle joint posture remains the same.
- If the frontal lower leg angle is 0, a positive frontal foot angle would indicate eversion of the left ankle and inversion of the right ankle.
- If the frontal lower leg angle is 0, a negative frontal foot angle would indicate a position of inversion of the left ankle and eversion of the right ankle.

5 Absolute Body Segment Angles in Transverse Plane

5.1 General instructions

All absolute, transverse body segment angles are determined by viewing the subject from above, as these angles reflect rotations of a single body segment around the vertical Y-axis in the transverse (XZ) plane. Contrary to angles in the sagittal and frontal planes, rotations of a body segment in the transverse plane must be measured relative to an external reference other than the vertical or horizontal. The external reference for transverse angles is the wheelchair frame.

The value of an absolute body angle is the degree of rotation of the local body segment line away from its zero reference position as defined in the Seated Reference position (SRP). When the body is in the SRP, all transverse body segment lines are aligned with either the X or Z axis of the Wheelchair Axis System (WAS). **Therefore, all transverse body segment angles are determined by measuring the angle between the transverse body segment line and the wheelchair X or Z axis.** If the transverse body segment line is aligned with the forward projecting Wheelchair X-axis (X_{WAS}) in the SRP, then the zero reference line is the X_{WAS} . If the transverse body segment line is aligned with the Wheelchair Z-axis (Z_{WAS}) in the SRP, then the zero reference line is the Z_{WAS} . Remember, one can always take a perpendicular to the body segment line and compare it to the alternate reference, as the value will be the same. When a body segment is deviated in more than one plane at the same time, its segment line is projected to the transverse plane for measurement of the transverse body segment angle.

According to the right hand grip rule convention (see Chapter 1, Section 4.3.3), if you are viewing the person from above, rotations in a counterclockwise direction are positive, and rotations in a clockwise direction are negative. This means that rotation of a body segment to the person's left is positive, and a rotation to the person's right is negative.

5.2 Locating the wheelchair X-axis or Z-axis reference lines

The wheelchair Z-axis (Z_{WAS}) lies on the line passing through the rear wheel axles of the wheelchair. The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the Z axis.

To locate and sight to these reference axes for measures in the transverse plane, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis. You can then sight to these lines on the floor when measuring transverse angles; or you can sight to a structure on the wheelchair which you know is parallel to one of these axes.

If you are measuring transverse body segment angles with the person sitting on a mat table, you can use the front edge of the mat table to simulate the Z-axis of the WAS.

5.3 Transverse pelvic angle

Purpose:

To document the existing or desired orientation of the pelvis in the transverse plane

TRANSVERSE PELVIC ANGLE

Type of Angle: Absolute body segment angle

Description: The angle of orientation of the pelvis in the transverse plane with respect to the wheelchair frame, viewed from the top.

Landmarks used:

- Right ASIS
- Left ASIS

Lines used to form angle: □

- Wheelchair Z-axis (Z_{WAS})
- Transverse pelvic line

Angle defined: Degree of rotation from the Wheelchair Z-axis (Z_{WAS}) to the transverse pelvic line, viewed from the top and projected to the transverse plane.

Clinical Relevance:

This angular measure is used to quantify what is referred to as pelvic rotation. This is clinically relevant because

deviations of the pelvis in this plane can have a significant effect on the seated user's posture, health and function and therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture.

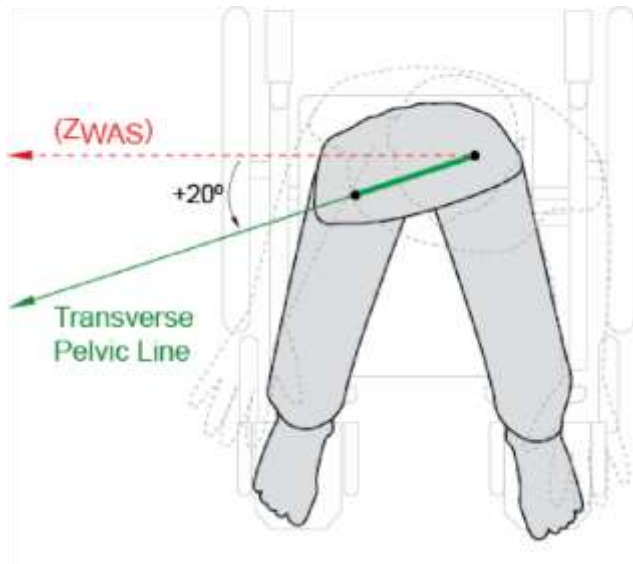


Fig. 2.35: Transverse pelvic angle

Sample Procedure:

1. Locate the wheelchair Z-axis (Z_{WAS})

- a) To locate the Z-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis.
- b) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair Z-axis, such as the back edge of the seat pan, or a line between the back canes.

2. Locate the body landmarks and transverse pelvic line

- a) Palpate the right and left ASIS's and extend a line between them. This is the *transverse pelvic line*.
 - *Right ASIS* - the most anterior inferior prominence of the right anterior superior iliac spine projected to the anterior surface of the body.
 - *Left ASIS* - the most anterior inferior prominence of the left anterior superior iliac spine projected to the anterior surface of the body.

3.

Measure angle using a goniometer

- a) Place the goniometer pivot center over the left ASIS if you are facing the seated person.
(Alternatively, you can place the goniometer pivot center over the right ASIS with the arms facing to the person's left. The angle value will be the same.)
- b) Align the stationary arm parallel to the wheelchair Z-axis.
- c) Align the moveable arm along or parallel to the transverse pelvic line. Read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair Z-axis

- If the left ASIS is posterior to the right ASIS, indicating a counterclockwise left rotation as viewed from the top, the value is positive.
- If the left ASIS is forward of the right ASIS, indicating a clockwise right rotation as viewed from the top of the person, the value is negative.

Typical values:

A value of 0 degrees would indicate that the transverse pelvic line is parallel to the wheelchair Z-axis, as in the Seated Reference Position, and the pelvis is not rotated. Positive values indicate a left pelvic rotation (right ASIS is farther forward than the left), and negative values indicate a right pelvic rotation (left ASIS farther forward than right).

Considerations:

- Note that the transverse pelvic angle is an absolute angle and thus describes the orientation of the pelvis with respect to the wheelchair (and most likely the seating system) and not relative to the trunk. Therefore, this measure does not necessarily reflect the degree of spinal rotation, unless one compared the transverse trunk angle to the transverse pelvic angle.
- If the transverse pelvic angle is not 0 degrees, this indicates an asymmetry of the pelvis in this plane relative to the wheelchair, and this measure is an indication of the magnitude of the asymmetry. This information can help in the appropriate prescription of a seat support and/or back support surface which accommodates the asymmetry.
- When taken both before and after seating intervention, this measure could provide an objective measure of postural change.
- A transverse pelvic angle that is not equal to 0 degrees may also result in a functional leg length discrepancy in which one femur appears to extend farther forward than the other, possibly necessitating an unequal seat depth configuration.

5.4 Transverse trunk angle

Purpose:

To document the existing or desired orientation of the trunk in the transverse plan

Clinical Relevance:

This angular measure is used to quantify what has been commonly referred to as trunk rotation. This is clinically relevant because deviations of the trunk in this plane can have a significant effect on the seated person's posture, health and function and therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture.

Type of Angle: Absolute body segment angle

Description: The angle of orientation of the trunk in the transverse plane with respect to the wheelchair, viewed from the top.

Landmarks used:

- Right Acromion Point
- Left Acromion Point

Lines used to form angle: □

- Wheelchair Z-axis (Z_{WAS})
- Transverse trunk line

Angle definition: The degree of rotation from the wheelchair Z-axis (Z_{WAS}) to the transverse trunk line, viewed from the top and projected to the transverse plane.

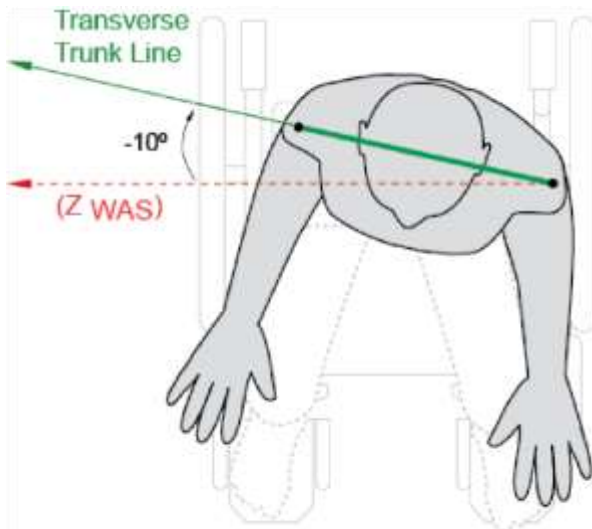


Fig. 2.36:

Transverse trunk angle

Sample Procedure:

1. Locate the wheelchair Z-axis (Z_{WAS})

- a) To locate the Z-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis.
- b) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair Z-axis, such as the back edge of the seat pan, or a line between the back canes.

2. Locate the body landmarks and transverse trunk line

- a) Locate the right and left acromion points. The *transverse trunk line* is a line passing through both acromion points.
 - *Right Acromion Point* - the most anterior - lateral prominences of the left acromion process.
 - *Left Acromion Point* - the most anterior - lateral prominences of the left acromion process.

Measure angle (using a goniometer)

- a) Standing behind the person, place the goniometer pivot center over the left acromion point. (Alternatively, you can place the goniometer pivot center over the right acromion point with the arms facing to the person's left. The angle value will be the same.)
- b) Align the stationary arm with the Z-axis of the wheelchair, either sighting down to the tape on floor or using the back support reference plane if it is parallel to the wheelchair Z-axis.
- c) Align the moveable arm along or parallel to the transverse trunk/shoulder line. Read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair Z-axis

- If the left acromion point is posterior to the right acromion, indicating a counterclockwise left rotation as viewed from the top, the value is positive.

3.

- If the left acromion point is forward of the right acromion point, indicating a clockwise right rotation as viewed from the top of the person, the value is negative.

Typical values:

A value of 0 degrees would indicate that the transverse trunk line is parallel to the Z-axis of the wheelchair and the trunk is not rotated relative to the wheelchair, as in the Seated Reference Position. Positive values indicate rotation to the left (right shoulder forward of left shoulder), and negative values indicate trunk rotation to the right (left shoulder forward of right shoulder).

Considerations:

- Note that the transverse trunk angle is an absolute angle and thus describes the orientation of the upper trunk with respect to the wheelchair and not relative to the pelvis. Therefore, this measure does not necessarily reflect true trunk or spinal rotation, unless one compared the transverse trunk angle to the transverse pelvic angle.
- If the transverse trunk angle is not 0 degrees, this indicates an asymmetry of the upper torso in this plane relative to the wheelchair, and this measure is an indication of the magnitude of the asymmetry. This information can help in the appropriate prescription of a back support surface which accommodates the asymmetry if desired.
- When taken both before and after seating intervention, this measure could provide an objective measure of postural change.

5.5 Transverse head angle**Purpose:**

To document the existing or desired orientation of the head in the transverse plane

Clinical Relevance:

This angular measure is used to quantify a position of head rotation. This is clinically relevant because deviations of the head in this plane can have a significant effect on the seated user's posture and function and therefore a clinician may wish to measure this to document seating intervention outcomes relative to posture. This angle could also help determine the orientation of the head support in the transverse plane when significant fixed deviations are present.

TRANSVERSE HEAD ANGLE

96 **Type of Measurement:** Absolute body segment angle

Description: The angle of orientation of the head in the transverse plane with respect to the wheelchair, viewed from the top.

Landmarks used:

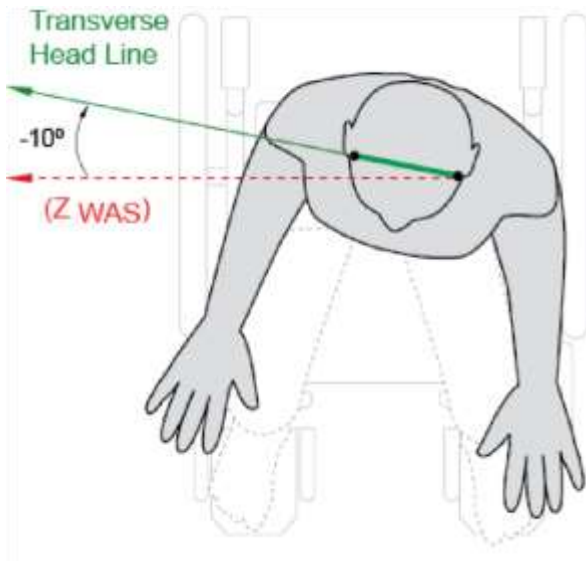
- Right tragon
- Left tragon

Lines used to form angle: □

- Wheelchair Z-axis (Z_{WAS})
- Transverse head line

Angle defined: Degree of rotation from the wheelchair Z-axis (Z_{WAS}) to the transverse head line, viewed from the top and projected to the transverse plane.

Fig. 2.37: Transverse head angle



Sample Procedure:

1. Locate wheelchair Z-axis (Z_{WAS})

- To locate the Z-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis.
- Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair Z-axis, such as the back edge of the seat pan, or a line between the back canes.

2. Locate the body landmarks and transverse head line

- Locate the right and left tragions of the ears. The transverse head line is the line connecting these two points.
 - *Right tragon* - the most anterior and superior notch of right ear.
 - *Left tragon* - the most anterior and superior notch of left ear.

Measure angle (using a goniometer)

- Place the goniometer pivot center over the left tragon, or at the left end of the transverse head line.
- Align the stationary arm with the Z-axis of the wheelchair, either sighting down to the tape on floor or using the back support reference plane if it is parallel to the wheelchair Z-axis.
- Align the moveable arm along or parallel to the transverse head line. Read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair Z-axis reference line

- If the head is rotated to the left, indicating a counterclockwise rotation as viewed from the top, the value is positive.

3.

- If the head is rotated to the right, indicating a clockwise rotation as viewed from the top, the value is negative.

Typical values:

If the person's head is forward facing relative to the wheelchair, the value of this measure will be 0 degrees because the transverse head line will be parallel to the Z-axis of the wheelchair, as in the Seated Reference Position. Positive values indicate that the face is rotated towards the left, and negative values indicate that the face is rotated towards the right.

Considerations:

- Note that the transverse head angle is an absolute angle and thus describes the orientation of the head with respect to the wheelchair and not relative to the trunk. Therefore it is not a measure of neck rotation, which is rotation of the head relative to the trunk. Consequently, a change in the transverse head angle may occur with or without neck rotation. For example, if the trunk is rotated the same degree as the head relative to the wheelchair Z-axis, then one can assume that there is no neck rotation.

5.6 Transverse thigh angle**Purpose:**

To document the existing or desired orientation of the thigh in the transverse plane

Clinical Relevance:

This angular measure is used to quantify what has been commonly (but often inaccurately) referred to as a position of hip abduction or adduction. This is clinically relevant because deviations of the thighs in this plane may reflect underlying fixed contractures or skeletal deformity, and can have a significant effect on the seated user's posture, health and function. Therefore a clinician may wish to measure this angle to document seating intervention outcomes relative to posture, or to help specify the orientation of lateral and medial thigh supports in the transverse plane.

TRANSVERSE THIGH ANGLE

98

Type of Measurement: Absolute body segment angle, left and right

Description: The angle of orientation of the thigh in the transverse plane with respect to the wheelchair, viewed from the top.

Landmarks used:

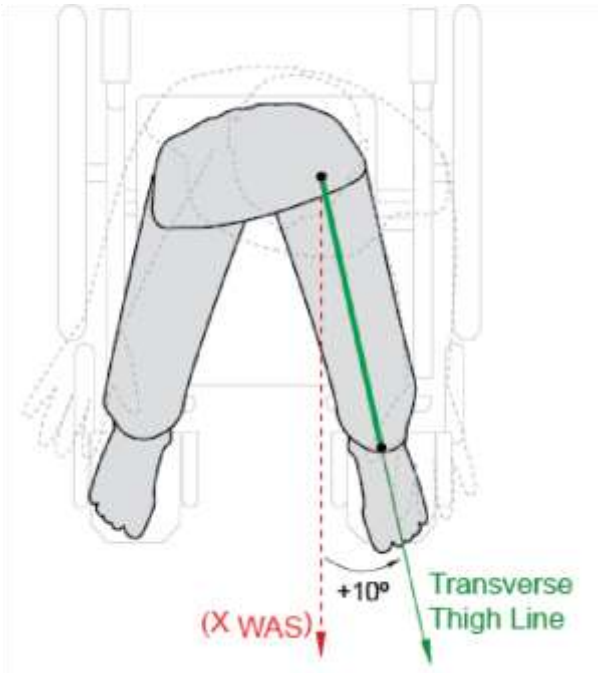
- ASIS
- Superior knee point

Lines used to form angle: □

- Wheelchair X-axis (X_{WAS})
- Transverse thigh line

Angle defined: The degree of rotation from the wheelchair X-axis (X_{WAS}) to the transverse thigh line, viewed from the top and projected to the transverse plane.

Fig. 2.38:



Transverse thigh angle

Sample Procedure:

1. Locate the wheelchair X-axis (X_{WAS})

a) To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's

wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.

- b) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rails.
- c) If the seat is rectangular and mounted "square" on the wheelchair frame, a clinician could assume that a line across the front of the seat is parallel to the Z-axis of the wheelchair, and visualize a line perpendicular to the front edge of the seat to represent the wheelchair X-axis.

2. Locate the body landmarks and transverse thigh line

- a) *The transverse thigh line* is the line passing through the ASIS and the superior knee point on the same side, projected to the transverse plane.

- *ASIS* – most anterior inferior prominence of the anterior superior iliac spine
- *Superior knee point* - midpoint between the lateral and medial femoral condyles, projected to the superior surface of the knee.

3. Measure angle (using a goniometer)

- Place the goniometer pivot center over the thigh just in front of the ASIS.
- Align the stationary arm with the wheelchair X-axis pointing forward.
- Align the moveable arm along or parallel to the transverse thigh line. Read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair X-axis reference line

- If the thigh is rotated to the left, indicating a counterclockwise rotation as viewed from the top, the value is positive.
- If the thigh is rotated to the right, indicating a clockwise rotation as viewed from the top, the value is negative.

Typical values:

When the thigh is pointing straight forward in line with the wheelchair X axis, the value will be 0 degrees as in the Seated Reference Position. Positive values indicate that the thigh is angled towards the left side of the wheelchair, and negative values indicate that the thigh is angled towards the right side of the wheelchair.

Considerations:

- Note that this is an absolute angle, and therefore by itself is not an accurate indication of the degree of hip abduction or adduction, as those terms reflect a relative angle between the femur and pelvis.
- For example, as shown in Fig. 2.39, a left transverse thigh angle of 0 degrees does not necessarily mean that the left hip joint is in a neutral position of 0 degrees hip abduction, unless the transverse pelvic angle is also 0 degrees. If the transverse pelvic angle is +15 degrees, and the right transverse thigh angle is also +15 degrees as in Fig. 2.39, then one could assume that the right hip is in 0 degrees of hip abduction.

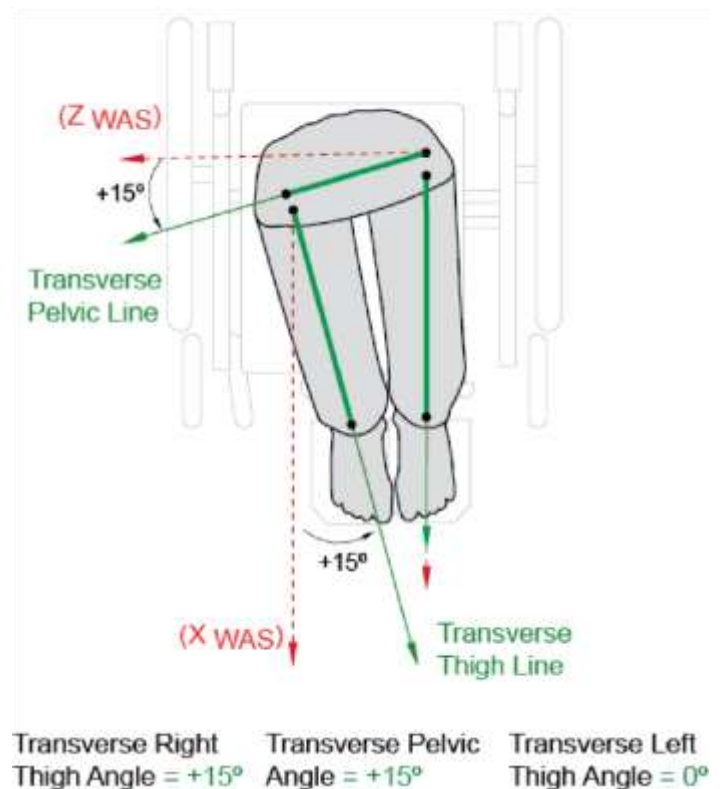


Fig. 2.39: Relationship of transverse pelvic and thigh angles to hip abduction/adduction

- If the pelvis is not rotated (transverse pelvic angle of 0 degrees), a negative transverse thigh angle would indicate a position of left hip adduction and right hip abduction, such as in a windswept posture to the right (Fig. 2.40). If the pelvis is not rotated, a positive transverse thigh angle would indicate a position of left hip abduction and right hip adduction, windswept to the left (Fig. 2.41).
- Note also that if the Transverse pelvic angle is 0 degrees, and both hips are in 20 degrees of abduction, then the left transverse thigh angle will be +20 degrees and the right transverse thigh angle will be -20 (Fig. 2.41).
- Measuring the desired transverse thigh angle may help with specification and positioning of lateral and medial knee supports.

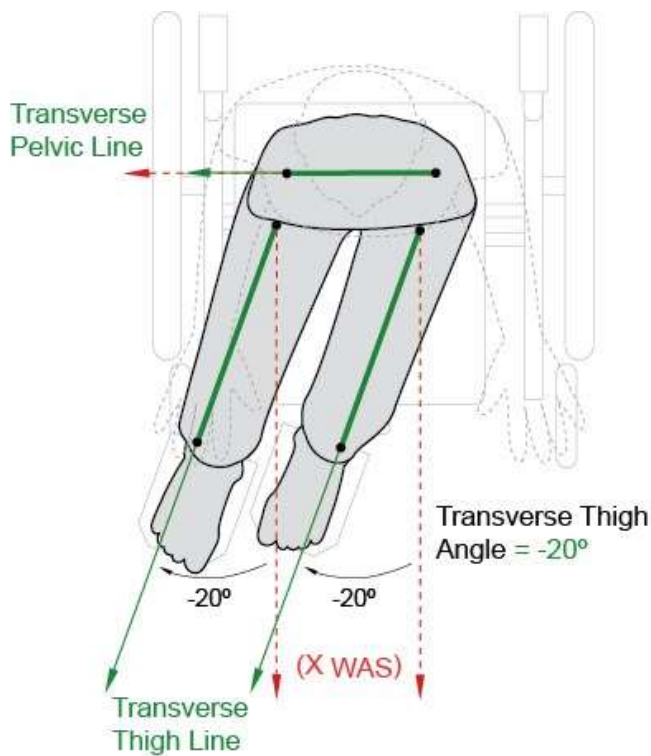


Fig. 2.40: Right windswept posture

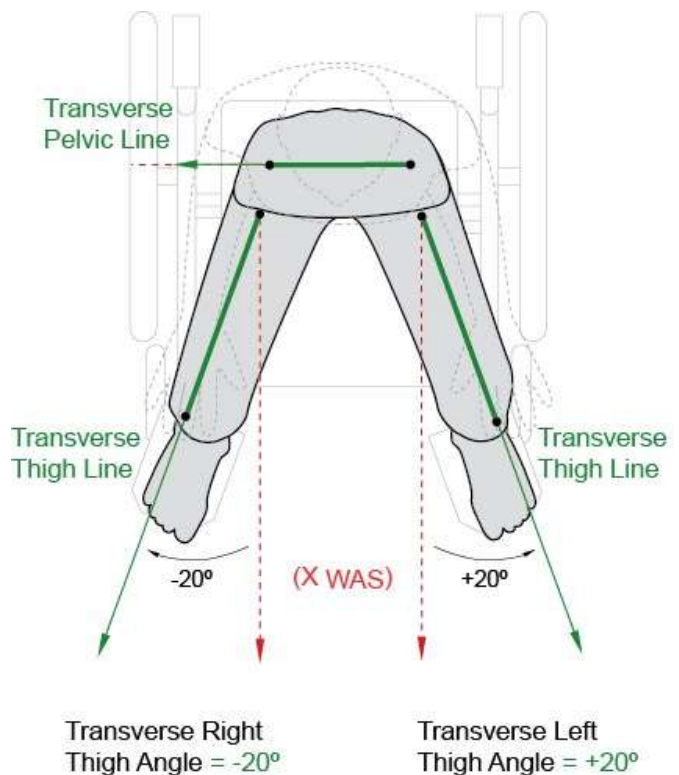
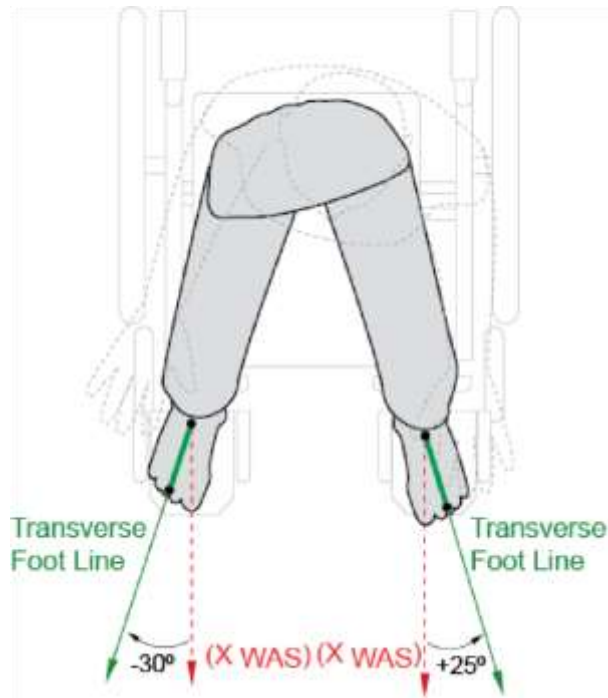


Fig. 2.41: "Abducted" posture

5.7



Type of Measurement: Absolute body segment angle, left and right

Description: The angle of orientation of the foot in the transverse plane with respect to the wheelchair, viewed from the top.

Landmarks used:

- Anterior ankle point
- Superior toe point

Lines used to form angle: □

- Wheelchair X-axis (X_{WAS})
- Transverse foot line

Angle defined: The degree of rotation from the wheelchair X-axis (X_{WAS}) to the transverse foot line, viewed from the top and projected to the transverse plane.

Transverse foot angle

Purpose:

To document the existing or desired orientation of the foot

in the transverse plane

Clinical Relevance:

This measure is used to quantify the degree of lateral rotation of the foot, sometimes referred to as “in-toeing” or “out-toeing”. It can also help determine the orientation of the foot support in the transverse plane (foot support transverse angle) or the foot support width required to support the foot in this orientation.

Fig. 2.42: Transverse foot angle

Sample Procedure:

1. Locate the wheelchair X-axis (X_{WAS})

- To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a “T”. Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rails.
- If the seat is rectangular and mounted “square” on the wheelchair frame, a clinician could assume that a line across the front of the seat is parallel to the Z-axis of the wheelchair, and visualize a line perpendicular to the front edge of the seat to represent the wheelchair X-axis.

2. Locate the body landmarks and transverse foot line

- The *transverse foot line* is the line passing through the anterior ankle point and superior foot point.
 - *Anterior ankle point* - midpoint of the line between the medial and lateral malleoli on the top surface of the ankle/foot.

- *Superior toe point* - midpoint between the base of the second and third metatarsal heads on the top of the foot.

3. Measure angle (using a goniometer)

- Place the goniometer pivot center over the foot just in front of the anterior ankle point.
- Align the stationary arm with the wheelchair X-axis pointing forward, sighting down to the tape on the floor. Alternatively, align the stationary arm perpendicular to the front edge of the seat if it is 'square' to the wheelchair frame.
- Align the moveable arm along or parallel to the transverse foot line. Read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair X-axis reference line

- If the foot is rotated to the left, indicating a counterclockwise rotation as viewed from the top, the value is positive.
- If the foot is rotated to the right, indicating a clockwise rotation as viewed from the top, the value is negative.

Typical values:

A value of 0 degrees indicates that the foot is forward facing and in line with the wheelchair X-axis, as in the Seated Reference Position. Positive values indicate that the foot is angled towards the left side of the wheelchair, and negative values indicate that the foot is angled towards the right side of the wheelchair.

Considerations:

- Note that this is an absolute angle, and therefore by itself is not an accurate indication of ankle or knee joint pathology or positioning. For example, a left transverse foot angle of +10 degrees does not necessarily mean that there is either 10 degrees of external tibial rotation at the left knee, or eversion of the left ankle joint. A left transverse foot angle of +10 degrees could result from a left transverse thigh angle of +10 degrees, with neutral alignment of the ankle joint.
- If the transverse thigh angle is zero, a positive transverse foot angle would indicate a position of internal deviation of the right foot or external deviation of the left foot. If the transverse thigh angle is zero, a negative transverse foot angle would indicate a position of external deviation of the right foot and internal deviation of the left foot.
- Measuring the desired transverse foot angle may help with specification of the foot support transverse angle and/or placement of foot positioning components.

6 References

- Hirose, H. (2005). Development of clinical methods for measuring geometric alignment of the thoracic and lumbar spines of wheelchair-seated persons, *J Rehabil Res Dev*, 42(4), 437-446.

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1 Introduction

In this chapter, both relative and absolute angular measures of the most commonly prescribed seating support surfaces are defined. Similar to the body, absolute angles measure a support surface's orientation with respect to an external reference, and relative angles measure the angle between two adjacent support surfaces.

The angular orientation of seating support surfaces in a wheelchair can have a significant impact on the occupant's posture, comfort, health and function. Therefore, these angular terms and measures can be used to either (1) document the **existing** angular orientation of support surfaces during assessment or follow-up,

and/or (2) specify the **desired** orientation of supports as part of a prescription of new postural support devices, or a plan for adjustments or modifications.

1.1 Relative angle measures

Relative support surface angles are defined in the sagittal plane only, as relative angles of support surfaces in the frontal and transverse planes are rarely used in practice. All relative angles are measured from one support surface reference plane to the adjacent support surface reference plane, with the surfaces unloaded. As any angle can be measured on two sides (one side less than 180 degrees and the other greater than 180 degrees), this guide will indicate which of the two possible angles should be measured (see Ch.2, Section 2.1 for more detail). The side of the angle which was chosen was based on clinical intuitiveness, with a preference for using the angle which gives a smaller value when the surfaces are oriented in the Support Surface Reference Position (SSRP). The three primary support surface relative angles - seat to back support angle, seat to lower leg support angle, and lower leg support to foot support angle - are the most commonly specified support surface angles in practice, because deviations in these angles can have a profound effect on seated posture.

1.2 Absolute angle measures

Absolute support surface angles describe the orientation in space of a single support surface with respect to an external fixed reference – the X-, Y- or Z-axis of the Wheelchair Axis System (WAS). The value of an absolute support surface angle is the degree to which the support surface's local reference axis has rotated away from the corresponding axis of the Wheelchair Axis System. This is determined by measuring the angle between the specified external reference axis and the corresponding local support surface axis for that view, and noting the direction of rotation away from the wheelchair reference axis using positive and negative notations according to the right hand grip rule (see Chapter 1, Section 4.3.3).

1.2.1 Sagittal angles

All sagittal absolute angles are determined by viewing the support from the side, as these angles reflect rotations of a single support surface around the Z axis in the sagittal (XY) plane. Because the wheelchair Y- and X-axes represent gravitational vertical and horizontal, **all sagittal support surface angles are determined by measuring the angle between the support's local reference axis and either the vertical or horizontal.**

According to the right hand grip rule convention (see Chapter 1, Section 4.3.3), if you are viewing the support from the right side, rotations in a counterclockwise direction are positive, and rotations in a clockwise direction are negative. (This will be reversed if you are viewing the body support system from the left side.)

1.2.2 Frontal angles

All frontal absolute angles are determined by viewing the seating system from the front, as these angles reflect rotations of a single support surface around the X-axis in the frontal (YZ) plane. Because the wheelchair Y- and Z-axes represent gravitational vertical and horizontal, **all frontal support surface angles are determined by measuring the angle between the support's local reference axis and either the vertical or horizontal.**

According to the right hand grip rule convention (see Chapter 1, Section 4.3.3), if you are viewing the wheelchair body support system from the front, rotations in a counterclockwise direction are positive, and rotations in a clockwise direction are negative. This means that rotations in the frontal plane to the wheelchair's right are positive, and to the wheelchair's left are negative.

1.2.3 Transverse angles

All transverse absolute angles are determined by viewing the body support system from above as these angles reflect rotations of a single support surface around the Y-axis in the transverse (XZ) plane. When a support surface deviates in the transverse plane, you can't use gravitational horizontal or vertical as a zero reference because both the X- and Z-axes of the wheelchair lay in the horizontal/transverse plane. **All transverse support surface angles are therefore determined by measuring the angle between the support's local reference axis and either the wheelchair X- or Z-axis, as defined by the rear wheel axles of the wheelchair.**

According to the right hand grip rule convention (see Chapter 1, Section 4.3.3), if you are viewing the support from the top, rotations in a counterclockwise direction are positive, and rotations in a clockwise direction are negative. This means that rotation of a support surface in the transverse plane to the left side of the wheelchair is positive, and to the right side of the wheelchair is negative.

1.3 Locating the gravitational vertical or horizontal reference line

If you are using an inclinometer or angle finder, these tools automatically align their zero reference with either the vertical or horizontal. If you are using a goniometer, this can be done by sighting along a line which you know is vertical or horizontal, or by using a goniometer with a bubble level attached to the stationary arm.

1.4 Locating the wheelchair X-axis or Z-axis reference lines

The wheelchair Z-axis (Z_{WAS}) lies on the line passing through the rear wheel axles of the wheelchair. The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the Z-axis. (See Chapter 1, Section 3.5.1) To locate and sight to these reference axes for measures in the transverse plane, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis. You can then sight to these lines on the floor when measuring transverse angles.

1.5 Locating support surface reference planes

Being able to identify a support surface reference plane is important for both relative and absolute angle measures in this chapter. Relative support surface angles are defined as the angle between two adjacent planes, and so you need to be able to locate the reference planes of the two adjacent support surfaces in order to align your goniometer with these planes. To measure absolute angles, you need to be able to align your goniometer or angle finder along a reference line which lies on the reference plane.

1.5.1 Locating support surface reference planes of flat support surfaces

If the contact surface side of the body support device is flat, the support surface reference plane is easily identified. In this situation, you can lay the arms of the goniometer or angle finder directly on the contact surface itself, or parallel to the flat contact surface side of the support.

1.5.2 Locating support surface reference planes of contoured support surfaces

For contoured seat or back support surfaces, this is more difficult. There are two ways to identify a support surface reference plane when the surface is contoured:

- (1) **Using the solid, flat structure on the non-contact surface side of the support:** The support surface reference planes of a contoured seat or back support cushion can be approximated using

the flat pan or shell on the non contact surface side of the seat or back support device. In this situation, align your measurement device along or parallel to the flat solid backing behind the back support cushion or under the seat cushion.

(2) *Using a clipboard or other flat surface placed on the contact surface:*

Alternatively, place a clipboard or other flat surface, over the center of the contact surface and use this surface to approximate the reference plane.

1.5.3 Locating the lower leg support reference plane

The lower leg support reference plane is difficult to identify because frequently there is not an actual lower leg support device, such as a 'calf pad', on the wheelchair. However, being able to align your goniometer or inclinometer with this reference plane is necessary for measuring the seat to lower leg support angle, the lower leg support to foot support angle and the lower leg support sagittal angle. There are two ways to identify the lower leg support reference plane, based on whether or not there is a posterior lower leg support device on the system being measured.

(1) *Identifying the lower leg support reference plane when there IS NOT a posterior lower leg support device, such as a calf pad, on the wheelchair:*

When there is not an actual posterior lower leg support (which is very common), the lower leg support reference plane is an imaginary plane intersecting the rear edge of the foot supports or heel loops and the most forward projection of the seat [1]. This imaginary plane is approximated by a line connecting the rear edge of the foot support or heel loop with the front top edge of the seat contact surface (Fig. 3.1a).

(2) *Identifying the lower leg support reference plane when there IS a lower leg support device, such as a calf pad, on the wheelchair:*

The lower leg support reference plane is defined by the contact surface of the posterior lower leg support at its geometric center. For a flat calf pad, this reference plane is easily visualized as the plane created by the flat contact surface. If the lower leg support surface is contoured, its reference plane can be approximated by using the flat backing behind the pad on the non contact surface side.

Note that this lower leg support reference plane may project forward of the end of the seat, and the bottom may not project to the back of the footplate; *however the posterior lower leg support plane will be defined by the orientation of this pad* (Fig. 3.1b). This makes sense clinically, because the location and orientation of a calf pad will affect the person's lower leg alignment.

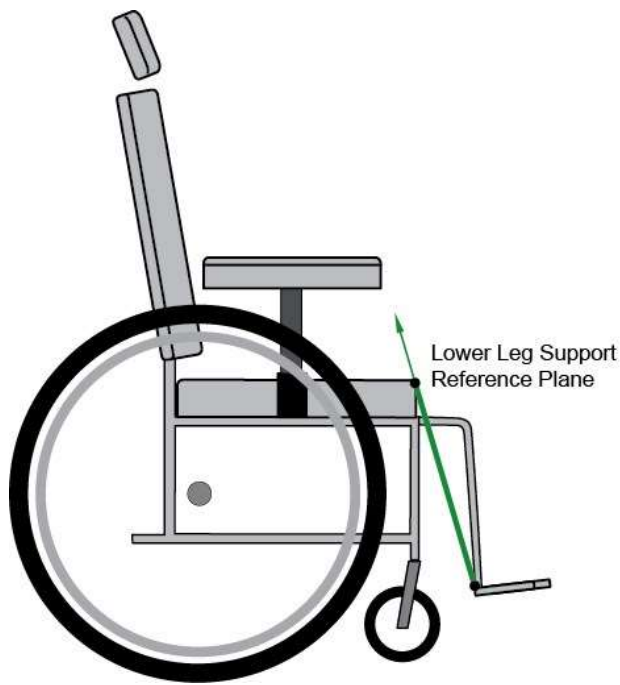


Fig. 3.1a: Lower leg support reference plane without calf pad

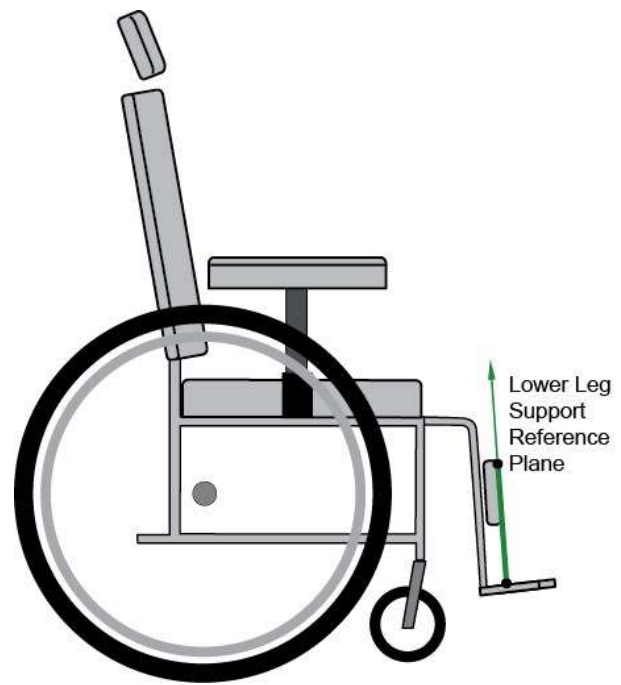


Fig. 3.1b: Lower leg support reference plane with calf pad

1.6 Locating the local reference axis of the individual support surface

To measure absolute angles of body support devices, you need to be able to locate a reference line on the support surface which represents the specified local axis. Simply stated, the reference line will always be a line which lies either along the support's width dimension, or perpendicular to that along the support's length or depth dimension. These lines represent one of the support's local axes.

As explained in Chapter 1, Section 3.5.2, a postural support device's local axis system originates at the geometric center of the contact surface. The three axes then project from the center of the support, perpendicular to each other, in an orientation which aligns with the Wheelchair Axis System (WAS) when the supports are in the Support Surface Reference Position (SSRP). Two of the local axes always lay in the support surface reference plane, and the third axis projects away from the surface perpendicular to the support surface reference plane (see Figs. 3.11 and 3.23). We use the notation $X_{\text{NAME OF SUPPORT}}$, $Y_{\text{NAME OF SUPPORT}}$, and $Z_{\text{NAME OF SUPPORT}}$ to represent these local reference axes, for example X_{SEAT} , Y_{SEAT} and Z_{SEAT} .

1.7 Special measurement protocol for sagittal absolute angles

All absolute angles of support surfaces in the sagittal plane will be affected by changes in the orientation in space of the wheelchair's entire body support system. Consequently, sagittal angles of body support surfaces which are part of a seating system with adjustable tilt or recline will change with these adjustments. Therefore, before measuring any support surface sagittal angle, adjust the seating system to its most upright position with the seat sagittal angle 0 degrees. Alternatively, note the baseline orientation during measurement by recording the seat sagittal angle if it cannot be adjusted to zero, before measuring other sagittal angles.

1.8 Recommended measures based on complexity of client need

We have chosen to define the absolute angular measures of only a subset of all the possible postural support devices one could identify on a body support system. However, the measures included will serve to illustrate the application of the principles encompassed within the standard. Once these principles have been grasped, then extrapolation to angular measures of less common support surfaces which are not included in this guide is relatively simple.

The support surface angular measures defined in this chapter of the guide are listed in the charts below (Tables 1 and 2). They have been identified as either a Level I or Level II measure, to suggest a selection of measures to take based on complexity of client need. This is not intended to be prescriptive since the choice of measurements used in any one assessment process will depend not only on the clinical presentation of the individual, but also the complexity of their body support system, the goals of the measurement process and the availability of measurement tools. ***In fact, in most situations it will be sufficient to document or specify only the three level one relative angles.***

Table 1: Suggested relative support surface angular measures based on complexity of need

Level I	Level II
Seat to back support angle Seat to lower leg support angle Lower leg support to foot support angle	Seat to lower back support angle Seat to upper back support angle

Relative angles are defined first, then absolute angles. The absolute angular measures in this chapter have been organized by type of support surface (e.g. posterior, inferior, lateral, medial, etc) instead of by plane, because all supports within a particular grouping are measured similarly. Additionally, this helps relate these terms to the original ISO 16840-1:2006 standard [2], which defines and labels these absolute angles generically (e.g. inferior support sagittal angle) instead of for a specific postural support device (e.g. foot support sagittal angle).

Within each category, the most common postural support devices are included. All three absolute angles of a particular body support device are listed - sagittal, frontal and transverse angles - even though some of these angles would rarely be measured in practice. For some of these very uncommon angles, the guide will provide only a summary of information, without a detailed methodology or clinical consideration section. Once the reader understands the underlying measurement and labeling principles, extrapolation of procedures to more uncommon support surface angles is not difficult.

Table 2: Suggested absolute support surface angular measures based on complexity of need

Category	Support name	Level 1 Measures	Level 2 Measures
	Seat	Seat sagittal angle	Seat frontal angle Seat transverse angle

Inferior	Foot support		Foot support sagittal angle Foot support frontal angle Foot support transverse angle
	Arm support	Arm support sagittal angle	Arm support frontal angle Arm support transverse angle
Posterior	Back support	Back support sagittal angle	Back support frontal angle Back support transverse angle
	Head support	Head support sagittal angle	Head support frontal angle Head support transverse angle
	Lower leg support		Lower leg support sagittal angle Lower leg support frontal angle Lower leg support transverse angle*
Lateral	Lateral trunk support		Lateral trunk support sagittal angle Lateral trunk support frontal angle Lateral trunk support transverse angle*
	Lateral head support		Lateral head support sagittal angle Lateral head support frontal angle Lateral head support transverse angle
	Lateral pelvic support		Lateral pelvic support sagittal angle* Lateral pelvic support frontal angle* Lateral pelvic support transverse angle
	Lateral knee support		Lateral knee support sagittal angle* Lateral knee support frontal angle* Lateral knee support transverse angle
Medial	Medial knee support		Medial knee support sagittal angle* Medial knee support frontal angle* Medial knee support transverse angle
Anterior	Anterior knee support		Anterior knee support sagittal angle* Anterior knee support frontal angle* Anterior knee support transverse angle

*These angles are significantly less common, and therefore only summary information on the angle is included in this guide.

2 Relative Support Surface Angles

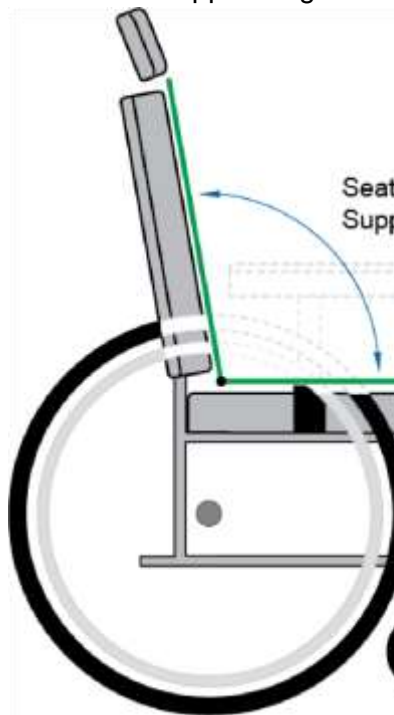
2.1 Seat to back support angle

Purpose:

To provide a standard measure of the angular position of the back support relative to the seat in the sagittal plane

Clinical relevance:

The angle between the seat and back support can have a significant influence on the individual's comfort, posture, health and function, and therefore it can be clinically useful to document the existing and/or desired seat to back support angle.



SEAT TO BACK SUPPORT ANGLE

Type of Measurement: Relative support surface angle

Description: The angle between the seat and the back support viewed from the side.

Reference Planes Used:

- Back support reference plane
- Seat reference plane

Angle measured: The anterior side of the angle formed between the back support reference plane and the seat reference plane, as viewed from the side.

SSRP Value: 90 degrees

Typical Values: 80 -120 degrees

Fig. 3.2: Seat to back support angle

Sample Procedure (using a goniometer):

1. Locate the seat and back support reference planes

- a) *If the seat and/or back support surface is flat*, their reference planes are easily identified. In this situation, align the arms of the goniometer along or parallel to the flat contact surface side of the seat or back support cushion.
- b) *If the seat and/or back support surface is contoured*, their reference planes can be approximated using the flat pan or shell on the non contact surface side of the seat or back cushions. In this situation, align the arms of the goniometer along or parallel to the flat solid backings behind the back support cushion and under the seat cushion to approximate the seat to back support angle. Alternatively, place a clipboard or other firm flat surface on top of the contact surface to approximate the reference plane.

2. Measure the angle

- a) Align the stationary arm of the goniometer along or parallel to the back support reference plane.

- b) Align the moveable arm of the goniometer along or parallel to the seat reference plane.
- c) Read the internal, anterior side of the angle.

Procedure Helpful Hint: *If the contact surfaces of the back support and seat are flat, you can lay the arms of a 180 degree goniometer right on top of the contact surfaces, with the center of the goniometer at the intersection of the seat and back support reference planes, usually the seat/back junction.*

Typical Values:

Values may range between 80 and 140 degrees, but will typically be between 90 and 110 degrees. The value of this angle is 90 degrees in the Support Surface Reference Position (SSRP).

Considerations:

- This measure is used when there is a single continuous back support surface. If the back support is sectioned, as in a bi-angular back support, you may wish to measure both the seat to lower back support and the seat to upper back support angles.
- The seat to back support angle is very critical as it can influence the user's posture and function in many ways. This relative angle is typically chosen to support the person's body at the desired thigh to trunk angle, which is unique to that individual. The desired thigh to trunk angle is typically based on the user's hip joint flexibility, level of postural control of the trunk, presence of muscle spasticity, and functional needs with respect to orientation of the trunk, head and upper extremities.
- If the seated person's trunk is parallel to the back support reference plane, and their thigh is parallel to the seat reference plane, then the seat to back support angle will be the same as the person's thigh to trunk angle.

2.2 Seat to lower back support angle

Purpose:

To provide a standard measure of the angular position of the lower back support relative to the seat in the case of a bi-angular or multi section back support

Clinical relevance:

The angle between the seat and lower back support can have a significant influence on the individual's comfort, posture, health and function, and therefore it can be clinically useful to document the existing and/or desired seat to lower back support angle.

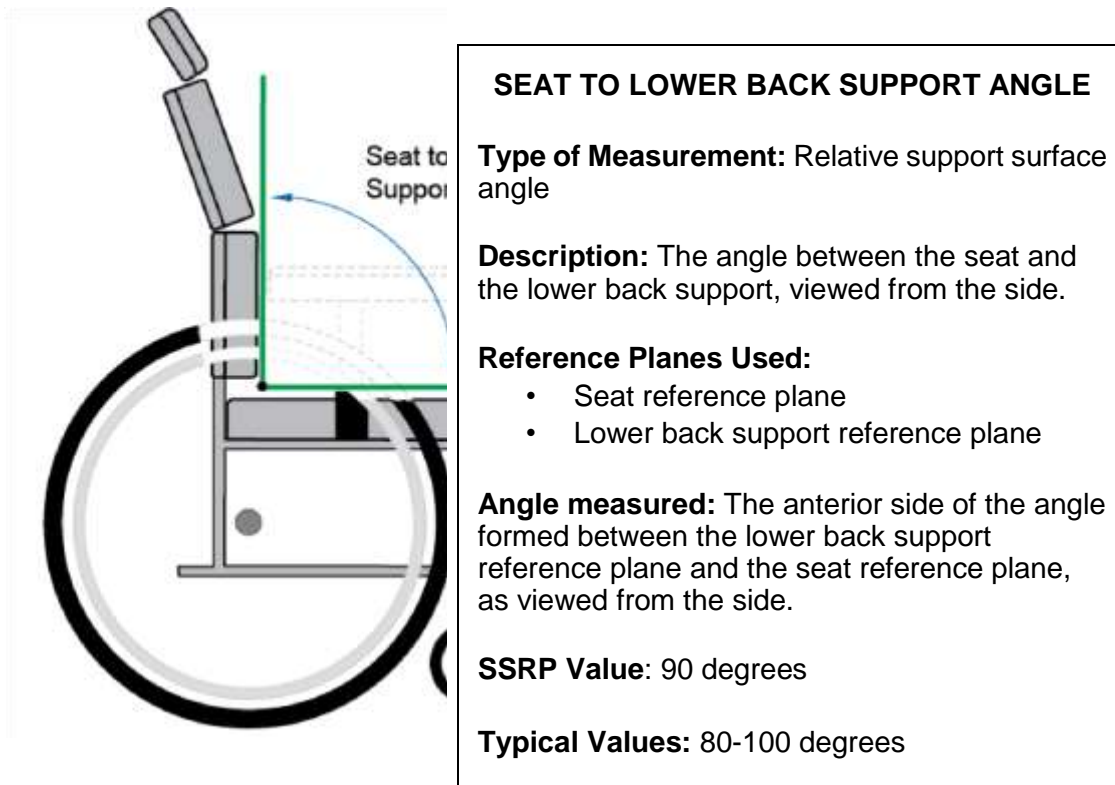


Fig. 3.3: Seat to lower back support angle

Sample Procedure:

1. Locate the seat and lower back support reference planes

- If the seat and/or back support surface is flat*, their reference planes are easily identified. In this situation, align the arms of the goniometer along or parallel to the flat contact surface side of the seat or back support cushion.
- If the seat and/or back support surface is contoured*, their reference planes can be approximated using the flat pan or shell on the non contact surface side of the seat or back cushions. In this situation, align the arms of the goniometer along or parallel to the flat solid backings behind the back support cushion and under the seat cushion to approximate the seat to back support angle. Alternatively, place a clipboard or other firm flat surface on top of the contact surface to approximate the reference plane.

2. Measure the angle (using a goniometer)

- Align the stationary arm of the goniometer along or parallel to the lower back support reference plane.
- Align the moveable arm of the goniometer along or parallel to the seat reference plane.
- Read the internal, anterior side of the angle.

Procedure Helpful Hints: *If the contact surfaces of the back support and seat are flat, you can lay the arms of a 180 degree goniometer right on top of the contact surfaces, with the center of the goniometer at the intersection of the seat and back support reference planes, usually the seat/back junction.*

Typical Values:

Values may range from 80 to 110 degrees, but would typically be between 85 and 95 degrees. This angle is 90 degrees in the Support Surface Reference Position (SSRP).

Considerations:

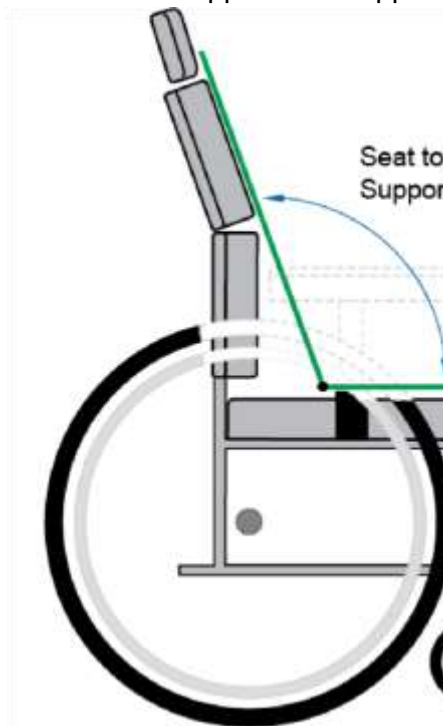
- This measure is used in conjunction with the seat to upper back support angle when a multi section back support or 'bi-angular' back support is used. These two measures would then be used instead of the more common seat to back support angle.
- A multi-section or bi-angular back support is typically prescribed for a client with specific pelvic vs upper trunk postural support needs, making this a more complex postural support device and a Level II (or less common) measure.
- This angle corresponds to the thigh to pelvis angle and is generally prescribed based on the user's hip joint flexibility, presence of muscle spasticity, and postural/functional needs with respect to orientation of the trunk, head and upper extremities. The intention is typically to prescribe the seat to lower back support angle to support and maintain the user in a specific degree of true hip flexion and corresponding thigh to pelvis angle, while allowing greater recline of the upper trunk for balance.
- If the seated person's sagittal pelvic line is perpendicular to the lower back support reference plane, and their thigh is parallel to the seat reference plane, then the seat to lower back support angle will be the same as the person's thigh to pelvis angle.

2.3 Seat to upper back support angle**Purpose:**

To provide a standard measure of the angular position of the upper back support relative to the seat in the case of a bi-angular or multi section back support

Clinical relevance:

The angle between the seat and upper back support can have a significant influence on the individual's comfort, posture, health and function, and therefore it can be clinically useful to document the existing and/or desired seat to upper back support angle.

**SEAT TO UPPER BACK SUPPORT ANGLE**

Type of Measurement: Relative support surface angle

Description: The angle between the seat and the upper back support, viewed from the side

Reference Planes Used:

- Upper back support reference plane
- Seat reference plane

Angle measured: The anterior side of the angle formed between the upper back support reference plane and the seat reference plane, as viewed from the side.

SSRP Value: 90 degrees

Typical Values: 90 – 120 degrees

Fig. 3.4: Seat to upper back support angle

Sample Procedure:**1. Locate the seat and upper back support reference planes**

- a) *If the seat and/or back support surface is flat*, their reference planes are easily identified. In this situation, align the arms of the goniometer along or parallel to the flat contact surface side of the seat or back support cushion.
- b) *If the seat and/or back support surface is contoured*, their reference planes can be approximated using the flat pan or shell on the non contact surface side of the seat or back cushions. In this situation, align the arms of the goniometer along or parallel to the flat solid backings behind the back support cushion and under the seat cushion to approximate the seat to back support angle. Alternatively, place a clipboard or other firm flat surface on top of the contact surface to approximate the reference plane.

2. Measure the angle (using a goniometer)

- a) Align the stationary arm of the goniometer along or parallel to the upper back support reference plane.
- b) Align the moveable arm of the goniometer along or parallel to the seat reference plane.
- c) Read the internal, anterior side of the angle.

Procedure Helpful Hints:

- If the contact surfaces of the back support and seat are flat, you can lay the arms of a 180 degree goniometer right on top of the contact surfaces, with the center of the goniometer at the intersection of the seat and back support reference planes, usually the seat/back junction.
- Since the upper back support section and the seat are not contiguous, the moveable arm will likely be above the level of the seat, therefore it may be useful to align the stationary arm along the upper back support and then slide the pivot center of the goniometer down to the level of the seat, being careful not to change the orientation of the stationary arm. Depending on the height of the upper back support section above the seat and the length of the goniometer arms, it may be useful to place a long straight edge along the upper back support and projecting down to the seat, to make the reference planes contiguous for easier and more accurate measurement.

Typical Values:

Values may range from 85 to 120 degrees, but would typically be between 90 and 110 degrees. This angle is 90 degrees in the Support Surface Reference Position (SSRP).

Considerations:

- This measure is used in conjunction with the seat to lower back support angle when a multi section back support or 'bi-angular' back support is used. These two measures would then be used instead of the more common seat to back support angle. The difference between the seat to lower back support angle and the seat to upper back support angle would then describe the angle between the upper and lower back supports. This angular difference is typically not more than 5 to 10 degrees.
- A multi-section or bi-angular back support is typically prescribed for a client with specific pelvic vs. upper trunk postural support needs, making this a more complex postural support device and a Level 2 (or less common) measure.

- This relative angle is typically chosen to support the person's body at the desired overall thigh to trunk angle, which is unique to that individual. This angle is generally prescribed based on the user's hip joint and lumbar spine flexibility, shape of the user's back, level of postural control of the trunk, and functional needs with respect to orientation of the trunk, head and upper extremities.

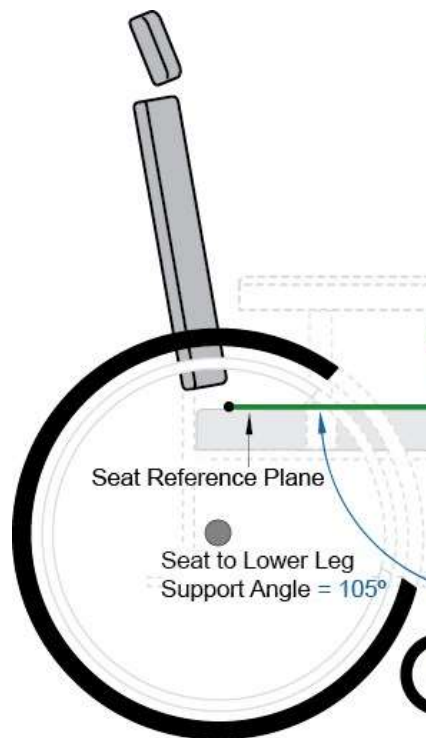
2.4 Seat to lower leg support angle

Purpose:

To provide a standard measure of the angular position of the lower leg support relative to the seat in the sagittal plane

Clinical relevance:

The angle between the seat and lower leg support can have a significant influence on the individual's comfort, posture, health and function because of its affect on the individual's thigh to lower leg angle and related degree of knee flexion. Therefore, it can be clinically useful to document the existing and/or desired seat to lower leg support angle, and use this value to help specify the type of lower leg support assembly on the wheelchair frame.



SEAT TO LOWER LEG SUPPORT ANGLE

Type of Measurement: Relative support surface angle, right and left

Description: The angle between the seat and the lower leg support, viewed from the side.

Reference Planes Used:

- Seat reference plane
- Lower leg support reference plane

Angle measured: The posterior side of the angle formed between the seat reference plane and the lower leg support reference plane, as viewed from the side.

SSRP Value: 90 degrees

Typical Values: 80 – 120 degrees

Fig. 3.5: Seat to lower leg support angle, no calf pad

Sample Procedure:

1. Locate the seat reference plane

- a) For a planar seat, the seat reference plane is easily visualized as the plane created by the flat contact surface. If the seat surface is contoured, the seat reference plane can be approximated using the flat pan or shell on the non contact surface side of the seat cushion.

2. Locate the lower leg support reference plane

- a) If there is no calf pad, the lower leg support reference plane is approximated by a line connecting the rear edge of the foot support or heel loop with the front top edge of the seat contact surface (Fig. 3.5).
- b) If there IS a calf pad, the contact surface of the pad represents the reference plane (Fig. 3.6).

3. Measure the angle (using a goniometer)

a) Method #1, no calf pad (Fig. 3.5)

- i. Align the goniometer pivot center with the top front top edge of the seat.
- ii. Align the stationary arm of the goniometer parallel to the seat reference plane, pointing towards the back of the seat.
- iii. Align the moveable arm parallel to the approximated lower leg support reference plane, by pointing down to the back of the footplate or heel loops.
- iv. Read the value which represents the posterior side of the angle.

b) Method #2, with calf pad positioned anterior to the front edge of the seat (Fig. 3.6)

- i. Align the goniometer pivot center at the intersection of the seat and lower leg support reference planes, which is going to be forward of the front edge of the seat.
- ii. Align the stationary arm of the goniometer parallel to the seat reference plane, pointing towards the back of the seat, and align the moveable arm parallel to the lower leg support reference plane, pointing down to the back of the footplate.
- iii. Read the value which represents the posterior side of the angle.

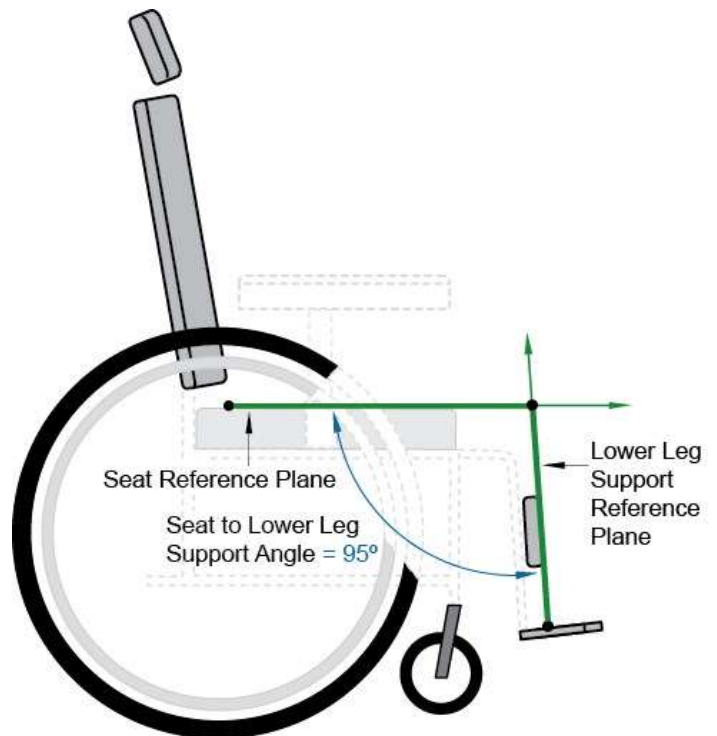


Fig. 3.6: Seat to lower leg support angle, with calf pad

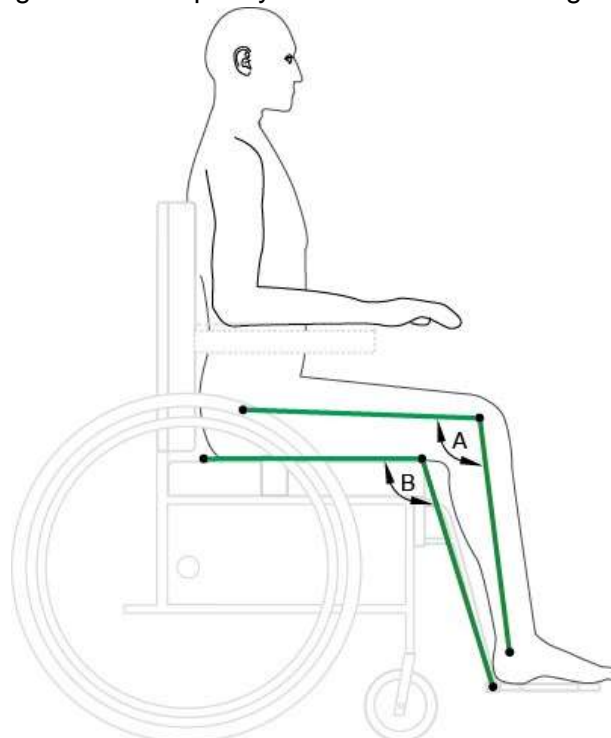
Typical Values:

Values may range from 80 to 130 degrees, but are typically 90 to 120 degrees. The value of this angle is 90 degrees in the Support Surface Reference Position (SSRP).

Considerations:

- This angle is generally prescribed to match the desired thigh to lower leg angle of the person, which is based on the user's hamstring flexibility, knee joint range of motion, comfort and stability needs, as well as other functional considerations such as maneuverability of the mobility base.
- If the person's thigh is parallel to the seat, and their lower leg is parallel to the lower leg support reference plane, then the thigh to lower leg angle will be the same as the seat to lower leg support angle.

- The most common way to alter the seat to lower leg support angle is to change the anterior-posterior position of the foot support relative to the front edge of the seat.
- This angle generates a significant amount of confusion among clinicians and suppliers, yet it is a critical dimension to specify and therefore it is important for team members to communicate information about this dimension accurately.
- First, the seat to lower leg support angle is a support surface angle, not a body segment angle. Specification of this angle is used to achieve a certain thigh to lower leg angle, however they are often not exactly the same value. This is because the center of the user's knee is forward of the end of the seat, and therefore the center point, or vertex, of the body segment angle and the support surface angle do not line up. For example, if a user's knee is several inches forward of the end of the seat (in a system with no posterior lower leg support), the user's thigh to lower leg angle will be significantly less than the seat to lower leg support angle (Fig. 3.7) Additionally, if the back of the user's foot is not positioned at the back of the footplate, there will be a greater discrepancy between these two angles.



A – Thigh to Lower Leg Angle = 95°

B – Seat to Lower Leg Support = 105°

Fig. 3.7: Seat to lower leg support angle vs. thigh to lower leg angle

- The other confusion regarding this angle is its relationship to the angle of the lower leg support assembly of the wheelchair frame. The lower leg support assembly (sometimes called the “legrest hanger”) options of a wheelchair frame have been traditionally defined by an angle, such as a 60, 70 or 90 degree hanger. This lower leg support assembly angle is a *wheelchair frame angle*, and not a seating support surface angle, and it is defined and measured very differently. The 60-70-90 degree angle of the lower leg support assembly of the wheelchair frame, used by manufacturers, refers to the angle formed between the forward projection of the seat rail and the leg support hanger tube. (Figs. 3.8a and 3.8b) Not only is the value determined differently, but it also represents the orientation of frame components and not necessarily the orientation of seating support surface components mounted onto the wheelchair frame.

The wheelchair's lower leg support assembly angle is typically fixed, and does not change with varied placements of the seat or foot supports. Conversely, changes in the position and/or angle of the seat cushion or foot support will change the seat to lower leg support angle.

- Figure 3.8a shows a typical configuration where the front edge of the seat aligns with the front of the seat rail, and the back of the foot support is in line with the vertical hanger tube. In this situation, the two angles are supplementary angles.
- Figure 3.8b shows a set up where the front edge of the seat is behind the front of the seat rail, and the back of the foot support is significantly forward of the front edge of the seat. In this situation, even though the lower leg support assembly angle is 90 degrees, the seat to lower leg support angle may be greater than 90 degrees. This may result in the person sitting with a more open thigh to lower leg angle than anticipated.

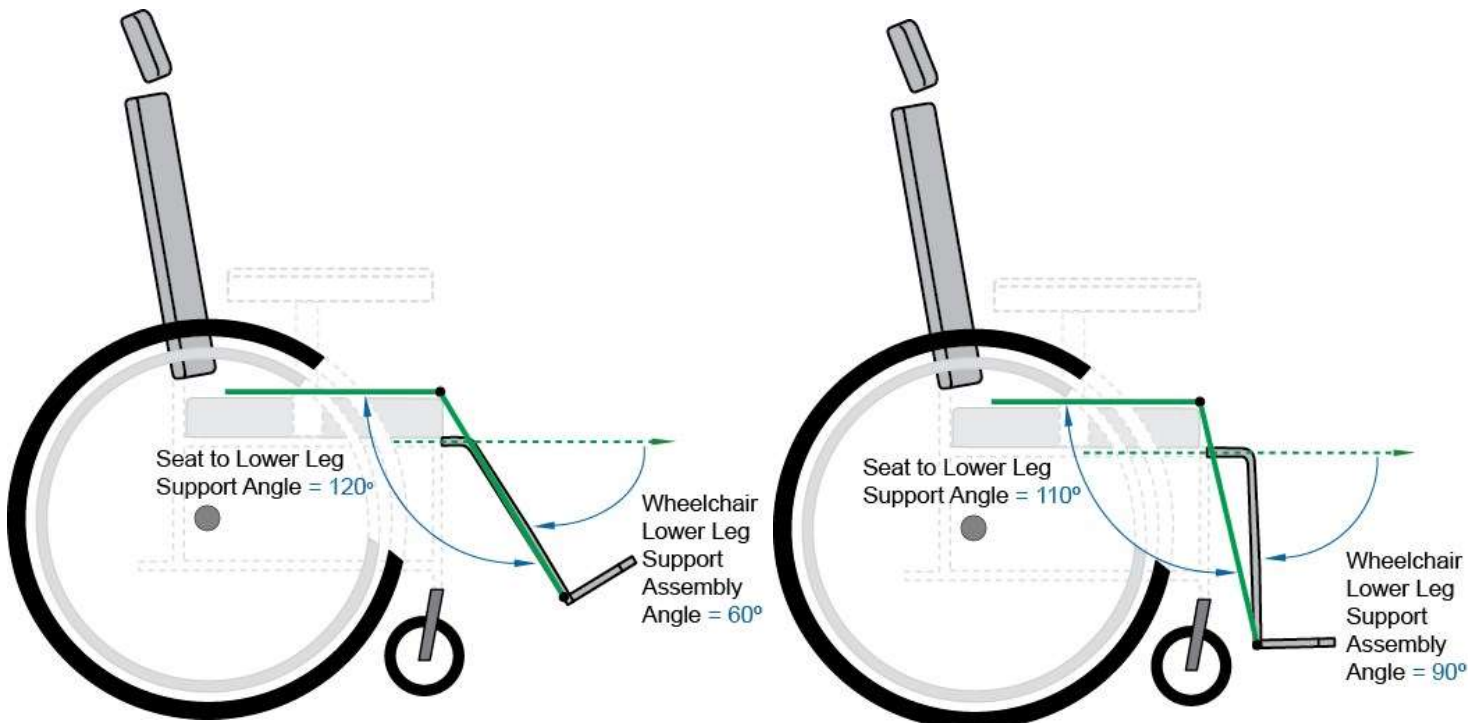


Fig. 3.8a: Seat to lower leg support angle vs. wheelchair lower leg support assembly angle, lower leg support reference plane aligned with vertical hanger tube

Fig. 3.8b: Seat to lower leg support angle vs. wheelchair lower leg support assembly angle, lower leg support reference plane NOT aligned with vertical hanger tube

2.5 Lower leg support to foot support angle

Purpose:

To provide a standard measure of the angular position of the foot support relative to the lower leg support.

Clinical Relevance:

This angle is important as it influences the degree of ankle plantarflexion or dorsiflexion required to achieve full contact with the foot support. Therefore, it can be clinically useful to document the existing and/or desired lower leg support to foot support angle.

LOWER LEG SUPPORT TO FOOT SUPPORT ANGLE

Type of Measurement: Relative support surface angle, right and left

Description: The angle between the lower leg support reference plane and the foot support reference plane, viewed from the side

Reference planes used to form angle:

- Lower leg support reference plane
- Foot support reference plane

Angle measured: The anterior side of the angle formed between the lower leg support reference plane and the foot support reference plane, as viewed from the side.

SSRP Value: 90 degrees

Typical Values: 80-100 degrees

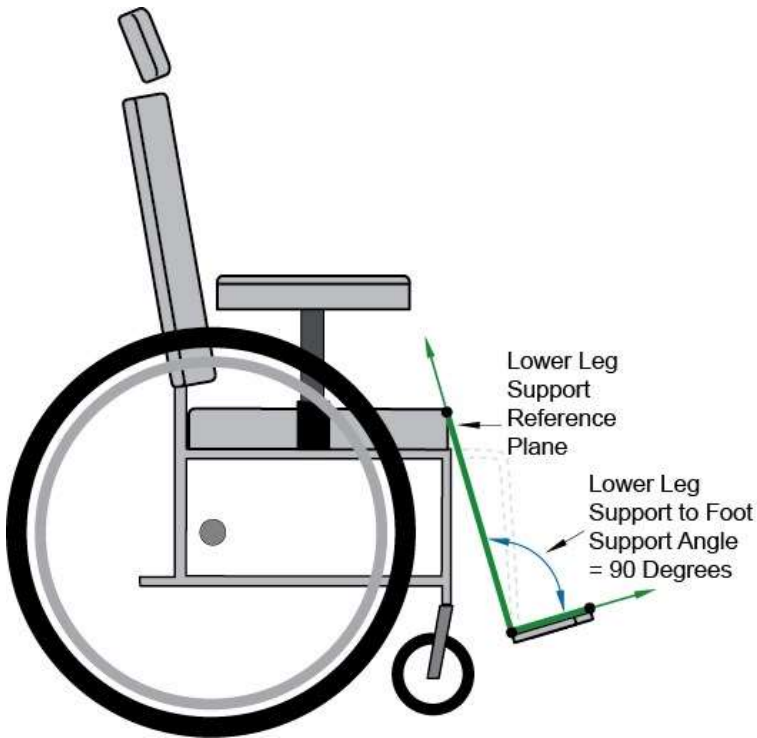


Fig. 3.9: Lower leg support to foot support angle

Sample Procedure:

1. Locate the lower leg support reference plane

- If there is no calf pad, the lower leg support reference plane is approximated by a line connecting the rear edge of the foot support or heel loop with the front top edge of the seat contact surface (Fig. 3.9)
- If there IS a calf pad, the contact surface of the pad represents the reference plane (Fig. 3.10)

2. Measure the angle (using a goniometer)

a) Method #1, no calf pad (Fig. 3.9)

- Align the goniometer's pivot center at the back edge of the foot support, or at the contact surface of the most rearward point of the heel loop.
- Align the stationary arm of the goniometer on or parallel to the lower leg support reference plane, sighting up to the front edge of the seat. Place the other arm of the goniometer on or parallel to the foot support reference plane, pointing forward.
- Read the anterior side of the angle.

b. Method #2, with calf pad positioned anterior to the front edge of the seat (Fig 3.10)

- Place the moveable arm of the goniometer on the midline of the foot support, on or parallel to the foot support reference plane, and the stationary arm on the vertical midline of the calf support, on or parallel to the lower leg support reference plane. The pivot center of the goniometer will be at the intersection of these two planes, and not necessarily at the back of the footplate.
- Read the internal, anterior side of the angle.

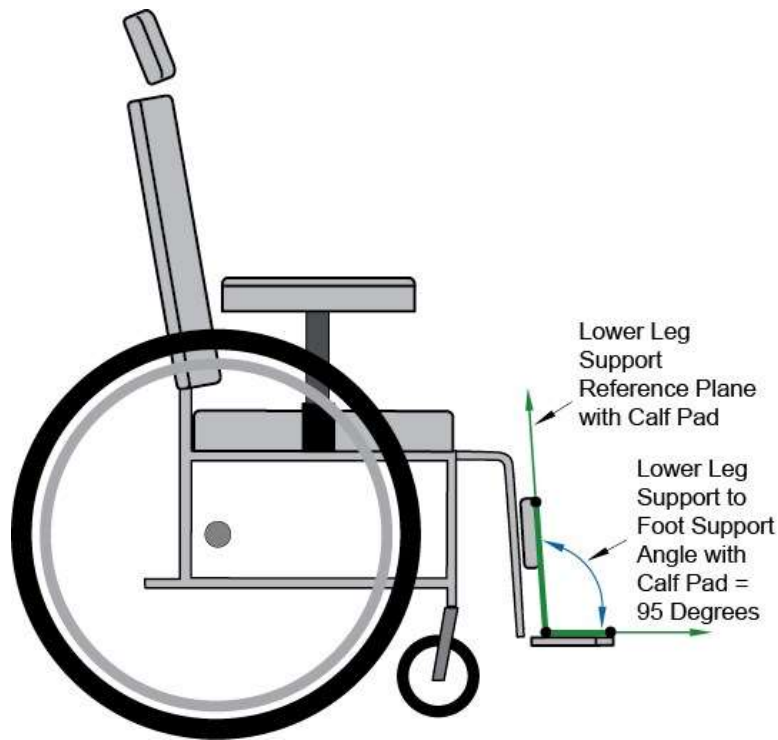


Fig. 3.10: Lower leg support to foot support angle, with calf pad

Typical Values:

Values may range from 80 to 120 degrees, but are typically 90 to 100 degrees. The value of this angle is 90 degrees in the Support Surface Reference Position (SSRP).

Considerations:

- If the person's lower leg and foot are parallel to the lower leg support and foot support reference planes, then the person's lower leg to foot angle will be the same as the lower leg support to foot support angle.
- The angle of a foot support can be defined and measured in one of two ways: either as an absolute angle (referenced to the horizontal) or as a relative angle. However it is the relative angle which affects the angle of dorsiflexion or plantarflexion required to maintain contact with the foot support.
- Note that if you adjust the placement of a footplate rearward or forward, without changing its absolute angle, the relative angle (lower leg support to foot support angle) WILL change. This is due to the change in orientation of the lower leg support reference plane because the plane intersects with the back of the footplate. (Alternatively, if there is a fixed posterior lower leg support, such as a calf pad, in place, then moving the foot support fore and aft will NOT change the relative angle.)

3 Absolute Angles of Inferior Supports

Inferior supports are those supports which are intended to contact the inferior surface of a body segment in the sitting position. The primary inferior supports in a wheelchair body support system are the seat, foot support and arm support. Their local X- and Z-axes lie in the support surface reference plane, and are therefore used as reference lines to represent the orientation of the support in each plane. (Fig. 3.11)

The method of determining absolute angles of inferior supports is the same regardless of whether it is a seat, foot support or arm support. The zero reference for both sagittal and frontal angles is the horizontal (either X_{WAS} for sagittal angles or Z_{WAS} for frontal angles). The zero reference for transverse angles is the X-axis of the wheelchair (X_{WAS}), which projects forward and is perpendicular to the line passing through the axles of the rear wheels.

Remember: The axis of the Wheelchair Axis System (WAS) used as the zero reference to define a particular absolute angle was chosen based on clinical intuitiveness. You can always choose to use one of the other two axes, as long as you measure to the corresponding local axis of the support surface. Because they are perpendiculars, the value of the angle will be the same.

This section includes the following inferior supports and their absolute angles:

- Seat
- Foot support
- Arm support

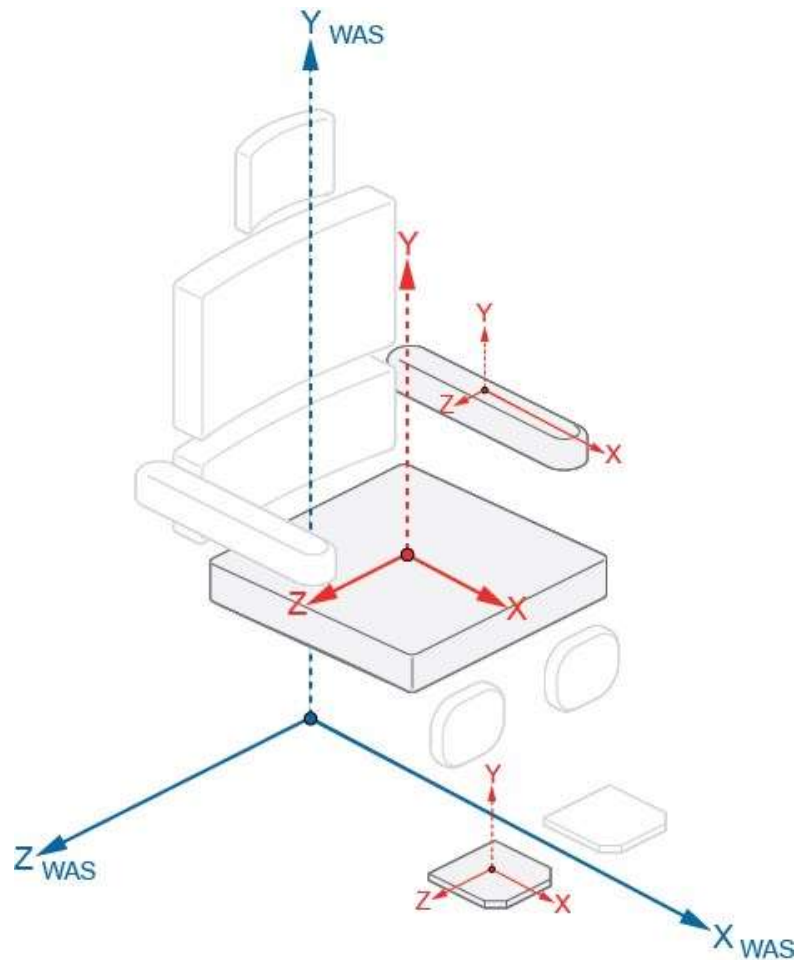


Fig. 3.11: Inferior supports

3.1 Seat sagittal angle

Purpose:

To provide a standard measure and term for the orientation of the seat in the sagittal plane relative to the horizontal

Clinical Relevance:

It is very common to have either a fixed or adjustable orientation of the seat in the sagittal plane, as changes in this angle can have a significant effect on the wheelchair user's posture, balance and function. Therefore, it can be clinically useful to document the existing and/or desired orientation (or range of orientations) of the seat in the sagittal plane. Many terms have been used to describe this angle, such as seat tilt, seat incline or seat plane angle. The term *seat sagittal angle* is recommended to maintain consistency in terms following the principles of the international standard.

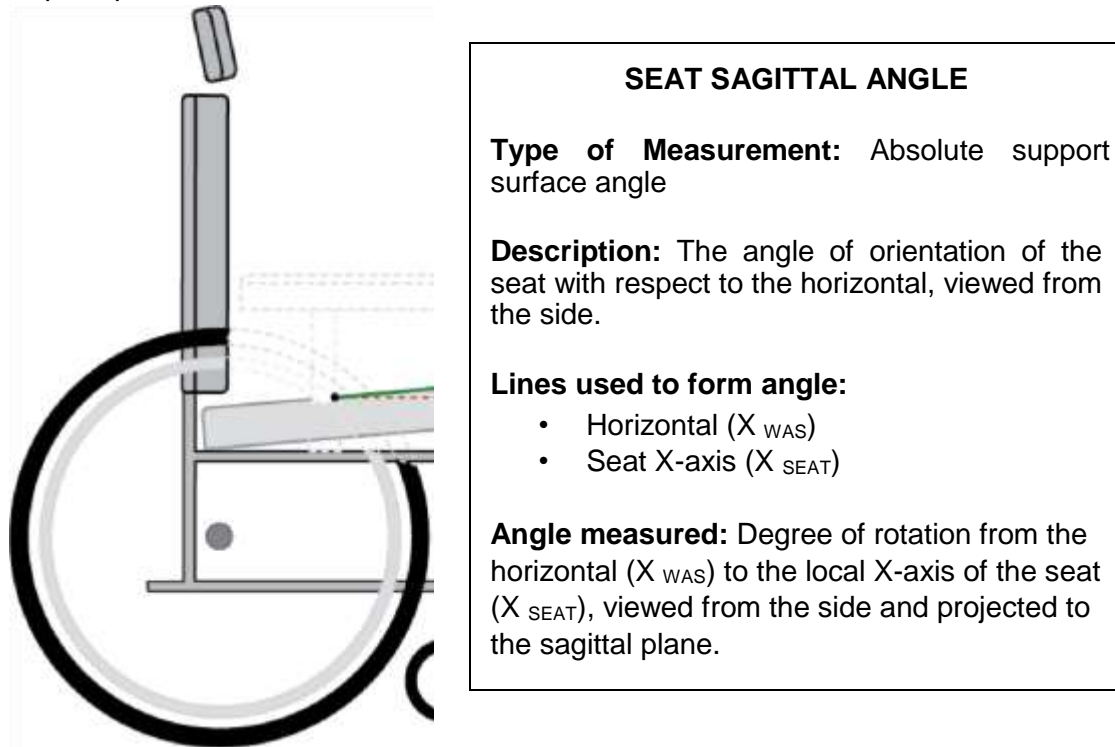


Fig. 3.12: Seat sagittal angle

Sample procedure:

1. Locate the seat reference plane and local X-axis reference line

- a) The local X-axis of the seat projects forward in an anterior direction from the geometric center of the seat, lying on the seat reference plane. This can be visualized as a line on the contact surface projecting forward along the midline of the seat.
- b) For contoured seats, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and seat X-axis reference line. Alternatively, place a clipboard on the top of the seat to approximate the reference plane.

2. Measure the angle

- a) Using an inclinometer or angle finder
 - i. Align the horizontal straight edge of the inclinometer or angle finder along or parallel to the seat X-axis reference line, and read the angle value.

b) Using a goniometer

- i. Stand to the side of the wheelchair and hold the goniometer so that the arms are pointing towards the front of the wheelchair.
- ii. Align the stationary arm of the goniometer with the horizontal.
- iii. Align the moveable arm with the seat X-axis reference line, on or parallel to the seat reference plane, pointing towards the front of the seat.
- iv. Read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the horizontal reference line

- If the front of the seat is higher than the back of the seat, signifying an upward rotation of the seat from the horizontal, the value is positive.
- If the front of the seat is lower than the back of the seat, signifying a downward rotation of the seat from the horizontal, the value is negative.

Typical values:

A seat sagittal angle of 0 degrees would indicate that the seat is horizontal, or parallel to the ground. Positive values indicate a posterior tilt, or *incline*, of the seat, and negative values indicate an anterior tilt, or *decline*, of the seat. Values up to +55 degrees could be recorded with adjustable tilt wheelchair seating systems.

Considerations:

- The absolute body segment angle which corresponds to the seat sagittal angle is the sagittal thigh angle. If the seated person's thigh is parallel to the seat reference plane, then the sagittal thigh angle will be the same as the seat sagittal angle.
- The seat sagittal angle can deviate from the zero reference position with or without changes in the seat to back support angle or seat to lower leg support angle. For example, if the seat sagittal angle is changed from 0 to +10 degrees, without changes in the absolute angles of the lower leg support or back support, then this would decrease the seat to back support angle and the seat to lower leg support angle by 10 degrees, as shown in Figs. 3.13a and 3.13b. Conversely, if the orientation of the back support and lower leg support change the same degree as the seat, then this would indicate a posterior tilt of the entire seating system, without changes in the three relative seating angles, such as that which occurs in a tilt-in-space wheelchair frame (Fig. 3.13c).
- Deviations of the seat in the sagittal plane are very common, as this angle can affect the orientation in space of the user's lower and/or upper body, as well as the degree of hip flexion that the user is in if the back support sagittal angle remains constant.

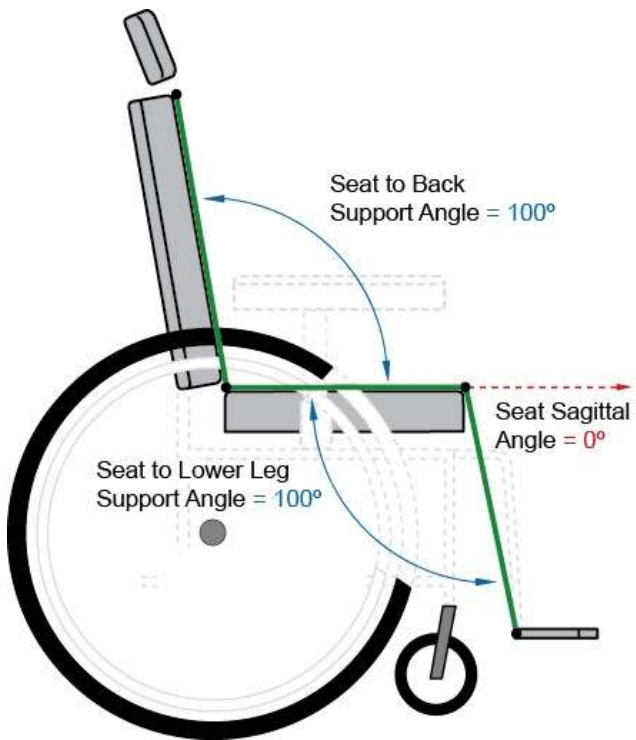


Fig. 3.13a: Seat sagittal = 0

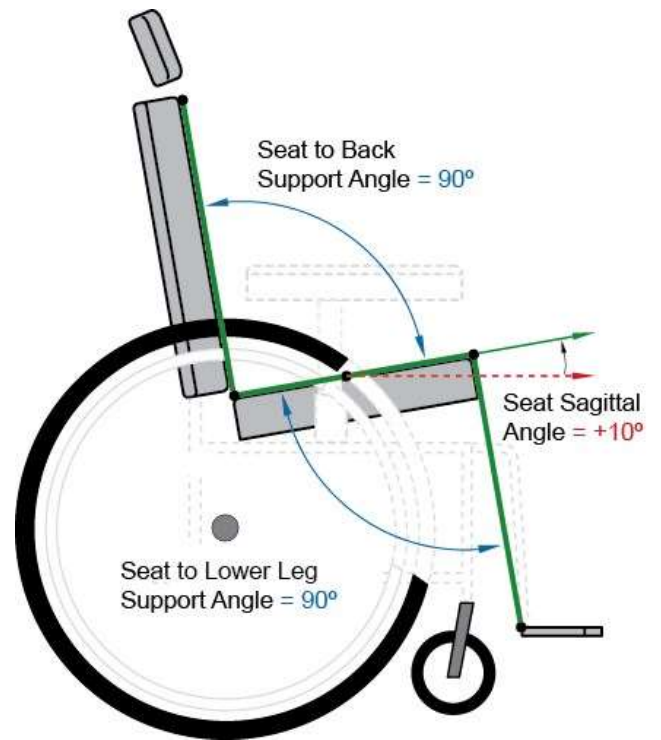


Fig. 3.13b: Seat sagittal = +10

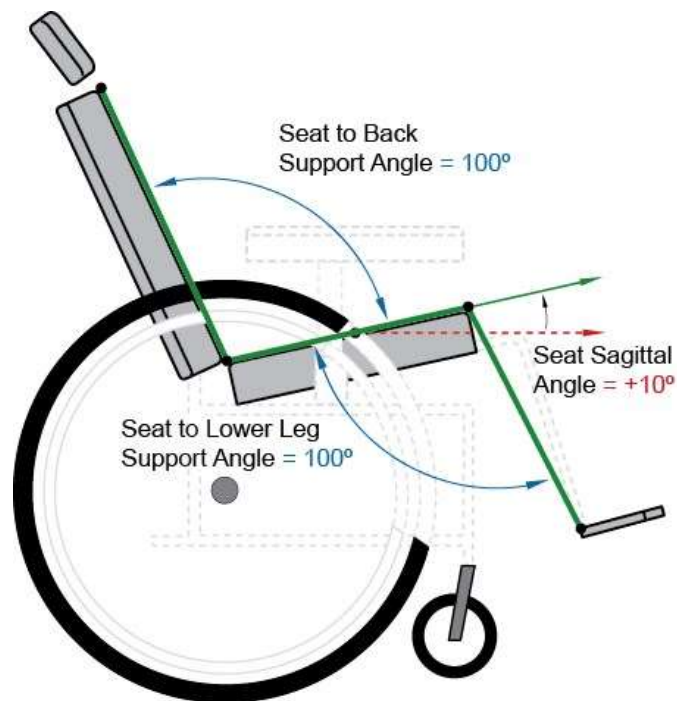


Fig. 3.13c: Seat sagittal = +10 via tilt in space

3.2 Seat frontal angle

Purpose:

To provide a standard measure and term for the orientation of the seat in the frontal plane relative to the horizontal

Clinical Relevance:

Purposeful deviations of the seat in this plane are uncommon, with the exception of a seat which is part of a body support system designed to rotate laterally, such as the custom lateral rotation feature offered on some power wheelchair bases. Understanding the term seat frontal angle may also be useful to describe or document a non-purposeful deviation of the seat in this plane, resulting from hardware mal-alignment or asymmetrical compression of foam. Therefore, this measurement can be used to document the existing or desired orientation (or range of orientation) of the seat in the frontal plane.

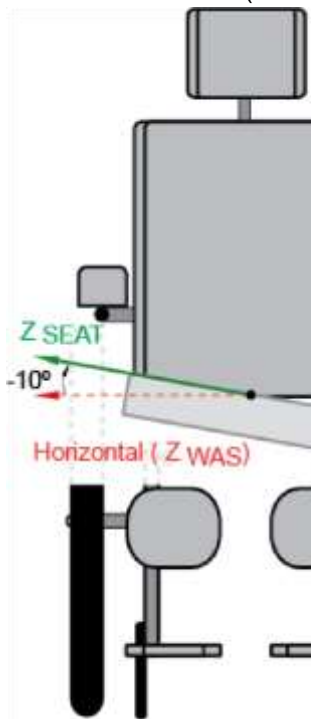


Fig. 3.14: Seat frontal angle

SEAT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the seat with respect to the horizontal, viewed from the front.

Lines used to form angle:

- Horizontal (Z_{WAS})
- Seat Z-axis (Z_{SEAT})

Angle measured: The degree of rotation from the horizontal (Z_{WAS}) to the local Z-axis of the seat (Z_{SEAT}), viewed from the front and projected to the frontal plane.

Sample procedure:

1. Locate the seat reference plane and local Z-axis reference line

- a) The local Z-axis of the seat projects to the right side in a lateral direction from the geometric center of the seat, lying on the seat reference plane. This can be visualized as a line lying crosswise on the contact surface at the middle of the seat.
- b) For contoured seats, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and seat Z-axis reference line. Alternatively, place a clipboard on the top of the seat to approximate the reference plane.

2. Measure the angle

- a) Using an inclinometer or angle finder:
 - i. Place the horizontal straight edge of the inclinometer or angle finder along or parallel to the seat Z-axis reference line, and read the angle value.

b) Using a goniometer:

- i. Stand in front of the wheelchair, and hold the goniometer on the left side of the seat, with the arms pointing to the right side.
- ii. Align the stationary arm of the goniometer with the horizontal, and align the moveable arm with the seat Z-axis reference line, on or parallel to the seat reference plane, and read the angle value.

3. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the right side of the seat is lower than the left side, signifying a counter-clockwise rotation of the seat from the horizontal when viewed from the front, the value is positive.
- If the left side of the seat is lower than the right side, signifying a clockwise rotation of the seat from the horizontal when viewed from the front, the value is negative.

Typical values:

A typical value would be 0, indicating that the seat is level, or horizontal in the frontal plane. A positive seat frontal angle would indicate that the seat is tilted down on its right side, and a negative value would indicate that the seat is tilted down on its left side.

Considerations:

- The absolute body angle which corresponds to the seat frontal angle would be the frontal pelvic angle. If the seated person's pelvis is parallel to the seat reference plane in this view - or more specifically, if the frontal pelvic line is parallel to the Z-axis reference line of the seat - then the frontal pelvic angle will be the same as the seat frontal angle.
- Deviations of the seat in the frontal plane are not common, except perhaps in the case of a custom contoured seat where the contact surface of the rear portion of the seat is angled in order to accommodate a fixed pelvic obliquity. Additionally, some manufacturers of custom contoured seating systems may intentionally rotate the seat in the frontal plane after fabrication in order to orient the person's upper torso and head in line with the vertical in the case of a fixed scoliosis. In effect, this would be setting the seat frontal angle at something other than zero. This measure provides a standardized term for defining that angular deviation.

3.3 Seat transverse angle

Purpose:

To provide a standard measure and term for the orientation of the seat in the transverse plane, relative to the wheelchair frame

Clinical Relevance:

Purposeful deviations of the seat in this plane are uncommon, with the exception of a seat which is part of a body support system designed to rotate or pivot, such as the captain's seat on a scooter which is designed to pivot in this plane for transfers. However, understanding the term seat transverse angle may also be useful to describe or document a non-purposeful deviation of the seat in this plane, resulting from hardware mal-alignment. This measurement can thus be used to document either the existing or desired orientation of the seat in this plane.

SEAT TRANSVERSE ANGLE

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the seat in the transverse plane with respect to the wheelchair frame, viewed from above.

Lines used to form angle:

- Wheelchair X-axis (X_{WAS})
- Seat X-axis (X_{SEAT})

Angle measured: The degree of rotation from the wheelchair X-axis (X_{WAS}) to the local X-axis of the seat (X_{SEAT}) viewed from above and projected to the transverse plane.

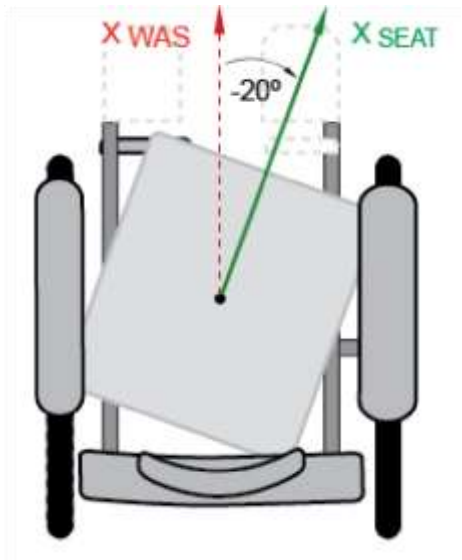


Fig. 3.15:
Seat

transverse angle

Sample procedure:

1. Locate the wheelchair X-axis

- The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the line passing through the axles of the rear wheels.
- To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rails.

2. Locate the seat X-axis reference line

- The seat X-axis reference line projects forward along the midline of the seat, perpendicular to the back edge of the seat.

3. Measure the angle (using a goniometer)

- Standing to the side or back of the wheelchair, hold the goniometer pivot center at the middle of the seat with the arms facing towards the front of the wheelchair.
- Align the stationary arm of the goniometer along or parallel to the wheelchair X-axis reference line (marked on the floor) and align the moveable arm with the seat X-axis reference line, and read the angle value.

4. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the front of the seat is rotated to the left, signifying a counter-clockwise rotation of the seat from the wheelchair X-axis when viewed from above, the value is positive.
- If the front of the seat is rotated to the right, signifying a clockwise rotation of the seat from the wheelchair X-axis when viewed from above, the value is negative.

Typical values:

A typical value would be 0, indicating that the seat is "square" with the wheelchair frame when viewed from above, as in the Support Surface Reference Position (SSRP). A positive seat transverse angle would

indicate that the seat is rotated to the left relative to the wheelchair frame, and a negative value would indicate that the seat is rotated to the right relative to the wheelchair frame.

Considerations:

- The absolute body angle which corresponds to the seat transverse angle would be either the transverse pelvic angle and/or the transverse thigh angle.
- Purposeful deviations of the seat in the transverse plane are not common, as typically the shape of the seat would be altered to support transverse pelvic or thigh angles which deviate from neutral, instead of rotating the entire seat.
- However, some custom contoured seats may be intentionally rotated in the transverse plane to accommodate a fixed windswept posture of the thighs, creating a seat transverse angle to support a desired transverse thigh angle. This measure provides a standardized term for defining that angular deviation.

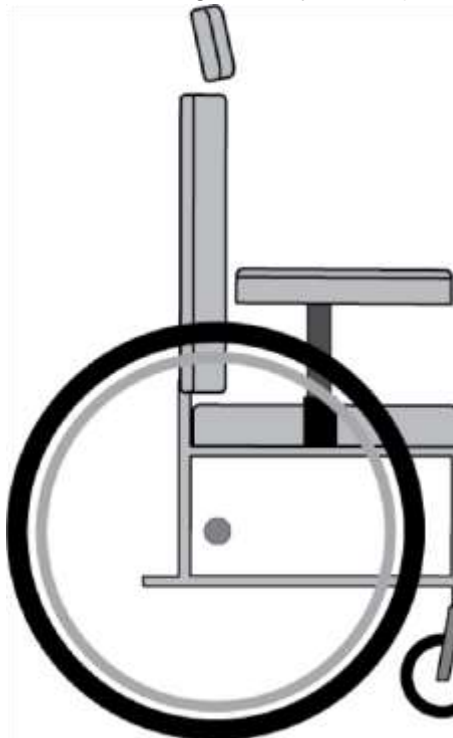
3.4 Foot support sagittal angle

Purpose:

To provide a standard measure and term for the orientation of the foot support in the sagittal plane, relative to the horizontal

Clinical Relevance:

Deviations of the foot support in this plane are very common, and may affect either the orientation of the whole lower leg and foot of the user, or the degree of ankle dorsiflexion or plantarflexion. This measurement can be used either to document the existing orientation or to specify the desired orientation (or range of orientation if angle is adjustable) of the foot support.



FOOT SUPPORT SAGITTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the foot support with respect to the horizontal, viewed from the side.

Lines used to form angle:

- Horizontal (X_{WAS})
- Foot support X-axis (X_{FS})

Angle measured: The degree of rotation from the horizontal (X_{WAS}) to the local Xaxis of the foot support (X_{FS}), viewed from the side and projected to the sagittal plane.

Fig. 3.16: Foot support sagittal angle

Sample procedures:**1. Locate the foot support reference plane and local X-axis reference line**

- a) The local X-axis of the foot support projects forward in an anterior direction from the geometric center of the support, lying on the foot support reference plane. This can be visualized as a line on the contact surface projecting forward along the midline of the foot support.

2. Measure the anglea) Using an inclinometer or angle finder

- i. Align the horizontal straight edge of the inclinometer or angle finder along or parallel to the foot support X-axis reference line, and read the angle value.

b) Using a goniometer

- i. Stand to the side of the wheelchair and hold the goniometer so that the arms are pointing towards the front of the wheelchair.
- ii. Align the stationary arm of the goniometer with the horizontal.
- iii. Align the moveable arm with the foot support X-axis reference line, on or parallel to the foot support reference plane, pointing towards the front of the support.
- iv. Read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the horizontal reference line

- If the front of the foot support is higher than the back of the foot support, signifying an upward rotation of the foot support from the horizontal, the value is positive.
- If the front of the foot support is lower than the back of the foot support, signifying a downward rotation of the foot support from the horizontal, the value is negative.

Typical values:

A foot support sagittal angle of 0 degrees would indicate that the foot support is horizontal, or parallel to the ground. Positive values indicate a posterior tilt, or incline, of the foot support, and negative values indicate an anterior tilt, or decline, of the foot support. Values up to +55 degrees may be recorded with adjustable tilt wheelchair seating systems.

Considerations:

- The absolute body angle which corresponds to the foot support sagittal angle is the sagittal foot angle. If the seated person's foot is parallel to the foot support reference plane, then the sagittal foot angle will be the same as the foot support sagittal angle.
- The foot support sagittal angle can deviate from the zero reference position with or without changes in the lower leg support to foot support angle. For example, if the foot support sagittal angle is changed from 0 to +20 degrees, without changes in the orientation of the lower leg support, then this would decrease the lower leg support to foot support relative angle by 20 degrees (see Figs. 3.17a and 3.17b). Conversely, if the foot support sagittal angle changes from 0 to +20 degrees by elevating the whole lower leg support assembly, such as may occur with an elevating leg support, the lower leg support to foot support angle does not change (Fig. 3.17c).

- Deviations of the foot support in the sagittal plane are very common, as this angle can affect the orientation in space of the user's lower leg and foot, as well as the degree of ankle dorsiflexion that the user is in if the lower leg support sagittal angle remains constant.

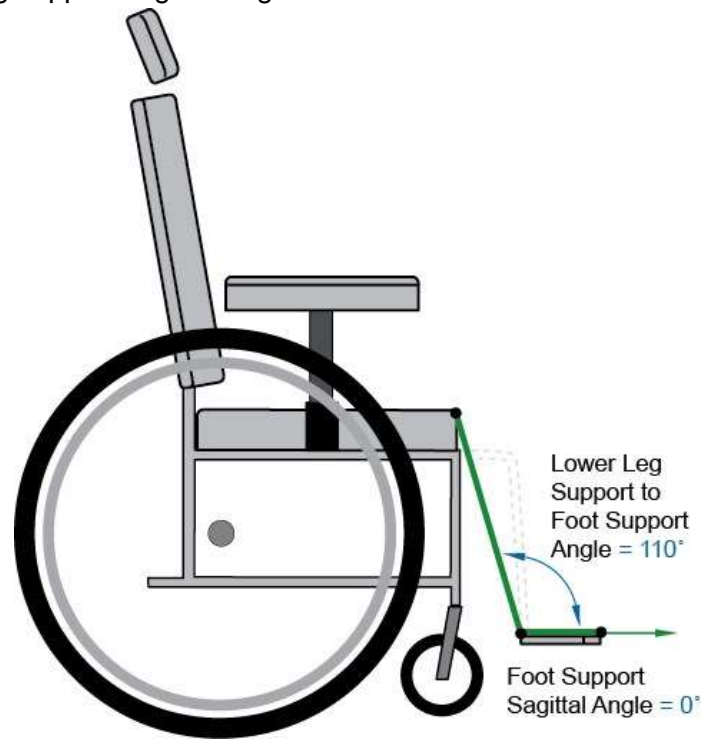


Fig. 3.17a: Foot support sagittal angle = 0

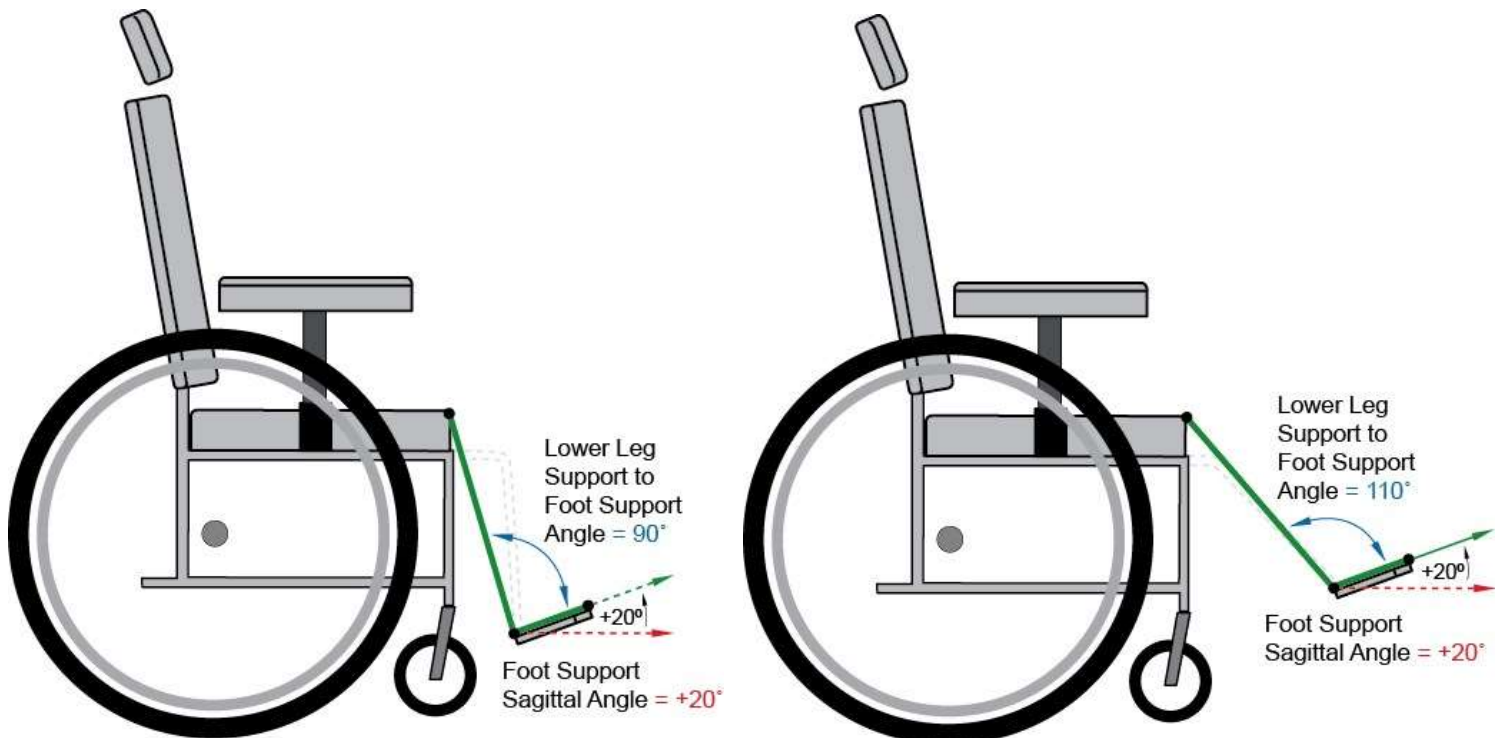


Fig. 3.17b: Foot support sagittal angle = +20

Fig. 3.17c: Foot support sagittal angle = +20 via elevating leg support

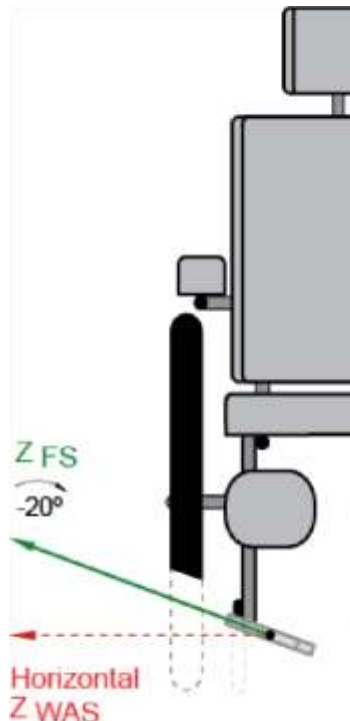
3.5 Foot support frontal angle

Purpose:

To provide a standard measure and term for the orientation of the foot support in the frontal plane (front view) relative to the horizontal

Clinical Relevance:

Deviations of the foot support in this plane are uncommon, but may be required to accommodate an ankle or foot deformity, or to support a user's lower leg in a non-neutral position (due to hip contracture or deformity). This measurement can be used to document either the existing or desired orientation of the foot support in the frontal plane.



FOOT SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the foot support with respect to the horizontal, viewed from the front.

Lines used to form angle:

- Horizontal (Z_{WAS})
- Foot support Z-axis (Z_{FS})

Angle measured: The degree of rotation from the horizontal (Z_{WAS}) to the local Z-axis of the foot support (Z_{FS}), viewed from the front and projected to the frontal plane.

Fig. 3.18: Foot support frontal angle

Sample procedure:

1. Locate the foot support reference plane and local Z-axis reference line

- a) The local Z-axis of the foot support projects sideways to the right from the geometric center of the support, lying on the foot support reference plane. This can be visualized as a line on the foot support surface projecting from side to side when viewed from the front.

2. Measure the angle

a) Using an inclinometer or angle finder

- i. Place the horizontal straight edge of the inclinometer or angle finder on the foot support surface, along or parallel to the foot support Z-axis reference line, and read the angle value.

b) Using a goniometer

- i. Stand in front of the wheelchair, and hold the goniometer on the left side of the foot support, with the arms pointing to the right side.

- ii. Align the stationary arm of the goniometer with the horizontal, and align the moveable arm with the foot support Z-axis reference line, on or parallel to the foot support reference plane, and read the angle value.

3. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the right side of the foot support is lower than the left side, signifying a counter-clockwise rotation of the foot support from the horizontal when viewed from the front, the value is positive.
- If the left side of the foot support is lower than the right side, signifying a clockwise rotation of the foot support from the horizontal when viewed from the front, the value is negative.

Typical values:

A typical value would be 0, indicating that the foot support is level, or horizontal in the frontal plane. A positive foot support frontal angle would indicate that the foot support is tilted down on its right side, and a negative value would indicate that the foot support is tilted down on its left side.

Considerations:

- The absolute body angle which corresponds to the foot support frontal angle would be the frontal foot angle. If the seated person's foot is parallel to the foot support reference plane in this view - or more specifically, if the frontal foot line is parallel to the foot support Z-axis reference line - then the frontal foot angle will be the same as the foot support frontal angle.
- Intentional deviations of the foot support in the frontal plane are not common in standard seating configurations. However, when seating individuals with lower extremity joint contractures or deformity, it may be necessary to angle the foot support in the frontal plane in order to accommodate an internal or external rotation contracture of the hip, or an inversion/eversion deformity of the ankle. This measure provides a standardized term for defining that angular deviation.
- For example, a right foot support frontal angle of +10 degrees could be used to support frontal lower leg and foot angles of +10 degrees, to accommodate user's right hip in 10 degrees of external rotation. The same foot support frontal angle would support the user's left hip in 10 degrees of internal rotation.

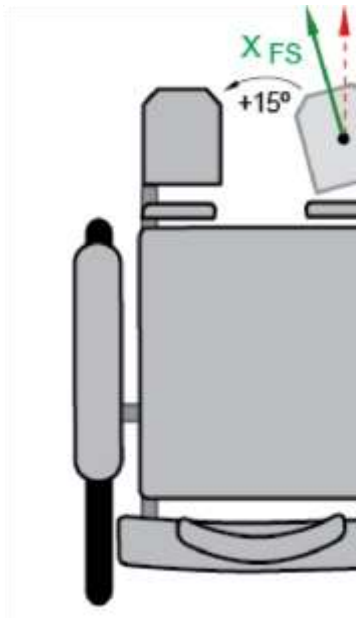
3.6 Foot support transverse angle

Purpose:

To provide a standard measure and term for the orientation of the foot support in the transverse plane (top view), relative to the wheelchair frame

Clinical Relevance:

Purposeful deviations of the foot support in this plane are uncommon; however it may be required to accommodate an ankle/foot deformity, out toeing of the foot resulting from external tibial torsion, or to support a user's lower extremity in a windswept position due to hip abduction or adduction contracture. This measurement can be used either to document the existing orientation or to specify the desired orientation of the foot support in the transverse plane.



FOOT SUPPORT TRANSVERSE ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the foot support in the transverse plane, with respect to the wheelchair, viewed from the top.

Lines used to form angle: □

Wheelchair X-axis (X_{WAS})

□ Foot support X-axis (X_{FS})

Angle measured: The degree of rotation from the wheelchair X-axis (X_{WAS}) to the local X-axis of the foot support (X_{FS}), viewed from above and projected to the transverse plane.

Fig. 3.19: Foot support transverse angle

Sample procedure:

1. Locate the wheelchair X-axis

- The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the line passing through the rear wheel axles.
- To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rails.

2. Locate the foot support reference plane and local X-axis reference line

- The local X-axis of the foot support projects forward in an anterior direction from the geometric center of the support, lying on the foot support reference plane. This can be visualized as a line on the surface projecting forward along the midline of the foot support, perpendicular to the back edge of the foot support if it is rectangular.

3. Measure the angle (using a goniometer)

- Viewing the foot support from above, hold the goniometer pivot center at the middle of the foot support, with the arms facing towards the front of the wheelchair.
- Align the stationary arm of the goniometer parallel to the wheelchair X-axis reference line (marked on the floor) and align the moveable arm with the foot support X-axis reference line, and read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the global reference line

- If the front of the foot support is rotated to the left, signifying a counter-clockwise rotation of the foot support from the wheelchair X axis when viewed from above, the value is positive.

- If the front of the foot support is rotated to the right, signifying a clockwise rotation of the foot support from the wheelchair X axis when viewed from above, the value is negative.

Typical values:

A typical value would be 0, indicating that the foot support is “square” with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP). A positive foot support transverse angle would indicate that the foot support is rotated to the left side of the wheelchair, and a negative value would indicate that the foot support is rotated to the right side of the wheelchair.

Considerations:

- The absolute body angle which corresponds to the foot support transverse angle would be either the transverse foot angle and/or the transverse thigh angle.
- If order to achieve a transverse thigh angle which is not zero, for instance as part of a fixed windswept posture, the foot supports may need to be rotated in the transverse plane a degree equal to the amount of rotation of the thigh in the transverse plane, in order to maintain neutral ankle alignment. This measure provides a standardized term for defining that angular deviation of the foot support.
- For example, to support a transverse left thigh angle of +10 degrees, the left foot support transverse angle may be adjusted to +10 degrees, to support the foot in line with the thigh from the top view.

3.7 Arm support sagittal angle

Purpose:

To provide a standard measure and term for the orientation of the arm support in the sagittal plane (side view) relative to the horizontal

Clinical Relevance:

Deviations of the arm support in this plane are very common when the arm support is part of a body support system which tilts in space. Independent adjustments of the arm support sagittal angle may also be prescribed to support the user’s elbow in more or less flexion. This measurement can be used either to document the existing orientation or to specify the desired orientation of the arm support in this plane.

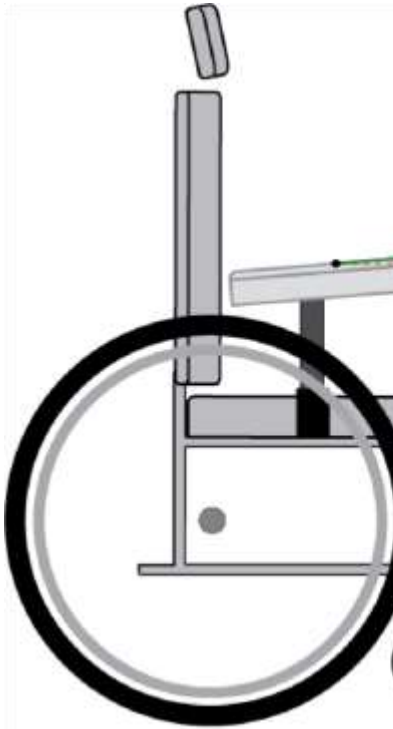


Fig. 3.20: Arm support sagittal plane

ARM SUPPORT SAGITTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the arm support with respect to the horizontal, viewed from the side.

Lines used to form angle:

- Horizontal (X_{WAS})
- Arm support X-axis (X_{AS})

Angle measured: The degree of rotation from the horizontal (X_{WAS}) to the local X-axis of the arm support (X_{AS}), viewed from the side and projected to the sagittal plane.

Sample procedures:

1. Locate the arm support reference plane and local X-axis reference line

- a) The local X-axis of the arm support projects forward in an anterior direction from the geometric center of the support, lying on the arm support reference plane. This can be visualized as a line on the surface projecting forward along the midline of the arm support, perpendicular to the back edge of the arm support if it is rectangular.

2. Measure the angle

a) Using an inclinometer or angle finder

- i. Place the horizontal straight edge of the inclinometer or angle finder onto the contact surface of the arm support (if it is flat), on or parallel to the arm support X-axis reference line, and read the angle value.

b) Using a goniometer

- i. Stand to the side of the wheelchair and hold the goniometer so that the arms are pointing towards the front of the wheelchair.
- ii. Align the stationary arm of the goniometer with the horizontal.
- iii. Align the moveable arm with the arm support X-axis reference line, on or parallel to the arm support reference plane, pointing towards the front of the support.
- iv. Read the angle value.

3. Determine positive or negative notation based on the direction of rotation away from the horizontal reference line:

- If the front of the support is higher than the back of the arm support, signifying an upward rotation of the arm support from the horizontal, the value is positive.
- If the front of the support is lower than the back of the support, signifying a downward rotation of the arm support from the horizontal, the value is negative.

Typical values:

An arm support sagittal angle of 0 degrees would indicate that the arm support is horizontal, or parallel to the ground. Positive values indicate a posterior tilt, or *incline*, of the arm support, and negative values indicate an anterior tilt, or *decline*, of the arm support. Values up to +55 degrees or more may be recorded with adjustable tilt and recline seating systems.

Considerations:

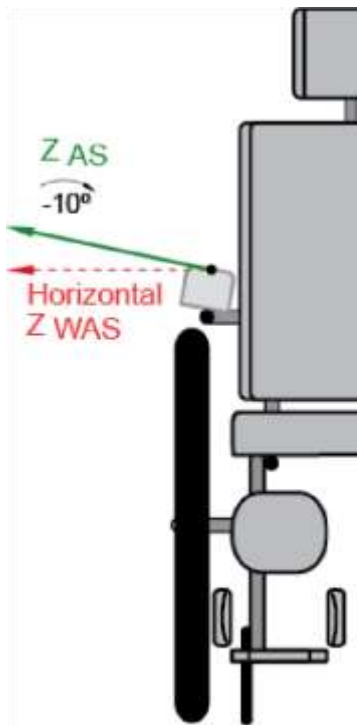
- The absolute body angle which corresponds to the arm support sagittal angle is the sagittal forearm angle (not included in this guide). If the seated person's forearm is parallel to the arm support reference plane, then the sagittal forearm angle will be the same as the arm support sagittal angle.
- The arm support sagittal angle can deviate from the zero reference position with or without changes in the seat or back support sagittal angles.
- Adjustments of the arm support sagittal angle independent of the seat or back support sagittal angles may be needed to support the user's arm in a position of greater than 90 degrees of elbow flexion.

3.8 Arm support frontal angle**Purpose:**

To provide a standard measure and term for the orientation of the arm support in the frontal plane (front view) relative to the horizontal

Clinical Relevance:

Purposeful deviations of the arm support in this plane are very uncommon. However, understanding the term arm support frontal angle may be useful to describe or document a non-purposeful deviation of the arm support in this plane resulting from hardware mal-alignment. This measurement can be used either to document the existing orientation or to specify the desired orientation of the arm support in the frontal plane.



ARM SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the arm support with respect to the horizontal, viewed from the front.

Lines used to form angle:

- Horizontal (Z_{WAS})
- Arm support Z-axis (Z_{AS})

Angle measured: The degree of rotation from the horizontal (Z_{WAS}) to the local Z-axis of the arm support (Z_{AS}), viewed from the front and projected to the frontal plane.

Fig. 3.21: Arm support frontal angle

Sample procedure:

1. Locate the arm support reference plane and local Z-axis reference line

- a) The local Z-axis of the arm support projects sideways to the right from the geometric center of the support, lying on the arm support reference plane. This can be visualized as a line on the arm support surface projecting from side to side when viewed from the front.

2. Measure the angle

a) Using an inclinometer or angle finder

- i. Place the horizontal straight edge of the inclinometer or angle finder on the arm support surface, along or parallel to the Z-axis reference line, and read the angle value.

b) Using a goniometer

- i. Stand in front of the seat, and hold the goniometer on the left side of the arm support, with the arms pointing to the right side.
- ii. Align the stationary arm of the goniometer with the horizontal, and align the moveable arm with the arm support Z-axis reference line, on or parallel to the arm support reference plane, and read the angle value.

3. Determine positive or negative value based on the direction of rotation from the horizontal reference line

- If the right side of the arm support is lower than the left side, signifying a counter-clockwise rotation of the arm support from the horizontal when viewed from the front, the value is positive.
- If the left side of the arm support is lower than the right side, signifying a clockwise rotation of the arm support from the horizontal when viewed from the front, the value is negative.

Typical values:

A typical value would be 0, indicating that the arm support is level, or horizontal in the frontal plane. A positive value would indicate that the arm support is tilted down on its right side, and a negative arm support frontal angle would indicate that the arm support is tilted down on its left side.

Considerations:

- Intentional deviations of the arm support in the frontal plane are not common in standard seating configurations. However, mal-alignment of the hardware attaching the arm support pad to the arm support structure may result in deviations of the arm support in this plane. This measure provides a standardized term for describing or defining that angular deviation.

3.9 Arm support transverse angle

Purpose:

To provide a standard measure and term for the orientation of the arm support in the transverse plane (top view), relative to the wheelchair frame

Clinical Relevance:

Deviations of standard arm supports in this plane are less common, however may be required to accommodate a windswept position of the upper extremities, or to support a user's shoulder in a position of internal or external rotation. This measurement can therefore be used either to document the existing orientation, or to specify the desired orientation of the arm support in the transverse plane.

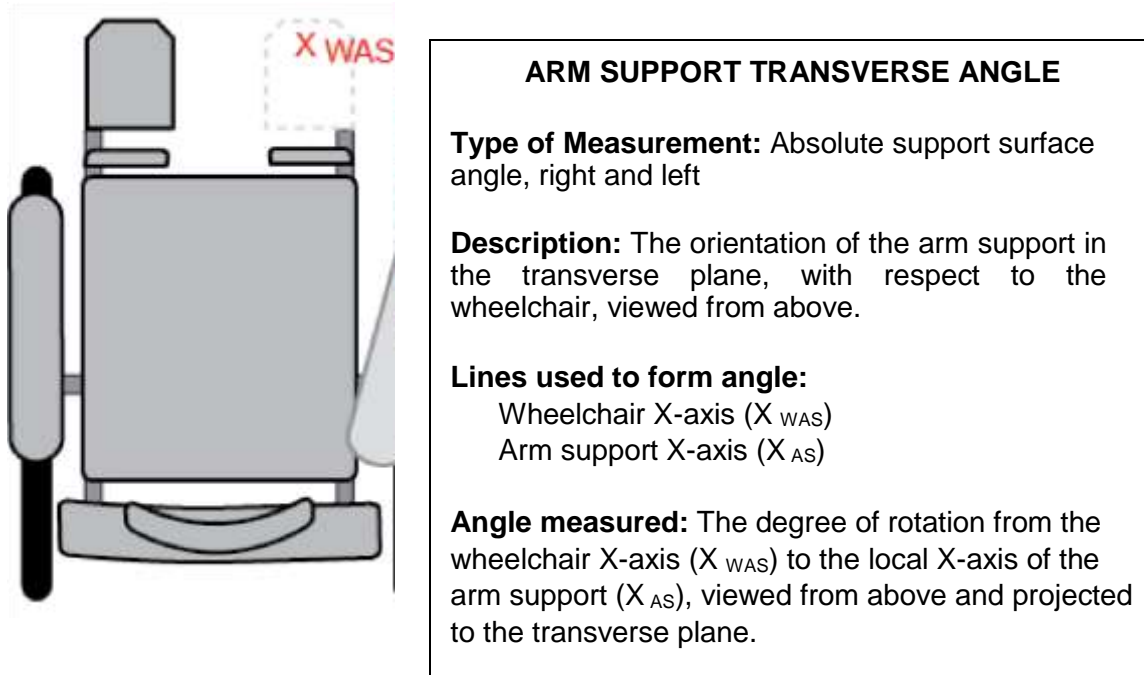


Fig. 3.22: Arm support transverse angle

Sample procedure:

1. Locate the wheelchair X-axis

- a) The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the line passing through the rear wheel axles.
- b) To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- c) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rails.

2. Locate the arm support reference plane and local X-axis reference line

- The local X-axis of the arm support projects forward in an anterior direction from the geometric center of the support, lying on the arm support reference plane. This can be visualized as a

line on the surface projecting forward along the midline of the arm support, perpendicular to the back edge of the arm support if it is rectangular.

3. Measure the angle (using a goniometer)

- a) Viewing the arm support from above, hold the goniometer pivot center at the middle of the support, with the arms facing towards the front of the wheelchair.
- b) Align the stationary arm of the goniometer parallel to the wheelchair X-axis reference line (marked on the floor) and align the moveable arm with the arm support X-axis reference line. Read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the global reference line

- If the front of the arm support is rotated to the wheelchair's left, signifying a counter-clockwise rotation of the arm support from the wheelchair X-axis when viewed from above, the value is positive.
- If the front of the arm support is rotated to the wheelchair's right, signifying a clockwise rotation of the arm support from the wheelchair X-axis when viewed from above, the value is negative.

Typical values:

A typical value would be 0, indicating that the arm support is "square" with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP). A positive value would indicate that the arm support is rotated to the left relative to the wheelchair frame, and a negative arm support transverse angle would indicate that the arm support is rotated to the right relative to the wheelchair frame.

Considerations:

- The absolute body angle which corresponds to the arm support transverse angle would be the transverse forearm arm angle (not included in this guide).
- If it is necessary to support a user's shoulder in a position of internal or external rotation, the arm support may need to be rotated in the transverse plane a degree equal to the amount of rotation of the shoulder joint. (Some arm support troughs are designed to rotate in this plane, using angle adjustable hardware.) This measure provides a standardized term for defining that angular deviation.
- For example, to support a transverse left forearm angle of -10 degrees, the transverse left arm support angle would be set up to be -10 degrees. This would support the left shoulder in a position of internal rotation.
- To support a position of 10 degrees of internal rotation in both right and left shoulders, the left arm support transverse angle would be set at -10 degrees, and the right arm support transverse angle would be set at +10 degrees.

4 Absolute Angles of Posterior Supports

Posterior supports are those supports which are intended to contact the posterior surface of a body segment in the sitting position. The primary posterior supports in a wheelchair seating system are the back support, head support and lower leg support. Their local Y- and Z-axes lie in the support surface reference plane, and are therefore used as reference lines to represent the orientation of the support in each plane (Fig. 3.23).

The method of determining absolute angles of posterior supports is the same regardless of whether it is a back support, head support or lower leg support. Because these posterior support surfaces align with the vertical in the Support Surface Reference Position (SSRP), the zero reference for both sagittal and frontal angles is the vertical. The exception is the head support frontal angle, which is referenced to the horizontal. The zero reference for transverse angles is the Z-axis of the wheelchair, represented by a line passing through the axles of the rear wheels.

Remember: The axis of the Wheelchair Axis System (WAS) used as the zero reference to define a particular absolute angle was chosen based on clinical intuitiveness. You can always choose to use one of the other two axes, as long as you measure to the corresponding local axis of the support surface. Because they are perpendiculars, the value of the angle will be the same.

This section includes the following posterior supports and their absolute angles:

- **Back support**

- Head support
- Lower leg support

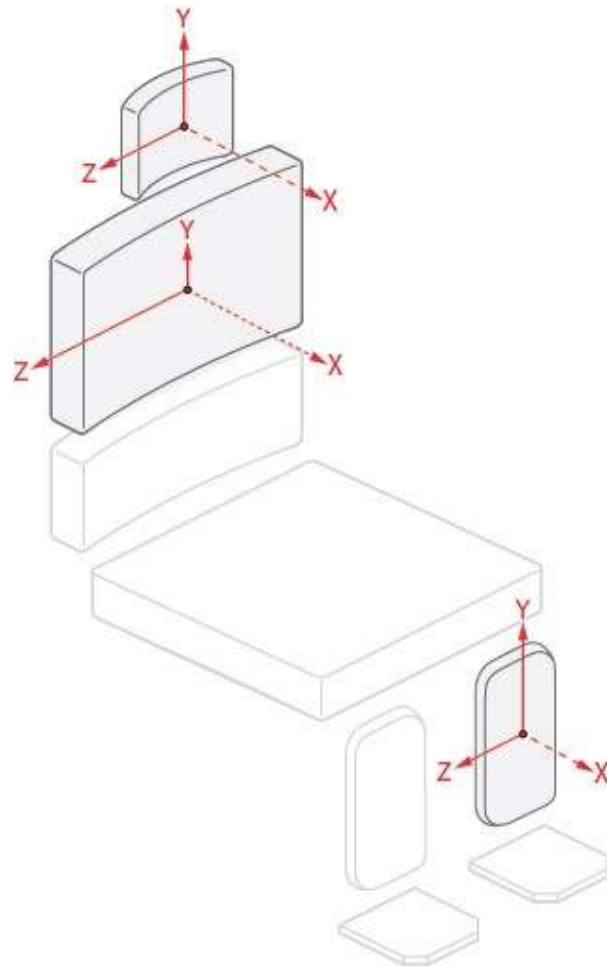


Fig. 3.23: Posterior supports

4.1 Back support sagittal angle

Purpose:

To provide a standard measure and term for the orientation of the back support in the sagittal plane relative to the vertical

Clinical Relevance:

Both adjustable and fixed deviations of the back support in this plane are very common, as this angle affects the orientation in space of the user's upper body, and consequently has a significant effect on both posture and function. This measurement can be used to document either the existing or desired orientation (or range of orientations if angle is adjustable) of the back support in this plane.

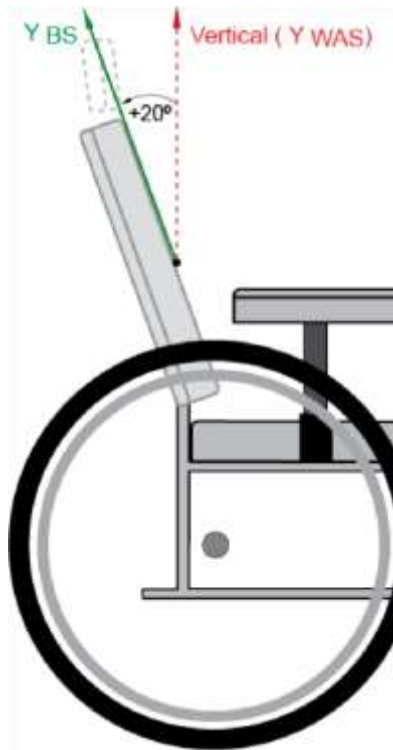


Fig. 3.24: Back support sagittal angle

BACK SUPPORT SAGITTAL ANGLE

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the back support with respect to the vertical, viewed from the side.

Lines used to form angle:

- Vertical (Y_{WAS})
- Back support Y-axis (Y_{BS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the back support (Y_{BS}), viewed from the side and projected to the sagittal plane.

Sample procedure:

1. Locate the back support reference plane and local Y-axis reference line

- a) The local Y-axis of the back support projects upwards from the geometric center of the back support, lying on the back support reference plane. This can be visualized as a line on the contact surface projecting upwards along the vertical midline of the back support.
- b) For contoured back supports, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and back support Y-axis reference line. Alternatively, hold a clipboard or flat surface on the contact surface to approximate the reference plane.

2. Measure the angle

a) Using an inclinometer or angle finder

- i. Align the vertical straight edge of the inclinometer or angle finder along the vertical midline of the back support, on or parallel to the back support Y-axis reference line, and read the angle value.

Hint: If your inclinometer does not have both a vertical and horizontal straight edge, make sure it is set to read 0 degrees when the straight edge is aligned with the vertical. b) Using a goniometer

- i. Standing on the right side of the wheelchair, hold the goniometer so that the arms are facing upwards.
- ii. Align the stationary arm of the goniometer with the vertical reference line. This can be done by sighting along a plumb line, or by using a goniometer with a bubble level attached to the stationary arm.

- iii. Align the moveable arm along the vertical midline of the back support, on or parallel to the back support Y-axis reference line, and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the vertical reference line

- If the top of the back support is more posterior than the bottom, signifying a posterior, backwards rotation from the vertical, the value is positive.
- If the top of the back support is more anterior than the bottom, signifying an anterior, forward rotation from the vertical, the value is negative.

Typical values:

A back support sagittal angle of 0 degrees would indicate that the back support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Negative values would indicate that the back support is *proclined*, or angled forward of the vertical, which is not very common. Values from 0 to +30 would be more typical, indicating that the back support is *reclined*, or angled backwards from the vertical. Values up to +55 degrees or more could be recorded with adjustable tilt or recline seating systems.

Considerations:

- The absolute body angle which corresponds to the back support sagittal angle is the sagittal trunk angle. If the seated person's trunk is parallel to the back support reference plane (or more specifically, if their sagittal trunk line is parallel to the back support Y-axis reference line), then the back support sagittal angle will be the same as the sagittal trunk angle.
- The back support sagittal angle can deviate from the zero reference position with or without changes in the seat to back support angle. For example, if the back support sagittal angle is changed from 0 to +10 degrees, without changes in the orientation of the seat, then this would increase the seat to back support angle by 10 degrees. Conversely, if both the back support sagittal angle and the seat sagittal angle changed from zero to +10 degrees, this would indicate a posterior tilt of the entire seating system, without changes in the seat to back support angle, such as that which occurs in a tilt-in-space wheelchair frame.
- Deviations of the back support in the sagittal plane are very common, as this angle effects the orientation in space of the user's upper body, as well as the degree of hip flexion that the user is in if the seat sagittal angle remains constant.
- The term 'recline' refers to the act of moving the back support posteriorly, independent of the seat. Reclining the back support will therefore change both the back support sagittal angle as well as the seat to back support angle.

4.2 Back support frontal angle

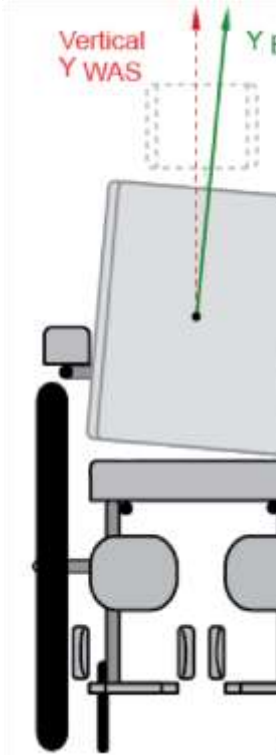
Purpose:

To provide a standard term and measure for the orientation of the back support in the frontal plane (front view) relative to the vertical

Clinical Relevance:

Deviations of the back support in this plane are uncommon, with the exception of a back support which is part of a body support system designed to rotate laterally, such as the custom lateral rotation feature offered on some power wheelchair bases, or a custom back support whose hardware may allow rotation in this plane to accommodate fixed spinal deformity. This measurement can be used to document either the existing or desired orientation of the back support in the frontal plane. Understanding the term back support frontal

angle may also be useful to describe or document a non-purposeful deviation of the back support in this plane, resulting from hardware mal-alignment.



BACK SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the back support with respect to the vertical, viewed from the front.

Lines used to form angle:

- Vertical (Y_{WAS})
- Back support Y-axis (Y_{BS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the back support (Y_{BS}), viewed from the front and projected to the frontal plane.

Fig. 3.25: Back support frontal angle

Sample procedure:

1. Locate the back support reference plane and local Y-axis reference line

- a) The local Y-axis of the back support projects upwards from the geometric center of the back support, lying on the back support reference plane. This can be visualized as a line on the contact surface projecting upwards along the vertical midline of the back support.
- c) For contoured back supports, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and back support Y-axis reference line.

2.

Measure the anglea) Using an inclinometer or angle finder

- i. Place the vertical straight edge of the inclinometer or angle finder along or parallel to the back support Y-axis, along the vertical midline of the back support, and read the angle value.

***Hint:** If your inclinometer does not have both a vertical and horizontal straight edge, make sure it is set to read 0 degrees when the straight edge is aligned with the vertical*

b) Using a goniometer

- i. Standing in front of the wheelchair, place the goniometer pivot center at the center of the back support, with the arms facing upwards.
- ii. Align the stationary arm of the goniometer with the vertical. This can be done by sighting along a known vertical reference such as a plumb line, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm parallel to the back support Y-axis reference line and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the vertical reference line

- If the back support is tilted to its right signifying a counterclockwise rotation from the zero reference position when viewed from the front, the value is positive.
- If the back support is tilted to its left, signifying a clockwise rotation from the zero reference position when viewed from the front, the value is negative.

Typical Values:

A typical value would be 0, indicating that the back support is in a neutral position as in the Support Surface Reference Position (SSRP). A positive back support frontal angle would indicate that the back support is tilted to the user's right, and a negative value would indicate that the back support is tilted to the user's left. Values may range from -45 to +45 degrees in a seating system with lateral rotational tilt.

Considerations:

- The absolute body angle which corresponds to the back support frontal angle would be either the frontal trunk angle or the frontal sternal angle. However, purposeful deviation of the back support in the frontal plane to support a non-zero frontal sternal angle is not common. Typically, the shape of the back support would be altered to support a deviation of the upper trunk in the frontal plane such as may occur with a fixed scoliosis.
- However, some custom contoured back supports may be intentionally rotated in the frontal plane to accommodate a fixed scoliosis or pelvic obliquity, in order to change the orientation of a person's upper torso or head in this plane. This measure provides a standardized term for defining that angular deviation.

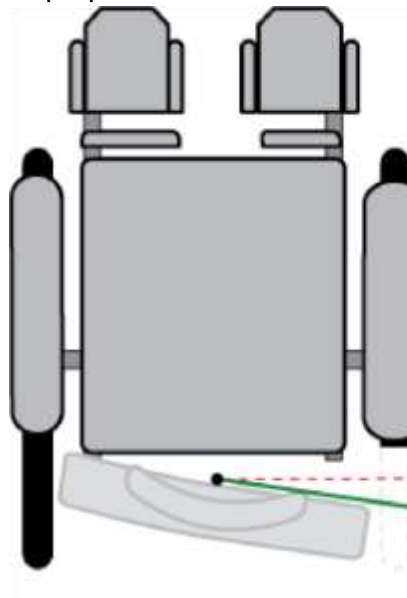
4.3 Back support transverse angle

Purpose:

To provide a standard measure and term for the orientation of the back support in the transverse plane (top view), relative to the wheelchair

Clinical Relevance:

Purposeful deviations of the back support in this plane are uncommon, with the exception of a back support which is part of a body support system designed to rotate laterally, such as the captain's seat on a scooter which is designed to pivot in this plane for transfers, or a back support whose hardware may allow rotation in this plane to accommodate fixed spinal deformity. This measurement can be used to document the existing or desired orientation (or range of orientation if angle is adjustable) of the back support in this plane. Understanding the term back support transverse angle may also be useful to describe or document a nonpurposeful deviation of the back support in this plane, resulting from hardware mal-alignment.



BACK SUPPORT TRANSVERSE ANGLE

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the back support in the transverse plane, with respect to the wheelchair, viewed from above.

Lines used to form angle: □

Wheelchair Z-axis (Z_{WAS})

□ Back support Z-axis (Z_{BS})

Angle measured: The degree of rotation from the wheelchair Z-axis (Z_{WAS}) to the local Z-axis of the back (Z_{BS}) viewed from above and projected to the transverse plane.

Fig. 3.26: Back support transverse angle

Sample procedure:

1. Locate the wheelchair Z-axis

- The wheelchair Z-axis (Z_{WAS}) is a line passing through the rear wheel axles of wheelchair.
- To locate the Z-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting

2.

forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis.

- c) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair Z-axis, such as the back edge of the seat pan, or a line between the back canes.

Locate the back support reference plane and local Z-axis reference line

- a) The local Z-axis of the back support projects to the right side from the geometric center of the back support, lying on the back support reference plane. This can be visualized as a line on the contact surface extending sideways across the middle of the back support.
- b) For contoured back supports, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and back support Z-axis reference line. Alternatively, hold a clipboard or flat surface on the contact surface to approximate the reference plane.

3. **Measure the angle (using a goniometer)**

- a) Place the goniometer pivot center at the top of the back support, with the arms facing towards the right side.
- b) Align the stationary arm of the goniometer with the wheelchair Z-axis. This can be done by sighting down to a piece of tape placed along the floor, or any other line which is parallel to the wheelchair Z-axis.
- c) Align the moveable arm parallel to the back support Z-axis reference line and read the angle value.

4. **Determine positive or negative notation based on the direction of rotation from the zero reference line**

- If the back support is rotated to the left signifying a counter-clockwise rotation from the zero reference position when viewed from above, the value is positive.
- If the back support is rotated to the right signifying a clockwise rotation from the zero reference position when viewed from above, the value is negative.

Typical Values:

A typical value would be 0, indicating that the back support is in a neutral position as in the Support Surface Reference Position (SSRP), without rotation relative to the wheelchair frame when viewed from above. A positive value would indicate that the back support is rotated to the left relative to the wheelchair frame, and a negative back support transverse angle would indicate that the back support is rotated to the right relative to the wheelchair frame.

Considerations:

- The absolute body segment angle which corresponds to the back support transverse angle would be the transverse trunk angle.
- In more complex seating configurations, one may need to rotate the back support in the transverse plane to accommodate a user with a fixed rotation of the upper torso, however this type of deformity is usually accommodated with a custom contoured shape, as opposed to rotating the entire back support.

- It is not uncommon for an off the shelf back support to deviate in this plane due to improper adjustment, mounting or failure of the attaching hardware to the back canes of the wheelchair.

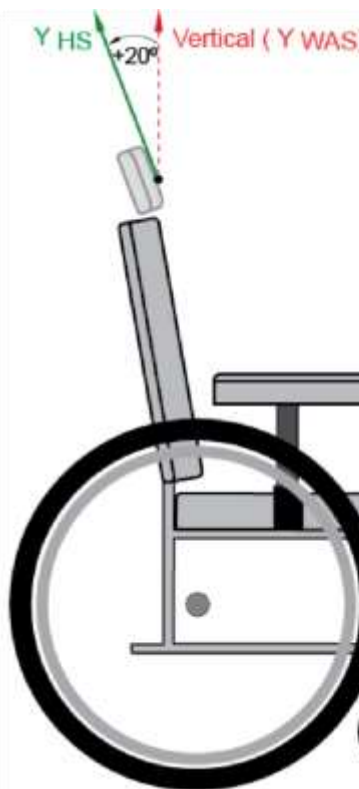
4.4 Head support sagittal angle

Purpose:

To provide a standard measure and term for the orientation of the head support in the sagittal plane with respect to the vertical

Clinical Relevance:

Deviations of the head support in this plane are very common and may be required to support a user's head in the desired position of neck flexion or extension for optimum comfort or function. This measurement can be used to document either the existing or desired orientation of the head support in this plane.



HEAD SUPPORT SAGITTAL ANGLE

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the head support with respect to the vertical, viewed from the side.

Lines used to form angle:

- Vertical (Y_{WAS})
- Head support Y-axis (Y_{HS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y axis of the head support (Y_{HS}) viewed from the side and projected to the sagittal plane.

Fig. 3.27: Head support sagittal angle

Sample procedures:

1. Locate the head support reference plane and local Y-axis reference line

- a) The head support Y-axis lies on the reference plane, projecting upwards from the geometric center. This can be visualized as a line on the contact surface projecting upwards along the vertical midline of the head support.

2.

- b) For contoured head supports, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and head support Y-axis reference line.

a) Using an inclinometer or angle finder

- i. Align the vertical straight edge of the inclinometer or angle finder along the vertical midline of the head support, on or parallel to the head support Y-axis reference line, and read the angle value.

Hint: *If your inclinometer does not have both a vertical and horizontal straight edge, make sure it is set to read 0 degrees when the straight edge is aligned with the vertical.* b) Using a goniometer

- i. Standing on the right side of the wheelchair, hold the goniometer so that the arms are facing upwards.
- ii. Align the stationary arm of the goniometer with a vertical reference line. This can be done by sighting along a plumb line, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm along the vertical midline of the head support, on or parallel to the head support Y-axis reference line, and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the vertical reference line

- If the top of the head support is more posterior than the bottom, signifying a posterior rotation from the vertical, the value is positive.
- If the top of the head support is more anterior than the bottom, signifying an anterior rotation from the vertical, the value is negative.

Typical Values:

A head support sagittal angle of 0 degrees would indicate that the head support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Negative values would indicate that the head support is *proclined*, or angled forward of the vertical. Values from 0 to +30 would be more typical, indicating that the head support is *reclined* or angled backwards from the vertical. Values up to +55 degrees or more could be recorded with adjustable tilt or recline seating systems.

Considerations:

- The absolute body angle which corresponds to the head support sagittal angle is the sagittal head angle. If the seated person's sagittal head line (from ear to eye corner) is perpendicular to the head support Yaxis reference line, then the head support sagittal angle will be the same as the sagittal head angle.
- The head support sagittal angle is an absolute angle, and therefore says nothing of the angular relationship between the head support and the back support.
- Adjustments of the head support in the sagittal plane are very common, as this angle may affect the orientation in space of the user's head, as well as the degree of neck flexion or extension that the user is in if the back support sagittal angle remains constant. Adjusting the head support sagittal angle may also help to ensure a better fit between the contours of the head support and the posterior surface of the user's head.

4.5 Head support frontal angle

Purpose:

To provide a standard measure and term for the orientation of the head support in the frontal plane (front view) relative to the horizontal

2. Measure the angle

Clinical Relevance:

Deviations of the head support in this plane may be required to support a user's head in an asymmetrical position due to a lateral neck flexion contracture or fixed scoliosis. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the head support in this plane.



HEAD SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the head support with respect to the horizontal, viewed from the front.

Lines used to form angle:

- Horizontal (Z_{WAS})
- Head support Z-axis (Z_{HS})

Angle measured: The degree of rotation from the horizontal (Z_{WAS}) to the local Z-axis of the head support (Z_{HS}) viewed from the front and projected to the frontal plane.

Fig. 3.28: Head support frontal angle

Sample procedure:

1. Locate the head support reference plane and local Z-axis reference line

- a) The head support Z-axis lies on the reference plane, projecting sideways to the right from the geometric center. This can be visualized as a line on the contact surface projecting from side to side across the middle of the head support.
- b) For contoured head supports, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and head support Z-axis reference line. Alternatively, hold a clipboard or flat surface on the contact surface to approximate the reference plane.
- a. Using an inclinometer or angle finder
 - i. Place the horizontal straight edge of the inclinometer or angle finder along or parallel to the head support Z-axis reference line, along the horizontal midline of the head support, and read the angle value.
- b. Using a goniometer
 - i. Standing in front of the wheelchair, place the goniometer pivot center at the center of the head support, with the arms facing to the right.

- ii. Align the stationary arm of the goniometer with the horizontal. This can be done by sighting along a known horizontal reference, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm parallel to the head support Z-axis reference line and read the angle value.

2. Determine positive or negative notation based on the direction of rotation from the horizontal reference line

- If the head support is tilted down on its right side, signifying a counter-clockwise rotation from the zero reference position when viewed from the front, the value is positive.
- If the head support is tilted down on its left side signifying a clockwise rotation from the zero reference position when viewed from the front, the value is negative.

Typical Values:

A typical value would be 0, indicating that the head support is in a neutral position with its frontal reference line aligned with the vertical as in the Support Surface Reference Position (SSRP). A positive head support frontal value would indicate that the head support is tilted laterally to the user's right, and a negative angle would indicate that the head support is tilted laterally to the user's left.

Considerations:

- The absolute body angle which corresponds to the head support frontal angle would be the frontal head angle. If the frontal head line is parallel to the head support Z-axis reference line, then the angles will be the same.
- For clients with complex seating needs, it is not uncommon for a head support to be intentionally rotated in the frontal plane to accommodate and support a desired frontal head angle which is not zero, due to a fixed scoliosis or contracture of the neck. This measure provides a standardized term for defining that angular deviation.

4.6 Head support transverse angle

Purpose:

To provide a standard measure and term for the orientation of the head support in the transverse plane (top view), relative to the wheelchair

Clinical Relevance:

Deviations of the head support in this plane, often referred to as "rotation", may be required to support a user's head in an asymmetrical position due to a neck rotation contracture or fixed rotational scoliosis; or, to counteract asymmetrical movement patterns due to abnormal muscle tone or spastic movement patterns. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the head support in this plane.

Type of Measurement: Absolute support surface angle

Description: The angle of orientation of the head support in the transverse plane, relative to the wheelchair, viewed from above.

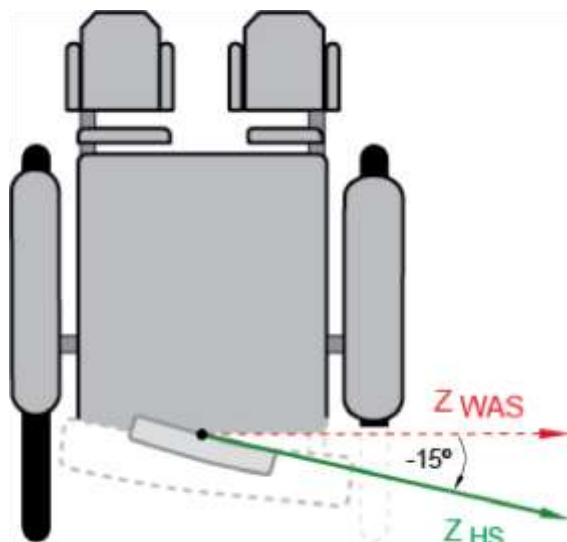
Lines used to form angle: □

Wheelchair Z-axis (Z_{WAS})

□ Head support Z-axis (Z_{HS})

Angle measured: The degree of rotation from the wheelchair Z-axis (Z_{WAS}) to the local Z-axis of the head support (Z_{HS}), viewed from above and projected to the transverse plane.

Fig.
3.29:
Head



support transverse angle

Sample procedure:

1. Locate the wheelchair Z-axis

- The wheelchair Z-axis (Z_{WAS}) is line passing through the rear wheel axles
- To locate the Z-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis.
- Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair Z-axis, such as the back edge of the seat pan, or a line between the back canes.

2. Locate the head support reference plane and local Z-axis reference line

- The head support Z-axis lies on the reference plane, projecting sideways to the right from the geometric center. This can be visualized as a line on the contact surface projecting from side to side across the middle of the head support.
- For contoured head supports, you can use the planar mounting surface on the non contact surface side as an approximation of the support surface reference plane and head support Z-axis reference line. Alternatively, hold a clipboard or flat surface on the contact surface to approximate the reference plane.

3. (using a goniometer)

Place the goniometer pivot center at the top of the head support, with the arms facing towards the right side.

- b) Align the stationary arm of the goniometer with the wheelchair Z-axis. This can be done by sighting down to a piece of tape placed along the floor, or any other line which you know is parallel to the wheelchair axle.
- c) Align the moveable arm parallel to the head support Z-axis reference line and read the angle value.

4. Determine positive or negative notation based on the direction of rotation from the zero reference line

- If the head support is rotated to the left signifying a counter-clockwise rotation from the zero reference position when viewed from above, the value is positive.
- If the head support is rotated to the right signifying a clockwise rotation from the zero reference position when viewed from above, the value is negative.

Typical Values:

A typical value would be 0, indicating that the head support is in a neutral position as in the Support Surface Reference Position (SSRP), without rotation relative to the wheelchair frame when viewed from above. A positive head support transverse angle would indicate that the head support is rotated to the left relative to the wheelchair frame, and a negative value would indicate that the head support is rotated to the right.

Considerations:

- The absolute body segment angle which corresponds to the head support transverse angle would be the transverse head angle. If the transverse head line is parallel to the head support Z-axis reference line, then the angles will be the same.
- For clients with complex seating needs, it is not uncommon for a head support to be intentionally rotated in the transverse plane to accommodate and support a head in an asymmetrical position due to a fixed rotational scoliosis or contracture of the neck. This measure provides a standardized term for defining that angular deviation.

4.7 Lower leg support sagittal angle

Purpose:

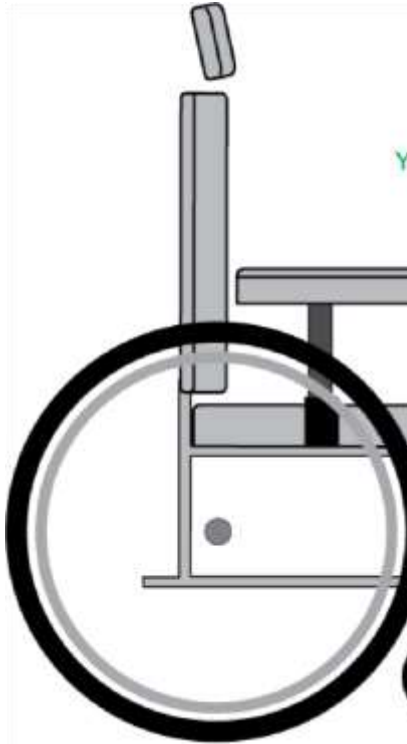
To provide a standard measure and term for the orientation of the lower leg support in the sagittal plane (side view) relative to the vertical

Clinical Relevance:

Deviations of the lower leg support in the sagittal plane are very common, as this angle effects the orientation in space of the user's lower leg, as well as the degree of knee flexion that the user is in if the seat sagittal angle remains constant. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the lower leg support in this plane.

Measure the angle

a)

**LOWER LEG SUPPORT SAGITTAL ANGLE**

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the lower leg support with respect to the vertical, viewed from the side.

Lines used to form angle:

- Vertical (Y_{WAS})
- Lower leg support Y-axis (Y_{LLS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the lower leg support (Y_{LLS}) viewed from the side and projected to the sagittal plane.

Fig. 3.30: Lower leg support sagittal angle

Sample procedures:**1. Locate the lower leg support reference plane and local Y-axis reference line**

- a) The local Y-axis of the lower leg support projects upward from the geometric center of the support. This can be visualized as a line lying on the contact surface along the vertical midline of the support.
- b) For contoured lower leg supports, such as a contoured calf pad, you can use the planar non contact surface side as an approximation of the support surface reference plane and local Y-axis reference line. Alternatively, hold a flat surface such as a ruler in the middle of the contact surface to approximate the reference plane.

2.Using an inclinometer or angle finder

- i. Align the straight edge of the inclinometer or angle finder along the vertical midline of the lower leg support surface, on or parallel to the lower leg support Y-axis reference line (or simulated reference plane if there is no support), and read the angle value.

Hint: If your inclinometer does not have both a vertical and horizontal straight edge, make sure it is set to read 0 degrees when the straight edge is aligned with the vertical. b) Using a goniometer

- i. Standing on the right side of the wheelchair, hold the goniometer so that the arms are facing upwards, with the goniometer pivot center at the back of the footplate or bottom of the lower leg support (whichever is most forward).
- ii. Align the stationary arm of the goniometer with the vertical. This can be done by sighting along a known vertical reference such as a plumb line, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm along the vertical midline of the lower leg support, on or parallel to the lower leg support Y-axis reference line (or simulated reference plane), and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the vertical reference line

- a) If the top of the lower leg support is more posterior than the bottom, the value is positive
- b) If the top of the lower leg support is more anterior than the bottom, the value is negative.

Typical values:

A lower leg support sagittal angle of 0 degrees would indicate that the lower leg support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Negative values would indicate that the top of the lower leg support is *proclined*, or angled forward of the vertical, with the back of the foot support behind the front edge of the seat. Values from 0 to +30 would be more typical, indicating that the top of the lower leg support is *reclined*, or angled backwards from the vertical, with the foot support forward of the front edge of the seat, as in elevating leg supports. Values up to +55 or even +100 degrees could be recorded with adjustable tilt or recline seating systems with elevating leg supports.

Considerations:

- The absolute body angle which corresponds to the lower leg support sagittal angle is the sagittal lower leg angle. If the seated person's lower leg is parallel to the lower leg support reference plane (or more specifically, if the sagittal lower leg line is parallel to the lower leg support Y-axis reference line), then the lower leg support sagittal angle will be the same as the sagittal lower leg angle.
- The lower leg support sagittal angle can deviate from the zero reference position with or without changes in the seat to lower leg support angle.

4.8 Lower leg support frontal angle

Purpose:

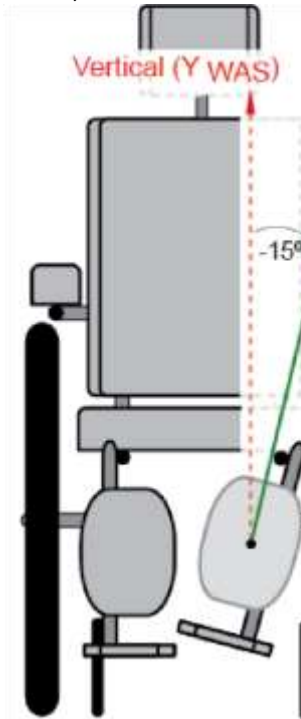
To provide a standard measure and term for the orientation of the lower leg support in the frontal plane relative to the vertical

Clinical relevance:

Deviations of a lower leg support in this plane are uncommon. However, if the user's lower leg is angled in this plane due to a hip internal or external rotation contracture, and if it is necessary to support the lower leg posteriorly with a separate pad, the practitioner may need to specify a lower leg support frontal angle. This measurement can therefore be used to document the existing or desired orientation of the lower leg support in this plane.

Measure the angle

a)

**LOWER LEG SUPPORT FRONTAL ANGLE**

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the lower leg support with respect to the vertical, viewed from the front.

Lines used to form angle:

- Vertical (Y_{WAS})
- Lower leg support Y-axis (Y_{LLS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the lower leg support (Y_{LLS}), viewed from the front and projected to the frontal plane.

Fig. 3.31: Lower leg support frontal angle

Sample procedure:**1. Locate the lower leg support Y-axis reference line**

- When there is a posterior lower leg support component: The local Y-axis of the lower leg support projects upward from the geometric center of the support. This can be visualized as a line lying on the contact surface along the vertical midline of the support, perpendicular to the bottom edge of the pad.
- When there is no posterior lower leg support component, you cannot measure this angle accurately because the local Y-axis cannot be identified: However, you can simulate the orientation of an imaginary local Y-axis if you can identify a medial-lateral location along the front edge of the seat that is the intended location of the user's knee – for example the center of a leg trough. In this case, a line connecting the intended location of the knee down to the center of the footplate would simulate the orientation of a lower leg support Y-axis.

2.Using an inclinometer or angle finder

- Place the vertical straight edge of the inclinometer or angle finder along or parallel to the lower leg support Y-axis reference line, along the vertical midline of the lower leg support, and read the angle value.

Hint: If your inclinometer does not have both a vertical and horizontal straight edge, make sure it is set to read 0 degrees when the straight edge is aligned with the vertical. b) Using a goniometer

- Standing in front of the wheelchair, place the goniometer pivot center at the bottom midpoint of the lower leg support, with the arms facing upwards.

- ii. Align the stationary arm of the goniometer with the vertical. This can be done by sighting along a known vertical reference such as a plumb line, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm parallel to the lower leg support Y-axis reference line and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the horizontal reference line

- If the top of the lower leg support is tilted to the wheelchair's right, signifying a counter-clockwise rotation from the zero reference position when viewed from the front, the value is positive.
- If the top of the lower leg support is tilted to the wheelchair's left signifying a clockwise rotation from the zero reference position when viewed from the front, the value is negative.

Typical Values:

A typical value would be 0, indicating that the lower leg support is in a neutral position as in the Support Surface Reference Position (SSRP). A positive value would indicate that the top of the lower leg support is tilted laterally to the user's right, with the bottom of the support sweeping to the left. A negative lower leg support frontal angle would indicate that the top of the lower leg support is tilted laterally to the user's left, with the bottom of the support sweeping to the right. Values may range from -45 to +45 degrees in a seating system with lateral rotational tilt.

Considerations:

- The absolute body angle which corresponds to the lower leg support frontal angle would be the frontal lower leg angle. If the frontal lower leg line is parallel to the lower leg support Y- axis reference line, then the frontal angles will be the same.
- Deviations of the lower leg support in this plane are not common, however may be required to support the lower leg in an asymmetrical position due to a fixed contracture of the hip or a pelvic obliquity.

4.9 Lower leg support transverse angle *(Summary information only)*

Purpose:

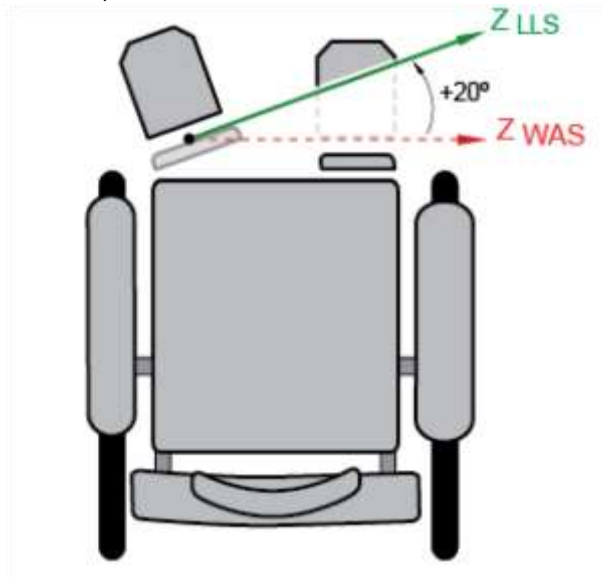
To provide a standard measure and term for the orientation of the lower leg support in the transverse plane relative to the wheelchair

Clinical relevance:

In a complex seating configuration, a posterior lower leg support surface may be rotated in the transverse plane in combination with a deviation of the foot support in order to support a windswept posture of the lower extremities. This measurement can therefore be used either to document the existing orientation or to specify the desired orientation of a lower leg support in this plane.

Measure the angle

a)



LOWER LEG SUPPORT TRANSVERSE ANGLE

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Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the lower leg support surface in the transverse plane, with respect to the wheelchair frame, viewed from above.

Lines used to form angle:

- Wheelchair Z-axis (Z_{WAS}) – line passing through the rear wheel axles of wheelchair
- Lower leg support Z-axis (Z_{LLS})

Angle measured: The degree of rotation from the wheelchair Z-axis (Z_{WAS}) to the local Z-axis of the lower leg support (Z_{LLS}), viewed from above and projected to the transverse plane.

Fig. 3.32: Lower leg support transverse angle

Typical values:

A typical value would be 0, indicating that the lower leg support is “square” with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP). A positive value would indicate that the lower leg support is rotated to the left relative to the wheelchair frame, and negative lower leg support transverse angle would indicate that the lower leg support is rotated to the right relative to the wheelchair frame.

5 Absolute Angles of Lateral Supports

Lateral supports are those supports which are intended to contact the lateral surface of a body segment in the sitting position. Lateral supports in a wheelchair seating system are typically used at the sides of the head, trunk, pelvis, thighs or knees for individuals with more complex postural support needs. The local X- and Y-axes of lateral supports lie in the support surface reference plane, and are therefore used as reference lines to represent the orientation of the support in each plane (Fig. 3.33). The method of determining absolute angles of lateral supports is the same regardless of whether it is a lateral head, trunk, pelvis or knee support. For lateral support surfaces, the zero reference for sagittal angles is the horizontal (X_{WAS}) and for frontal angles is the vertical (Y_{WAS}). The zero reference for transverse angles is the X-axis of the wheelchair (X_{WAS}), represented by a line projecting forward perpendicular to the line passing through the axles of the rear wheels.

Remember: The axis of the WAS used as the zero reference to define a particular absolute angle was chosen based on clinical intuitiveness. You can always choose to use one of the other two axes, as long as you measure to the corresponding local axis of the support surface. Because they are perpendiculars, the value of the angle will be the same.

This section includes the following lateral supports and their absolute angles:

- **Lateral Trunk Supports**
- **Lateral Head Supports**
- **Lateral Pelvic Supports**
- **Lateral Knee Supports**

Note 1: Lateral trunk support surfaces can be incorporated into a back support's shape, or they can be separate support surface components. When separate, they are typically attached to the back support itself; however they may also be attached to the back canes of the wheelchair. The features of the attachment hardware will determine whether adjustments are possible in each of the three planes.

Note 2: If a lateral support surface is intended to contact the user's thigh (instead of the pelvis or knee), then the support would be called a "**lateral thigh support**". Lateral thigh support absolute angles are defined and measured exactly the same as lateral pelvic and lateral knee supports; therefore, they are not included here.

Note 3: Purposeful deviations of lateral supports in some planes are very uncommon. For these measures, only summary information is provided.

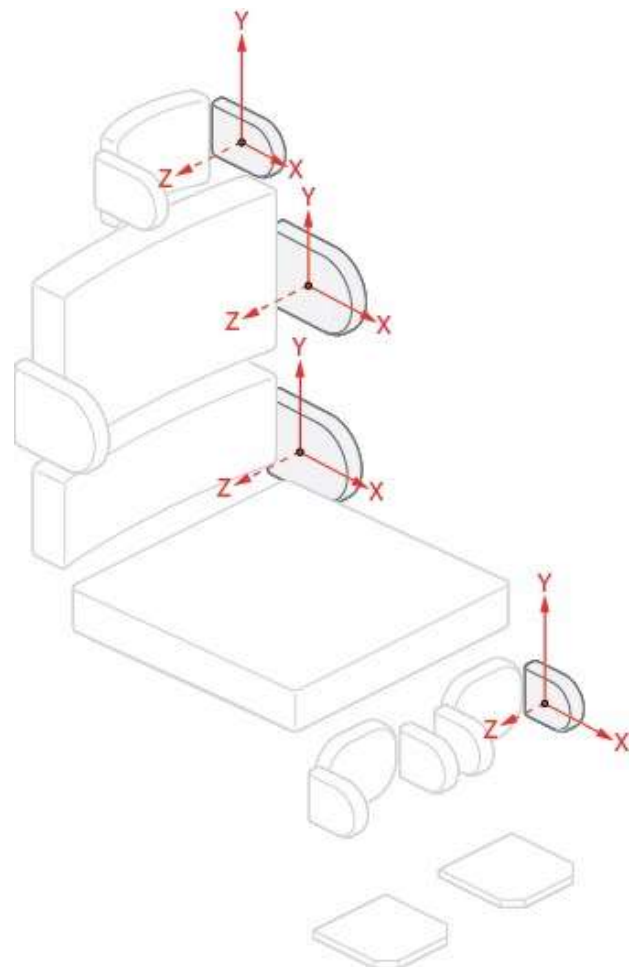


Fig. 3.33: Lateral supports

5.1 Lateral trunk support sagittal angle

Purpose:

To provide a standard measure and term for the orientation of a lateral trunk support in the sagittal plane (side view) relative to the horizontal

Clinical Relevance:

Deviations of the lateral trunk support in this plane are usually associated with deviations of the back support sagittal angle, when the lateral trunk support is attached directly to the back support. However, if a lateral trunk support is attached to the back canes of the wheelchair instead of the back support itself, it may be clinically important to document and/or specify the sagittal orientation of this pad, in order to provide appropriate contact with the user's trunk.

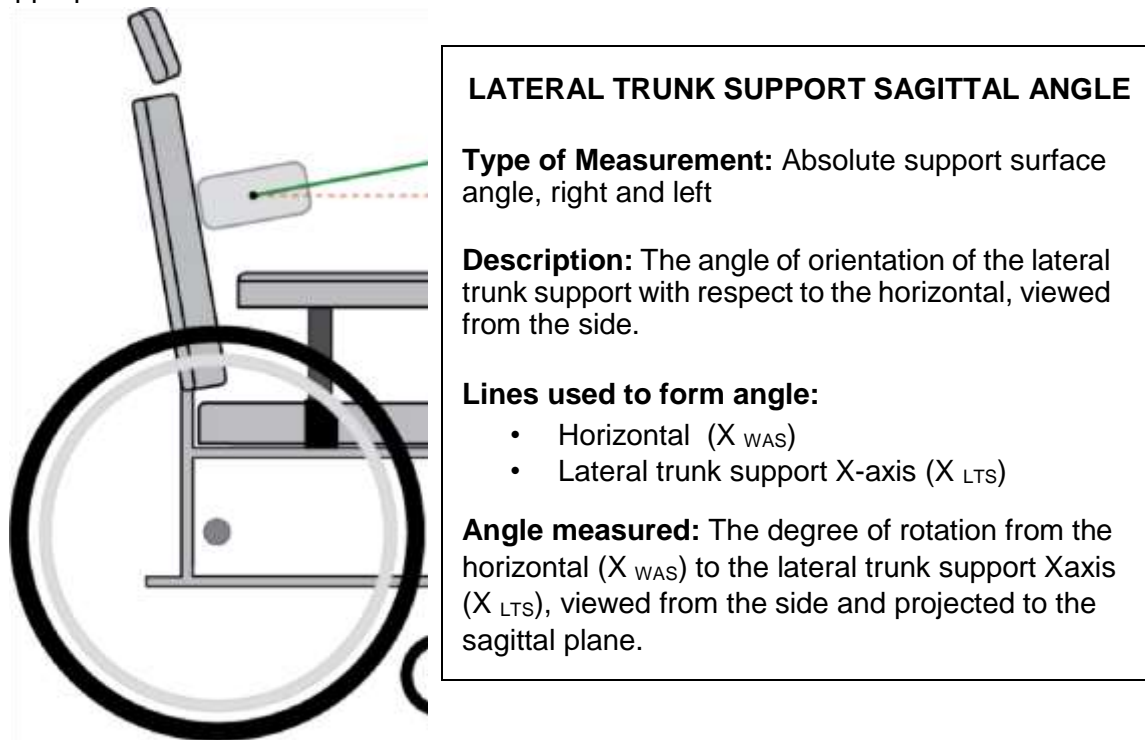


Fig. 3.34: Lateral trunk support sagittal angle

Sample procedures:

1. **Locate the lateral trunk support reference plane and local X-axis reference line**
 - a) The local X-axis of the lateral trunk support projects forward in an anterior direction from the geometric center of the support, lying on the support reference plane. This can be visualized as a line on the contact surface along the horizontal midline of the support.
 - b) If the lateral trunk support is rectangular, you can use the top or bottom edge of the support to approximate the local X-axis reference line.
2. **Measure the angle**
 - a) Using an inclinometer or angle finder
 - i. Align the horizontal straight edge of the inclinometer or angle finder along the horizontal midline of the lateral trunk support, or along the top edge of the support if it is square or rectangular, on or parallel to the lateral trunk support X-axis reference line, and read the angle value.

b) Using a goniometer

- i. Standing on the side of the wheelchair, hold the goniometer so that the arms are facing forward.
- ii. Align the stationary arm of the goniometer with the horizontal. This can be done by sighting along a known horizontal reference, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm along the horizontal midline of the lateral trunk support, on or parallel to the lateral trunk support X-axis reference line, and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the horizontal reference line

- If the front of the lateral trunk support is angled upward, signifying a posterior rotation from the horizontal, the value is positive.
- If the front of the lateral trunk support is angled downward (uncommon), signifying an anterior rotation from the horizontal, the value is negative.

Typical values:

A lateral trunk support sagittal angle of 0 would indicate that the lateral trunk support is aligned with the horizontal as in the Support Surface Reference Position (SSRP). A negative value would indicate that the lateral trunk support is *declined*, or angled downward from the horizontal. Positive values from 0 to 30 would be more typical, indicating that the lateral trunk support is *inclined*, or angled upwards from the horizontal.

Considerations:

- The absolute body angle which corresponds to the lateral trunk support sagittal angle is the sagittal trunk angle.
- The lateral trunk support sagittal angle would also typically match the back support sagittal angle.

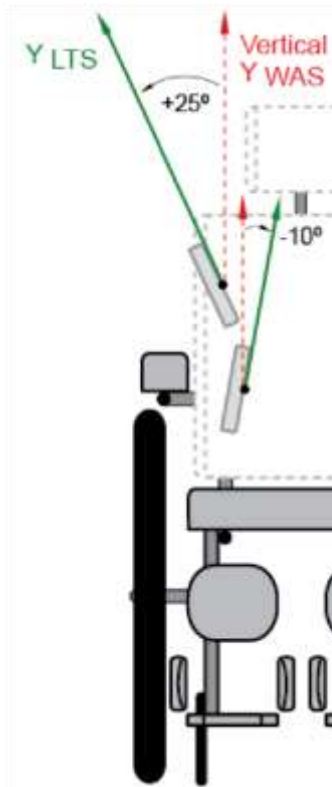
5.2 Lateral trunk support frontal angle

Purpose:

To provide a standard measure and term for the orientation of the lateral trunk support in the frontal plane (front view) relative to the vertical

Clinical Relevance:

Deviations of the lateral trunk support in this plane may be required to improve contact with the user's trunk in a specific location, particularly if the user has asymmetries of shape due to a fixed scoliosis or other deformities of the rib cage. This measurement can therefore be used to document either the existing or desired orientation of the lateral trunk support in this plane.



LATERAL TRUNK SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the lateral trunk support relative to the vertical, viewed from the front.

Lines used to form angle:

- Vertical (Y_{WAS})
- Lateral trunk support Y-axis (Y_{LTS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the lateral trunk support (Y_{LTS}), viewed from the front and projected to the frontal plane.

Fig. 3.35: Lateral trunk support frontal angle

Sample procedures:

1. Locate the lateral trunk support reference plane and local Y-axis reference line

- a) The local Y-axis of the lateral trunk support projects upward from the geometric center of the support, lying on the support reference plane. This can be visualized as a line on the contact surface along the vertical midline of the support.
- b) If the lateral trunk support is rectangular, you can use the front edge of the support to approximate the local Y-axis reference line.

2. Measure the angle

a) Using an inclinometer or angle finder

- i. Align the vertical straight edge of the inclinometer or angle finder along the contact surface of the lateral trunk support, on or parallel to the lateral trunk support Y-axis, and read the angle value.

Hint: If your inclinometer does not have both a vertical and horizontal straight edge, make sure it is set to read 0 degrees when the straight edge is aligned with the vertical.

b) Using a goniometer

- i. Standing in front of the wheelchair, hold the goniometer so that the arms are facing upwards, with the pivot center at the bottom of the support.
- ii. Align the stationary arm of the goniometer with the vertical reference line. This can be done by sighting along a plumb line, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm along the vertical midline of the lateral trunk support, on or parallel to the lateral trunk support Y-axis, and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the vertical

- If the top of the lateral trunk support is tilted to the wheelchair's right, signifying a counterclockwise rotation from the vertical, the value is positive.
- If the top of the lateral trunk support is tilted to the wheelchair's left, signifying a clockwise rotation from the vertical when viewed from the front, the value is negative.

Typical values:

A lateral trunk support frontal angle of 0 would indicate that the lateral trunk support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Positive values would indicate that the lateral trunk support is tilted to the user's right, and negative values would indicate that the lateral trunk support is tilted to the user's left.

Considerations:

- The absolute body segment angle which corresponds to the lateral trunk support frontal angle would most likely be the frontal sternal angle; however, due to the shape of the person's trunk and rib cage there may not be a correlation between these two angles.
- Deviations of the lateral trunk support in this plane may be required to improve contact with the user's trunk in a specific location, if there is a scoliosis or fixed lateral lean of the trunk, or if the user has other asymmetries of the chest or rib cage.

5.3 Lateral trunk support transverse angle *(Summary information only)*

Purpose:

To provide a standard measure and term for the orientation of the lateral trunk support in the transverse plane (top view), relative to the wheelchair

Clinical Relevance:

Purposeful deviations of the lateral trunk support in this plane are uncommon in planar seating systems; however they may be required to improve surface contact with the user's trunk due to a fixed asymmetry or deformity. This measurement can be used to document either the existing or desired orientation of the lateral trunk support in this plane. Understanding the term lateral trunk support transverse angle may also be useful to describe or document a non-purposeful deviation of a lateral trunk support in this plane, resulting from hardware mal-alignment or failure.

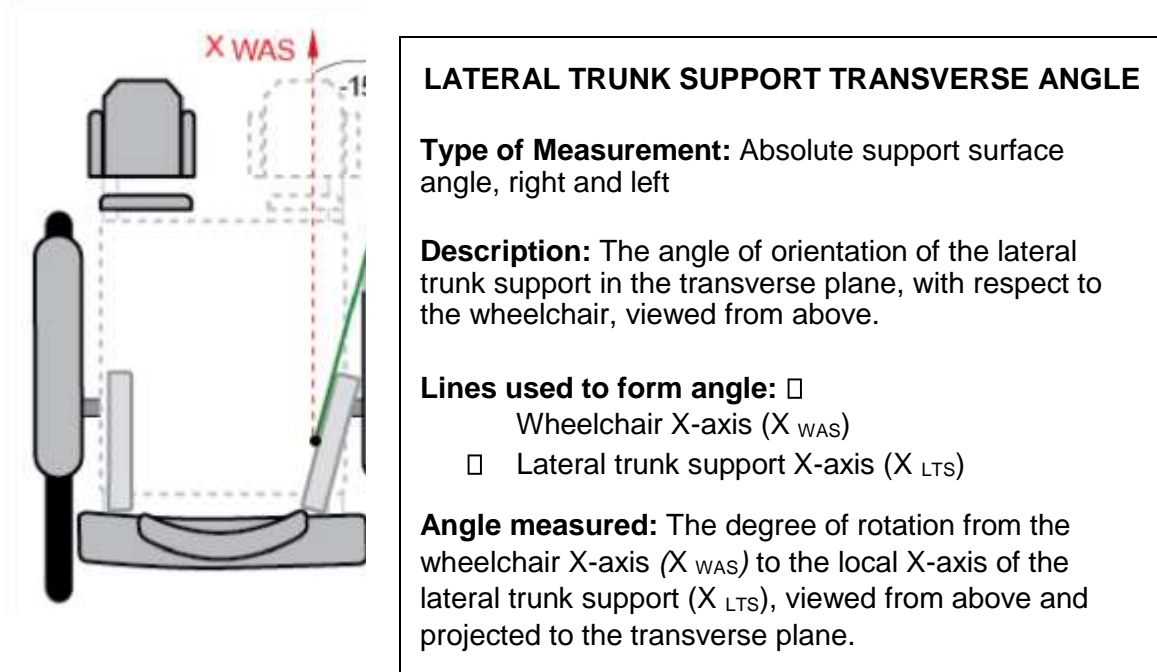


Fig. 3.36: Lateral trunk support transverse angle

Typical values:

A typical value would be 0, indicating that the lateral trunk support is “square” with the wheelchair frame when viewed from above, as in the Support Surface Reference Position (SSRP). A positive value would indicate that the lateral trunk support is rotated to the left relative to the wheelchair frame, and a negative lateral trunk support transverse angle would indicate that the lateral trunk support is rotated to the wheelchair's right side.

5.4 Lateral head support sagittal angle

Purpose:

To provide a standard measure and term for the orientation of a lateral head support in the sagittal plane (side view) relative to the horizontal

Clinical Relevance:

Deviations of a lateral head support in this plane may be required to contact a user's head in a specific location, particularly if the user has an atypical position due to a neck flexion or extension contracture; or, to counteract asymmetrical movement patterns due to abnormal muscle tone or spastic movement patterns. This measurement can be used to document either the existing or desired orientation (or range of orientation if adjustable) of a lateral head support pad or surface.

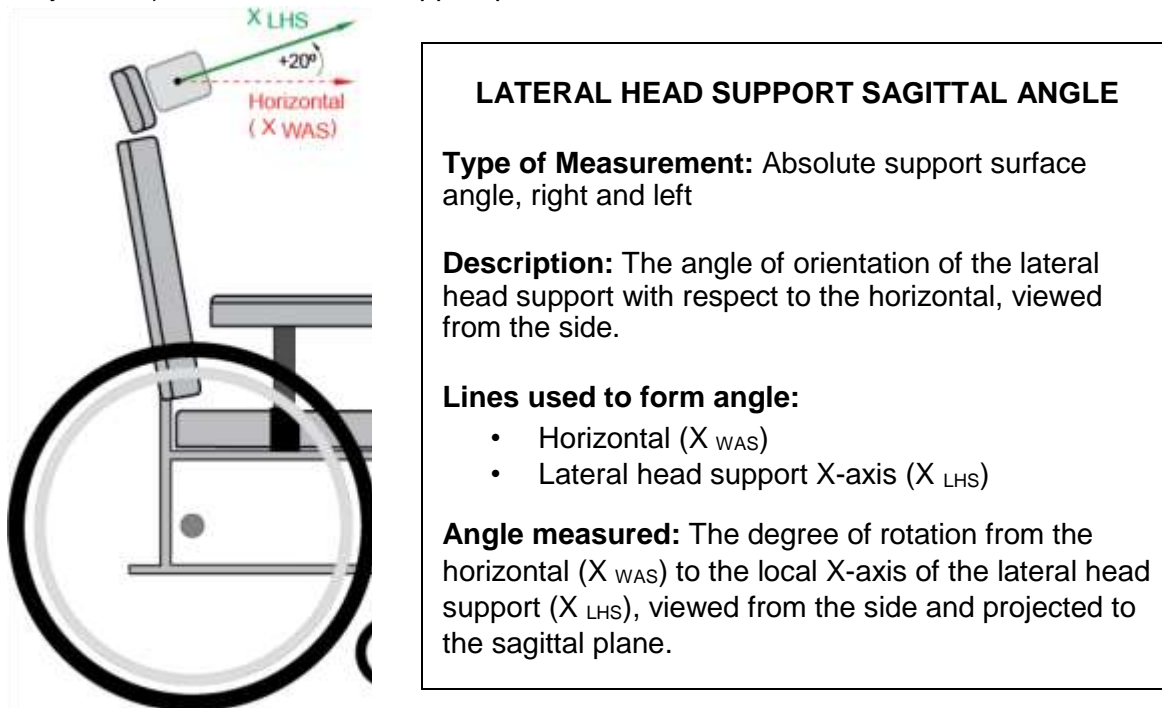


Fig. 3.37: Lateral head support sagittal angle

Sample procedures:

1. Locate the lateral head support reference plane and local X-axis reference line

- a) For a planar lateral head support, the local X-axis lays right on the contact surface, and projects forward from the geometric center of the pad along the horizontal midline of the lateral head support.
- b) If the lateral head support is rectangular, you can use the top or bottom edge of the support to approximate the local X-axis reference line.

2. Measure the angle

- a) Using an inclinometer or angle finder
 - i. If the lateral head support has a symmetrical shape, align the horizontal straight edge of the inclinometer or angle finder on the top edge of the support, and read the angle value.
 - ii. If the support is not symmetrical, align the horizontal straight edge of the inclinometer or angle finder along the horizontal midline of the support, on or parallel to the lateral head support X-axis, and read the angle value.
- b) Using a goniometer
 - i. Standing on the side of the wheelchair, hold the goniometer so that the arms are facing forward, with the pivot center at the back of the lateral head support.
 - ii. Align the stationary arm of the goniometer with the horizontal. This can be done by sighting along a known horizontal reference, or by using a goniometer with a bubble level attached to the stationary arm.

- iii. Align the moveable arm along the horizontal midline of the lateral head support, on or parallel to the lateral head support X-axis, and read the angle value.

3. Determine positive or negative notation based on the direction of rotation from the horizontal reference line

- If the front of the lateral head support is rotated upward from the horizontal, signifying a posterior rotation, the value is positive.
- If the front of the lateral head support is rotated downward, signifying an anterior rotation from the horizontal, the value is negative.

Typical values:

A lateral head support sagittal angle of 0 would indicate that the lateral head support is aligned with the horizontal as in the Support Surface Reference Position (SSRP). A negative value would indicate that the lateral head support is *declined*, or angled downward from the horizontal. Values from 0 to +30 would be more typical, indicating that the lateral head support is *inclined*, or angled upwards from the horizontal.

Considerations:

- If the lateral head support is attached to the primary, posterior head support surface, then changes in the lateral head support sagittal angle would typically match changes in the head support sagittal angle. However, some head supports used by clients with more complex needs have separately adjustable lateral head support components which allow individual adjustment in all three planes.

5.5 Lateral head support frontal angle

Purpose:

To provide a standard measure and term for the orientation of a lateral head support in the frontal plane (front view)

Clinical Relevance:

Deviations of the lateral head support in this plane may be required to contact a user's head in a specific location, particularly if the user has an asymmetrical position due to a lateral neck flexion contracture or posturing. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the lateral head support in this plane.

LATERAL HEAD SUPPORT FRONTAL ANGLE

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Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the lateral head support relative to the vertical, viewed from the front.

Lines used to form angle:

- Vertical (Y_{WAS})
- Lateral head support Y-axis (Y_{LHS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the lateral head support (Y_{LHS}), viewed from the front and projected to the frontal plane.

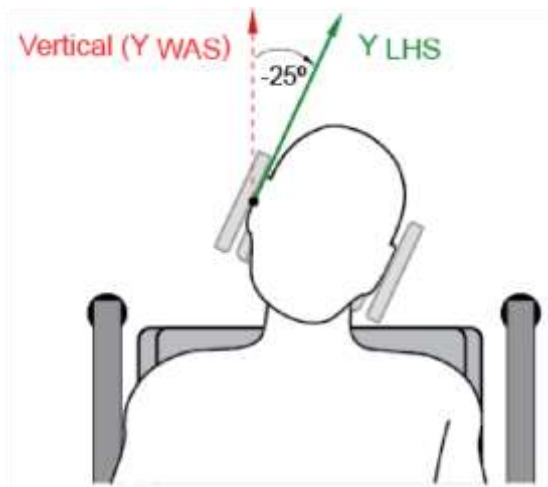


Fig. 3.38: Lateral head support frontal angle

Sample procedures:

1. Locate the lateral head support reference plane and local Y-axis reference line

- a) For a planar lateral head support, the local Y-axis lies right on the contact surface plane, and projects upwards from the geometric center of the pad along the vertical midline of the lateral head support.
- b) If the lateral head support is rectangular, you can use the front straight edge of the support to approximate the orientation of the local Y-axis reference line.

2. Measure the angle

a) Using an inclinometer or angle finder

- i. Align the vertical straight edge of the inclinometer or angle finder along the contact surface vertical midline of the lateral head support, on or parallel to the lateral head support Y-axis, and read the angle value.

Hint: If your inclinometer does not have both a vertical and horizontal straight edge, make sure it is set to read 0 degrees when the straight edge is aligned with the vertical.

b) Using a goniometer

- i. Standing in front of the wheelchair, hold the goniometer so that the arms are facing upwards, with the pivot center at the bottom of the lateral head support.
- ii. Align the stationary arm of the goniometer with the vertical reference line. This can be done by sighting along a plumb line, or by using a goniometer with a bubble level attached to the stationary arm.
- iii. Align the moveable arm along the vertical midline of the lateral head support, on or parallel to the lateral head support Y-axis reference line, and read the angle value.

4. Determine positive or negative notation based on the direction of rotation from the vertical

- If the top of the lateral head support is tilted to the wheelchair's right, signifying a counterclockwise rotation from the vertical, the value is positive.
- If the top of the lateral head support is tilted to the wheelchair's left, signifying a clockwise rotation from the vertical when viewed from the front, the value is negative.

Typical values:

A lateral head support frontal angle of 0 would indicate that the lateral head support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Positive values would indicate that the lateral head support is tilted to the user's right, and negative values would indicate that the lateral head support is tilted to the user's left.

Considerations:

- The absolute body segment angle which corresponds to the lateral head support frontal angle would most likely be the frontal head angle; however, depending on the shape of the person's head and where the lateral head support is positioned on the head, there may not be a correlation between these two angle values.

5.6 Lateral head support transverse angle

Purpose:

To provide a standard measure and term of the orientation of a lateral head support in the transverse plane (top view) relative to the wheelchair frame

Clinical Relevance:

Of the three planes, deviations of a lateral head support in the transverse plane are most common. Many head supports with separate lateral head support components allow adjustment in the transverse plane, and deviations of this angle may be specified to control rotational movement of the head. Therefore, this measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the lateral head support in this plane.

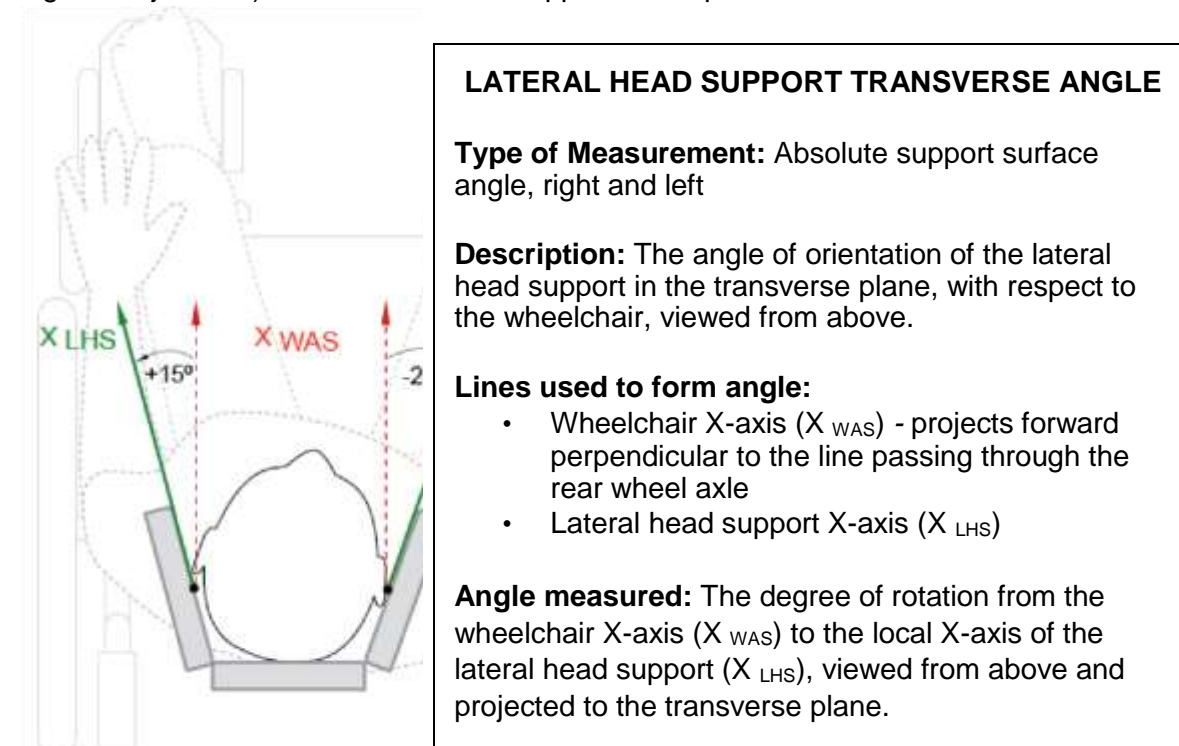


Fig. 3.39: Lateral head support transverse angle

Sample procedure:

1. Locate the wheelchair X-axis

- a) The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the line passing through the rear wheel axle.
- b) To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- c) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rail or lateral edge of the seat pan.

2. Locate the lateral head support reference plane and local X-axis reference line

- a) For a planar lateral head support, the local X-axis projects forward from the geometric center of the pad along the horizontal midline of the contact surface, perpendicular to the back edge of a rectangular lateral head support pad.

3. Measure the angle (using a goniometer)

- a) Viewing the lateral head support from above, hold the goniometer pivot center at the back of the lateral head support, on the top edge, with the arms facing towards the front of the wheelchair.
- b) Align the stationary arm of the goniometer parallel to the wheelchair X axis reference line (marked on the floor) and align the moveable arm parallel with the lateral head support's X-axis (along the top edge), and read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair X-axis reference line

- If the front of the lateral head support is rotated to the left, signifying a counter-clockwise rotation of the lateral head support from the wheelchair X-axis when viewed from above, the value is positive.
- If the front of the lateral head support is rotated to the right, signifying a clockwise rotation of the lateral head support from the wheelchair X-axis when viewed from above, the value is negative.

Typical values:

A value of 0 would indicate that the lateral head support is "square" with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP); however, this may not be typical. More typical values for a standard three piece rectangular head support would be +10 to +45 for a left lateral head support transverse angle, and -10 to -45 degrees for a right lateral head support transverse angle. A positive lateral head support angle would indicate that the lateral head support is rotated to the left relative to the wheelchair frame, and a negative value would indicate that the lateral head support is rotated to the right.

Considerations:

- Adjustments of the lateral head support transverse angle are typically done in order to limit the range of head movement when the user has poor head control. This may be needed to counteract asymmetrical movement patterns due to abnormal muscle tone or spastic movement patterns, or it may be needed to help maintain the head in an upright position when the user has muscle weakness.
- Note that an outward rotation of a right lateral head support would be negative and an outward rotation of a left lateral head support would be positive.

5.7 Lateral pelvic support sagittal angle *(Summary information only)*

Purpose:

To provide a standard measure and term for the orientation of a lateral pelvic support in the sagittal plane (side view)

Clinical Relevance:

Purposeful deviations of a lateral pelvic support in this plane separate from adjustments of the seat sagittal angle are uncommon. However, understanding the term lateral pelvic support sagittal angle may be useful to describe or document a non-purposeful deviation of the lateral pelvic support in this plane resulting from hardware mal-alignment.

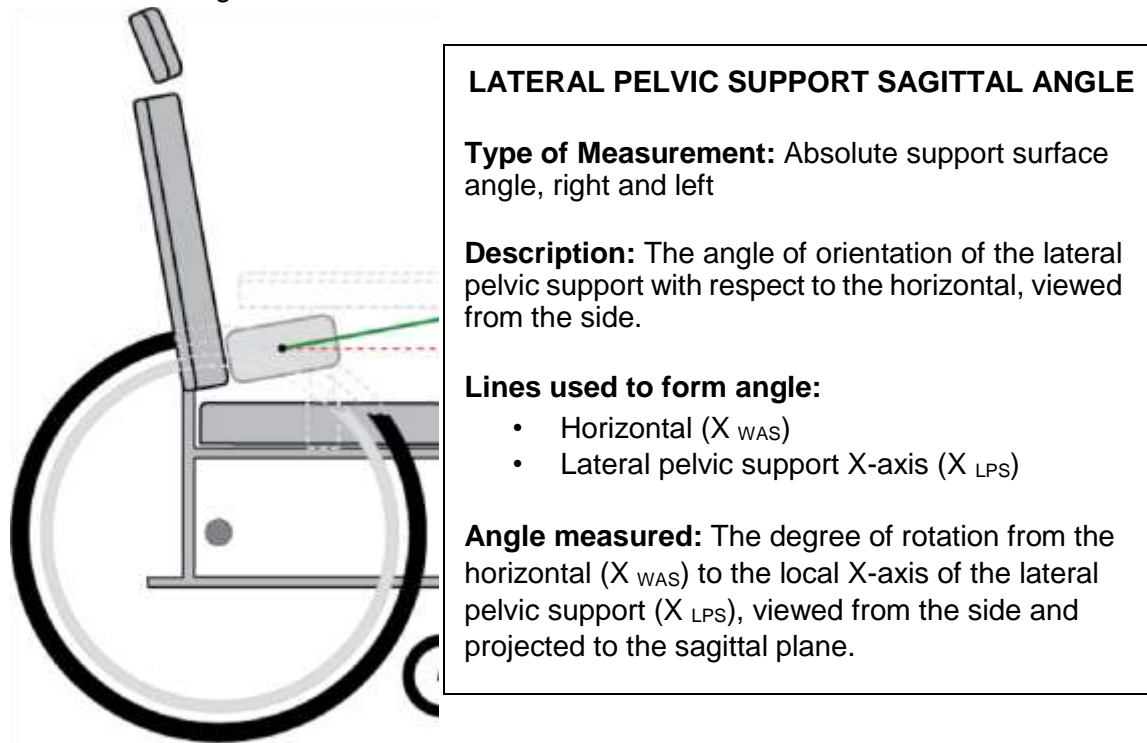


Fig. 3.40: Lateral pelvic support sagittal angle

Typical values:

A lateral pelvic support sagittal angle of 0 would indicate that the lateral pelvic support is aligned with the horizontal as in the Support Surface Reference Position (SSRP). A negative value would indicate that the lateral pelvic support is *declined*, or angled downward from the horizontal. Values from 0 to +30 would be more typical, indicating that the lateral pelvic support is *inclined*, or angled upwards from the horizontal. Values up to +55 degrees could be recorded with adjustable tilt wheelchair seating systems. If the lateral pelvic support is attached to the seat, then changes in the lateral pelvic support sagittal angle would typically match changes in the seat sagittal angle.

5.8 Lateral pelvic support frontal angle *(Summary information only)*

Purpose:

To provide a standard measure and term for the orientation of the lateral pelvic support in the frontal plane (front view)

Clinical Relevance:

Deviations of a lateral pelvic support in this plane are uncommon, but may be required to improve contact with the sides of a user's buttocks when the pelvis is asymmetrical. This measurement can be used to either document the existing orientation or specify the desired orientation of the lateral pelvic support. Additionally, understanding the term lateral pelvic support sagittal angle may also be useful to describe or document a non-purposeful deviation of the lateral pelvic support in this plane resulting from hardware mal-alignment.

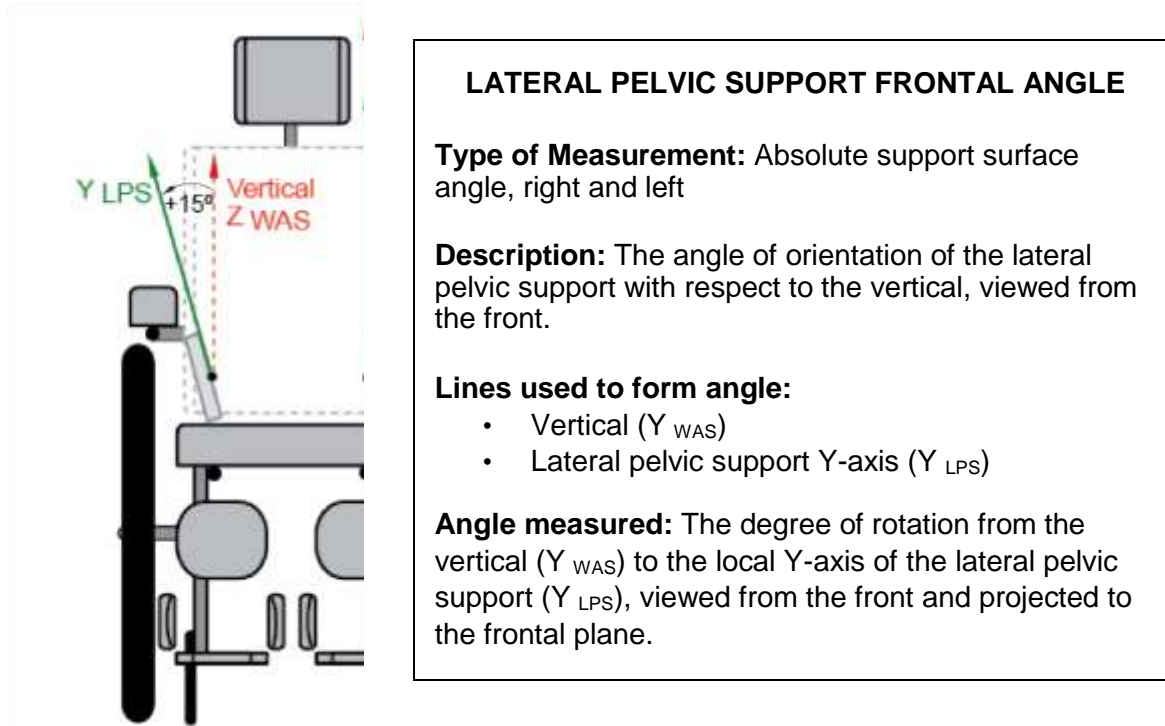


Fig. 3.41: Lateral pelvic support frontal angle

Typical values:

A lateral pelvic support frontal angle of 0 would indicate that the lateral pelvic support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Positive values would indicate that the lateral pelvic support is tilted to the user's right, and negative values would indicate that the lateral pelvic support is tilted to the user's left.

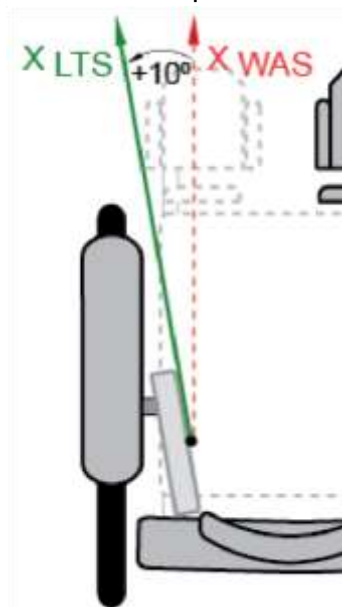
5.9 Lateral pelvic support transverse angle

Purpose:

To provide a standard term and measure for the orientation of a lateral pelvic support in the transverse plane (top view)

Clinical Relevance:

Deviations of the lateral pelvic support in this plane may be required to improve contact with the sides of a user's pelvis/hips due to soft tissue distribution or asymmetrical pelvic alignment. This measurement can be used to either document the existing orientation or specify the desired orientation of the lateral pelvic support in the transverse plane.



LATERAL PELVIC SUPPORT TRANSVERSE ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of a lateral pelvic support relative to the wheelchair, viewed from above.

Lines used to form angle: □

Wheelchair X-axis (X_{WAS})

□ Lateral pelvic support X-axis (X_{LPS})

Angle measured: The degree of rotation from the wheelchair X-axis (X_{WAS}) to the local X-axis of the lateral pelvic support (X_{LPS}) viewed from above and projected to the transverse plane.

Fig. 3.42: Lateral pelvic support transverse angle

Sample procedure:

1. Locate the wheelchair X-axis

- The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the line passing through the rear wheel axle.
- To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X axis, such as the seat rail or lateral edge of the seat pan.

2. Locate the lateral pelvic support reference plane and local X-axis reference line

- For a planar lateral pelvic support, the local X-axis projects forward from the geometric center of the pad along the horizontal midline of the contact surface, perpendicular to the back edge of a rectangular lateral pelvic support pad.

3. Measure the angle (using a goniometer)

- Viewing the lateral pelvic support from above, hold the goniometer pivot center at the back of the lateral pelvic support, on the top edge, with the arms facing towards the front of the wheelchair.

- b) Align the stationary arm of the goniometer parallel to the wheelchair X axis reference line (marked on the floor) and align the moveable arm parallel with the lateral pelvic support's X-axis (along the top edge), and read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair X-axis reference line

- If the front of the lateral pelvic support is rotated to the left, signifying a counterclockwise rotation of the lateral pelvic support from the wheelchair X-axis when viewed from above, the value is positive.
- If the front of the lateral pelvic support is rotated to the right, signifying a clockwise rotation of the lateral pelvic support from the wheelchair X-axis when viewed from above, the value is negative.

Typical values:

A value of 0 would indicate that the lateral pelvic support is "square" with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP). A positive lateral pelvic support angle would indicate that the lateral pelvic support is rotated to the left relative to the wheelchair frame, and a negative angle value would indicate that the lateral pelvic support is rotated to the right relative to the wheelchair frame. Lateral pelvic supports are typically rotated outward in order to follow the contours of the buttock. Therefore, typical values for a left lateral pelvic support would be +5 to +20 degrees and for a right lateral pelvic support would be -5 to -20 degrees.

Considerations:

- Adjustments of the lateral pelvic support transverse angle are typically done in order to improve contact with the lateral side of the buttocks at the hips. This may be needed due to the shape of the buttocks and pelvis, or due to asymmetries.

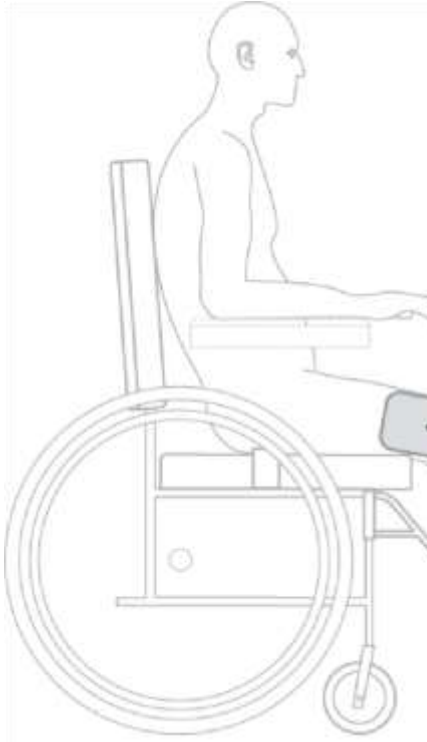
5.10 Lateral knee support sagittal angle *(Summary information only)*

Purpose:

To provide a standard term and measure for the orientation of a lateral knee support in the sagittal plane (side view)

Clinical Relevance:

Purposeful deviations of a lateral knee support in the sagittal plane separate from adjustments of the seat sagittal angle are uncommon. However, adjustments of the sagittal orientation of a lateral knee support may be useful to improve contact with a user's lateral knee, especially in the case of an adjustable lateral knee support which is not mounted to the seat. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the lateral knee support. Understanding the term sagittal lateral knee support angle may also be useful to describe or document a non-purposeful deviation of a lateral knee support in this plane resulting from hardware mal-alignment.



LATERAL KNEE SUPPORT SAGITTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the lateral knee support relative to the horizontal, viewed from the side.

Lines used to form angle:

- Horizontal (X_{WAS})
- Lateral knee support X-axis (X_{LKS})

Angle measured: The degree of rotation from the horizontal (X_{WAS}) to the local X-axis of the lateral knee support (X_{LKS}), viewed from the side and projected to the sagittal plane.

Fig. 3.43: Lateral knee support sagittal angle

Typical values:

A lateral knee support sagittal angle of 0 would indicate that the lateral knee support is aligned with the horizontal as in the Support Surface Reference Position (SSRP). A negative value would indicate that the lateral knee support is *declined*, or angled downward from the horizontal, and a positive value would indicate that the lateral knee support is *inclined*, or angled upwards from the horizontal. If the lateral knee support is attached to the seat, then changes in the lateral knee support sagittal angle would typically match changes in the seat sagittal angle.

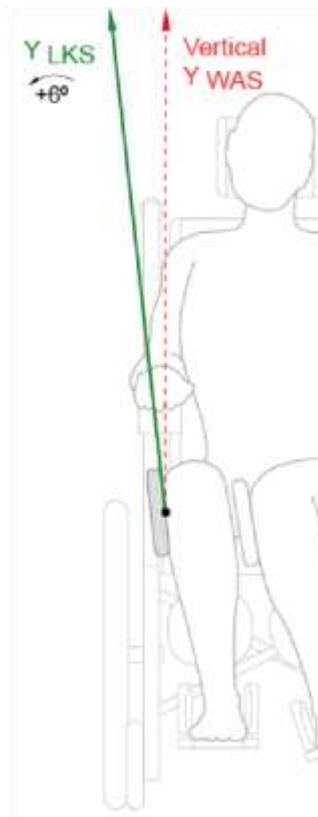
5.11 Lateral knee support frontal angle *(Summary information only)*

Purpose:

To provide a standard term and measure for the orientation of a lateral knee support in the frontal plane (front view)

Clinical Relevance:

Purposeful deviations of a lateral knee support in the frontal plane are uncommon; however it may be needed to improve contact with the lateral side of the knee when the lower leg is rotated due to a fixed hip internal or external rotation contracture. This measurement can therefore be used to document either the existing or desired orientation of a lateral knee support in the frontal plane.



LATERAL KNEE SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of a lateral knee support with respect to the vertical, viewed from the front.

Lines used to form angle:

- Vertical (Y_{WAS})
- Lateral knee support Y-axis (Y_{LKS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the lateral knee support (Y_{LKS}), viewed from the front and projected to the frontal plane.

Fig. 3.44: Lateral knee support frontal angle

Typical values:

A lateral knee support frontal angle of 0 would indicate that the lateral knee support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Positive values would indicate that the lateral knee support is tilted to the user's right, and negative values would indicate that the lateral knee support is tilted to the user's left.

5.12 Lateral knee support transverse angle

Purpose:

To provide a standard term and measure for the orientation of a lateral knee support in the transverse plane (top view)

Clinical Relevance:

Deviations of a lateral knee support in this plane may be required to provide improved contact on the lateral side of the knee when the thigh is angled in this plane due to a fixed asymmetry of the hips. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the lateral knee support in the transverse plane.

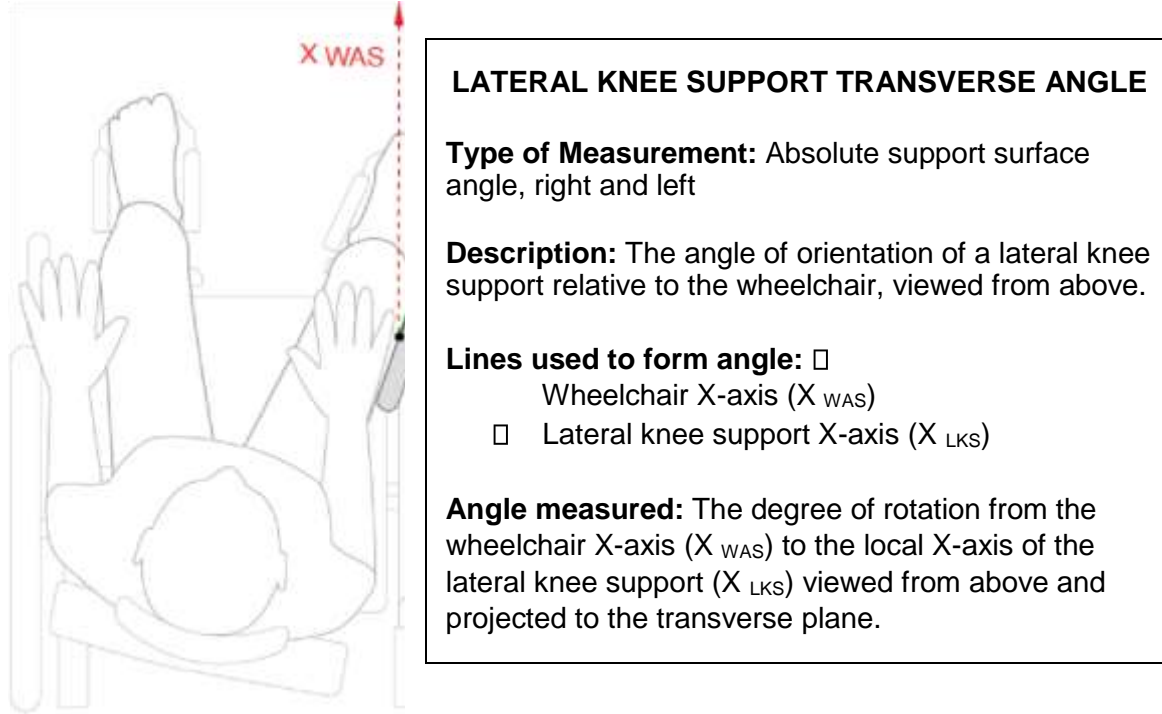


Fig. 3.45: Lateral knee support transverse angle

Sample procedure:**1. Locate the wheelchair X-axis**

- a) The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the line passing through the rear wheel axle.
- b) To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- c) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rail or lateral edge of the seat pan.

2. Locate the lateral knee support reference plane and local X-axis reference line

- a) For a planar lateral knee support, the local X-axis projects forward from the geometric center of the pad along the horizontal midline of the contact surface.

3. Measure the angle (using a goniometer)

- a) Viewing the lateral knee support from above, hold the goniometer pivot center at the back of the lateral knee support, on the top edge, with the arms facing towards the front of the wheelchair.

- b) Align the stationary arm of the goniometer parallel to the wheelchair X-axis reference line (marked on the floor) and align the moveable arm parallel with the lateral knee support's X-axis (along the top edge), and read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair X axis reference line

- If the front of the lateral knee support is rotated to the left, signifying a counterclockwise rotation of the lateral knee support from the wheelchair X-axis when viewed from above, the value is positive.
- If the front of the lateral knee support is rotated to the right, signifying a clockwise rotation of the lateral knee support from the wheelchair X-axis when viewed from above, the value is negative.

Typical values:

A value of 0 would indicate that the lateral knee support is “square” with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP). A positive lateral knee support transverse angle would indicate that the lateral knee support is rotated to the left relative to the wheelchair frame, and a negative angle would indicate that the lateral knee support is rotated to the right.

Considerations:

- The absolute body segment angle which corresponds to the lateral knee support transverse angle would be the transverse thigh angle. If the transverse thigh line is parallel to the lateral knee support X-axis, then the transverse thigh angle will be the same as the lateral knee support transverse angle.
- Intentional deviations of a lateral knee support in the transverse plane are not common in standard seating configurations. However, when seating individuals with lower extremity joint contractures or deformity, it may be necessary to angle the lateral knee support in the transverse plane in order to accommodate a windswept posture of the hips/thighs. This measure provides a standardized term for defining that angular deviation.
- For example, a left lateral knee support transverse angle of +10 degrees could be used to support and accommodate a left transverse thigh angle of +10 degrees which may result from a fixed hip abduction contracture.

6 Absolute Angles of Medial Supports

Medial supports are those supports which are intended to contact the medial surface of a body segment in the sitting position. Medial supports in a wheelchair seating system are uncommon, with the exception of medial knee supports. If there is a surface on the inside of an arm support or foot support, intended to contact the medial side of the forearm or foot/ankle, these would also be called medial supports.

The method of determining angular values for medial supports is similar to lateral supports such as a lateral trunk support or lateral knee support. For a medial support surface, the zero reference for sagittal angles is the horizontal (X_{WAS}), and for frontal angles is the vertical (Y_{WAS}). The zero reference for transverse angles is the X-axis of the wheelchair (X_{WAS}), represented by a line projecting forward perpendicular to the line passing through the axles of the rear wheels.

Remember: The axis of the WAS used as the zero reference to define a particular absolute angle was chosen based on clinical intuitiveness. You can always choose to use one of the other two axes, as long as you measure to the corresponding local axis of the support surface. Because they are perpendiculars, the value of the angle will be the same.

The only medial support included in this section is a **Medial Knee Support**.

Note 1: Purposeful deviations of a medial knee support in the sagittal and frontal planes are uncommon; therefore only summary information is provided for these measures. The most common absolute angle for a medial knee support is the transverse angle.

Note 2: If the medial support surface is intended to contact the user's thigh (instead of the knee), then the support would be called a "**medial thigh support**". Medial thigh support absolute angles are defined and measured exactly the same as lateral knee supports; therefore, they are not included here.

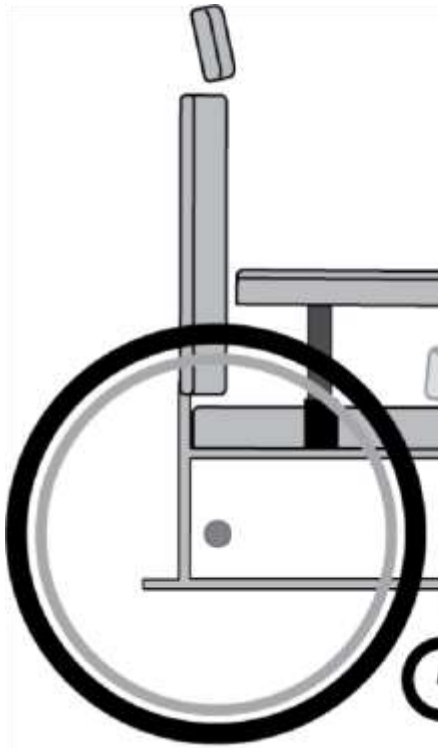
6.1 Medial knee support sagittal angle *(Summary information only)*

Purpose:

To provide a standard term and measure for the orientation of a medial knee support in the sagittal plane (side view)

Clinical Relevance:

Purposeful deviations of a medial knee support in the sagittal plane separate from adjustments of the seat sagittal angle are uncommon. However, adjustments of the sagittal orientation of a medial knee support may be needed to improve contact with a user's medial knee, especially in the case of an adjustable medial knee support which is not mounted to the seat. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the medial knee support in the sagittal plane.



MEDIAL KNEE SUPPORT SAGITTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation the medial knee support relative to the horizontal, viewed from the side.

Lines used to form angle:

- Horizontal (X_{WAS})
- Medial knee support X-axis (X_{MKS})

Angle measured: The degree of rotation from the horizontal (X_{WAS}) to the local X-axis of the medial knee support (X_{MKS}), viewed from the side and projected to the sagittal plane.

Fig. 3.46: Medial knee support sagittal angle

Typical values:

A medial knee support sagittal angle of 0 would indicate that the medial knee support is aligned with the horizontal as in the Support Surface Reference Position (SSRP). A negative value would indicate that the medial knee support is *declined*, or angled downward from the horizontal, and a positive value would indicate that the medial knee support is *inclined*, or angled upwards from the horizontal. Values up to +55 degrees could be recorded with adjustable tilt wheelchair seating systems. If the medial knee support is attached to the seat, then changes in the medial knee support sagittal angle would typically match changes in the seat sagittal angle.

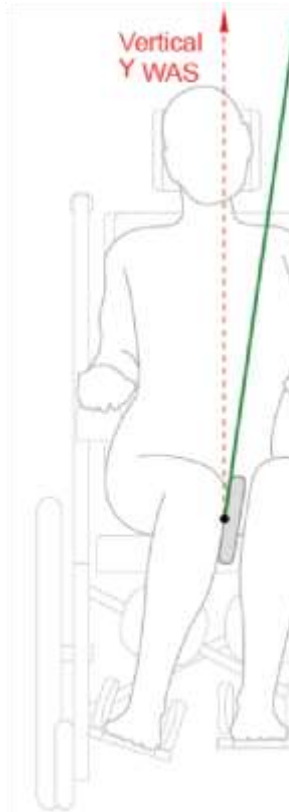
6.2 Medial knee support frontal angle *(Summary information only)*

Purpose:

To provide a standard term and measure for the orientation of a medial knee support in the frontal plane (front view)

Clinical Relevance:

Purposeful deviations of a medial knee support in the frontal plane are uncommon; however, it may be needed to improve contact with the medial side of the knee when the lower leg is rotated due to a fixed hip internal or external rotation contracture. This measurement can therefore be used to document either the existing or desired orientation of a medial knee support in the frontal plane.



MEDIAL KNEE SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of a medial knee support with respect to the vertical, viewed from the front.

Lines used to form angle:

- Vertical (Y_{WAS})
- Medial knee support Y-axis (Y_{MKS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the medial knee support (Y_{MKS}), viewed from the front and projected to the frontal plane.

Fig. 3.47: Medial knee support frontal angle

Typical values:

A medial knee support frontal angle of 0 would indicate that the medial knee support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Positive values would indicate that the medial knee support is tilted to the user's right, and negative values would indicate that the medial knee support is tilted to the user's left.

6.3 Medial knee support transverse angle

Purpose:

To provide a standard term and measure for the orientation of a medial knee support in the transverse plane (top view)

Clinical Relevance:

Deviations of a medial knee support in this plane may be required to provide improved contact on the medial side of the knee when the thigh is angled in this plane due to a fixed asymmetry of the hips or pelvis. This measurement can be used to document either the existing or desired orientation of the medial knee support.

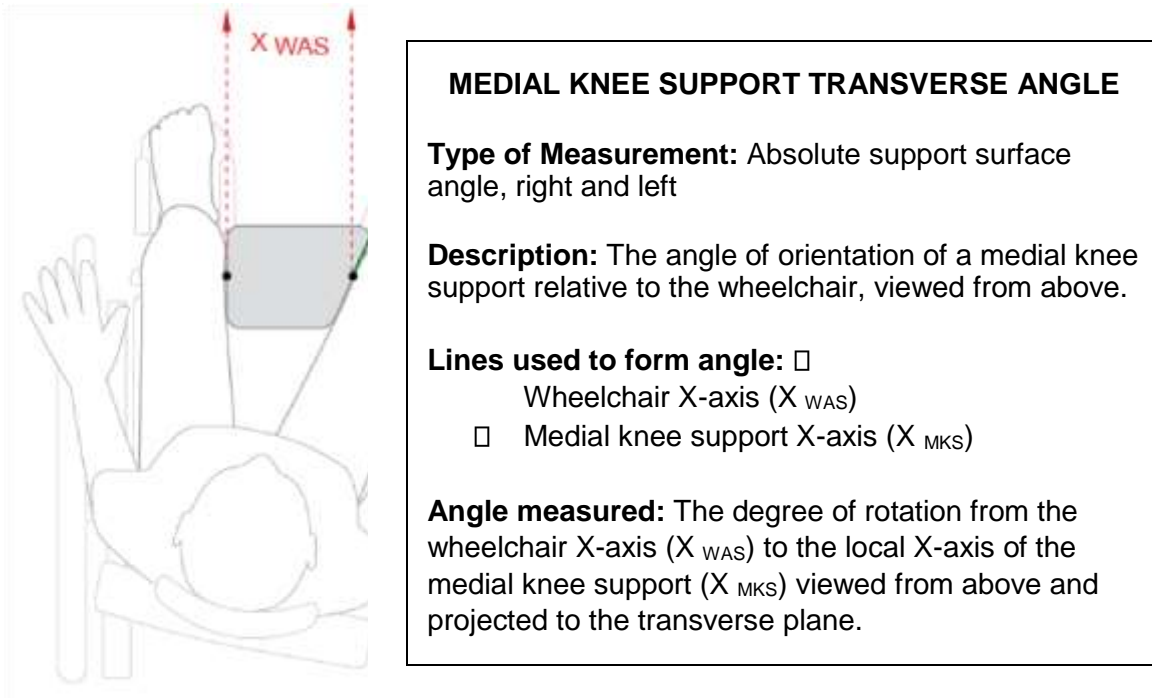


Fig. 3.48: Medial knee support transverse angle

Sample procedure:

1. Locate the wheelchair X-axis

- a) The wheelchair X-axis (X_{WAS}) projects forward perpendicular to the line passing through the rear wheel axle.
- b) To locate the X-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis. The line projecting forward represents the wheelchair X-axis.
- c) Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair X-axis, such as the seat rail or lateral edge of the seat pan.

2. Locate the medial knee support reference plane and local X-axis reference line

- a) For a planar medial knee support, the local X-axis projects forward from the geometric center of the pad along the horizontal midline of the contact surface.

3. Measure the angle (using a goniometer)

- a) Viewing the medial knee support from above, hold the goniometer pivot center at the back of the medial knee support, on the top edge, with the arms facing towards the front of the wheelchair.
- b) Align the stationary arm of the goniometer parallel to the wheelchair X-axis reference line (marked on the floor) and align the moveable arm parallel with the medial knee support's X-axis (along the top edge), and read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair X-axis reference line

- If the front of the medial knee support is rotated to the left, signifying a counterclockwise rotation of the medial knee support from the wheelchair X-axis when viewed from above, the value is positive.
- If the front of the medial knee support is rotated to the right, signifying a clockwise rotation of the medial knee support from the wheelchair X-axis when viewed from above, the value is negative.

Typical values:

A value of 0 would indicate that the medial knee support is “square” with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP). A positive medial knee support angle would indicate that the medial knee support is rotated to the left relative to the wheelchair frame, and a negative angle value would indicate that the medial knee support is rotated to the right.

Considerations:

- The absolute body segment angle which corresponds to the medial knee support transverse angle would be the transverse thigh angle. If the transverse thigh line is parallel to the medial knee support X-axis, then the transverse thigh angle will be the same as the medial knee support transverse angle.
- Intentional deviations of a medial knee support in the transverse plane are not common in standard seating configurations. However, when seating individuals with lower extremity joint contractures or deformity, it may be necessary to angle the medial knee support in the transverse plane in order to accommodate a windswept posture of the hips/thighs. This measure provides a standardized term for defining that angular deviation.
- The word “pommel” is often used to describe a postural support device that is intended to contact the medial sides of both knees. A “pommel” is a medial knee support which has two medial support surfaces built into one device. Therefore, it is possible to have a right medial knee support transverse angle and a left medial knee support transverse angle in one postural support device. An example of this is in the figure above (Fig. 3.48).

7 Absolute Angles of Anterior Supports

Anterior supports are those supports which are intended to contact the anterior surface of a body segment in the sitting position. Anterior supports in a wheelchair seating system are uncommon; however the most typical are anterior knee supports (sometimes called 'knee blocks') and anterior trunk supports (which are usually non-rigid surfaces such as straps or harnesses).

The method of determining angular values for anterior supports is similar to posterior supports such as a back support or lower leg support. For an anterior support, the zero reference for sagittal and frontal angles is the vertical (Y_{WAS}). The zero reference for transverse angles is the Z-axis of the wheelchair (Z_{WAS}) represented by a line passing through the axles of the rear wheels.

Remember: The axis of the WAS used as the zero reference to define a particular absolute angle was chosen based on clinical intuitiveness. You can always choose to use one of the other two axes, as long as you measure to the corresponding local axis of the support surface. Because they are perpendiculars, the value of the angle will be the same.

The only anterior support included in this section is an **Anterior Knee Support**.

Note 1: An anterior knee support is not a common support; however, it is used in some applications to prevent migration of the pelvis and thighs forward on the seat. Purposeful deviations of an anterior knee support in the sagittal and frontal planes are uncommon; therefore only summary information is provided for these measures. The most common angular deviation for an anterior knee support is the transverse angle.

Note 2: If the anterior support surface is intended to contact the user's lower leg, below the knee, then the support would be called an "**anterior lower leg support**". Anterior lower leg support absolute angles are defined and measured exactly the same as anterior knee supports; therefore, they are not included here.

7.1 Anterior knee support sagittal angle *(Summary information only)*

Purpose:

To provide a standard term and measure for the orientation of an anterior knee support in the sagittal plane (side view)

Clinical Relevance:

Anterior knee supports (sometimes called 'knee blocks') are sometimes used in complex seating applications in order to block migration of the pelvis and thigh forward on the seat, helping to maintain pelvic/spinal alignment. Purposeful deviations of an anterior knee support in the sagittal plane are uncommon, however small adjustments may be needed to match the sagittal lower leg angle if the user's knee is flexed more or less than 90 degrees. This measurement can be used to document either the existing or desired orientation (or range of orientation if angle is adjustable) of the medial knee support.



ANTERIOR KNEE SUPPORT SAGITTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of the anterior knee support relative to the vertical, viewed from the side.

Lines used to form angle:

- Vertical (Y_{WAS})
- Anterior knee support Y-axis (Y_{AKS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the anterior knee support (Y_{AKS}), viewed from the side and projected to the sagittal plane.

Fig. 3.49: Anterior knee support sagittal angle

Typical Values:

An anterior knee support sagittal angle of 0 would indicate that the anterior knee support is aligned with the vertical as in the Support Surface Reference Position (SSRP). A negative value would indicate that the anterior knee support is *proclined*, or angled forward from the vertical, and a positive value would indicate that the anterior knee support is *reclined*, or angled backwards from the vertical. Values up to +55 degrees could be recorded with adjustable tilt wheelchair seating systems.

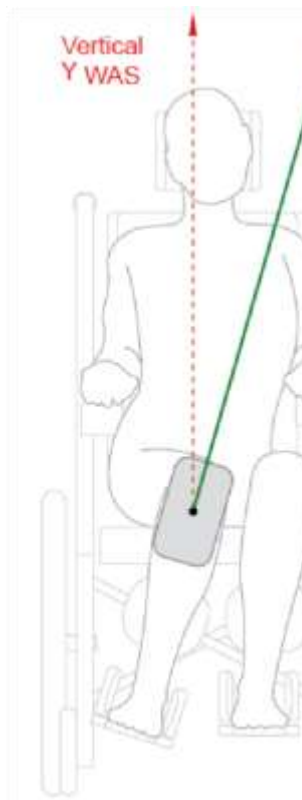
7.2 Anterior knee support frontal angle *(Summary information only)*

Purpose:

To provide a standard term and measure for the orientation of an anterior knee support in the frontal plane (front view)

Clinical Relevance:

Anterior knee supports (sometimes called 'knee blocks') are sometimes used in complex seating applications in order to block migration of the pelvis and thigh forward on the seat, helping to maintain pelvic/spinal alignment. Purposeful deviations of an anterior knee support in the frontal plane are uncommon; however they may be needed when the lower leg is angled in the frontal plane due to a fixed hip internal or external rotation contracture. This measurement can therefore be used to document either the existing or desired orientation of an anterior knee support in the frontal plane.



ANTERIOR KNEE SUPPORT FRONTAL ANGLE

Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of an anterior knee support with respect to the vertical, viewed from the front.

Lines used to form angle:

- Vertical (Y_{WAS})
- Anterior knee support Y-axis (Y_{AKS})

Angle measured: The degree of rotation from the vertical (Y_{WAS}) to the local Y-axis of the anterior knee support (Y_{AKS}), viewed from the front and projected to the frontal plane.

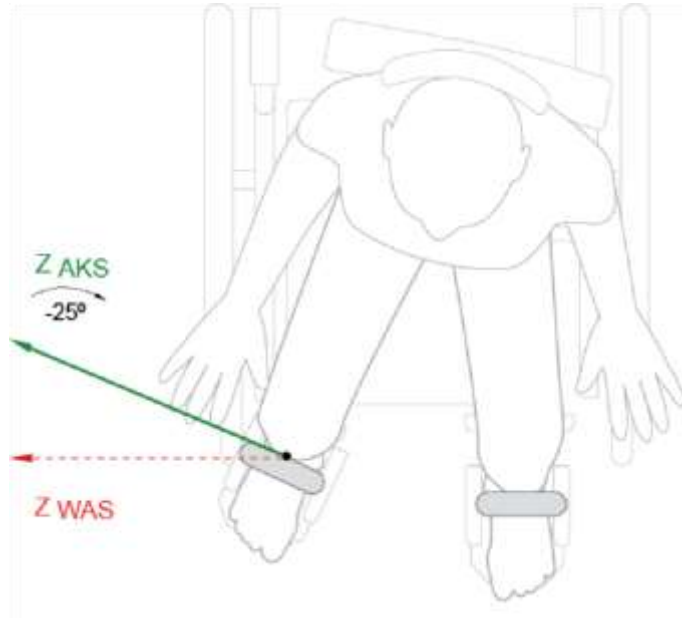
Fig. 3.50: Anterior knee support frontal angle

Typical values:

An anterior knee support frontal angle of 0 would indicate that the anterior knee support is aligned with the vertical as in the Support Surface Reference Position (SSRP). Positive values would indicate that the anterior knee support is tilted to the user's right, and negative values would indicate that the anterior knee support is tilted to the user's left.

ANTERIOR KNEE SUPPORT TRANSVERSE ANGLE

7.3 Anterior knee support transverse angle



Type of Measurement: Absolute support surface angle, right and left

Description: The angle of orientation of an anterior knee support relative to the wheelchair, viewed from above.

Lines used to form angle: □

Wheelchair Z-axis (Z_{WAS})

□ Anterior knee support Z-axis (Z_{AKS})

Angle measured: The degree of rotation from the wheelchair Z-axis (Z_{WAS}) to the local Z-axis of the anterior knee support (Z_{AKS}), viewed from above and projected to the transverse plane.

Purpose:

To provide a standard measure of the orientation of the anterior knee support in the transverse plane (top view)

Clinical Relevance:

Anterior knee supports (sometimes called 'knee blocks') are sometimes used in complex seating applications in order to block migration of the pelvis and thigh forward on the seat, helping to maintain pelvic/spinal alignment. Angular adjustments of the anterior knee support in the transverse plane would be needed in order to accommodate an abducted or adducted hip position, or a transverse thigh angle which deviates from zero. This measurement can be used to either document the existing orientation or specify the desired orientation of the anterior knee support.

Fig. 3.51: Anterior knee support transverse angle

Sample procedure:

1. Locate the wheelchair Z-axis

- The wheelchair Z-axis (Z_{WAS}) is a line passing through the rear wheel axles of wheelchair.
- To locate the Z-axis of the wheelchair, place two long pieces of tape onto the floor (recommend 5' long) at right angles to each other forming a "T". Align the user's wheelchair over the tape so that one line passes below and in line with the axles of the drive wheels, and the other line projecting forward is centered between the two axles. The line parallel to the axles represents the wheelchair Z-axis.
- Alternatively you can sight to any structure on the wheelchair frame that you know is parallel to the wheelchair Z-axis, such as the front edge of the seat pan.

2. Locate the anterior knee support reference plane and local Z-axis reference line

- a) For a planar anterior knee support, the local Z-axis projects sideways to the right from the geometric center of the pad along the horizontal midline of the contact surface.

3. Measure the angle (using a goniometer)

- a) Viewing the anterior knee support from above, hold the goniometer pivot center at the left side of the anterior knee support, on the top edge, with the arms facing towards the right side of the wheelchair.
- b) Align the stationary arm of the goniometer parallel to the wheelchair Z axis reference line (marked on the floor) and align the moveable arm parallel with the anterior knee support's Z-axis (along the top edge), and read the angle value.

4. Determine positive or negative value based on the direction of rotation away from the wheelchair Z-axis reference line

- If the anterior knee support is rotated to the left, signifying a counterclockwise rotation of the anterior knee support from the wheelchair Z-axis when viewed from above, the value is positive.
- If the anterior knee support is rotated to the right, signifying a clockwise rotation of the anterior knee support from the wheelchair Z-axis when viewed from above, the value is negative.

Typical values:

A value of 0 would indicate that the anterior knee support is “square” with the wheelchair frame when viewed from the top, as in the Support Surface Reference Position (SSRP). A positive anterior knee support transverse angle would indicate that the anterior knee support is rotated to the left relative to the wheelchair frame, and a negative angle would indicate that the anterior knee support is rotated to the right.

Considerations:

- The absolute body segment angle which corresponds to the anterior knee support transverse angle would be the transverse thigh angle.
- When seating individuals with lower extremity joint contractures or deformity, it may be necessary to angle the anterior knee support in the transverse plane in order to accommodate a windswept posture of the hips/thighs. This measure provides a standardized term for defining that angular deviation.
- For example, a left anterior knee support transverse angle of +10 degrees could be used to accommodate a left transverse thigh angle of +10 degrees, which may reflect a position of left hip abduction.

8 References

1. ISO 7176-7 (1998): Wheelchairs-- Part 7: Measurement of seating and wheel dimensions, International Organization for Standardization, Geneva, Switzerland, May 1998.
2. ISO 16840 (2006): Wheelchair Seating, Section 1 - Vocabulary, reference axis convention and measures for body posture and postural support surfaces, International Organization for Standardization, TC-173, SC-1, WG-11.

CHAPTER 4: LINEAR BODY MEASURES

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1 General Instructions

The measures in this section describe the client's linear body dimensions in a sitting position. To determine and prescribe appropriate seating support surface dimensions, it is necessary to take measurements of the client's body, and then translate these into desired equipment dimensions using clinical judgment. Because body measurements do not necessarily coincide exactly with desired seating dimensions or placement, it is important to differentiate body measurements from support surface measurements. For example, the prescribed seat depth of the wheelchair is usually less than the actual buttock/thigh depth of the client.

1.1 Comments on procedure

Many linear measurements of the body will be highly affected by the alignment of the body segments. Therefore, *the client should be positioned in the desired sitting posture prior to taking the measurements.* Measurements are most accurate when the client is supported on a firm flat surface, such as seated on the edge of a mat table. In the case of an individual with poor sitting balance and/or significant abnormal movement or postural deviation, it may require several sets of hands to support the client in the desired posture. In this situation, more accurate measurement will result when the individual can be supported in the desired alignment using a mockup of desired seating components, either in a trial wheelchair or a seating simulator.

All measures in this section are direct linear measurements of the client's body in sitting without any spacing or allowances included, and without compressing soft tissues. Because these body measures are used to determine both wheelchair frame and seating component dimensions and placement, all body measures are 'straight' linear dimensions. In other words, one should not follow the contours of the person's body surface during measurement. To help prevent this error, the measurement device should be as inflexible as possible, such as a yardstick, caliper, or heavy duty metal tape measure.

1.2 Terminology conventions

As explained in the introduction to this guide, all linear measures taken along or parallel to the body segment's local Y-axis are termed *length*; measures taken along (or parallel to) the segment's local Z-axis are termed *width*; and measures taken along (or parallel to) the segment's X-axis are termed *depth*. The term *height* is used when taking a measurement from an external reference point outside of the body to a point on the body. For example, elbow height is a measure of the vertical distance from the seat surface to the elbow.

1.3 "Effective" measures

Several of the body measures in this section reflect the actual linear dimension of a particular body segment in the sitting position. For example, buttock thigh depth, foot depth, lower leg length and chest width are all measures of the actual depth, length or width of that body segment. These types of measures are defined as linear dimensions taken parallel to the body segment axes. This means that if a body segment deviates away from the Seated Reference Position in a particular plane, you should "follow" the segment in the plane of deviation when taking these linear measures, staying parallel to the relevant body segment line.

However, in many instances it is not clinically useful to "follow the body segment" in a particular plane of deviation because this does not help with prescription of the corresponding relevant equipment dimension. In this case, you may want to differentiate between the actual dimension of the body segment and an "effective" dimension. For example, if the desired sitting posture is with windswept thighs (a deviation in the transverse plane), it would not be useful to align the tape measure parallel to the transverse thigh line when taking a

buttock/thigh depth measurement for the purpose of determining desired seat depth (measure A in Fig. 4.1). In this case, it would be more useful to take the measure perpendicular to the Z-axis of the seat (measure B in Fig. 4.1), as this is the relevant dimension needed to translate into an appropriate seat depth. In order to make it clear that you have not followed the body segment in a particular plane of deviation, but rather have stayed orthogonal (at right angles) to one of the support surface axes, add the word “effective” to the measure so there is no confusion as to how the measure was taken and to indicate that it is not the *actual* dimension of the body segment. In the example above, the B measure taken would be called “effective buttock/thigh depth” (Fig. 4.1).

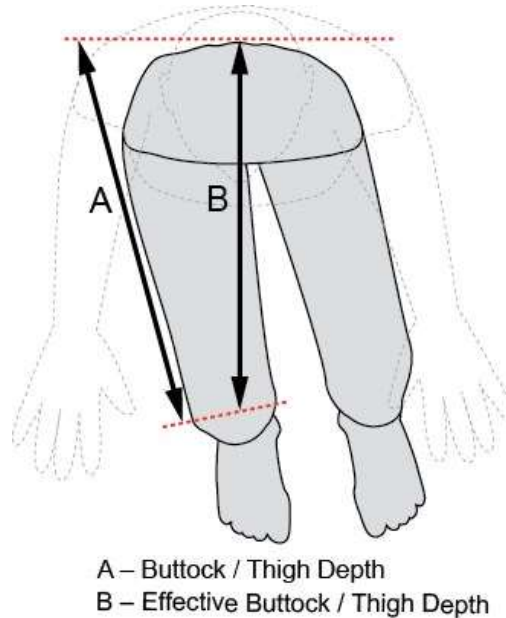


Fig. 4.1: Effective buttock/thigh depth

There may be other situations when a practitioner alters the methodology of a measure for some specific purpose, such as adding space for accommodation of a rotated pelvis (see Buttock/thigh depth), or for accommodation of clothing thickness or footwear (see lower leg length). In these situations the addition of the word “effective” to the measure is appropriate, but the difference in methodology should be noted.

To summarize, the word “effective” should be added to any length, depth or width measure to indicate that the measure does not reflect the actual dimension of the body segment as defined, because the methodology has been altered in some way for clinical reasons. Most commonly, the dimension has been taken without following the body segment in one plane of deviation, such as in the example of a windswept posture. Examples of when it may be useful to take an effective linear body dimension are included in the Considerations section of particular measures.

In contrast, there are several depth and width measures that *do not* reflect dimensions of a specific body segment, but rather are linear dimensions taken from a point on one body segment to a point on another body segment. Examples of these measures are: lumbar curve depth, maximum sitting depth, external knee width, and maximum lower body width. These measures are defined as being horizontal dimensions, always taken parallel to either the wheelchair X- or Z-axis. Because these measures do not represent the dimension of a single body segment but rather represent multiple body segments, it is not necessary to add the word ‘effective’ to these measures to differentiate between an actual and effective dimension. Therefore, the general rule outlined above regarding the use of the term ‘effective’ does not apply to these types of depth and width measures. Similarly, because height measures do not necessarily represent the dimension of a

single body segment, it is not necessary to add the word “effective” to any height measures to differentiate between the actual dimension of a body segment and the effective dimension. Therefore, the general rule outlined above regarding the use of the term “effective” also does not apply to height measures.

1.4 Recommended measures

Table 1 includes a list of the body measures defined in this chapter. They have been identified as either Level I or Level II measures, to suggest a selection of measures to take based on complexity of client need. The “Level I” column indicates the baseline measurements that are necessary for most seating and wheeled mobility evaluations. The Level II measurements are intended to provide extra information about the client which may be needed to determine parameters of more complex seating components and wheelchair configurations. However, this is not intended to be prescriptive since the measurements used in any one assessment process will depend not only on the clinical presentation of the individual, but also on the complexity of their postural support needs and the goals of the measurement process. **Table 1: Suggested linear body measures based on complexity of client need**

	Level I	Level II
Measures taken in direction of X-axis (Depth)	Buttock/thigh depth	Trunk depth Occiput depth Lumbar curve depth Thoracic curve depth Ischial depth Foot depth Forearm depth Maximum sitting depth
Measures taken in direction of Y-axis (Height, Length)	Lower leg length Elbow height Scapula height Axilla height Shoulder height Maximum sitting height	Thigh height PSIS height Occiput height Occiput to C7 Sternal length
Measures taken in direction of Z-axis (Width)	Shoulder width Chest width Hip width External knee width	Head width Waist width External thigh width Knee width External foot width Internal knee width Internal foot width Occiput to centerline Medial knee to centerline Lateral knee to centerline Maximum lower body width Maximum sitting width

Figure 4.2 below shows all of the Level I measures, and some of the more common Level II measures included in this chapter. The first figure on the left includes depth measures; the middle figure includes height and length measures, and the figure on the right shows width measures.

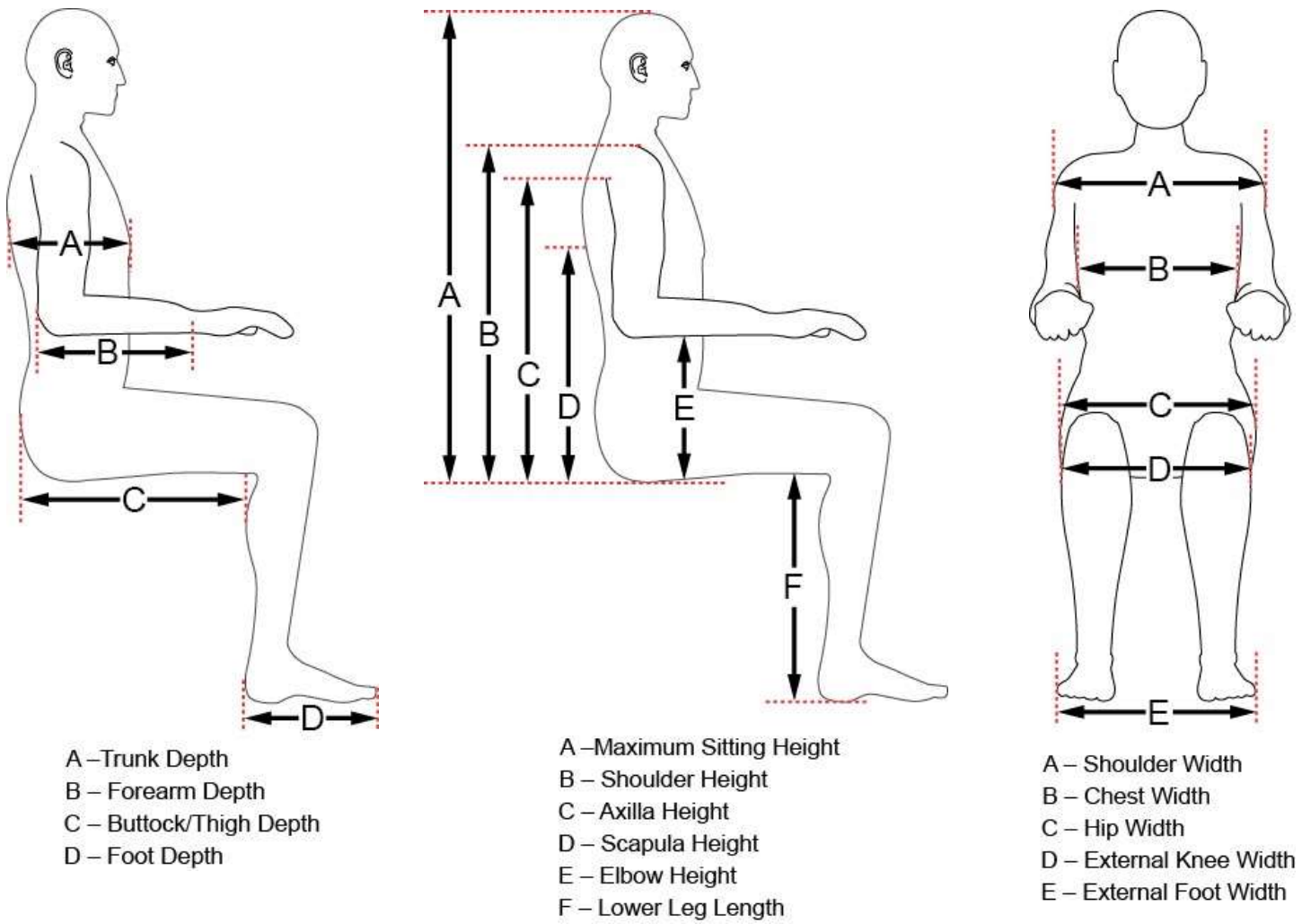


Fig. 4.2: Examples of common linear body measures

2 Level I Measures 2.1

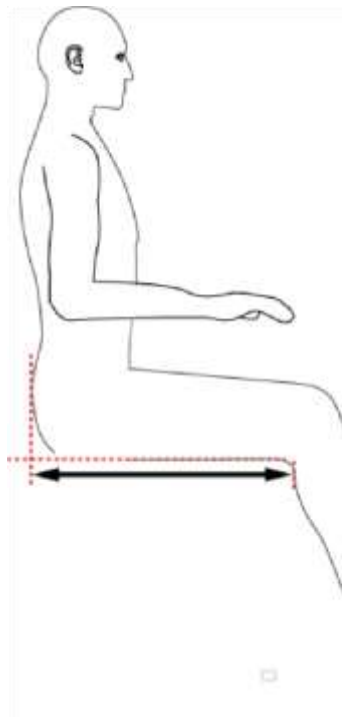
Buttock/thigh depth

Purpose:

To document the depth of the buttock/thigh segment when seated in the desired sitting posture

Clinical relevance:

This measure is used to help specify the desired seat depth.



BUTTOCK/THIGH DEPTH

Type of Measurement: Body Linear, left and right

Description: The distance from the back of the buttocks to behind the knee for a seated person.

Landmarks (end points) used: Most posterior aspect of the buttock
Left and right popliteal fossa

Definition: Linear distance from the most posterior point of the buttocks to the popliteal fossa, measured parallel to the thigh.

Fig. 4.3: Buttock/thigh depth

Sample procedure:

1. Support person in desired seated posture.
2. Place a firm flat surface behind the most posterior surface of the buttocks, making sure to align this surface parallel to the sagittal trunk line if the desired alignment is with an open thigh to trunk angle. This is your reference surface for measurement, as it helps identify the most posterior point of the buttocks. Do not press into the soft tissue.
3. Measure the distance from this surface to the client's popliteal fossa, holding the tape measure parallel to the thigh if it deviates in the sagittal plane. Repeat for both sides.

Considerations:

- This measure represents the full length of the client's buttock and thigh when seated in the desired posture. Therefore measure all the way into the popliteal fossa, and be sure to include all soft tissue for a heavy client.
- This measure can then be used to determine the desired seat depth, which is likely to be shorter than this dimension.
- The buttock/thigh depth measure may differ between the person's left and right sides. This could be due to such things as asymmetrical alignment of the thighs, asymmetry of buttock tissue, a leg length discrepancy or a rotated pelvis.

- **Windswept posture:** When the desired sitting alignment is with thighs angled to right or left as with this posture, the actual buttock/thigh depth measure as defined (staying parallel to the thigh) may not be very useful for determining seat depth. Therefore, you should take an *effective buttock thigh depth* measurement to reflect the amount of depth the thighs will actually take up on the seat. To take an effective buttock/thigh depth measure in this situation, hold the tape measure perpendicular to the simulated seat Z-axis (the back support reference plane or back edge of seat cushion), even though it will not lie parallel to the thigh in the transverse plane. You will need to place a pencil or other thin straight object behind the popliteal fossa to project this endpoint laterally or medially to the tape measure which is being held perpendicular to the surface behind buttocks. If you take the measurement this way, make sure that you label the dimension “effective buttock/thigh depth” to indicate that the measure does not reflect the actual depth of the person’s thigh, but rather the *effective depth* available to interface with a seat in this asymmetrical posture. See Fig. 4.1 at the beginning of the chapter for an illustration of effective buttock/thigh depth.
- **Rotated pelvis:** If the desired seated posture is with the pelvis rotated relative to the Z-axis of the seat (such as may be required in a fixed roto-scoliosis), the back of the buttocks on one side may be more forward than the other side. If you hold the flat surface behind the buttocks in a manner which simulates the seat’s Z-axis (usually parallel to back edge of seat cushion), there may be a space behind the buttocks on the side which is rotated forward, and this should be noted. If you take the measurement from this surface (instead of the actual posterior point of the buttocks on this forward side), call the dimension “effective buttock/thigh depth”, to indicate that the measure does not reflect the actual depth of the person’s thigh, but rather the effective depth, and note the reason.
- **Bariatric clients:** Due to the bulk of the lower leg, it may not be possible or desirable to measure all the way into the popliteal fossa. If the posterior surface of an individual’s lower leg protrudes more posteriorly than the popliteal fossa, this will decrease the depth of their thigh available to interface with a seat. In this case, measure to the most posterior surface of the calf, and label the measure “effective buttock/thigh depth”, indicating the endpoint of the dimension as taken.
- If it is difficult or impossible to measure the client in the desired seated posture, this measure can be taken in supine. However, note that if taken in supine it will usually be shorter than when taken in sitting, because buttock soft tissue which would normally spread posteriorly when sitting is compressed when lying supine.

2.2 Lower leg length

Purpose:

To document the length of the lower leg in the sitting position

Clinical relevance:

This measure is used to help specify the desired seat surface to foot support distance for proper adjustment and placement of the foot support, as well as to help specify other parameters of the wheelchair.

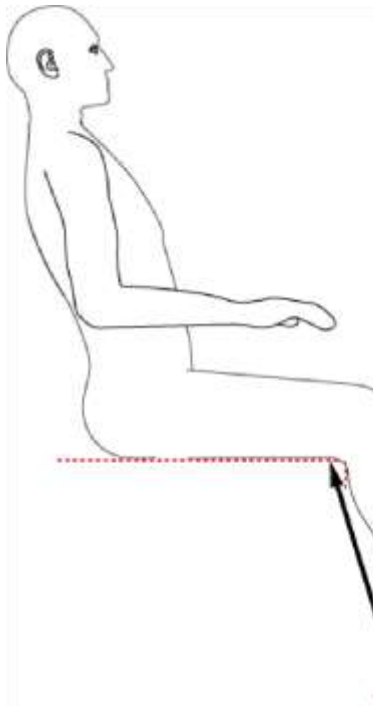


Fig. 4.4: Lower leg length

LOWER LEG LENGTH

Type of Measurement: Body Linear, left and right

Description: The length of the lower leg from back of knee to bottom of heel.

Landmarks (endpoints):

- Inferior surface of distal thigh
- Inferior surface of heel

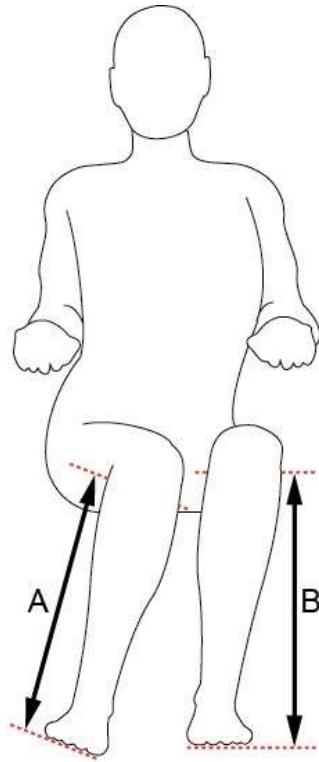
Definition: Maximum distance from the inferior surface of the thigh immediately behind the knee to the inferior surface of the heel, measured parallel to the lower leg.

Sample procedure:

1. Support person in desired seated posture.
2. Hold tape measure parallel to the lower leg (parallel to both the sagittal and frontal lower leg lines), and measure the distance from the inferior (lower) surface of the thigh, immediately behind the knee, to the inferior surface of the heel, with the ankle in the desired position.

Considerations:

- This measure will be affected by the lower leg to foot angle. For example, if the person's ankle is in dorsiflexion, this dimension will tend to be longer. Therefore, maintain the desired lower leg to foot angle when taking measurement.
- As defined, this measure is taken without footwear. If the measure is taken with footwear on, this should be called "effective lower leg length", with a note indicating that the dimension includes footwear.
- This measure is primarily used to help determine the required seat surface to foot support distance and subsequent placement and adjustment of the footplates for proper lower leg and foot support.
- Additionally, this body measure is clinically useful in helping to determine other wheelchair parameters which may be required to achieve ground clearance, caster clearance under footplates, or other features related to the overall seat to floor height.
- **Windswept lower legs:** If the lower legs are deviated in the frontal plane (e.g. hips internally or externally rotated), you may wish to take an effective lower leg length measurement in addition to – or instead of – the actual lower leg length. In this case, while facing the person from the front, hold the tape measure perpendicular to the seat reference plane (or seat Z-axis) and not parallel to the lower leg in the frontal plane. Refer to this measure as 'effective lower leg length' to differentiate it from actual lower leg length. (Fig. 4.5) This effective lower leg length may be a more useful measure for specifying the seat to foot support distance.



A – Lower Leg Length
B – Effective Lower Leg Length

Fig. 4.5: Example of effective lower leg length

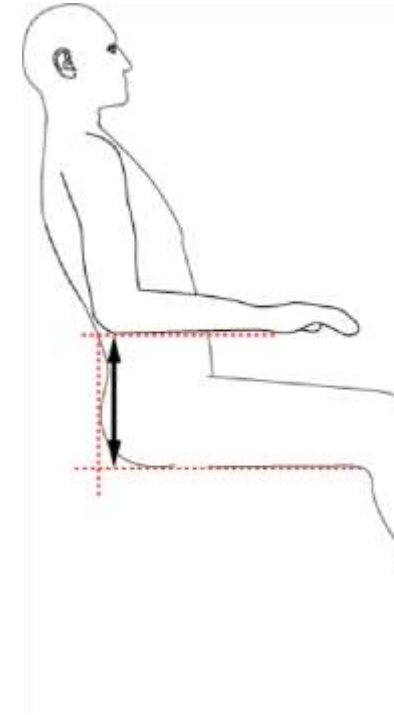
2.3 Elbow height

Purpose:

To document the height of the elbow and forearm from the seat surface when seated in the desired sitting posture

Clinical relevance:

This measure is used to help determine the height placement of upper extremity supports such as arm supports or trays.



ELBOW HEIGHT

Type of Measurement: Body Linear, left and right

Description: The vertical distance from the top of sitting surface to the inferior aspect of the elbow in the sitting position.

Landmarks (end points used):

- Loaded, contact surface side of horizontal sitting surface under buttocks
- Inferior point of elbow

Definition: The vertical distance from a horizontal sitting surface under the buttocks to the lowest bony point of the elbow.

Fig. 4.6: Elbow height

Sample procedure:

1. Support person in desired seated posture.
2. Place the subject's arm in the desired resting position.
3. Measure the vertical distance from the contact surface side (top) of the horizontal seating surface, to the lowest bony point of the elbow. Repeat for both arms.

Considerations:

- Note that this body measure represents the distance from the contact surface side of the seat and does not include seat cushion thickness. Therefore, when using this measure to specify the placement of the arm support structure relative to the seat pan or seat rail of the wheelchair, one must allow for the thickness of the loaded seat cushion.
- Similarly, use of a non-solid seat base for a cushion, such as a sling seat, will impact the translation of this body measure into a prescription of the wheelchair's arm support height.
- The thickness of the arm support material should also be taken into consideration when determining required wheelchair arm support structure height.
- **When the desired position of the trunk is reclined, such as with an open thigh to trunk angle (as shown in Fig. 4.6):** This measure is defined as the **vertical** distance from the seat surface to the elbow; therefore, you must still measure perpendicular to the seat reference plane. Depending on the degree of

fixed recline (sagittal trunk angle), you may need to use a flat surface under the elbow/forearm to project the endpoint forward in order to measure up from the sitting surface.

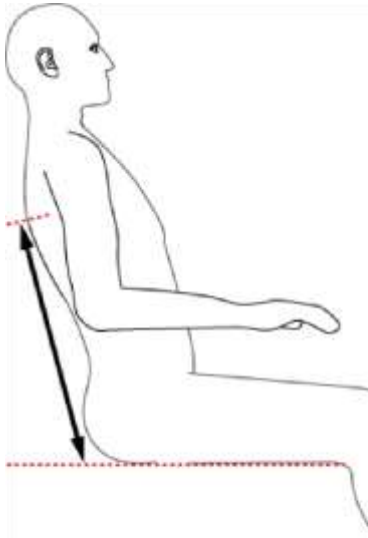
2.4 Scapula height

Purpose:

To document the height of the scapula in the sitting position

Clinical relevance:

This measure can assist in determining the length, shape and height of a back support.



SCAPULA HEIGHT

Type of Measurement: Body Linear, left and right

Description: The distance from the top of sitting surface to the inferior angle of the scapula.

Landmarks (end points) used:

- Loaded, contact surface side of seat under buttocks
- Inferior angle of the scapula left and right

Definition: The distance from the sitting surface under buttocks to the inferior angle of the scapula measured parallel to the sagittal trunk line and perpendicular to the seat Z-axis.

Fig. 4.7:Scapula Height

Sample procedure:

1. Support person in desired seated posture.
2. Measure the distance from the top contact surface of loaded seat to the inferior angle of the scapula on the left and right sides. Hold the tape measure parallel to the sagittal trunk line and perpendicular to the seat in the front view.

Considerations:

- If the desired sitting posture is with an open thigh to trunk angle, remember to measure parallel to the sagittal trunk line, in line with the trunk in the sagittal plane. This is important because the back support length is measured parallel to the back support reference plane, which would deviate in the sagittal plane to match the angle of the trunk.
- Conversely, if the trunk is deviated in the frontal plane, as in an asymmetrical lean or scoliosis posture, the scapula height dimension is **not taken parallel to the frontal trunk line**, but rather perpendicular to the seat reference plane in the front view. This will result in an accurate reflection of the potential difference in scapula height between the right and left sides.

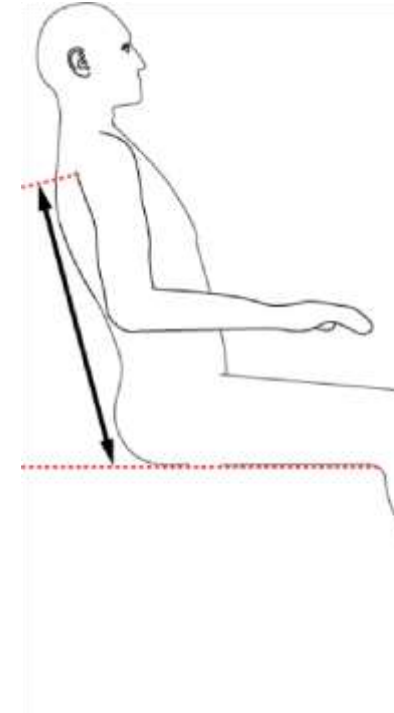
2.5 Axilla height

Purpose:

To document the height of the axilla in the sitting position

Clinical relevance:

This measure can assist in determining the length, shape and height of a back support or the vertical placement of lateral trunk supports.



AXILLA HEIGHT

Type of Measurement: Body Linear, left and right

Description: The distance from the top of sitting surface to the axilla.

Landmarks (end points) used:

- Loaded, contact surface side of seat under buttocks
- Axilla, left and right sides

Definition: The distance from the sitting surface under buttocks to the axilla, measured parallel to the sagittal trunk line and perpendicular to the seat Z-axis.

Fig. 4.8: Axilla height

Sample procedure:

1. Support person in desired seated posture.
2. Measure the distance from the top contact surface of the loaded seat to the axilla on the left and right sides. Hold the tape measure parallel to the sagittal trunk line and perpendicular to the seat in the frontal view.

Considerations:

- Axilla height may differ on the right and left sides due to postural variations, such as when the trunk is angled in the frontal plane. In this case, remember to measure perpendicular to the seat in the front view, and not parallel to the frontal trunk line. This will result in an accurate reflection of the potential difference in axilla height between the right and left sides.
- This measure can be used to help determine the vertical location of lateral trunk supports (lateral trunk support height).

2.6 Shoulder height

Purpose:

To document the height of the shoulders in the sitting position

Clinical relevance:

This measure is used to help specify the length and height of the back support.

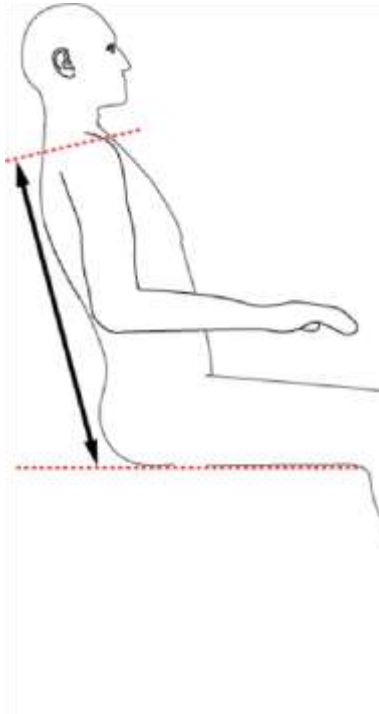


Fig. 4.9: Shoulder height

SHOULDER HEIGHT

Type of Measurement: Body Linear, right and left

Description: The distance from the sitting surface to the top of the shoulder, right and left.

Landmarks (end points) used:

- Loaded, contact surface side of seat under buttocks
- Acromion process of the shoulder both right and left

Definition: The distance from the loaded contact surface side of the seat under buttocks to each acromion process, measured parallel to the sagittal trunk line and perpendicular to the seat Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Measure the distance from the loaded contact surface side of the seat under the buttocks to the tip of the acromion process, on the left and right sides.
3. Hold the tape measure parallel to the sagittal trunk line and perpendicular to the seat in the front view.

Considerations:

- Shoulder height may differ on the right and left sides due to postural variances such as when the trunk is angled in the frontal plane. In this case, remember to measure perpendicular to the seat reference plane in the front view and not parallel to the frontal trunk line. This will result in an accurate reflection of the potential difference in shoulder height between the right and left sides.

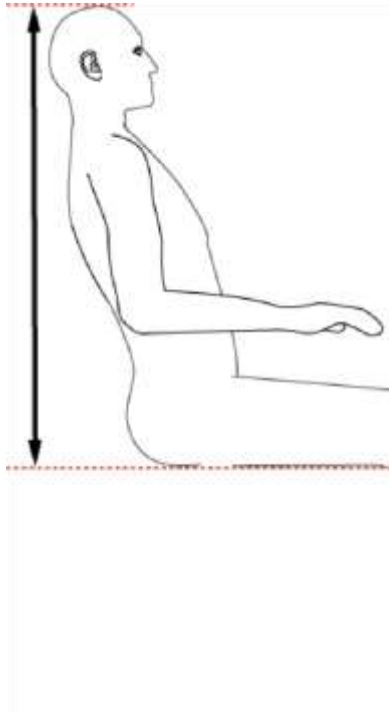
2.7 Maximum sitting height

Purpose:

To document the maximum vertical height to the top of the head in sitting from the seat

Clinical relevance:

This measure is used to help specify the overall seated height of a person in their wheelchair to assist in determining head clearance needs within the environment.



MAXIMUM SITTING HEIGHT

Type of Measurement: Body Linear

Description: The vertical distance from the top of the seat to the top of the head in sitting.

Landmarks (end points) used:

- Loaded, contact surface side of seat under buttocks
- The most superior point of the head

Definition: The vertical distance from the horizontal sitting surface to the highest point of the head.

Fig. 4.10: Maximum sitting height

Sample procedure

1. Support person in desired seated posture.
2. Measure from the loaded contact surface side of the seat under the buttocks, to the top of the head.
3. Hold the tape measure in line with the vertical, and **not parallel to the sagittal trunk line**, even if the person has an open thigh to trunk angle.

Note: If the person is sitting in a seat with adjustable tilt during this measurement, bring the seat frame to its most upright position with the seat sagittal angle set at zero degrees (or note seat sagittal angle), before taking this measurement.

Considerations:

- The maximum sitting height represents the vertical height of the upper body above the seat cushion. The seat pan to floor height of the wheelchair, plus loaded thickness of the cushion, can be added to this body measure to estimate the overall seated height of the client from the floor to top of head.
- This is a vertical linear measurement that does not follow the body segment angle in any plane, however it is *affected* by body posture and orientation in both the sagittal and frontal planes. If the person sits with an open trunk to thigh angle, this dimension will be less than if they were to sit with a more upright trunk. If the person has adjustable components on their wheelchair such as adjustable tilt or recline, this measure should be taken with the person in the most upright position, with any baseline sagittal angles noted.

2.8 Shoulder width

Purpose:

To document the maximum width of the shoulders in the sitting position

Clinical relevance:

This measure may be used to help specify the width of the back support surface or other wheelchair frame parameters.



Fig. 4.11: Shoulder width

SHOULDER WIDTH

Type of Measure: Body Linear

Description: The maximum width of the upper body between the outside borders of the upper arms.

Landmarks (end points) used:

- Right and left outer border of the upper arms with arms at side, at the widest aspect

Definition: Maximum horizontal distance between the outer borders of the upper arms, with the arms at the sides, measured parallel to the seat Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Using a caliper, measuring stick or tape measure, measure the distance between the outside borders of the upper arms, staying parallel to the seat Z-axis in both the frontal (front) and transverse (top) views.

Considerations:

- If one shoulder is lower than the other, you may need to hold a flat vertical surface against the outside border of the lower arm in order to project this endpoint upwards, to ensure that the linear measure is taken parallel to the seat Z-axis.
- If the upper torso is rotated significantly in the transverse plane, remember to take the measurement parallel to the seat Z-axis in the transverse view as well - do not stay parallel to the body in this plane.

2.9 Chest width

Purpose:

To document the width of the widest part of the upper trunk

Clinical relevance:

This measure can be used to help specify the width and/or shape of the back support, and/or the distance between lateral trunk supports.



Fig. 4.12: Chest width

CHEST WIDTH

Type of Measurement: Body Linear

Description: The maximum width of the chest.

Landmarks/Endpoints:

- Left and right lateral surfaces of upper torso
- Midpoint between upper and lower sternal notch

Definition: The maximum width of the upper trunk measured at the midpoint between the upper and lower sternal notches, measured perpendicular to the sternum.

Sample procedure:

1. Support person in desired seated posture.
2. Using a measuring stick, calipers or tape measure, measure the width of the chest (including soft tissue) at the level of the midpoint of the sternum. Stay perpendicular to the upper trunk segment (as represented by the frontal sternal line) if it deviates in the frontal or transverse planes.

Considerations:

- This measure as defined reflects the actual width of the upper trunk segment. Therefore, if the person has a fixed upper trunk lean to the left or right (a deviation in the frontal plane), the actual chest width is measured perpendicular to the frontal sternum line, “following” the deviation in the frontal plane. If you choose to take the measure parallel to the wheelchair Z-axis (i.e. in line with the horizontal), without following the deviation in the frontal plane, add the word “effective” to the measure. This will make it clear that the dimension does not reflect the actual width of the chest, but the effective width because the upper trunk is angled in the frontal plane. In this situation, both of these measures –actual and effective chest width – may be clinically useful.

- Similarly, if there is significant rotation of the upper trunk in the desired seated position, you may wish to take both an *actual chest width* measurement – “following” the trunk in the transverse plane – as well as an *effective chest width* measurement where you maintain the tape measure parallel to the seat Z-axis and do not follow the rotation of the trunk. This effective chest width may be less than the actual chest width, but both may be clinically relevant.
- If the widest point of the trunk is at a level above or below the midpoint of the sternum, then take the measurement at the widest point, and indicate where on the trunk this was taken.
- If this dimension is smaller than waist width, then waist width may be more relevant to selection of wheelchair or back support width.

2.10 Hip width

Purpose:

To document the width of the buttocks, or pelvic segment, at the level of the greater trochanters when seated in the desired sitting posture

Clinical relevance:

This measure can be used to help specify the width of the seat support and/or wheelchair frame in the area of the hips, as well as the distance between lateral pelvic or thigh supports.



Fig. 4.13: Hip width

HIP WIDTH

Type of Measurement: Body Linear

Description: The width of the hips including soft tissue, at the level of the greater trochanters.

Landmarks (end points) used:

- Left and right greater trochanters (most lateral aspect)

Definition: The distance between the outside of the hips, including non-compressed soft tissue, measured at the level of the greater trochanters and parallel to the line between the right and left ASIS's.

Sample procedure:

1. Support person in desired seated posture.
2. Using a measuring stick, calipers or tape measure, measure the distance between the right and left greater trochanters, without compressing into the soft tissue.
3. Hold the tape measure or calipers parallel to the pelvis in both the frontal and transverse planes for actual hip width.

Considerations:

- This body measure can be used to help determine the width of the wheelchair seat frame or the space needed between the lateral components of the arm supports or any other wheelchair attachments (e.g. clothing guards, lateral pelvic supports, etc.)
- If a person has a significant deviation of the pelvis in the frontal and/or transverse planes when in the desired seated position, it may be more useful to maintain the tape measure parallel to the seat and back support (in front and top view), and not parallel to the line between the right and left ASIS's. In this case, call the measure "effective hip width". Effective hip width may be less than the actual hip width in the case of significant postural deviations in these planes, especially significant pelvic rotation.

2.11 External knee width

Purpose:

To document the distance between the outside of the knees when seated in the desired sitting posture

Clinical relevance:

This measure can be used to help specify the desired width of the seat cushion and other wheelchair parameters.

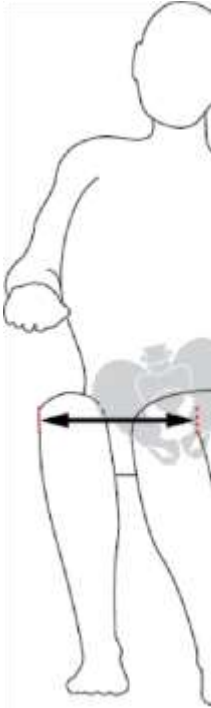


Fig. 4.14: External knee width

EXTERNAL KNEE WIDTH

Type of Measurement: Body Linear

Description: The distance between the outside of the knees when person is sitting in desired posture.

Landmarks (end points) used:

- Lateral femoral condyles of both knees

Definition: Horizontal distance between the lateral surfaces of the knees measured at the lateral femoral condyles and parallel to the seat Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Place firm flat vertical surfaces lateral to the knees on both sides, contacting the lateral femoral condyles.
3. Measure the distance between these two surfaces, staying parallel to the seat Z-axis in both the frontal and transverse views.

Considerations:

- This measure can be used to help specify the width of the cushion support and/or the wheelchair frame, and to ensure clearance with other wheelchair components such as the lower leg support assembly, the front of the arm support structure, or lateral thigh/knee support surfaces.
- This body measure may also help determine placement of lateral knee or thigh supports.
- In the case of a windswept posture, additional measures will be needed in order to effectively specify seat and wheelchair width (e.g. Maximum lower body width).
- If one knee is farther forward than the other, you may need to project a surface forward from the lateral surface of the knee which is more posterior, in order to assist in keeping the measuring device parallel to the seat Z-axis.

3 Level II Measures

3.1 Trunk depth

Purpose:

To document the depth of the trunk

Clinical relevance:

This measure may assist in specifying the depth of lateral trunk supports or back support contour depth.

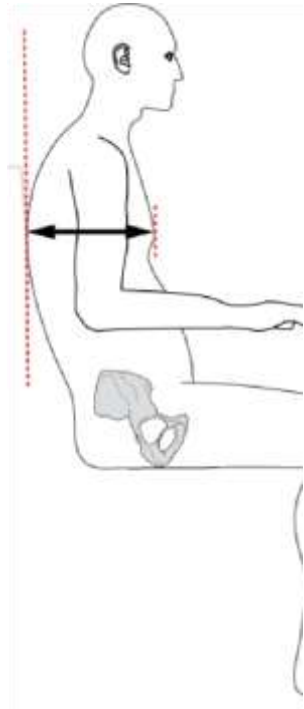


Fig. 4.15: Trunk depth

TRUNK DEPTH

Type of Measurement: Body Linear

Description: The depth, or thickness of the trunk.

Landmarks (end points) used:

- The most posterior point of the thorax
- The most anterior point of the trunk

Definition: The maximum depth of the torso from the most posterior point of the thorax to the most anterior point of the trunk measured perpendicular to the sternum.

Sample procedure:

1. Support the person in the desired seated posture, with a firm surface behind the trunk simulating the back support. This surface will simulate the location of the most posterior point of the thorax.
2. Place a firm flat surface along the front of the trunk, at about the level of the sternum. This surface will simulate the location of the most anterior point of the trunk, and allow you to project this endpoint laterally.
3. Measure the distance between these flat surfaces as this will represent the linear distance from the most posterior aspect of the trunk to the most anterior point of the trunk. Hold the tape measure perpendicular to the sternum, and not horizontal if the trunk is reclined.

Considerations:

- While this measure can be used to help specify the depth of lateral trunk supports, it is important to observe the shape of the person's trunk to ensure that the lateral trunk support will provide adequate contact without being too long. Depending on the shape of the person's trunk, the desired lateral trunk support depth may be less than this body dimension.
- This measure may also be used to help determine the desired lateral contour depth in the case of an off the shelf, pre-contoured back support.
- This measure can also be used to help determine the depth of the cutout in a lap tray.

3.2 Occiput depth

Purpose:

To document the location of the back of the head with respect to the trunk in the sagittal plane

Clinical relevance:

This measure may be used to help determine the size, shape and placement of the head support and its location relative to the plane of the back support.

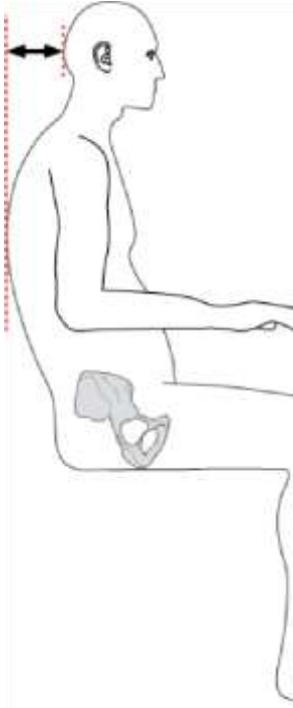


Fig. 4.16: Occiput depth

OCCIPUT DEPTH

Type of Measurement: Body Linear

Description: The horizontal distance between the back of the head and the back of the trunk in the sitting position.

Landmarks (end points) used:

- The most posterior point of the thorax
- The occipital protuberance

Definition: The maximum distance from the most posterior point of the thorax to the occipital protuberance on posterior surface of head, when seated in the desired posture, measured perpendicular to the sagittal upper trunk line.

Sample procedure:

1. Support person in desired seated posture.
2. Using two flat surfaces as reference planes, measure the distance between the most posterior aspect of the trunk to the most posterior aspect of the head in the sagittal plane. A simulated back support surface can be used as the reference plane for the most posterior aspect of the trunk, and a simulated posterior head support surface can be used as the reference plane for the most posterior aspect of the head.
3. Hold the tape measure perpendicular to the simulated back support reference plane, which should be approximately perpendicular to the sagittal upper trunk line.
4. In order to differentiate an occipital position forward of the trunk from a position behind the trunk, the linear measure needs to be noted as positive or negative. When the back of the head is anterior to the back of the trunk the value is positive. When the back of the head is posterior to the back of the trunk, the value is negative.

Considerations:

- This measure is basically describing how far back or forward the posterior surface of the head is relative to the posterior surface of the trunk, when the person is in the desired seated posture and neck

alignment. This can assist in determining the desired location of the head support relative to the back support in the side view.

- For example, if the client has a large protruding occiput, the head support may need to be placed well posterior of the plane of the back support in order to achieve optimal neck alignment. This measure can help to determine this placement.
- Alternatively, if the client has a fixed kyphotic posture, the posterior surface of the head may be somewhat forward of the plane of the back support, and this measure could help to determine the placement and mounting needs for the head support.
- This measurement can therefore be critical in ensuring the proper selection of head support features, as well as the hardware necessary to achieve the proper placement of the head support in the sagittal plane.

3.3 Lumbar curve depth

Purpose:

To document the depth of the lumbar curve or the location of the lumbar surface of the trunk relative to the back of the buttocks in the seated position

Clinical relevance:

This measure can assist with matching the shape or location of the back support surfaces to the shape of the client.

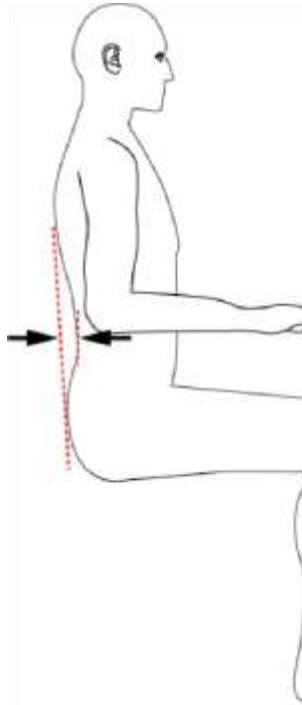


Fig. 4.17: Lumbar curve depth

LUMBAR CURVE DEPTH

Type of Measurement: Body Linear

Description: The depth of the lumbar curve in the seated position relative to the most posterior aspect of the buttocks.

Landmarks (end points) used:

- The most posterior aspect of the buttocks
- The deepest part of the lumbar curve

Definition: Linear distance from the most posterior point of the buttocks to the spinous process of the most anterior point of the lumbar spine measured perpendicular to the sagittal trunk line.

Sample procedure:

1. Support person in desired seated posture.
2. Using two flat surfaces as reference points, measure the distance between the most posterior aspect of the buttocks to the deepest point of the lumbar curve.
3. A simulated back support surface can be used as the reference point for the back of the buttocks, and then you can then place a pencil or other thin straight object at the most anterior point of the lumbar spine and project this endpoint laterally. Measure the distance between the back support surface and this endpoint, perpendicular to the sagittal trunk line.

Considerations:

- This measure can also help specify the forward location of a back support surface in the case of a client with a large protruding buttock.
- **Pelvic rotation:** If the client's desired seated posture is with pelvic rotation, such as in the case of a fixed rotational scoliosis, one side of the buttock will be more posterior than the other. Take the measurement from the most posterior side of the buttocks, in order to capture the greatest depth, and note the rotation.

- In the case of a severe fixed posterior pelvic tilt and kyphotic sitting posture, this measurement cannot be taken because there is no lumbar curve. In this case a more appropriate measurement to take would be the thoracic curve depth.

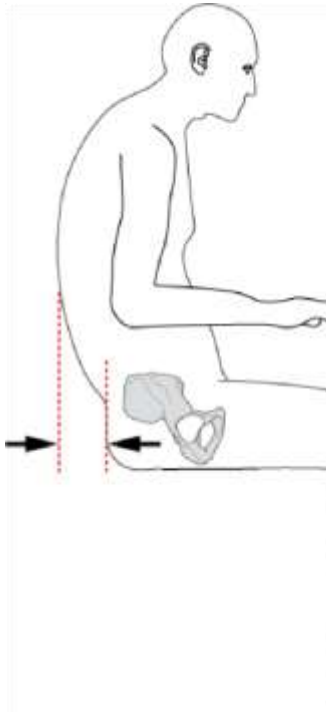
3.4 Thoracic curve depth

Purpose:

To document the depth of the thoracic curve or the location of the back of the trunk relative to the back of the buttocks in the desired sitting position

Clinical relevance:

This measure can assist in specifying the shape and/or location of a back support or custom posterior trunk support surface.



THORACIC CURVE DEPTH

Type of Measurement: Body Linear

Description: The depth of the thoracic curve in the seated position relative to the most posterior aspect of the buttocks.

Landmarks (end points) used:

- The most posterior aspect of the buttocks
- The most posterior aspect of the upper trunk

Definition: Linear distance from the most posterior point of the buttocks to the most posterior point of the thorax measured perpendicular to the sagittal upper trunk line.

Fig. 4.18: Thoracic curve depth

Sample procedure:

1. Support person in desired seated posture.
2. Using two flat surfaces as reference points, measure the distance between the most posterior aspect of the buttocks to the most posterior part of the trunk.
3. If the trunk is reclined (e.g. thigh to trunk angle of greater than 90 degrees) the flat surfaces behind the thorax and the buttocks should be held parallel to the sagittal upper trunk line for ease in measurement. Measure the distance between the two surfaces, perpendicular to the sagittal upper trunk line.

Considerations:

- This measure can help specify the shape or rearward location of a back support surface in relation to the back of the buttocks. This can be especially useful when planning for a custom contoured back support, when sufficient depth of the surface is required to accommodate a large thoracic kyphosis or rib hump.
- **Pelvic rotation:** If the client's desired seated posture is with pelvic rotation, such as in the case of a fixed rotational scoliosis, one side of the buttock will be more posterior than the other. Take the

measurement from the most anterior side of the buttocks, in order to capture the greatest depth, and note the rotation.

3.5 Ischial depth

Purpose:

To document the distance from the back of the buttocks to the ischial tuberosities (ITs) in the sitting position

Clinical relevance:

This measure can assist in specifying the shape and size of a seat surface, and provide insight into how a particular seat shape matches the user's anatomy. This measure is clinically relevant because changes in the sagittal orientation of the pelvis will be reflected in this dimension, and deviations of the pelvis in this plane can have a significant effect on the seated user's posture, health and function.

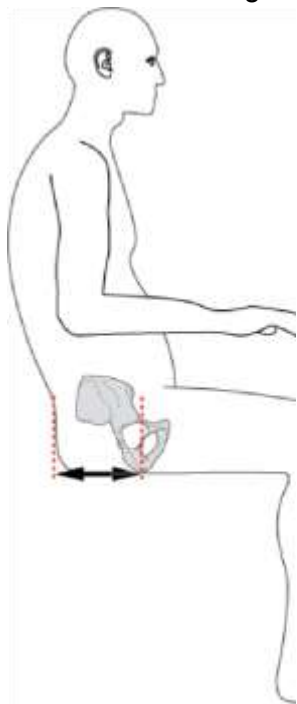


Fig. 4.19: Ischial depth

ISCHIAL DEPTH

Type of Measurement: Body Linear, right and left

Description: Distance from the back of the buttocks to the ischial tuberosities in the desired sitting posture.

Landmarks (end points) used:

- The most posterior aspect of the buttocks
- The most anterior point of the ischium, right and left

Definition: Horizontal distance from the most posterior point of the buttocks to the most anterior point of the ischium measured perpendicular to the seat Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Place a firm flat surface behind the buttocks to represent the most posterior point of the buttocks.
3. Place your hand under the buttocks and locate the anterior part of the IT by palpation with your index finger. Carefully slide your hand out to the side, and measure the distance from the surface behind the buttocks to your finger.
4. Hold the tape measure parallel to the sitting surface in the side view, but stay perpendicular to the seat Z-axis (top view) even if the pelvis is rotated.

Considerations:

- As the pelvis posteriorly tilts, the ITs will tend to migrate farther forward and this dimension will increase. As the pelvis anteriorly tilts, the ITs will tend to move rearward and this dimension will decrease.

- This dimension is difficult to measure because of the challenge in accurately locating the ischial tuberosity in the sitting position.
- The location of the ITs in relation to the most posterior aspect of the buttocks may be a significant consideration when specifying the dimensions and shape of a seat support surface, especially when a client has excessive redundant gluteal tissue that needs to be accommodated.
- If the pelvis is rotated in the transverse plane, or if there is asymmetry of gluteal tissue, the ischial depth may differ between right and left sides.
- Since this measure will be affected by the orientation of the pelvis in the sagittal plane, it could be used to document a change in posture if taken in sitting before and after seating intervention; however the difficulty of locating the IT.s will affect the accuracy of this measurement.

3.6 Foot depth

Purpose:

To document the depth of the foot for proper specification of foot support size

Clinical relevance:

This measure may assist in the selection of the size and style of foot supports.



Fig. 4.20: Foot depth

FOOT DEPTH

Type of Measurement: Body Linear, left and right sides

Description: The depth of the foot without a shoe.

Landmarks (end points) used:

- Rear most point of the heel
- Tip of the longest toe

Definition: Maximum distance from rear of the heel to tip of the longest toe; measured parallel to the foot.

Sample procedure:

1. Support person in desired seated posture.
2. Place a firm flat surface behind the most posterior point of the heel. Measure the distance from this surface to the tip of longest toe, holding the tape measure parallel to the foot in both the sagittal (side) and transverse (top) views. Repeat for both sides.

Considerations:

- This measure can be used to help specify the foot support depth.
- As defined, this measure is taken without footwear. If the measure is taken with footwear on, this should be called “effective foot depth”, with a note indicating that the dimension includes footwear.
- Allowance may need to be made for foot depth discrepancies between the right and left foot.
- The term foot depth as defined refers to the actual dimension of the foot. Much like a windswept thigh, a foot which deviates in the transverse plane requires less foot support depth to be supported compared to a foot which is not rotated inward or outward, even though the actual depth of the person’s foot has not changed. Therefore, when the desired resting position of the foot is not neutral in the transverse plane (i.e., rotated outward or inward), you may wish to take an *effective foot depth* measurement to help specify the depth of a footplate which will be oriented in a standard forward facing configuration. In this case, you would measure the linear distance from the back of the heel to the tip of the toe staying parallel

to the wheelchair X-axis, and not staying parallel to the transverse foot line. To do this you will need to project a line laterally from the tip of the toe to the tape measure in order to stay in line with the wheelchair axis. An effective foot depth dimension will be less than the actual foot depth dimension.

- Conversely, if you are intending to rotate a foot support in the transverse plane to accommodate and match a preferred foot posture of inward or outward rotation, the actual foot depth dimension will be more useful for specifying foot support depth.

3.7 Forearm depth

Purpose:

To document the overall length of the forearm in the sitting position

Clinical relevance:

This measure may be used to help specify the arm support depth.

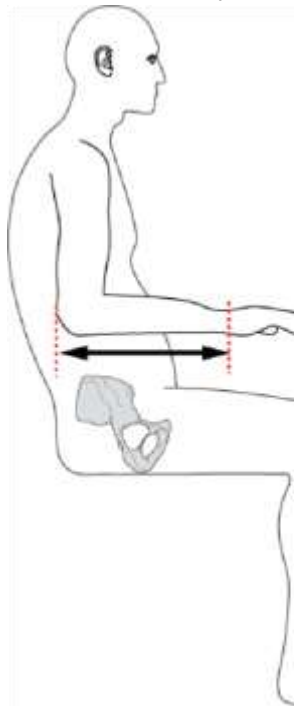


Fig. 4.21: Forearm depth

FOREARM DEPTH

Type of Measurement: Body Linear, right and left

Description: The length of the forearm from behind the elbow to the styloid process of the wrist.

Landmarks (end points) used:

- The most posterior portion of the elbow
- Styloid process of the wrist

Definition: The maximum distance from the most posterior point of the elbow to the styloid process of the wrist, measured parallel to the forearm segment.

Sample procedure:

1. Support the arm in the desired resting posture.
2. Measure the distance from behind the elbow to the styloid process of the wrist, holding the tape measure parallel to the forearm in both the sagittal (side) and transverse (top) views. Repeat for both sides.

Considerations:

- This measure can assist with selection of appropriate style and depth of a wheelchair arm support pad or arm support trough.
- The term *forearm depth* as defined refers to the actual depth of the forearm. Much like a windswept thigh, a forearm which deviates in the transverse plane requires less arm support depth to be supported compared to a forearm which is not rotated inward or outward, even though the actual depth of the person's forearm has not changed.
- Therefore, when the desired resting position of the forearm is not neutral in the transverse plane (e.g. rotated outward or inward), you may wish to take an *effective forearm depth* measurement to help specify the depth of an arm support which will be oriented in a standard forward facing configuration. In this case, you would measure the linear distance from the back of the elbow to the styloid process of the wrist

staying parallel to the wheelchair X-axis, and not staying parallel to the transverse forearm in the top view. To do this you will need to project a line laterally from the wrist to the tape measure in order to stay in line with the wheelchair axes. An effective forearm depth dimension will be less than the actual forearm depth dimension when the forearm is rotated in the transverse plane.

- Conversely, if you are intending to rotate an arm support in the transverse plane to accommodate and match a preferred forearm posture of inward or outward rotation, the actual forearm depth dimension will be more useful for specifying arm support depth.
- The standard does not include a definition for “hand depth”; therefore we have not included a hand depth measure in this version of the guide. However, if an arm support needs to be prescribed to support both the forearm and the hand, measure from the elbow to the tip of the fingers, and document this as forearm + hand depth.

3.8 Maximum sitting depth

Purpose:

To document the maximum linear depth that the person's body occupies in their seated position

Clinical relevance:

This dimension can be useful in specifying wheelchair frame parameters needed to accommodate an unusually long sitting depth.

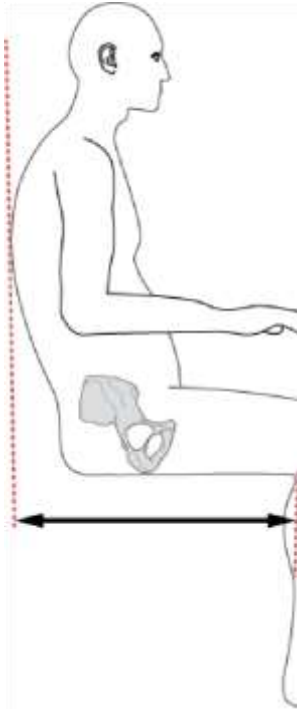


Fig. 4.22: Maximum sitting depth

MAXIMUM SITTING DEPTH

Type of Measurement: Body Linear

Description: The distance from the most posterior aspect of the trunk to behind the knees.

Landmarks (end points) used:

- The most posterior aspect of the upper body/trunk
- The most distal popliteal fossa

Definition: Maximum horizontal distance from the most posterior aspect of the trunk to the most forward popliteal fossa, measured parallel to the wheelchair X-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Place a flat vertical surface behind the most posterior point on the person's upper body (usually the most posterior aspect of the trunk).
3. Measure the horizontal distance from this surface to the most distal popliteal fossa. Keep the tape measure parallel to the ground.

Considerations:

- The intent of this measure is to capture the maximum depth of the person's body, minus the head and lower legs/feet, as this may help plan for accommodation of this depth within the wheelchair frame.
- For example, if the person has a large fixed kyphosis or rib hump, additional room for a more posterior placement of the back support may be required, affecting wheelchair parameters such as seat frame depth or the adjustability of back canes.

3.9 Thigh height

Purpose:

To document the distance from the seat support surface to the top of the thigh in the sitting position

Clinical relevance:

This measure is used to help determine the vertical space occupied by the thighs from the seat surface. This dimension may be useful for specifying a variety of seating or wheelchair frame parameters related to thigh clearance.

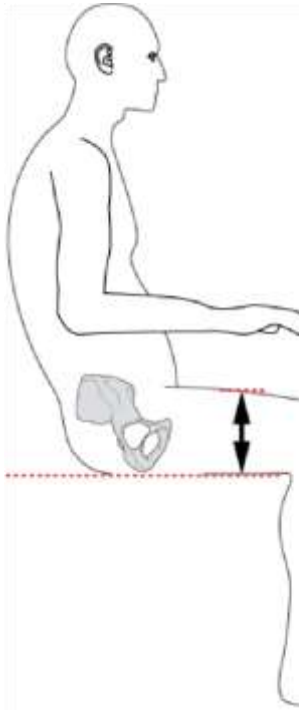


Fig. 4.23: Thigh height

THIGH HEIGHT

Type of Measurement: Body linear, left and right

Description: The distance from the top of the seat support surface to the top of the thigh, left and right

Landmarks (end points) used:

- Loaded, contact surface side of seat under thighs
- Highest point on superior surface of thigh, right and left sides

Definition: The vertical distance from the loaded contact surface side of the seat to the highest point on the thigh.

Sample procedure:

1. Support person in desired seated posture.
2. Measure the vertical distance from the top of the sitting surface to the top of each thigh at the highest point along the thigh, measured perpendicular to the seat reference plane.

Considerations:

- This measure may provide important information relevant to positioning of any superior thigh support pads or straps, or to the clearance needed under a tray.
- The seat pan to floor height of the wheelchair plus the loaded thickness of the cushion can be added to this body measure to estimate the overall vertical distance from the floor to top of thighs. This can then be used to determine clearance needed under desks or tables.

3.10 PSIS height

Purpose:

To document the height of the PSIS from the seat surface when seated in the desired sitting posture

Clinical relevance:

This measure can be used to help specify the height or shape of the lower most component of the back support, or any surface intended to contact the posterior pelvis.

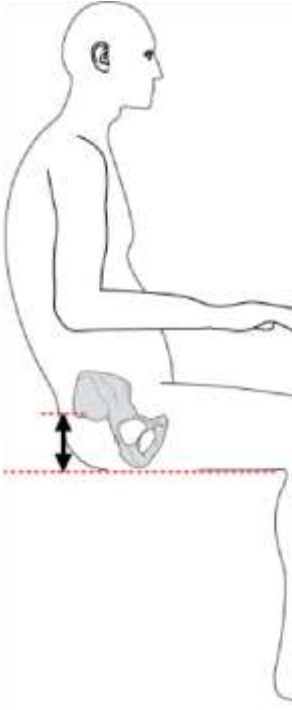


Fig. 4.24: PSIS height

PSIS HEIGHT

Type of Measurement: Body Linear, left and right sides

Description: The distance from the sitting surface up to the PSIS.

Landmarks (end points) used:

- Loaded, contact surface side of the seat under the buttocks
- Left and right PSIS

Definition: The vertical distance from the loaded sitting surface under buttocks to the PSIS measured perpendicular to the seat Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Measure the distance from the top contact surface of the loaded seat to the PSIS on the left and right sides. Hold the tape measure perpendicular to the seat in the front view, even if the pelvis is angled in the frontal plane.

Considerations:

- This measure can be used to help specify the dimensions, shape and/or location of any surface intended to contact the posterior pelvis. For example, this measure can be used to specify the length and/or height of the lower most posterior back support component, for example the lower section of a bi-angular back support.
- Additionally, this measure is clinically relevant because changes in the sagittal orientation of the pelvis will be reflected in this dimension. Therefore, it can be used as an indication of postural change.

3.11 Occiput height

Purpose:

To document the height of the head (lowest point of occiput) above the seat surface when seated in the desired posture

Clinical relevance:

This measure can be used to help specify the vertical location of the head support.

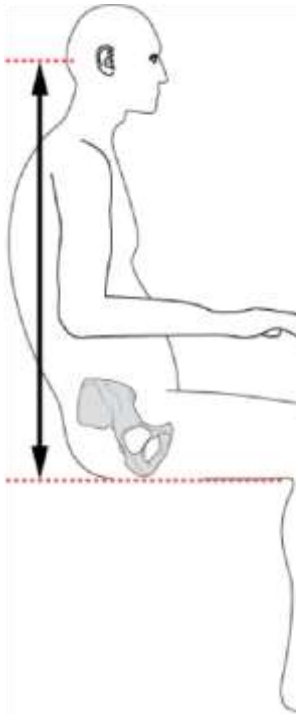


Fig. 4.25: Occiput height

OCCIPUT HEIGHT

Type of Measurement: Body Linear

Description: The distance from the top of the sitting surface to the occiput of the head.

Landmarks (end points) used:

- Loaded, contact surface side of seat under buttocks
- Lowest point of the occipital protuberance

Definition: Linear distance from the loaded contact surface side of the seat to the lowest point of the occipital protuberance, measured parallel to the sagittal upper trunk line and perpendicular to the seat Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Support the head as needed in the desired position.
3. Measure the distance from the top of the loaded seating surface to the lowest point on the client's occiput. Hold the tape measure parallel to the sagittal upper trunk line (side view) and perpendicular to the seat in the front view.

Considerations:

- This measure can help specify the vertical location of the head support relative to the seat surface.
- This is not a vertical measure taken perpendicular to the ground if the person's trunk is angled in the sagittal plane. This measure is taken parallel to the sagittal upper trunk line because it is assumed that if the person's upper trunk is reclined, the supporting back support and head support will also be reclined to match the person's sagittal upper trunk and head angles. This allows accurate translation of this body measure into the corresponding measure of head support height.

3.12 Occiput to C7

Purpose:

To document the height of the head above the C7 spinous process when seated in the desired sitting posture

Clinical relevance:

This measure can be used to help specify the distance between the upper most portion of the back support and the lower most portion of the head support.



Fig. 4.26: Occiput to C7

OCCIPUT TO C7

Type of Measurement: Body Linear

Description: The vertical distance from the occiput to the C7 vertebra.

Landmarks (end points) used:

- C7 spinous process
- Occipital protuberance (most posterior aspect of the occiput)

Definition: The linear distance between the occipital protuberance and C7 vertebra, measured parallel to the sagittal upper trunk line and perpendicular to the wheelchair Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Measure the distance from the spinous process of C7 to the most posterior aspect of the occipital protuberance of the skull, holding the tape measure parallel to the sagittal upper trunk line and perpendicular to the wheelchair Z-axis.

Considerations:

- This body measure may help specify the relative locations of the upper most portion of the back support surface and the lower most portion of the head support.
- This is not a vertical measure taken perpendicular to the ground if the person's trunk is angled in the sagittal plane. This measure is taken parallel to the sagittal upper trunk line because it is assumed that if the person's upper trunk is reclined, the supporting back support and head support will also be reclined to match the person's sagittal upper trunk and head angles. This allows accurate translation of this body measure into the corresponding measures of head support height above the back support.

3.13 Sternal length

Purpose:

To document the length of the sternum

Clinical relevance:

This measure may assist in the selection and specification of anterior trunk supports such as a chest or shoulder harness.



Fig. 4.27: Sternal length

STERNAL LENGTH

Type of Measurement: Body Linear

Description: The length of the sternum.

Landmarks (end points) used:

- ☐ The lower sternal notch
- ☐ The upper sternal notch

Definition: The distance from the lower sternal notch to the upper sternal notch, measured parallel to the sternum (frontal sternal line).

Sample procedure:

1. Measure the distance from the lower sternal notch to the upper sternal notch, along and parallel to the sternum.

Considerations:

- This measure may assist in the size selection of anterior supports such as a shoulder or chest harness.
- This measure represents the actual length of the sternum, therefore measure parallel to the sternum even if it deviates in the frontal plane.
- If the sternum deviates significantly in the frontal plane, it may be more clinically relevant to take an effective sternal length. In this case, stay perpendicular to the seat in the front view instead of following the frontal sternal line.

3.14 Head width

Purpose:

To document the overall width of the head

Clinical relevance:

This measure may be used to help specify the size and shape of the head support.



Fig. 4.28: Head width

HEAD WIDTH

Type of Measurement: Body Linear

Description: The width of the head above the level of the ears.

Landmarks (endpoints) used:

- Left side of head just superior to the ear
- Right side of head just superior to the ear

Definition: The maximum width of head above the ears, measured parallel to the frontal and transverse head lines.

Sample procedure:

1. Support person in desired seated posture.
2. Measure the distance between the left and right sides of the head, at the level just superior to the ears.
3. This measure is easiest to take using calipers. Alternatively, hold a firm flat surface on either side of the head and measure the distance between them.
4. Hold the tape measure or caliper so that it is in line with the frontal angle of the head (parallel to the frontal head line), and in line with the transverse angle of the head (parallel to the transverse head line) if the head is not in neutral.

Considerations:

- The width of the head is an important consideration when specifying the size and shape of a head support, especially if the head support includes lateral support surfaces or contour.
- To take an effective head width measure, stay parallel to the wheelchair Z-axis instead of following the deviation of the head in the frontal or transverse planes.

3.15 Waist width

Purpose:

To document the width of the upper body at the level of the waist

Clinical relevance:

This measure may be used to help specify the shape and/or width of the back support, or placement of lateral trunk support surfaces.

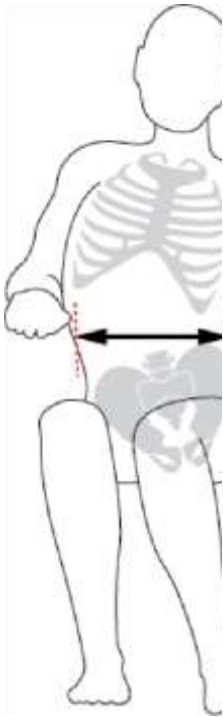


Fig. 4.29: Waist width

WAIST WIDTH

Type of Measurement: Body Linear

Description: The width of the body at the waist.

Landmarks (end points) used:

- The left side of the trunk at the level of the umbilicus
- The right side of the trunk at the level of the umbilicus

Definition: The maximum horizontal width of the waist measured at the level of the umbilicus.

Sample procedure:

1. Support person in desired seated posture.
2. Using a caliper or rigid measuring tape or stick, measure the width of the waist at the level of the umbilicus, staying parallel with the horizontal.

Considerations:

- If this dimension is smaller than chest width, then chest width may be more relevant to selection of back support width.

3.16 External thigh width

Purpose:

To document the maximum width of the lower body along the thighs when seated in the desired posture

Clinical relevance:

This measure, along with other body width measures, is used to help specify the width of the seat support and other wheelchair parameters.

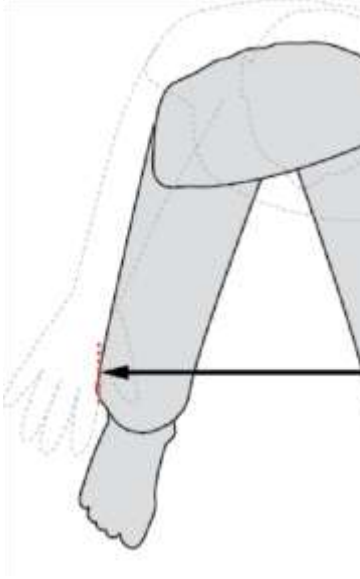


Fig. 4.30: External thigh width

EXTERNAL THIGH WIDTH

Type of Measurement: Body Linear

Description: The distance between the outside of the thighs at their widest point, when seated in desired posture.

Landmarks (endpoints) used:

- Widest point along external surface of each thigh

Definition: Maximum horizontal width of the lower body measured at the widest point along the thighs.

Sample procedure:

1. Support person in desired seated posture.
2. Place a firm, flat surface on either side of the widest part of the thigh, or use a firm tape measure or calipers. Do not compress the soft tissue. Measure the horizontal distance between these flat surfaces or the outside of the thighs.
3. This measurement should be taken parallel to the simulated Z-axis of the seat.

Considerations:

- A practitioner may want to document external thigh width in addition to hip width when the widest part of the lower body is not at the hips.
- This measure may be used to help specify the final seat width or placement of lateral pelvic, thigh or knee supports.

3.17 Knee width

Purpose:

To document the width of each knee

Clinical relevance:

This measure may be used to help specify the parameters of medial and lateral thigh supports, anterior knee blocks or distal seat surface contours.

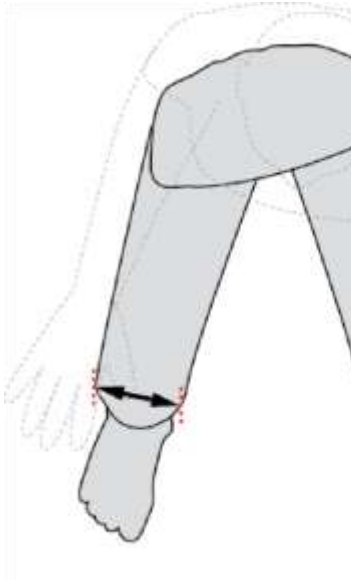


Fig. 4.31: Knee width

KNEE WIDTH

Type of Measurement: Linear, left and right

Description: Width of each knee across the femoral condyles.

Landmarks (end points) used:

- Medial femoral condyle
- Lateral femoral condyle

Definition: Maximum width of the knee measured at the level of the femoral condyles, perpendicular to the transverse thigh line.

Sample procedure:

1. Support person in desired seated posture.
2. Using a caliper or rigid measuring tape or stick, measure the distance across each knee from the lateral to the medial femoral condyles.

Considerations:

- This measure may assist with the selection and specification of lateral and medial knee supports relative to the available width of the wheelchair.
- Some anterior knee supports (commonly referred to as “knee blocks”) contour around the knee anteriorly, and this measure is needed to specify size or width of these supports.
- This measure may also influence the choice of seat surface shape relative to the width of the distal seat contours or “leg troughs”.
- If the thighs are angled in the transverse plane, such as may occur with a fixed windswept posture, this dimension should be taken perpendicular to the transverse thigh line to reflect the actual knee width. If you wish to take an “effective knee width” in this situation, stay parallel to the seat Z-axis instead.

3.18 External foot width

Purpose:

To document the widest distance between the outside borders of the feet when seated in the desired sitting posture

Clinical relevance:

This measure may be used to help specify the size and lateral placement of individual foot supports, as well as other wheelchair frame parameters.



Fig. 4.32: External foot width

EXTERNAL FOOT WIDTH

Type of Measurement: Body Linear

Description: The distance between the outside borders of the feet when seated in desired posture.

Landmarks (end points) used:

- Most anterior lateral point of each forefoot

Definition: Horizontal distance between the outer borders of the left and right feet, measured at most anterior-lateral point on forefoot.

Sample procedure:

1. Support person in desired seated posture, simulating desired lower extremity alignment and foot placement.
2. Using a metal tape measure or caliper, measure the distance between the lateral borders of the feet, at the most forward, lateral point of the forefoot.
3. This measurement should be taken parallel to the simulated Z-axis of the wheelchair. In cases where one foot is forward of the other, it may be helpful to place a firm flat surface against the outside border of each forefoot, projecting the surface forward so that the measurement can be taken in proper alignment with the axes.

Considerations:

- In addition to the specification of foot support width, this measure can be used to help specify the lateral placement of foot supports or to identify other features and components needed to support or align the lower legs and feet.
- This measurement can also help specify the overall width of the wheelchair frame and/or lower leg support assembly, to ensure there is enough room for optimal foot placement.

3.19 Internal knee width

Purpose:

To document the distance between the inside of the knees in the desired seated posture

Clinical relevance:

This measure can be used to help specify the dimensions and/or placement of medial knee support surfaces which may be prescribed to maintain separation of knees/thighs.

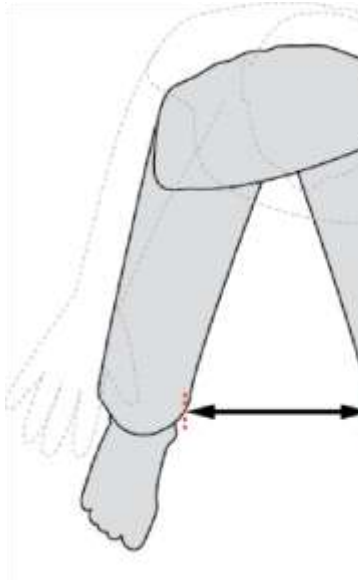


Fig. 4.33: Internal knee width

INTERNAL KNEE WIDTH

Type of Measurement: Body Linear

Description: The distance between the inside of the knees when person is sitting in desired posture.

Landmarks (end points used):

- Medial femoral condyles, right and left

Definition: Horizontal distance between the medial surfaces of the knees measured at the medial femoral condyles.

Sample procedure:

1. Support person in desired seated posture.
2. Measure the distance between the medial femoral condyles parallel to the simulated seat Z-axis.

Considerations:

- The most common use of this measurement is to specify the dimensions of a single medial knee support, sometimes referred to as a “pommel,” as well as the placement of individual medial knee supports.
- This measure can also impact the seat width, as well as other parameters affected by overall width requirements.

3.20 Internal foot width

Purpose:

To document the distance between the inside of the feet when seated in the desired sitting posture

Clinical relevance:

This measure can be used to help specify the dimensions and placement of the wheelchair foot supports or other components designed to maintain alignment of the lower legs and/or feet.



Fig. 4.34: Internal foot width

INTERNAL FOOT WIDTH

Type of Measurement: Body Linear

Description: The distance in between the feet when seated in desired posture.

Landmarks (end points) used:

- Most anterior-medial point on each forefoot

Definition: Horizontal distance between the inner borders of the left and right feet, measured at most anterior-medial point on forefoot.

Sample procedure:

1. Support person in desired seated posture, simulating desired lower extremity alignment and foot placement.
2. Using a metal tape measure or caliper, measure the distance between the inside borders of the feet, at the most forward, medial point of the forefoot. This is usually the most prominent point at the metatarsal head of big toe.
3. This measurement should be taken parallel to the simulated Z-axis of the wheelchair. In cases where one foot is forward of the other, it may be helpful to place a firm flat surface against the inside border of each forefoot, projecting the surface forward so that the measurement can be taken in proper alignment with the axes.

Considerations:

- This measure will impact the medial/lateral placement of foot supports or other components designed to align or protect the feet.
- It will also impact the overall width requirements of the front end of the wheelchair frame, as well as the style of the lower leg support assembly.

3.21 Occiput to centerline

Purpose:

To document the lateral location of the head in the frontal plane with respect to the centerline of the back support

Clinical relevance:

This measure may be used to help specify the lateral location of the head support in the frontal plane.



Fig. 4.35: Occiput to centerline

OCCIPUT TO CENTERLINE

Type of Measurement: Body Linear

Description: The lateral distance of the occiput from centerline when seated in desired posture.

Landmarks (end points) used:

- Most posterior aspect of occipital protuberance
- Back support vertical centerline

Definition: Horizontal distance from the occipital protuberance to the back support vertical centerline.

Sample procedure:

1. Support person in desired seated posture.
2. Locate the most posterior aspect of the occipital protuberance.
3. Locate the vertical centerline of the back support (or simulated back support), and project it upwards using a flat vertical surface.
4. Using a metal tape measure, measure the distance from the flat vertical surface representing centerline, to the occipital protuberance, keeping tape measure parallel to the seat Z-axis.
5. In order to differentiate an occipital position to the right or left of centerline, one can either use the terms “left” and “right”, or the linear dimension can be noted as positive or negative. When the back of the head is to the right of centerline, the value is positive. When the back of the head is to the left of centerline, the value is negative. When the back of the head is aligned with the centerline the value will be zero.

Considerations:

- This measure will reflect changes in the posture or position of the head in the frontal plane.
- For example, this measure can be used to describe a position of the head which is offset from centerline 2” to the left due to a fixed scoliosis. This objective measure can then be used to document changes in posture from seating intervention, or it can be used to specify the medial-lateral mounting location of the head support.

3.22 Medial knee to centerline

Purpose:

To document the location of the inside of the knee relative to the centerline of the seat in the sitting position

Clinical relevance:

This measure is used to help specify the location of support surfaces intended to contact the inside of the knees, especially when the thighs are not in standard symmetrical alignment.

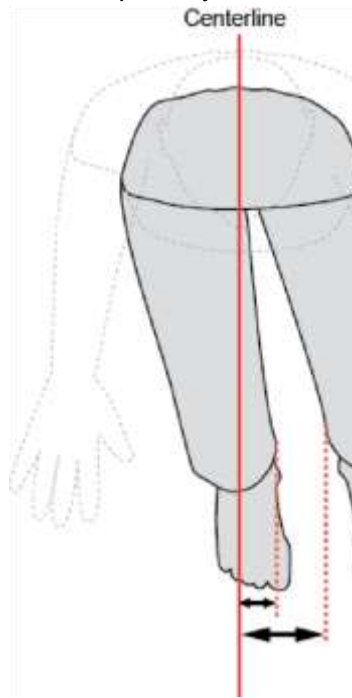


Fig. 4.36: Medial knee to centerline

MEDIAL KNEE TO CENTERLINE

Type of measurement: Body linear, right and left

Description: The distance from the inside of the knee to the centerline of the seat

Landmarks (end points) used:

- Medial femoral condyle
- Centerline of seat at front edge

Definition: Distance to the right or left from the centerline of the seat to the medial surface of the knee, measured at medial femoral condyle parallel to seat Zaxis.

Sample procedure:

1. Support person in desired seated posture.
2. Locate the centerline of the seat at front edge.
 - a. The centerline is a line parallel to the seat X-axis located at the midpoint of the seat. Mark the center point of the front edge of the seat with tape.
3. Using a metal tape measure, measure the distance from the centerline to the inside surface of the knee, holding the tape measure parallel to the seat Z-axis. Repeat for both knees if necessary.
4. In order to differentiate a knee position to the right or left of centerline, one can either use the terms “left” and “right”, or the linear dimension can be noted as positive or negative. When the inside of the knee is to the right of centerline, the value is positive. When the inside of the knee is to the left of centerline, the value is negative.

Considerations:

- This measure can be used to specify the location of a medial knee support surface relative to the centerline of the seat. This is especially useful if the person’s thighs are windswept, and a medial knee support surface is required which is not at midline.

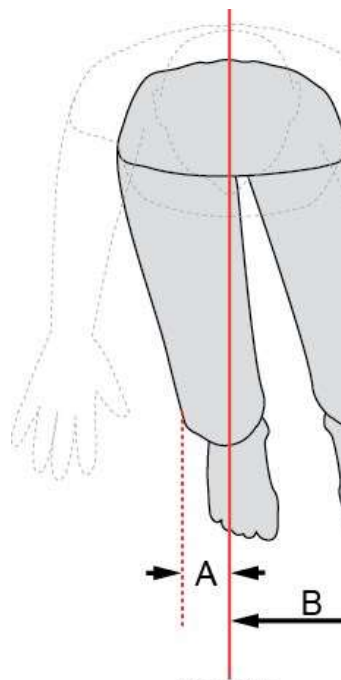
3.23 Lateral knee to centerline

Purpose:

To document the location of the outside of the knees relative to the centerline of the seat in the sitting position

Clinical relevance:

This measure is used to help specify the location of support surfaces intended to contact the outside of the knees, especially when the thighs are not in standard symmetrical alignment.



Centerline
A – Right Lateral Knee to C
B – Left Lateral Knee to C

Fig. 4.37: Lateral knee to centerline

LATERAL KNEE TO CENTERLINE

Type of measurement: Body linear, right and left

Description: The distance from the outside of the knee to the centerline of the seat

Landmarks (endpoints used):

- Lateral femoral condyle
- Centerline of seat at front edge

Definition: Distance to the right or left from the centerline of the seat to the lateral surface of the knee, measured at the lateral femoral condyle parallel to the seat Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Locate the centerline of the seat.
 - a. The centerline is a line parallel to the seat X-axis located at the midpoint of the seat. Mark the center point of the front edge of the seat with tape.
3. Using a metal tape measure, measure the distance from the centerline of the seat at front edge to the outside surface of the knee, holding the tape measure parallel to the seat Z-axis. Repeat for both knees if necessary.
4. In order to differentiate a knee position to the right or left of centerline, one can either use the terms “left” and “right”, or the linear dimension can be noted as positive or negative. When the outside of the knee is to the right of centerline, the value is positive. When the outside of the knee is to the left of centerline, the value is negative.

Considerations:

- This measure can be used to specify the lateral location of a lateral knee support surface relative to the centerline of the seat. This is especially useful if the person’s thighs are windswept.
- This measure can also help predict the location of the user’s knee relative to other wheelchair frame components or the distal contours of a seat cushion.

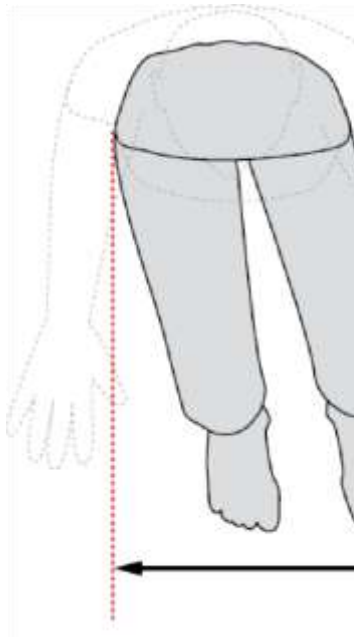
3.24 Maximum lower body width

Purpose:

To document the maximum width that the person’s lower body (buttock/thighs to feet) occupies in the sitting position.

Clinical relevance:

This measure is used to help specify the width of the seating system or the wheelchair frame when other simpler measures do not reflect overall width, usually due to asymmetry of the lower extremities.



MAXIMUM LOWER BODY WIDTH

Type of Measurement: Body Linear

Description: The maximum distance between the most lateral parts of the lower body.

Landmarks (endpoints used):

- The most lateral part of the lower body on the left side
- The most lateral part of the lower body on the right side

Definition: Maximum horizontal distance between the most lateral part of the lower body on the left and the most lateral part of the lower body on the right, measured parallel to the wheelchair Z-axis.

Fig. 4.38: Maximum lower body width

Sample procedure:

1. Support person in desired seated posture.
2. Place firm flat surfaces against the most lateral part of each side of the body (usually the hip on one side, and the knee or foot on the other side).
3. Measure the distance between these surfaces, holding tape measure parallel to the ground and Z-axis of the wheelchair.

Considerations:

- This measure is most commonly used when other width measures (such as hip width or external knee width) do not reflect the total width of the lower body, such as when the person is seated with windswept thighs.
- This measure can be used to help specify the overall width of the wheelchair and/or seat support, as well as the type and placement of foot supports.

3.25 Maximum sitting width

Purpose:

To document the maximum width that the person's entire body occupies in the sitting position

Clinical relevance:

This measure is used to help specify the width of the seating system or the wheelchair frame when other simpler measures do not reflect overall width.

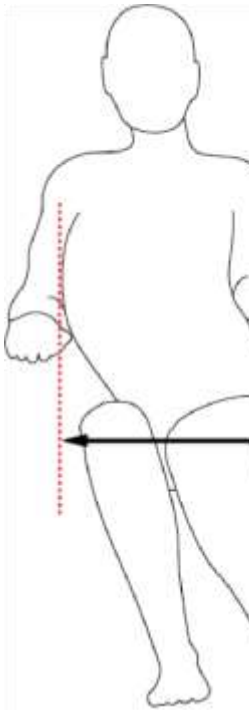


Fig. 4.39: Maximum sitting width

MAXIMUM SITTING WIDTH

Type of Measurement: Body Linear

Description: The distance between the most lateral parts of the upper and lower body.

Landmarks (endpoints used):

- The most lateral part of the upper body
- The most lateral part of the lower body

Definition: Maximum horizontal distance between the most lateral part of the upper body and the most lateral part of the lower body measured parallel to the wheelchair Z-axis.

Sample procedure:

1. Support person in desired seated posture.
2. Place firm flat surfaces against the most lateral part of the upper body (not including arms) and the most lateral part of the lower body (not including feet).
3. Measure the distance between these surfaces, holding tape measure parallel to the ground and Z-axis of the wheelchair.

Considerations:

- This measure is most commonly used when other width measures (such as hip width, external knee width or maximum lower body width) do not reflect the total width of the whole body, such as when the person is seated with windswept thighs **and** a lateral trunk lean or offset trunk due to a fixed scoliosis.

CHAPTER 5: LINEAR SUPPORT SURFACE MEASURES

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1 General Instructions

The measures in this section describe the linear size dimensions, as well as some common placement dimensions, of seating support surfaces intended to contact the body of the user. These dimensions are not the same as the linear dimensions of the wheelchair frame, but will affect the prescription of frame dimensions. In order to prescribe seating products and specify wheelchair frame parameters to allow integration of the two, it is always important to refer to the manufacturer's literature regarding frame and seating dimensions because manufacturers often measure and report their product differently.

As emphasized throughout this guide, the linear measures of seating support surfaces included in this chapter will not necessarily be the same as the corresponding measures of the user's body, nor of the wheelchair frame. Linear dimensions of the seated person's body are used to help prescribe desired support surface dimensions, and these support surface dimensions will impact the specification of wheelchair frame parameters. Therefore, particular care needs to be taken during assessment and prescription to utilize the proper terms in order to distinguish among these different sets of measures.

It is also important to note that the development of standardized terminology in our industry is in its infancy; therefore manufacturers may not yet be reporting product dimensions according to these guidelines.

1.1 Terminology conventions for size measures

The terms used to describe linear size measurements for seating support surfaces are depth, length, width and thickness. As explained in the introduction to this guide, all linear support surface measures taken along or parallel to the support's Y-axis are termed **length**; measures taken along (or parallel to) the Z-axis are termed **width**; and measures taken along (or parallel to) the support's X-axis are termed **depth** (Fig.

5.1). Therefore, posterior supports such as a back support and head support have a *length* (measured in an inferior/superior direction from bottom to top) and *width* (measured from side to side). Inferior supports such as the seat, foot supports and arm supports have a *depth* (measured in an anterior/posterior direction from back to front) and a *width* (measured from side to side). All supports have a thickness measure. The term thickness is used to represent the dimension which is perpendicular to the support surface reference plane.

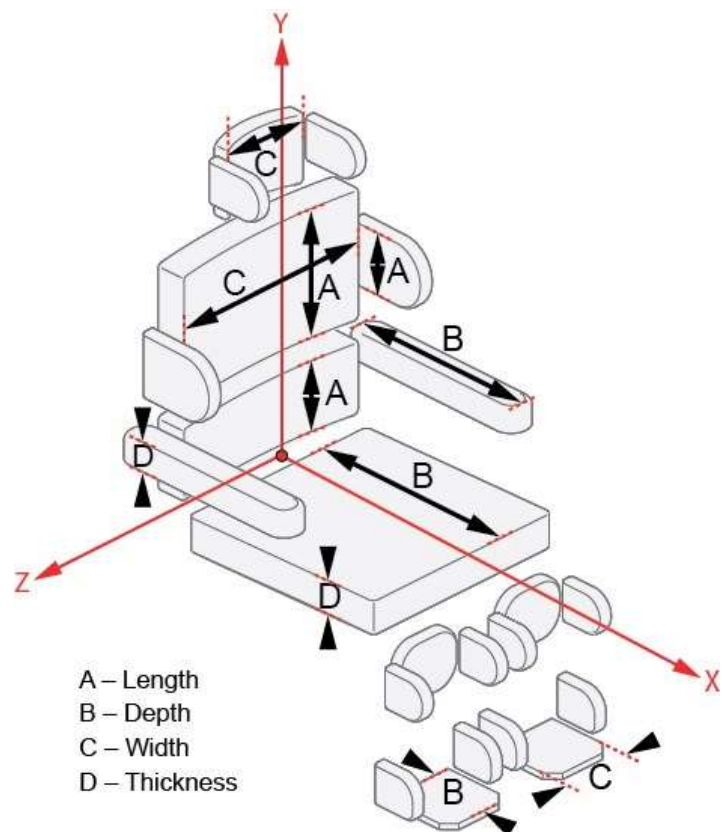
The term used to describe the vertical location or placement of a postural support device is **height**.

The term height is used when taking a measurement from an external reference point, usually the seat surface, to a point on the postural support device of interest. **Fig. 5.1: Terminology conventions**

Height dimensions can typically be changed with

adjustments to the placement of the postural support device. For example, **back support height** is

measured from the top of the seat cushion to the top of the back support. The back support height can be changed by adjusting the vertical placement of the back support device on the wheelchair back canes. This



is different than **back support length**, which is the actual size dimension of the back support from bottom to top edge.

1.2 “Effective” measures

The word “effective” can be added to any length, depth or width measure to indicate that the useable contact surface has been either increased or reduced by the location of a separate, adjacent or attached component. For example, effective measures can be taken when the juxtaposition or intersection of two support surfaces reduces the useable space of the primary support surface. The most common example is when the use and location of separate lateral supports reduces the available width of the primary contact surface, such as lateral thigh supports attached to a seat (Fig. 5.2). Another common example is when the rear edge of the seat cushion is tucked under and behind the back support, thereby reducing the useable seat depth (Fig. 5.3). In such cases, both the actual seat depth measure and the effective seat depth measure should be recorded.

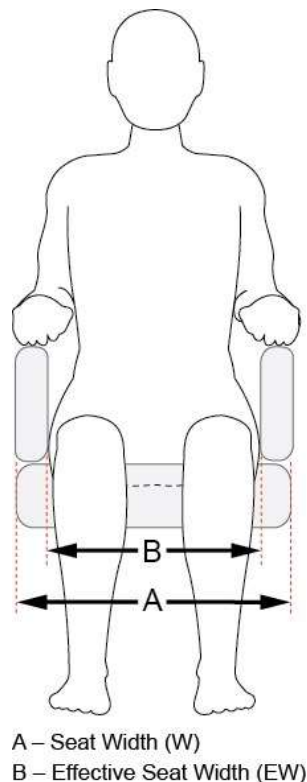


Fig. 5.2: Example of effective width measure

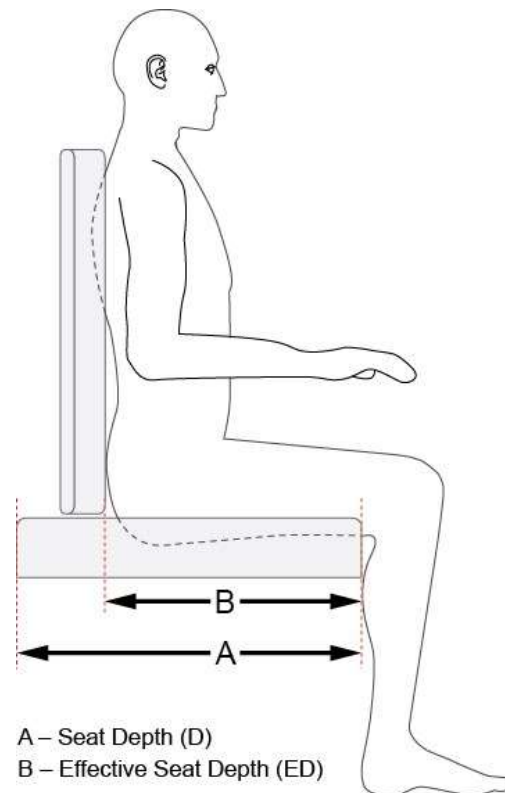


Fig. 5.3: Example of effective depth measure

1.3 Other general terms used in this chapter

The following general terms are used in this chapter when discussing wheelchair seating products and components. Refer to Chapter 1, Section 1.2, or the glossary, for an explanation of these terms:

- Body Support System
- Postural Support Device
- Postural Support Device Assembly
- Contact Surface
- Pre-contoured

1.4 Other general guidelines

In addition to the conventions explained in Section 1.1 above, there are four consistent “rules” that apply to all of the dimensions defined in this chapter. These are as follows:

(1) Measures are taken on the contact surface side of the support

The terms for basic linear size dimensions listed in this chapter are always defined as measures taken on the contact surface side of the body support device, to describe the dimensions of the surface intended to contact the user’s body. These can be differentiated from the outside dimensions of a pre-contoured postural support device, which may have a solid panel on the non-contact surface side. Both sets of dimensions are important – one to fit the client’s body properly to the support surface; and the other to know how much space the postural support device will occupy within the frame. For example, the “outside width” of a curved back or head support, measured at the posterior, non-contact surface side is often *greater* than the inside contact surface width. Furthermore, the “overall width” of the entire body support *assembly* (including the mounting hardware) may be even greater. These outside and overall dimensions may be noted separately as they impact the interface with the wheelchair frame. However, *using the term “back support width” or “head support width” means that the dimension was taken on the contact surface side*. If there is another width dimension that differs from the contact surface dimension, then additional clarifying words (e.g. “outside” or “overall”) need to be added to the term. While these additional terms have not yet been standardized, some suggestions are included in the Considerations section of relevant measures.

(2) Measures are taken parallel to the support surface reference plane at centerline

As a general rule, all linear dimensions with the exception of thickness are taken parallel to the support surface reference plane, along the centerline of the support surface, unless otherwise noted. This is usually the maximum dimension; however, if it is not the maximum dimension you may want to take an additional dimension at the point on the component which gives the maximum dimensions, and note where this was taken. This is discussed in the Considerations section of each relevant measure.

(3) Measures are taken in an unloaded state

As a general rule, size dimensions of body support devices are defined as measures taken with the surface unloaded. However, for greater accuracy in some situations you may also need to take measurements with the cushion in a loaded state. This would be particularly important to determine the final overall seated height of the person from the floor, the height of the back and head supports, the overall width of the seat when it is loaded, or the distance from the top of the seat to the foot support. If a measurement is taken with the surface loaded, add the word loaded to the dimension, for example “back support height from loaded seat.”

(4) Dimensions are straight linear measures, not curved.

For contoured supports, the measurements remain linear, or straight. They do not follow the curve of the support’s contact surface, which would lead to a false overestimation of the measurement. If clinically relevant, the curved dimension may be noted separately.

Finally, it is important to remember that ***additional measures, not included in this guide, may be needed to adequately describe complex support surfaces***. Taking measurements of simple body support surfaces that are flat and rectangular is straight forward. However, some seating support surfaces have nonrectangular shapes and/or complex contours, which cannot be adequately described with a basic set of

dimensions. In these situations, additional measures may be needed to completely describe the product and to properly interface the support surface with the client, or the body support device with the wheelchair.

1.5 Summary of size dimensions included in this chapter

Linear size dimensions of a postural support device describe the length, width, depth and/or thickness of the support. These dimensions are typically fixed and defined by the size of the support surface. The figures below summarize the basic depth measures (Fig. 5.4), length measures (Fig. 5.5) and width measures (Fig. 5.6) included in this chapter. A thickness dimension is also defined for all typical supports. Additional dimensions that help describe the features of a pre-contoured seat cushion are also included in Sections 3.1 – 3.4.

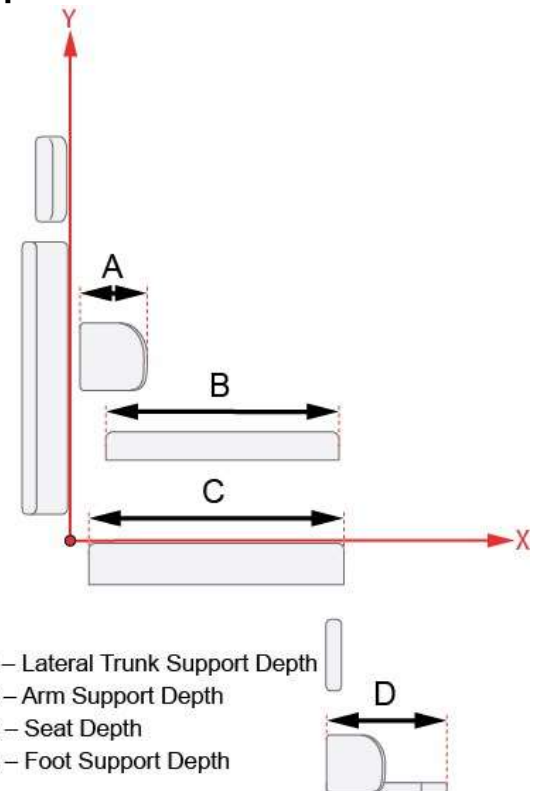


Fig. 5.4: Basic depth measures

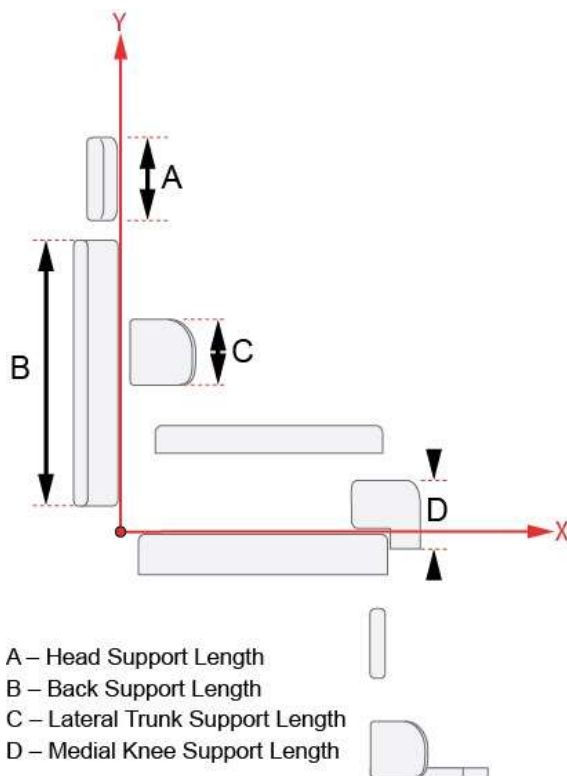


Fig. 5.5: Basic length measures

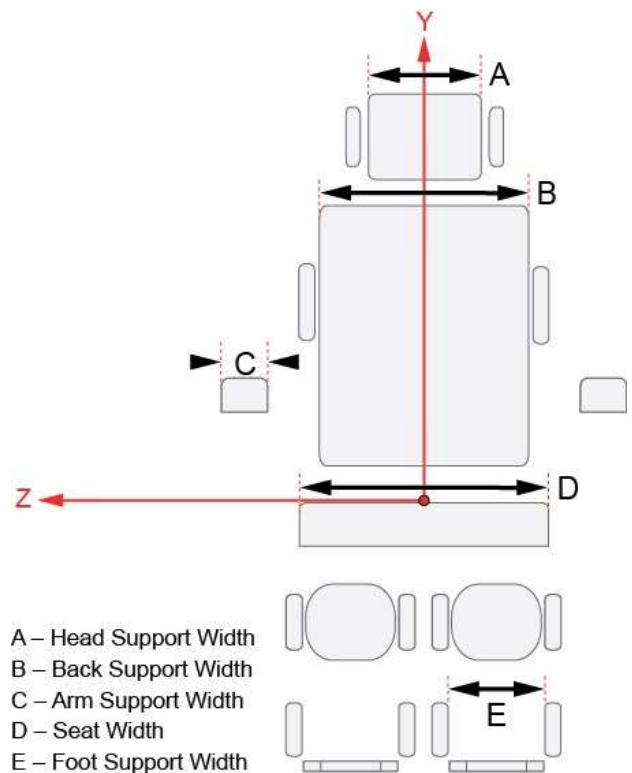


Fig. 5.6: Basic width measures

1.6 Summary of placement measures included in this chapter

Placement measures help to define the placement of an individual support component, usually relative to another support or external reference point. The term “height” is often used for placement measures. Placement measures usually refer to a dimension that is adjustable. The figure below summarizes the basic placement dimensions included in this chapter (Fig. 5.7).

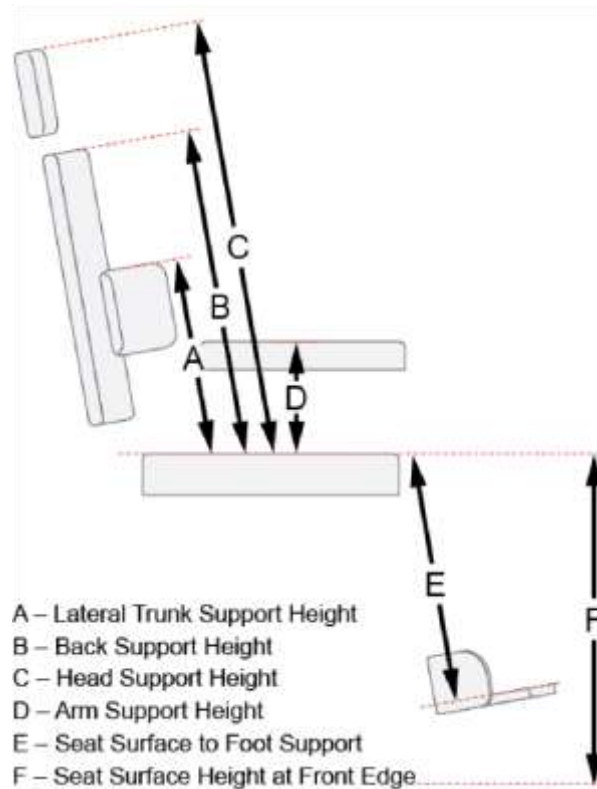


Fig. 5.7: Placement measures

1.7 Organization of dimensions in this chapter

Linear size dimensions are listed first. All size dimensions of a specific postural support device are grouped together, starting with seat dimensions. Size dimensions of the following common postural support devices are included: seat, back support, head support, foot support, arm support, lateral support and medial support. At the end of this chapter the following common placement dimensions are defined: seat surface height at front edge, seat surface to foot support, back support height, head support height, arm support height and lateral trunk support height.

2 Seat Dimensions, Basic

The figure below shows the three basic linear dimensions of a seat surface included in this section.

SEAT DEPTH

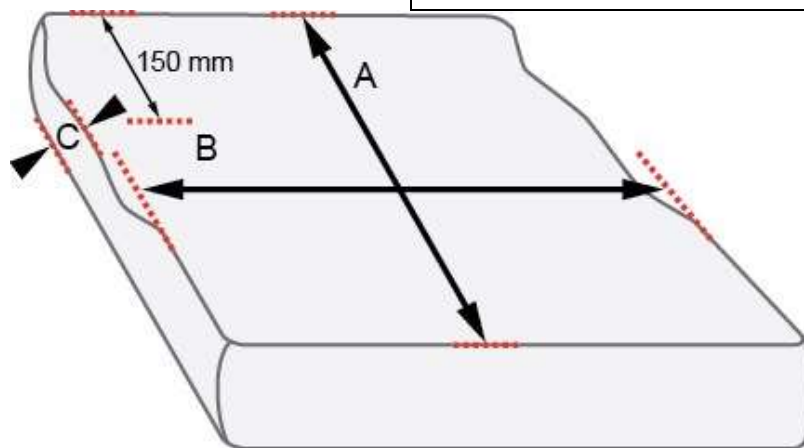
Type of Measurement: Support Surface Linear

Description: The distance from the back to the front of the seat contact surface.

End points used:

- Midpoint of back edge of the contact surface side of the seat.
- Midpoint of front edge of the contact surface side of the seat.

Definition: Linear distance from the back edge to the front edge of the contact surface side of the seat, measured parallel to the seat reference plane along the seat centerline.

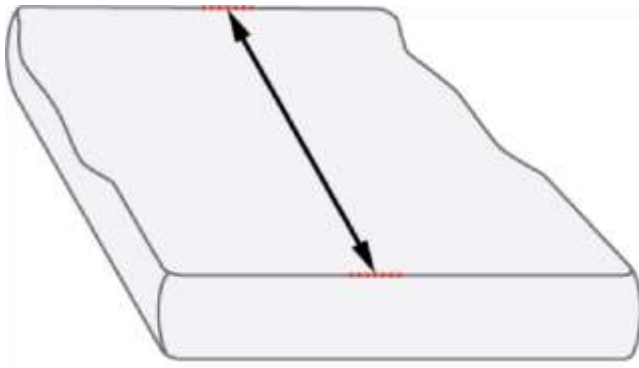


A – Seat Depth
B – Seat Width
C – Seat Thickness

Fig. 5.8: Basic seat dimensions

2.1 Seat depth

Fig. 5.9: Seat depth



centerline of the contact surface side of the seat, staying parallel to the seat reference plane.

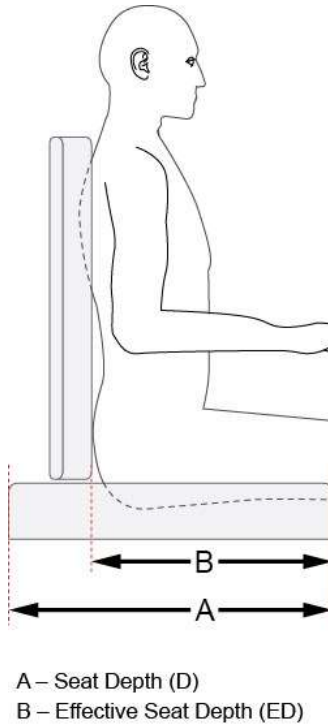
Sample procedure:

1. Locate the midpoints of the front and back edges on the contact surface side of the seat.
2. Measure the distance from the midpoint of the back edge to the midpoint of the front edge, along the

Considerations:

- The linear body measurement which corresponds to the seat depth and is typically used for its prescription is either the buttock/thigh depth or effective buttock/thigh depth.
- When the buttock/thigh depth measurement is different on one side vs. the other, the seat depth prescription may need to accommodate this with a right and left seat depth measure.
- Several manufacturers produce cushions with a convex rear edge to accommodate the contour of a back support. Be aware that these manufacturers may report the dimension of seat depth measured along the *side* of the cushion, e.g. with respect to back cane location. In these cases, the actual centerline seat depth measurement will be greater than the manufacturer reported depth.
- Note that the term seat depth in the context of the body support system refers to the depth of the seat surface intended for contact and support of the user's body. This measurement can relate to, but may not be the same as, the *wheelchair* seat depth, which is typically measured from the back canes to the front of the seat pan or seat sling (surfaces not intended for contact with the user's body).
- Seat cushions with deep contours or complex shapes may require additional measures to fully and accurately capture the depth at various locations if these differ and are clinically significant.

2.2 Effective seat depth



EFFECTIVE SEAT DEPTH

Type of Measurement: Support Surface Linear

Description: The distance from the back support to the front edge of the seat contact surface.

End points used:

- Midpoint of the intersection between the back support reference plane and the seat reference plane.
- Midpoint of front edge of the contact surface side of the seat.

Definition: Linear distance from the intersection of the back support and seat support reference planes to the front edge of the contact surface side of the seat, measured parallel to the seat reference plane along the seat centerline.

Fig. 5.10: Effective seat depth

Sample procedure:

Note: A back support must be in place to measure effective seat depth

1. Locate the midpoint of where the back support reference plane intersects the seat reference plane. This may be a point lying on the seat surface if the back support is mounted in front of the back of the seat (as in Fig. 5.10), or it may be a point lying in space if the back support is mounted posterior to the back edge of the seat.
 - a. If the bottom of the back support does not contact the seat because of its vertical location, place a thin flat surface (such as a ruler or clipboard) along the centre of the lowest segment of the back support to project the plane of the back support onto the seat surface.
 - b. If the projection of the plane of the back support falls *behind* the back edge of the seat cushion, you will need to place another flat surface along the seat, parallel to the seat reference plane, to project the plane of the seat rearward. The point where the two planes intersect, at the midpoint, is the starting point of this dimension.
2. Locate the midpoint of the front edge on the contact surface side of the seat.
3. Measure the distance from the midpoint of the intersection of the two planes to the midpoint of the front edge of the seat, along the centerline of the contact surface side of the seat, staying parallel to the seat reference plane.

Considerations:

- The linear body measurement that corresponds to the effective seat depth and is typically used for its prescription is either the buttock/thigh depth or effective buttock/thigh depth.
- The effective seat depth will be impacted by the anterior/posterior placement of the back support. This may be done intentionally to allow for growth, for instance in a pediatric body support system.

- Measuring the effective seat depth in addition to the actual seat depth during assessment will call attention to a back support that has been unintentionally mounted behind the back edge of the seat cushion (Fig. 5.11). This would result in an effective seat depth longer than the actual seat depth, potentially impacting the individual's posture and function.
- The effective seat depth will also be impacted by the angle of the back support, because this affects where the back support reference plane projects down onto the seat. In addition, the method of achieving the desired seat to back support angle will also affect this measure based on the location of the adjustment pivot point. Therefore, the effective seat depth can be altered by changes in the seat to back support angle (Fig. 5.12).

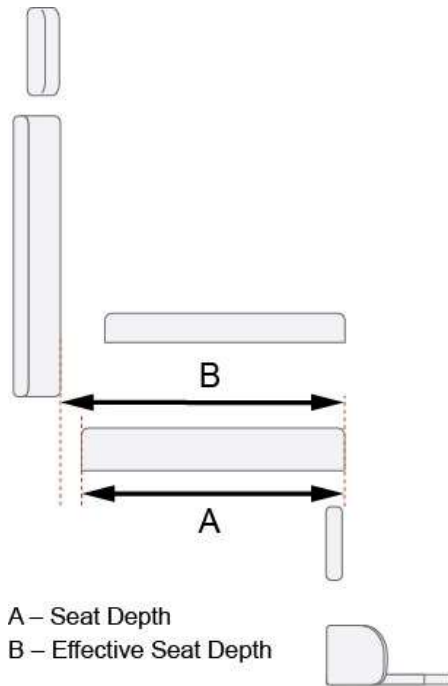


Fig. 5.11: Effective seat depth greater than seat depth

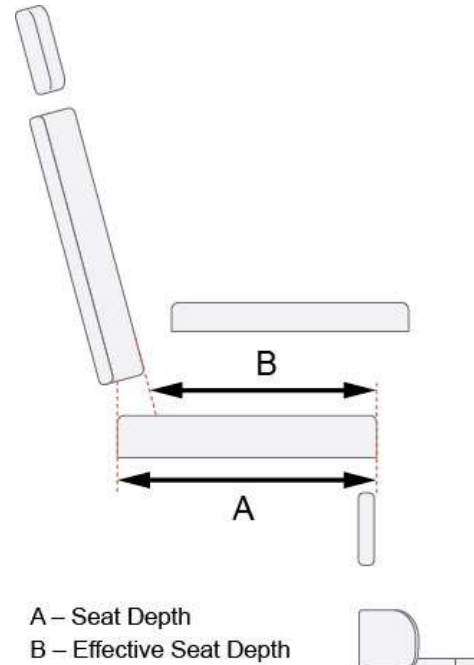


Fig. 5.12: Effective seat depth with angled back support

- If the vertical placement of the back support intentionally allows a gap above the seat contact surface to allow excessive posterior buttock soft tissue to protrude behind the back support reference plane, and the back support is placed in front of the back edge of the seat cushion, the user may still be able to use the full depth of the seat cushion, even though the effective seat depth is less than the actual seat depth. In this case, the actual allowable contact surface between user and cushion may exceed the measured effective seat depth.

SEAT WIDTH

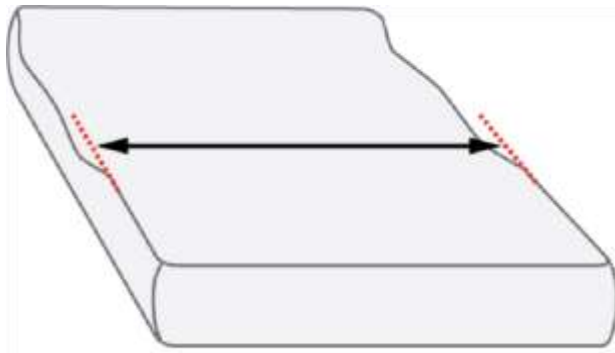
Type of Measurement: Support Surface Linear

Description: The distance between the lateral edges of the seat contact surface.

End points used:

- Midpoint of the right lateral edge of contact surface side of the seat.
- Midpoint of the left lateral edge of contact surface side of the seat.

Definition: Linear distance between the lateral edges of the seat contact surface, measured parallel to the seat reference plane along the centerline.



2.3 Seat width

Fig. 5.13: Seat width

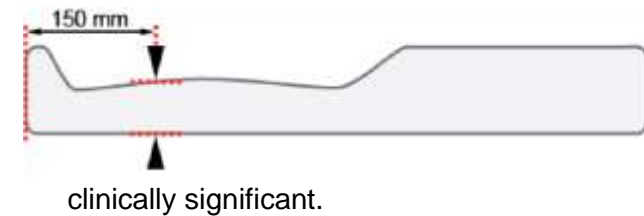
Sample procedure:

1. Locate the midpoints of the lateral edges on the contact surface side of the seat.
2. Measure the distance from the midpoint of the left side to the midpoint of the right side along the centerline of the contact surface side of the seat, staying parallel to the seat reference plane.

Considerations:

- The linear body measurement that corresponds to the seat width and is typically used for its prescription is the hip width.
- Note that the term seat width in the context of the body support system refers to the width of the seat surface intended for contact and support of the user's body. This measurement can relate to, but may not be the same as, the manufacturer's listed *wheelchair* seat width, which is typically measured from the outside lateral edges of the seat rails.
- Seat width is measured in the unloaded state. However, for some seat cushion types, such as air flotation seats, the loaded seat may be wider. If clinically relevant, e.g. for rear wheel clearance, the loaded seat width can also be measured and called "Seat width, loaded".
- **Effective Seat Width:** The use and location of separate lateral pelvic or thigh supports may reduce the useable seat width. The distance between the lateral supports can be measured and reported separately as either the "Effective seat width", or "Distance between lateral supports" (see Fig. 5.2).
- The width of a non-rectangular seat may vary depending on where the measurement is taken. If the width dimension at the center is not the widest dimension, you may need to take additional measures at the widest point(s). For example, if the seat is not rectangular, the width will be different if measured at the rear versus the front of the seat. In this case these additional measures can be labeled "seat width at back" or "seat width at front".
- The width of a seat cushion may be different on the contact surface side versus the inferior surface, which is intended to interface with the wheelchair seat pan or sling. While the term "seat width" is defined as the width at the centerline on the contact surface side, the width of the seat on the inferior side may be clinically important to note in order to interface the seat cushion correctly within the wheelchair seat frame width.

- Seat cushions with deep contours or complex shapes may require additional measures to fully and accurately capture the width at various locations if these differ and are



2.4 Seat thickness

Fig. 5.14: Seat thickness

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SEAT THICKNESS

Type of Measurement: Support Surface Linear

Description: The thickness from top to bottom of the unloaded seat in the area intended for pelvic loading.

End points used:

- Top surface of lateral edge of seat, 150 mm from the rear edge of the seat.
- Bottom surface of lateral edge of the seat, 150 mm from the rear edge of the seat.

Definition: Linear distance from the top to the bottom of the seat, measured perpendicular to the seat reference plane at a point 150 mm from the rear edge of the seat to represent the intended pelvic loading area.

Sample procedure:

1. Place the seat on a flat surface such as a table. The table represents the seat reference plane as well as the inferior surface, or bottom of the seat cushion.
2. Place a flat surface such as a ruler on top of the rear lateral portion of the seat cushion. The bottom surface of the ruler represents the top surface of the seat cushion.
3. Along one of the lateral edges of the seat, locate the point which is 150mm (approximately 6") from the rear edge of the cushion.
4. At this point, measure the distance from the table to the top edge, staying perpendicular to the seat reference plane.

Considerations:

- To standardize the term 'seat thickness', a specific location on the seat was identified for measuring seat thickness that represents the area of the cushion intended for pelvic loading. This definition of seat thickness was adapted from the recommendations outlined in the article by Sprigle et al [1]. Therefore, if a dimension is documented as "seat thickness", it indicates that the measurement was taken as defined above.
- Most pre-contoured seats have variable thicknesses in different areas of the cushion, particularly if the cushion has significant contouring at the buttock or distal thigh areas. Additional terms and measures have therefore been defined to further describe the features of pre-contoured seat cushions, and these are included as additional measures in the next Section 3. These measures were also adapted from

Sprigle et al., and include inferior thigh support thickness (3.1), medial thigh support height (3.2), lateral thigh support height (3.3) and pelvic contour height (3.4) (See Fig. 5.15).

- If it is clinically relevant to take a thickness dimension at an alternate location not represented by any of the above terms, add descriptive words to the term seat thickness to indicate the alternate methodology. For example, if you take the thickness measure at the midpoint of the back edge of the seat, this could be documented as “seat thickness at center back edge”.
- Remember that the seat thickness measure is taken with the seat unloaded. However, seats will have variable thicknesses as a result of loading, and while this can be clinically relevant it is difficult to measure loaded seat thickness in the clinic.
- Loaded seat thickness can impact the final vertical placement of the back support required to achieve the desired back support height. Loaded thickness at the lateral edges of the seat can impact the maximum seat width of a cushion when loaded, such as may occur with an air flotation seat. In this situation, as loaded thickness decreases, the maximum seat width may increase because the air cells protrude laterally when loaded.

3 Additional Seat Dimensions for Pre-Contoured Cushions

The figure below shows four additional linear dimensions that can be used to describe the contours of a precontoured seat surface. These were adapted from the article by Sprigle et al. [1].

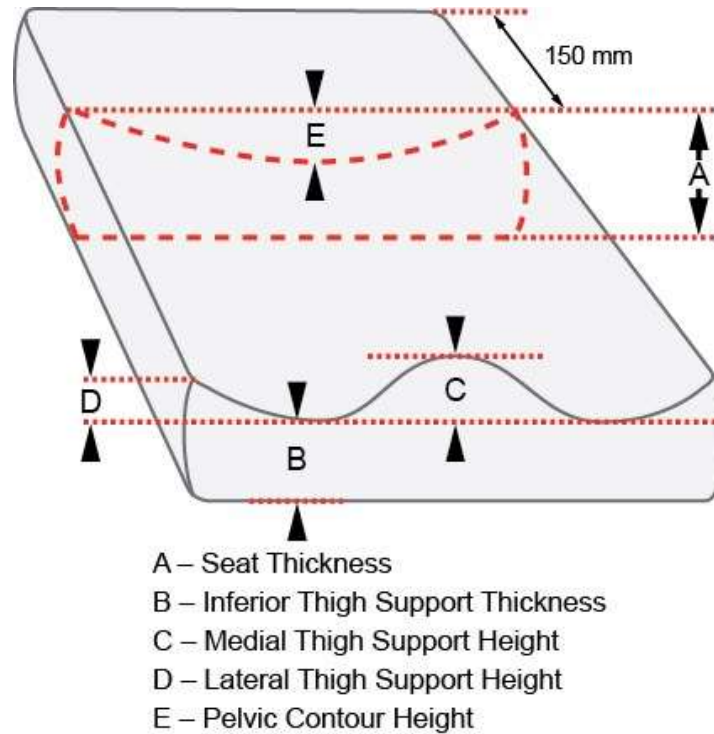


Fig. 5.15: Additional dimensions for pre-contoured seat cushions

INFERIOR THIGH SUPPORT THICKNESS

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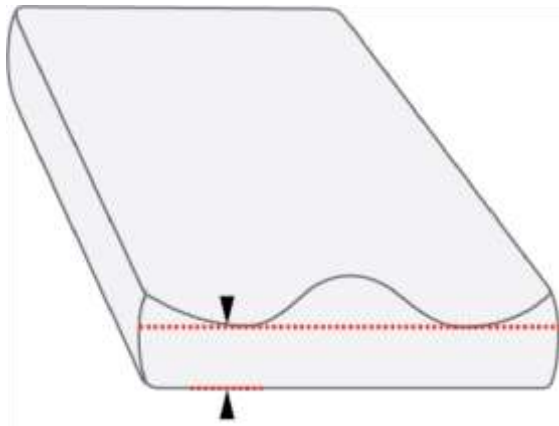
Type of Measurement: Support Surface Linear

Description: The thickness of the front of the unloaded seat in the area intended for thigh loading.

End points used:

- Top surface of front edge of the seat, midway between lateral edge of the seat and the center of the medial thigh support.
- Bottom surface of front edge of the seat, midway between lateral edge of the seat and the center of the medial thigh support.

Definition: Linear distance from the top to the bottom of the front edge of the seat, measured perpendicular to the seat reference plane at a point midway between lateral edge of the seat and the center of the medial thigh support to represent the intended thigh loading area.



3.1 Inferior thigh support thickness

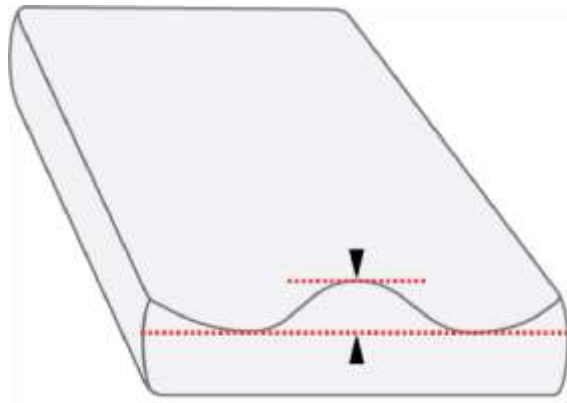
Fig. 5.16: Inferior thigh support thickness

Sample procedure:

1. Place the seat on a flat surface such as a table. The table represents the seat reference plane as well as the inferior surface, or bottom of the seat cushion.
2. Locate one of the points on the front edge of the seat which is midway between the lateral edge of the seat and the center of the medial thigh support contour. (There will be two such points, representing the center of the concave regions intended to support the right and left thighs.)
3. At this point, measure the distance from the table to the top contact surface of the seat, staying perpendicular to the seat reference plane.

Considerations:

- For flat cushions, the inferior thigh support thickness will be the same as the seat thickness, and therefore taking this additional measure is not necessary.
- For custom-contoured, non-symmetrical seats, the inferior thigh support thickness measurement should be taken at the estimated center of the intended thigh support area.
- For some custom contoured seat cushions, there may be right and left measures representing variable thickness at the right and left thigh areas.
- This dimension is clinically relevant because it directly affects the seat surface height above the floor (see 2.1 Seat surface height at front edge) as well as the distance from the seat to the foot supports (see Section 10.2, Seat Surface to foot support) Seat surface to foot support). This impacts the proximity of the client's feet to the wheelchair foot supports or to the ground for foot propulsion or transfers.



3.2 Medial thigh support height

Fig. 5.17: Medial thigh support height

MEDIAL THIGH SUPPORT HEIGHT

Type of Measurement: Support Surface Linear

Description: The distance from the top of the seat surface intended to support the distal thigh to the top of the medial thigh support, in a seat cushion with contour at the front edge.

End points used:

- Top surface of inferior thigh support at front edge of the seat, midway between lateral edge of the seat and the center of the medial thigh support.
- Top surface of medial thigh support, at the center of front edge of the seat.

Definition: Linear distance from the top of the inferior thigh support surface to the top of the medial thigh support contour, measured perpendicular to the seat reference plane at the front edge of the seat.

Sample procedure:

1. Place the seat on a flat surface such as a table. The table represents the seat reference plane as well as the inferior surface, or bottom of the seat cushion.
2. Locate the highest point of the top surface of the medial thigh support contour. Place a flat surface such as a clipboard on top of the medial thigh support at this point to project this point laterally over the inferior thigh support area. Hold this surface parallel to the seat reference plane.
3. Measure the vertical distance from the top of the seat in the middle of the inferior thigh support area to the top surface of the medial thigh support as represented by the clipboard or ruler, staying perpendicular to the seat reference plane.

Considerations:

- The medial thigh support height represents the difference in thickness at the front edge of the seat between the area intended for the distal thigh and the center of the medial thigh support contour. Therefore, an alternate method of determining this dimension would be to calculate the difference between the inferior thigh support thickness and the full thickness at the front edge of the seat at the location of the medial thigh support contour.
- This dimension is clinically relevant because it affects the degree of surface contact provided to the medial side of the thigh, which may impact the user's stability, posture and/or comfort. The medial thigh support height may also impact the user's ability to do a forward transfer in and out of the wheelchair.

LATERAL THIGH SUPPORT HEIGHT

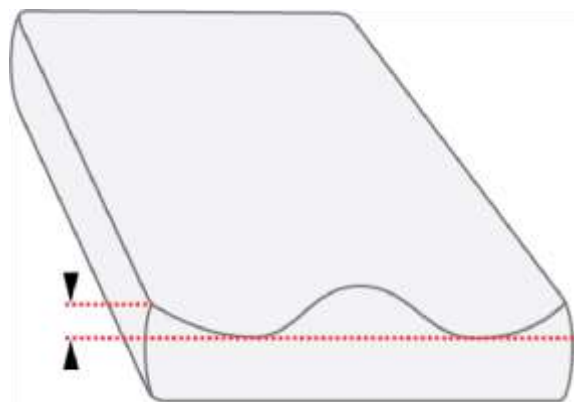
Type of Measurement: Support Surface Linear

Description: The distance from the top of the seat surface intended to support the distal thigh to the top of the lateral thigh support, in a seat cushion with contour at the front edge.

End points used:

- Top surface of inferior thigh support at front edge of the seat, midway between lateral edge of the seat and the center of the medial thigh support.
- Top surface of lateral thigh support at the lateral front edge of the seat.

Definition: Linear distance from the top of the inferior thigh support surface to the top of the lateral thigh support contour, measured perpendicular to the seat reference plane at the front edge of the seat.



3.3 Lateral thigh support height

Fig. 5.18: Lateral thigh support height

Sample procedure:

1. Place the seat on a flat surface such as a table. The table represents the seat reference plane as well as the inferior surface, or bottom of the seat cushion.
2. Locate the highest point of the top surface of the lateral thigh support contour. Place a flat surface such as a clipboard on top of the lateral thigh support at this point to project this point medially over the inferior thigh support area. Hold this surface parallel to the seat reference plane.
3. Measure the vertical distance from the top of the seat in the middle of the inferior thigh support area to the top of the lateral thigh support contour as represented by the clipboard or ruler, staying perpendicular to the seat reference plane.

Considerations:

- The lateral thigh support height represents the difference in thickness at the front edge of the seat between the area intended for the distal thigh and the lateral thigh support contour. Therefore, an alternate method of determining this dimension would be to calculate the difference between the inferior thigh support thickness and the full thickness at the lateral front edge of the seat.
- This dimension is clinically relevant because it affects the degree of surface contact provided to the lateral side of the thigh, which may impact the user's stability, posture, comfort and/or function. This dimension may also impact the user's ability to do a lateral transfer in and out of the wheelchair.

PELVIC CONTOUR HEIGHT

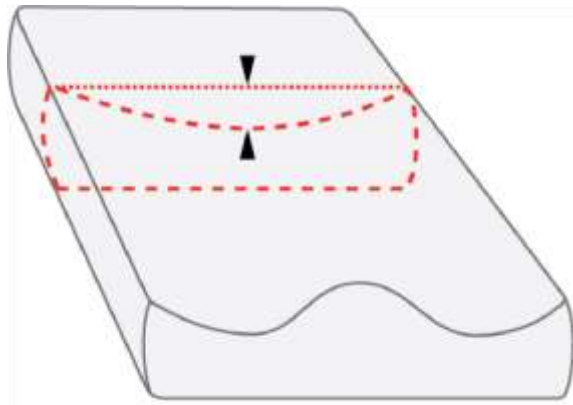
Type of Measurement: Support Surface Linear

Description: The distance from the top of the seat surface in the pelvic area, to the top of the lateral edge of the seat, in a seat cushion with unloaded contour.

End points used:

- Top surface of seat at centerline, 150 mm from the rear edge of the seat.
- Top surface of lateral edge of seat, 150 mm from the rear edge of the seat.

Definition: Linear distance from the top of the seat contact surface in the pelvic area at centerline, to the top of the lateral edge of the seat, measured perpendicular to the seat reference plane at a point 150 mm from the rear edge of the seat (to represent the intended pelvic loading area).



3.4 Pelvic contour height

Fig. 5.19: Pelvic contour height

Sample procedure:

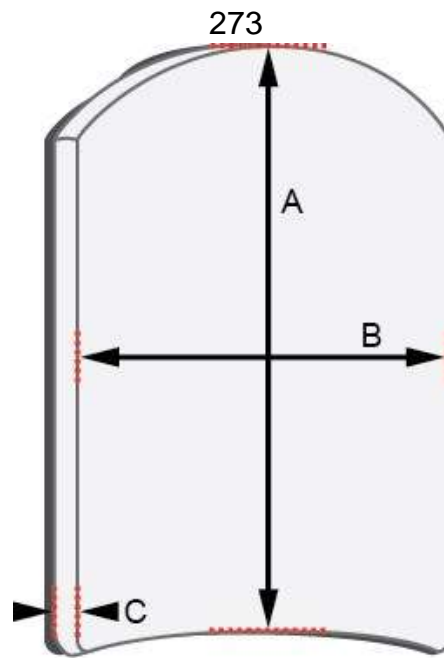
1. Place the seat on a flat surface such as a table. The table represents the seat reference plane as well as the inferior surface, or bottom of the seat cushion.
2. Locate the two points 150mm (approximately 6") from the rear edge of the cushion, one at the centerline of the seat and the other at the lateral edge of the seat.
3. Place a flat surface such as a ruler or clipboard on the top surface of the lateral edge of the cushion at the point located above, to project this point medially over the pelvic support area. Hold this surface parallel to the seat reference plane.
4. Measure the distance between these two points - from the top of the seat surface at centerline to the inferior surface of the ruler/clipboard, staying perpendicular to the seat reference plane.

Considerations:

- This dimension is clinically relevant because it impacts the potential degree of pelvic immersion or offloading for pressure re-distribution in a cushion with pre-loaded contour.
- If the pelvic contour is intended to provide significant surface area contact at the lateral pelvis for postural support, such as with some custom contoured seat cushions, this dimension can be labeled "lateral pelvic support height", instead of pelvic contour height.
- Similarly, if the height of the contours around the pelvis in different locations (posterior or anterior to the pelvis) is significantly different and it is clinically relevant, then additional measures can be taken at different locations. In this case, document the dimension in a manner which indicates where the measurement was taken, e.g. "Anterior pelvic contour height".

4 Back Support Dimensions

The figure below shows the three basic linear dimensions of a back support included in this section.



- A – Back Support Length
- B – Back Support Width
- C – Back Support Thickness

Fig. 5.20: Basic back support dimensions

BACK SUPPORT LENGTH

Type of Measurement: Support Surface Linear

Description: The length of the back support surface from bottom edge to top edge.

End points used:

Midpoint of bottom edge of the contact surface side of the back support.

Midpoint of top edge of the contact surface side of the back support.

Definition: Linear distance between the bottom edge and the top edge of the contact surface side of the back support, measured parallel to the back support reference plane along the centerline.



4.1

Back support length

Fig. 5.21: Back support length

Sample procedure:

1. Locate the two midpoints of the top and bottom edges of the contact surface side of the back support.
2. Measure the distance from the midpoint of the bottom edge to the midpoint of the top edge, along the centerline of the contact surface side of the back support, staying parallel to the back support reference plane.

Considerations:

- The linear body measurements that correspond to the back support length, and are typically used for its prescription, are scapular height, axilla height, or shoulder height.
- The contact surface side of the back support (padded surface) may be greater in length than the posterior aspect as represented by the solid mounting panel or shell. Note that manufacturers measure and label length in different ways, sometimes measuring the padding, and sometimes not.
- This measure is clinically relevant because it affects the amount of surface contact provided to the posterior aspect of the trunk, which may impact the user's posture, stability, comfort and/or function.
- It is important to note the difference between back support length and back support height. Back support length is the actual dimension of the back support cushion, whereas back support height represents the vertical location or placement of the back support relative to the seat. See Section 10.3 for the definition of back support height.
- Back supports with deep contours or complex shapes may require additional measures to fully and accurately capture the length at various locations if these differ and are clinically significant.

BACK SUPPORT WIDTH

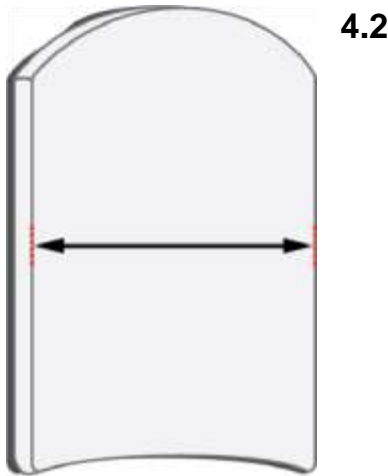
Type of Measurement: Support Surface Linear

Description: The distance between the lateral edges of the back support contact surface.

End points used:

- Midpoint of the right lateral edge of contact surface side of the back support.
- Midpoint of the left lateral edge of contact surface side of the back support.

Definition: Linear distance between the lateral edges of the back support contact surface, measured parallel to the back support reference plane along the centerline.



Back support width

Fig. 5.22: Back support width

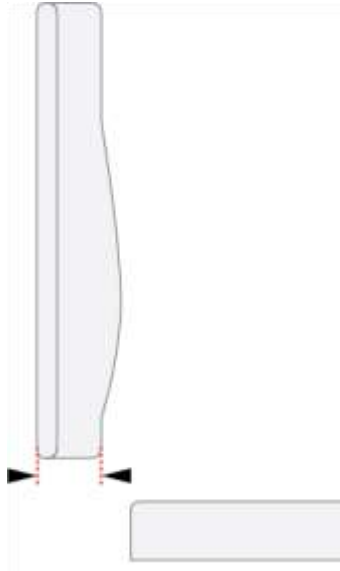
Sample Procedure:

1. Locate the midpoints of the lateral edges on the contact surface side of the back support.
2. Measure the distance from the midpoint of the left side to the midpoint of the right side along the horizontal centerline of the contact surface side of the back support, staying parallel to the back support reference plane.

Considerations:

- The linear body measurements which correspond to the back support width, and are typically used for its prescription, are chest width, and/or shoulder width.
- The width of a non-rectangular back support may vary depending on where the measurement is taken. If the width dimension at the center is not the widest dimension, you may need to take additional measures at the widest point(s). For example in the case of an I-back, you should take additional width measures at the top and bottom. In this case these additional measures should be labeled “back support width at top” and “back support width at bottom”.
- Similarly, the width of a back support device may be different on the contact surface side vs the noncontact surface side (the side that is intended to interface with the wheelchair). While the term ‘back support width’ is defined as the width at the centerline on the contact surface side, the width of the back support on the posterior side may be clinically important to note in order to interface the back support device correctly within the wheelchair seat and/or back cane width.
- **Effective back support width:** The use and location of separate lateral trunk supports may reduce the useable back support width. In this case, the distance between the lateral trunk supports can be measured and reported separately as either the *Effective back support width*, or the *Distance between lateral trunk supports*.
- Back supports with deep contours or complex shapes may require additional measures to fully and accurately capture the width at various locations if these differ and are clinically significant.

4.3 Back support thickness



BACK SUPPORT THICKNESS

Type of Measurement: Support Surface Linear

Description: The thickness from front to back of the unloaded back support, measured at the bottom.

End points used:

- Front surface of bottom edge of the back support at centerline.
- Rear surface of bottom edge of the back support at centerline.

Definition: Linear distance from the front to the back of the back support, measured perpendicular to the back support reference plane along the bottom edge at centerline.

Fig. 5.23: Back support thickness

Sample procedure:

1. Place a straight edge such as a ruler at the vertical centerline of the front surface of the back support, and another along the vertical centerline of the rear surface of the back support so that they both project beyond the lower edge of the support.
2. Measure the distance between these straight edges, staying perpendicular to the back support reference plane.

Considerations:

- This measure, in conjunction with the prescribed seat depth, may help to specify the depth of the wheelchair seat frame or other parameters required to accommodate the person's maximum sitting depth.
- The thickness measures reported by the manufacturer for contoured back supports refer to unloaded back supports. Thus, compression of the contact surface padding will need to be estimated when prescribing effective seat depth, wheelchair seat frame depth or lateral trunk support depth.
- Contoured back supports may have variable thicknesses. The thickness at the bottom of the back support is the most clinically relevant since it will impact the available wheelchair seat frame depth. However, it may be clinically relevant to measure thickness in different locations on a back support with variable thickness. If a dimension is documented as "back support thickness", it indicates that the measurement was taken as defined above, at the bottom of the back support at centerline. If it is clinically relevant to take the dimension at an alternate location, add descriptive words to the term to indicate the alternate methodology. For example, if you take the thickness measure at the midpoint of the top edge of the back support, this could be documented as "back support thickness at center top edge".
- In order to take a thickness measure at a location other than an outside edge, for example as may be needed for a custom contoured back support, you can use a set of large curved calipers to measure the thickness at the particular location of interest.

5 Head Support Dimensions

The figure below shows the three basic linear dimensions of a head support included in this section.

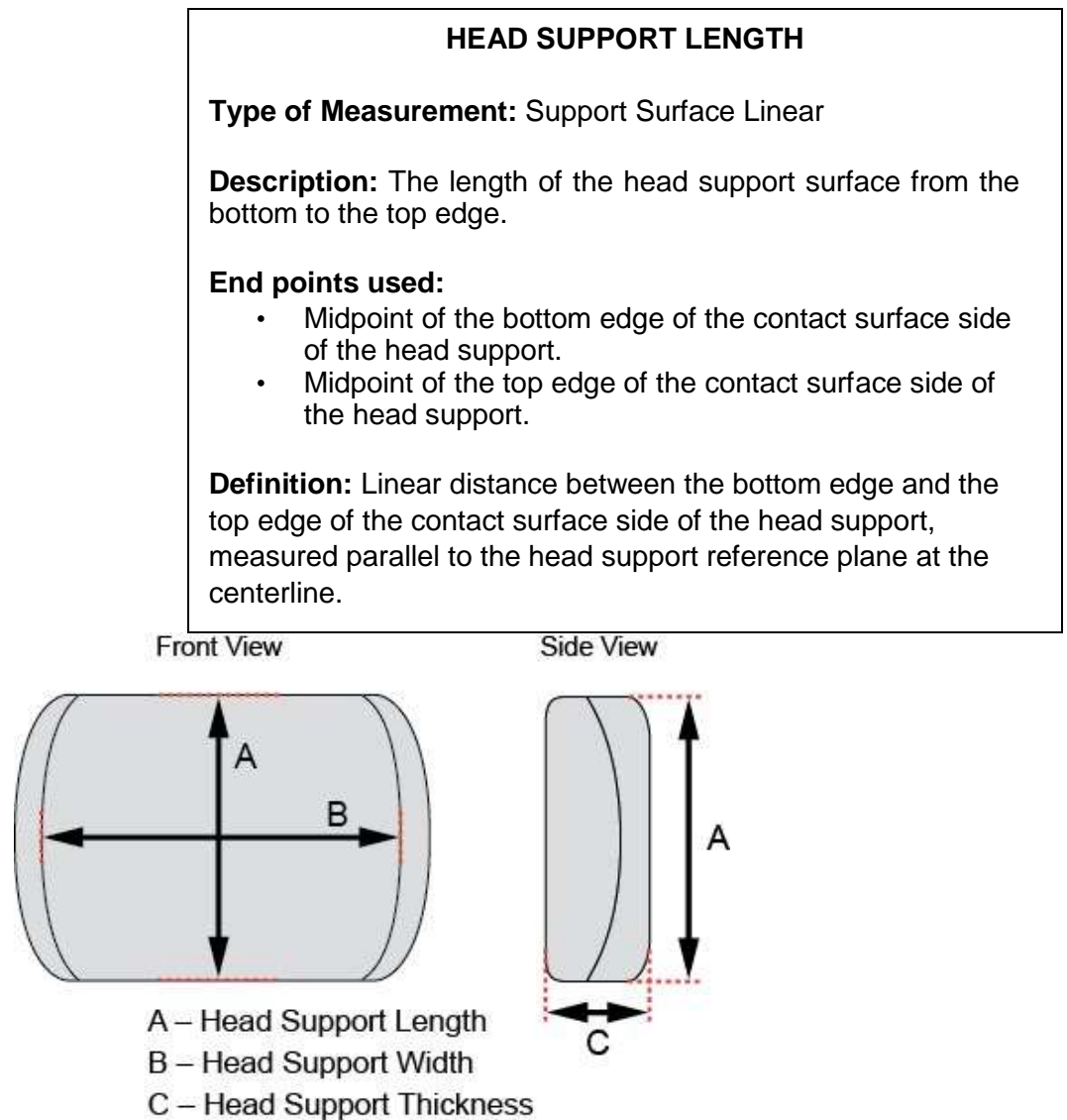
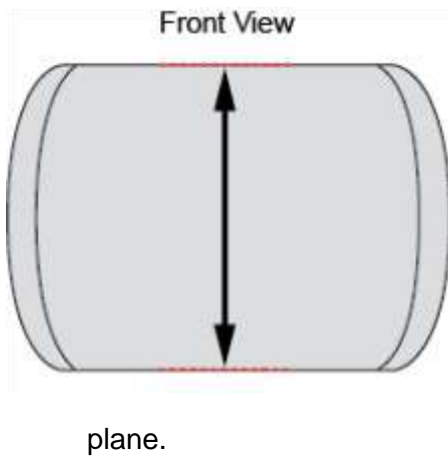


Fig. 5.24: Basic head support dimensions

5.1 Head support length

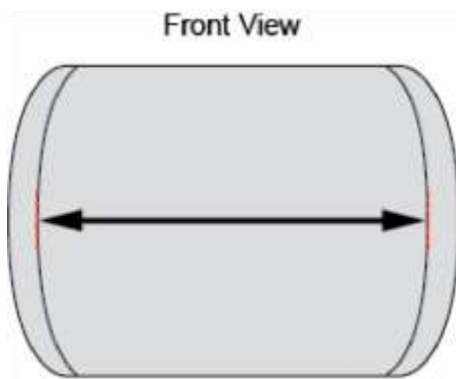
Fig. 5.25: Head support length

**Sample procedure:**

1. Locate the two midpoints of the top and bottom edges of the contact surface side of the head support.
2. Measure the distance from the midpoint of the bottom edge to the midpoint of the top edge, along the centerline of the contact surface side of the head support, staying parallel to the head support reference

Considerations:

- There is not a linear body measurement which specifically corresponds to the head support length.
- This measure is clinically relevant because it affects the amount of surface contact provided to the posterior aspect of the head, which may impact the user's head

**HEAD SUPPORT WIDTH**

Type of Measurement: Support Surface Linear

Description: The distance between the lateral edges of the head support contact surface.

End points used:

- Midpoint of the right lateral edge of contact surface side of the head support
- Midpoint of the left lateral edge of contact surface side of the head support

Definition: Linear distance between the lateral edges of the head support contact surface, measured parallel to the head support reference plane along the centerline.

alignment, stability, comfort and/or function.

- Head supports with deep contours or complex shapes may require additional measures to fully and accurately capture the length at various locations if these differ and are clinically significant. For example, head supports with built-in sub-occipital support may require

separate segmental length measurements to be taken.

5.2 Head support width

Fig. 5.26: Head support width

Sample procedure:

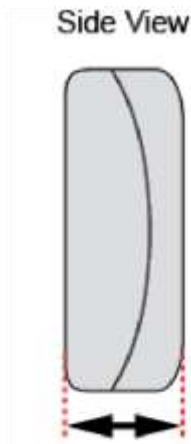
1. Locate the midpoints of the lateral edges on the contact surface side of the head support.

2. Measure the distance from the midpoint of the left side to the midpoint of the right side along the horizontal centerline of the contact surface side of the head support, staying parallel to the head support reference plane.

Considerations:

- The linear body measurement that corresponds to the head support width, and is typically used for its prescription, is head width.
- **Effective head support width:**

of



The use and location separate lateral head supports may

reduce the usable head support width. In this case, the distance between the lateral head supports can be measured and reported separately as either the *Effective Head Support Width*, or the *Distance between lateral head supports*.

- Head supports with deep contours or complex shapes may require additional measures to fully and accurately capture the width at various locations if these

differ and are clinically significant.

5.3 Head support thickness

Fig. 5.27: Head support thickness

Sample procedure:

1. Place a straight edge such as a ruler at the vertical centerline of the front surface of the head support, and another along the vertical centerline of the rear surface of the head support so that they both project beyond the lower edge of the support.
2. Measure the distance between the straight edges, staying perpendicular to the head support reference plane.

Considerations:

- Head support thickness will affect the anterior/posterior location of the head support surface relative to the back support.
- Contoured head supports may have variable thicknesses, and it may be clinically relevant to measure the thickness at a different location than as defined above (at center bottom edge). If a dimension is documented as 'head support thickness', it indicates that the measurement was taken as defined above, at the bottom of the head support at centerline. If it is clinically relevant to take the dimension at an alternate location, add descriptive words to the term to indicate the alternate methodology and location.

HEAD SUPPORT THICKNESS

Type of Measurement: Support Surface Linear

Description: The thickness from front to back of the head support, measured at the bottom.

End points used:

- Front surface of bottom edge of the head support at centerline
- Rear surface of bottom edge of the head support at centerline

Definition: Linear distance from the front to the back of the unloaded head support, measured perpendicular to the head support reference plane along the bottom edge at centerline.

For example, if you take the thickness measure at the midpoint of the top edge of the head support, this could be documented as “head support thickness at center top edge”.

- In order to take a thickness measure at a location other than an outside edge, for example in the center of the head support, you can use a set of large curved calipers to measure the thickness at the particular location of interest.

6 Foot Support Dimensions

The figure below shows the three basic linear dimensions of a foot support included in this section.

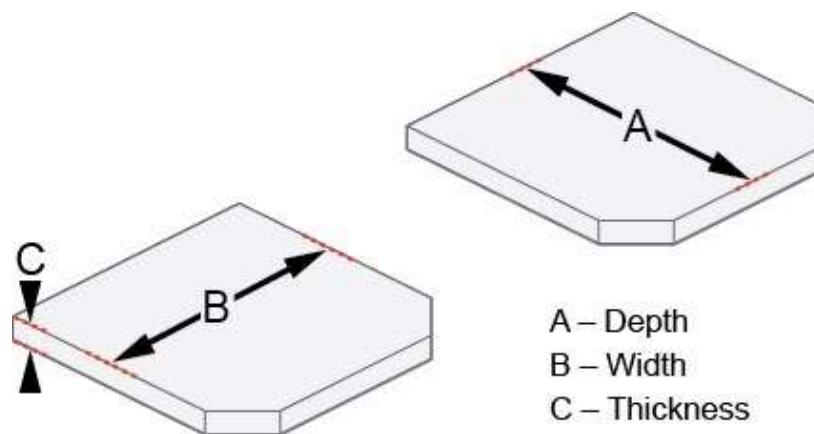


Fig. 5.28: Basic foot support dimensions

FOOT SUPPORT DEPTH

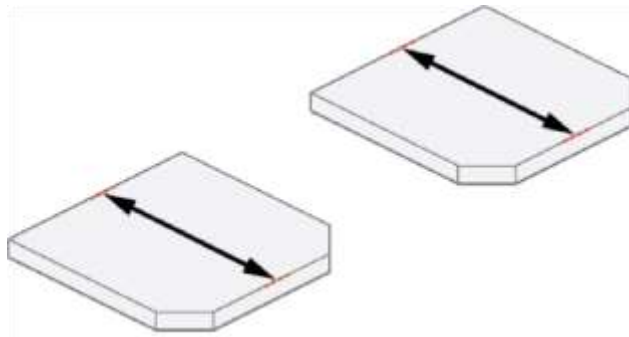
Type of Measurement: Support Surface Linear, right and left

Description: The distance from the back to the front of the foot support contact surface.

End points used:

- Midpoint of back edge of the contact surface side of the foot support.
- Midpoint of front edge of the contact surface side of the foot support.

Definition: Linear distance from the back edge to the front edge of the contact surface side of the foot support, measured parallel to the foot support reference plane along the centerline.



6.1 Foot support depth

Fig. 5.29: Foot support depth

Sample procedure:

1. Locate the midpoints of the front and back edges on the contact surface side of the foot support.
2. Measure the distance from the midpoint of the rear edge to the midpoint of the front edge, along the centerline of the contact surface side of the foot support, staying parallel to the foot support reference plane.

Considerations:

- The linear body measurement which corresponds to the foot support depth is the foot depth.
- This measure is clinically relevant because it affects the degree of surface contact under the person's foot. This dimension is also important because it can affect the overall wheelchair depth and turning radius.

FOOT SUPPORT WIDTH

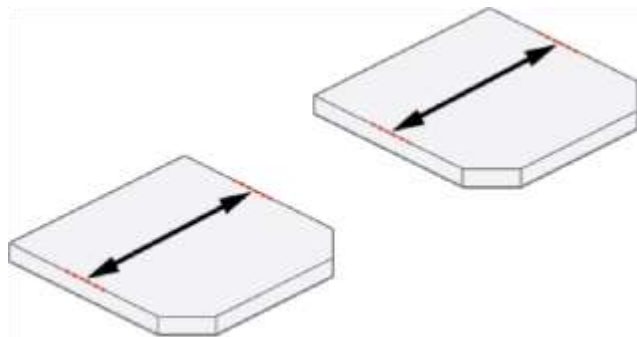
Type of Measurement: Support Surface Linear, right and left

Description: The distance between the lateral edges of the foot support surface.

End points used:

- Midpoint of the right lateral edge of contact surface side of the foot support.
- Midpoint of the left lateral edge of contact surface side of the foot support.

Definition: Linear distance between the lateral edges of the foot support contact surface, measured parallel to the foot support reference plane along the centerline.



6.2 Foot support width

Fig. 5.30: Foot support width

Sample procedure:

1. Locate the midpoints of the lateral edges on the contact surface side of the foot support.
2. Measure the distance from the midpoint of the left edge to the midpoint of the right edge across the centerline of the contact surface side of the foot support, staying parallel to the foot support reference plane.

Considerations:

- The linear body measurement that corresponds to the foot support width is the foot width (not included in this guide).
- **Effective foot support width:** The use and location of separate lateral foot support components, such as medial or lateral pads, heel loops or ankle/foot straps mounted to the inferior foot support surface, may reduce the usable foot support width. In this case, the distance in between the lateral support surfaces can be measured and reported separately as the *Effective foot support width*, or *Distance between lateral foot supports*.
- **Contoured foot supports:** Foot supports with integrated lateral borders or contour may have two different widths which are clinically significant depending on the thickness of the lateral border. An example of this type of foot support would be a shoe holder, typically used in pediatric systems; or a footplate with a pre-shaped lateral border. In this case, both an *inside foot support width* and an *outside foot support width* can be measured and reported. The inside width represents the available contact surface width for the foot and thus is clinically important for optimum fit. The outside width will impact clearance with other wheelchair frame components such as the lower leg support assembly or casters.
- The width of both right and left foot supports combined will impact the required front frame width of the wheelchair to accommodate placement of the two supports side by side.

FOOT SUPPORT THICKNESS

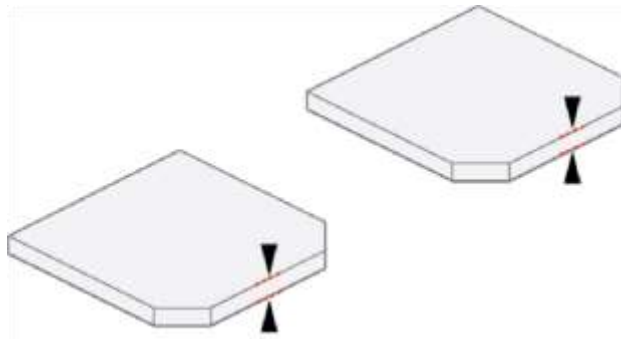
Type of Measurement: Support Surface Linear, right and left

Description: The thickness from the top to the bottom surfaces of the foot support.

End points used:

- Top surface of front edge of the foot support at centerline.
- Bottom surface of front edge of the foot support at centerline.

Definition: Linear distance from the top to the bottom surfaces of the foot support, measured perpendicular to the foot support reference plane at the midpoint of the front edge.



6.3 Foot support thickness

Fig. 5.31: Foot support thickness

Sample procedure:

1. Place a straight edge such as a ruler at the centerline of the top surface of the foot support, and another along the centerline of the bottom surface of the foot support so that they both project beyond the front edge of the support.
2. Measure the distance between the straight edges, staying perpendicular to the foot support reference plane.

Considerations:

- Foot support thickness will impact the foot support adjustment required to achieve the desired **Seat surface to foot support** dimension (see 10.2).
- Foot support thickness may also impact clearance of the foot support above the ground. The overall thickness of the foot support *assembly*, which includes hardware, may also need to be measured and considered in determining ground clearance requirements.

7 Arm Support Dimensions

The figure below shows the three basic linear dimensions of an arm support included in this section.

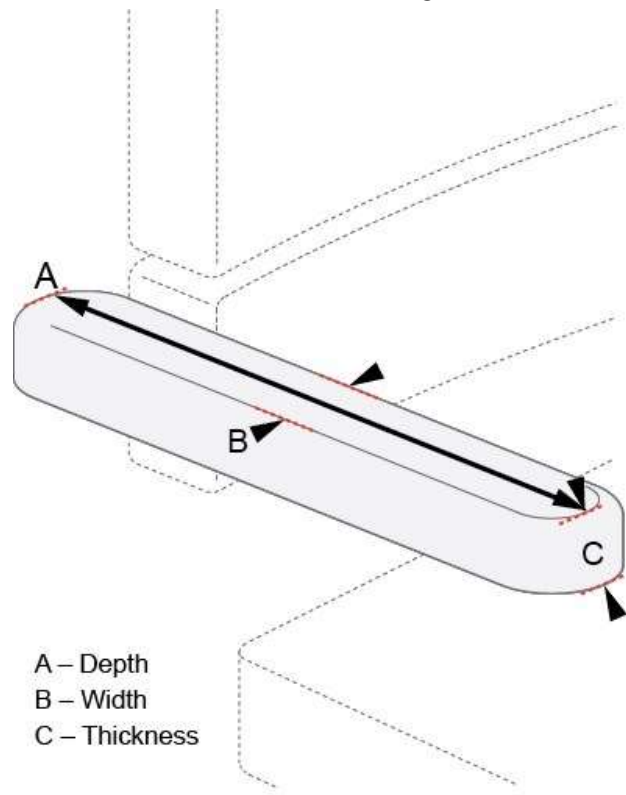


Fig. 5.32: Basic arm support dimensions

7.1 Arm support depth



ARM SUPPORT DEPTH

Type of Measurement: Support Surface Linear, right and left

Description: The distance from the back to the front of the arm support contact surface.

End points used:

- Midpoint of back edge of the contact surface side of the arm support.
- Midpoint of front edge of the contact surface side of the arm support.

Definition: Linear distance from the back edge to the front edge of the contact surface side of the arm support, measured parallel to the arm support reference plane along the centerline.

Fig. 5.33: Arm support depth

Sample procedure:

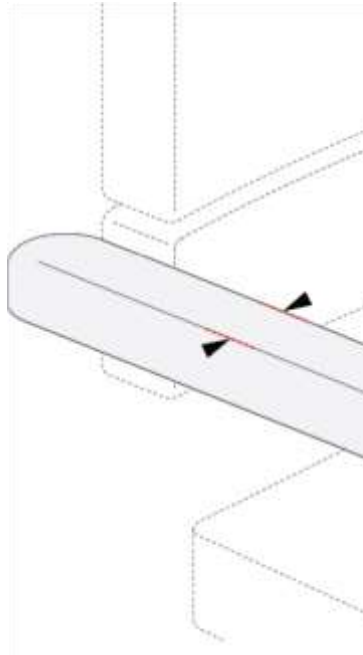
1. Locate the midpoints of the front and back edges on the contact surface side of the arm support.

2. Measure the distance from the midpoint of the rear edge to the midpoint of the front edge, along the centerline of the contact surface side, staying parallel to the arm support reference plane.

Considerations:

- The linear body measurements which correspond to the arm support depth and may be used for its prescription, are the forearm depth and hand depth.
- Depending on the level of support needed, the arm support depth may be prescribed to support both the forearm and hand, and in this case would correspond to the combined body measure of forearm depth plus hand depth. In the case of a two section arm support designed to support the forearm and the hand, the depth of these components may be reported separately by some manufacturers.

7.2 Arm support width



ARM SUPPORT WIDTH

Type of Measurement: Support Surface Linear, right and left

Description: The distance between the lateral edges of the arm support surface.

End points used:

- Midpoint of the right lateral edge of contact surface side of the arm support.
- Midpoint of the left lateral edge of the contact surface side of the arm support.

Definition: Linear distance between the lateral and medial edges of each arm support contact surface, measured parallel to the arm support reference plane along the centerline.

Fig. 5.34: Arm support width

Sample procedure:

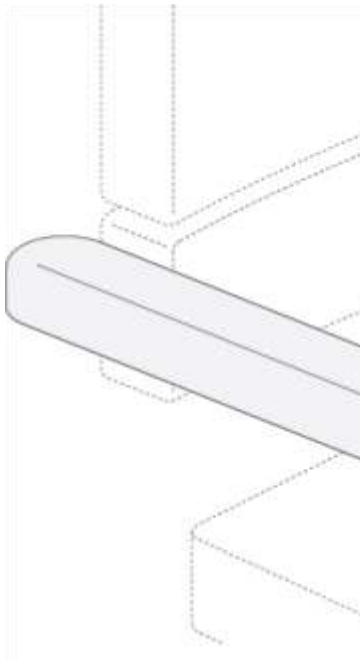
1. Locate the midpoints of the lateral and medial edges on the contact surface side of the arm support.
2. Measure the distance from the midpoint of the left edge to the midpoint of the right edge across the centerline of the contact surface side of the arm support, staying parallel to the arm support reference plane.

Considerations:

- The linear body measurement that corresponds to the arm support width is the forearm width.
- **Effective arm support width:** The use and location of separate medial and/or lateral forearm supports may reduce the usable arm support width. In this case, the distance in between the medial and lateral supports can be measured and reported separately as the *Effective Arm Support Width*, or *Distance between medial/lateral forearm supports*.
- **Contoured arm supports:** Arm supports with integrated lateral borders or contour may have two different widths which are clinically significant depending on the thickness of the lateral border or contour. An example of this type of arm support would be a contoured arm trough. In this case, both an inside arm support width and an outside arm support width can be measured and reported. The inside width

represents the available contact surface width for the forearm and thus is clinically important for optimum fit. The outside width will impact clearance with other components such as the wheelchair back canes, the back support or lateral trunk supports.

7.3 Arm support thickness



ARM SUPPORT THICKNESS

Type of Measurement: Support Surface Linear, right and left

Description: The thickness from the top to the bottom surfaces of the arm support device.

End points used:

- Top surface of front edge of the arm support at centerline.
- Bottom surface of front edge of the arm support at centerline.

Definition: Linear distance from the top to the bottom surfaces of the arm support, measured perpendicular to the arm support reference plane at the midpoint of the front edge.

Fig. 5.35: Arm support thickness

Sample procedure:

1. Place a straight edge such as a ruler at the centerline of the top surface of the arm support, and another along the centerline of the bottom surface of the arm support so that they both project beyond the front edge of the support.
2. Measure the distance between the straight edges, staying perpendicular to the arm support reference plane.

Considerations:

- Arm support thickness is clinically relevant because it will impact the arm support height adjustment.

8 Lateral Support Dimensions

The figure below shows the three basic linear dimensions of a lateral support included in this section.

LATERAL SUPPORT LENGTH

Type of Measurement: Support Surface Linear, right and left

Description: The length of the lateral support from the top to the bottom edges.

End points used:

- Midpoint of the top edge of the contact surface side of the lateral support.
- Midpoint of the bottom edge of the contact surface side of the lateral support.

Definition: Linear distance between the top edge and the bottom edge of the contact surface side of the lateral support, measured parallel to the support reference plane at centerline.

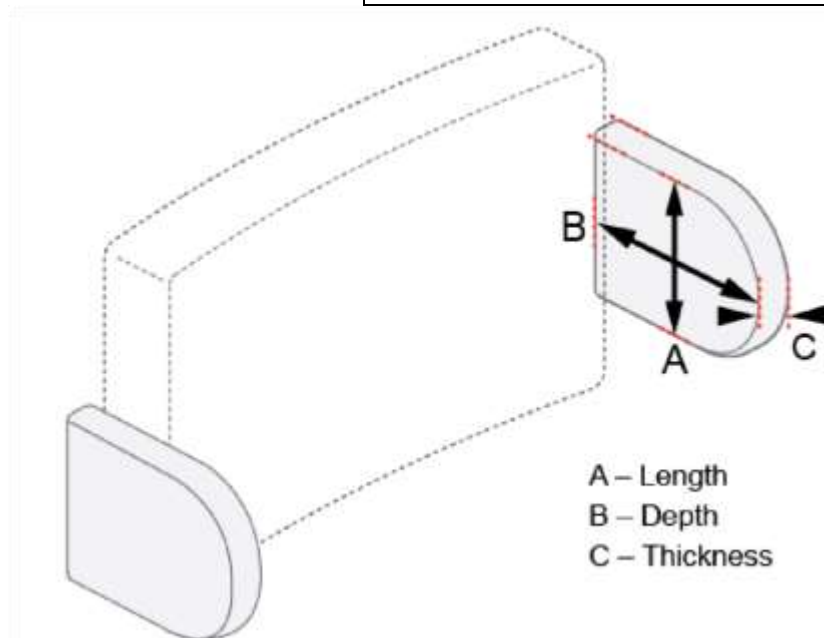
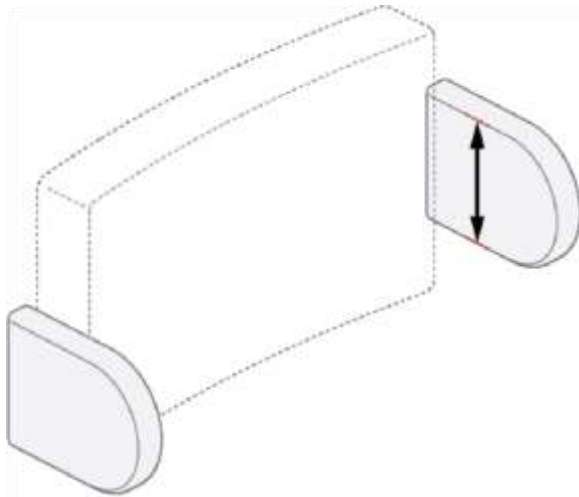


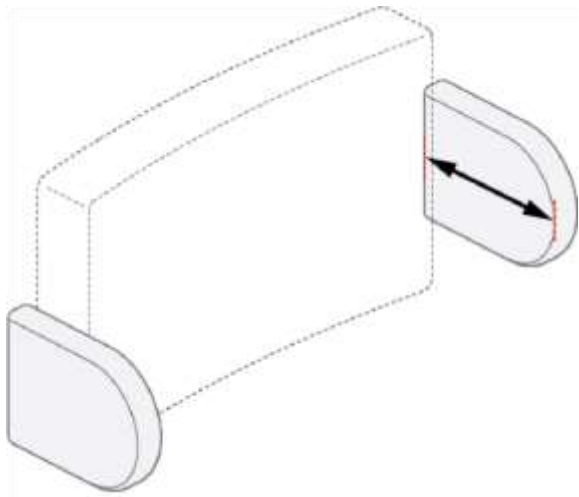
Fig. 5.36: Basic lateral support dimensions

8.1 Lateral support length

Fig. 5.37: Lateral support length



to the midpoint of the bottom edge, along the centerline of the contact surface side of the support, staying parallel to the support surface reference plane.



height. Lateral trunk support length is the actual size dimension from top to bottom of the support. Lateral trunk support height is a placement measure from the top of the seat support to the top edge of the lateral support.

8.2 Lateral support depth

Fig. 5.38: Lateral support depth

Sample procedure:

1. Locate the midpoints of the top and bottom edges on the contact surface side of the lateral support.
2. Measure the distance from the midpoint of the top edge

LATERAL SUPPORT DEPTH

Type of Measurement: Support Surface Linear, right and left

Description: The distance from the back to the front edges of the lateral support.

End points used:

- Midpoint of the back edge of the contact surface side of the lateral support.
- Midpoint of the front edge of the contact surface side of the lateral support.

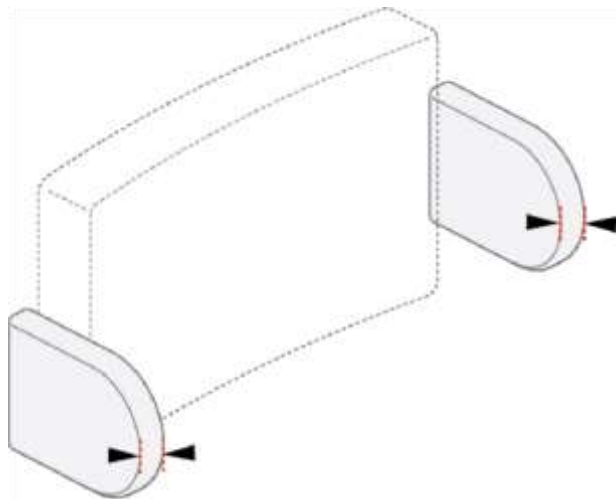
Definition: Linear distance from the back edge to the front edge of the contact surface side of the lateral support measured parallel to the support reference plane along the centerline.

Considerations:

- The above definition and procedure applies to any lateral support surface that is attached as a component in the body support system, and can include lateral trunk supports, lateral pelvic supports, lateral thigh or knee supports and lateral head supports.
- Note that in the case of a lateral trunk support, the lateral trunk support length is different than the lateral trunk support height.

Sample procedure:

1. Locate the midpoints of the front and back edges on the contact surface side of the lateral support.
2. Measure the distance from the midpoint of the rear edge to the midpoint of the front edge, along the centerline of the contact surface side of the lateral support, staying parallel to the support surface reference plane.



LATERAL SUPPORT THICKNESS

Type of Measurement: Support Surface Linear, right and left

Description: The thickness from the inside to outside surfaces of the lateral support component.

End points used:

- Outside surface of the front edge of the lateral support at centerline.
- Inside surface of the front edge of the lateral support at centerline.

Definition: Linear distance from the inside to outside of the lateral support, measured perpendicular to the support surface reference plane along the front edge at centerline.

Considerations:

- The above definition and procedure applies to any lateral support surface that is attached as a component in the body support system, and can include lateral trunk supports, lateral pelvic supports, lateral thigh or knee supports and lateral head supports.
- The linear body measurement which corresponds to the lateral trunk support depth and is typically used for its prescription is the trunk depth.

8.3 Lateral support thickness

Fig. 5.39: Lateral support thickness

Sample procedure:

1. Locate the midpoint of the front edge of the lateral support.
2. Measure the distance between the inner and outer surfaces of the lateral support component at the midpoint of the front edge, staying perpendicular to the support surface reference plane.

Considerations:

- The above definition and procedure applies to any lateral support surface that is attached as a component in the body support system, and can include lateral trunk supports, lateral pelvic supports, lateral thigh or knee supports and lateral head supports.
- Lateral pelvic, thigh or head support thickness may impact effective seat width, effective back support width and effective head support width.
- A custom contoured lateral support may have variable thickness. If it is clinically relevant to take the dimension at an alternate location than the midpoint of the front edge, add descriptive words to the term to indicate the alternate location. In this case, you can use curved calipers to measure the thickness at the particular location of interest.

9 Medial Support Dimensions

The figure below shows the three basic linear dimensions of a medial support included in this section.

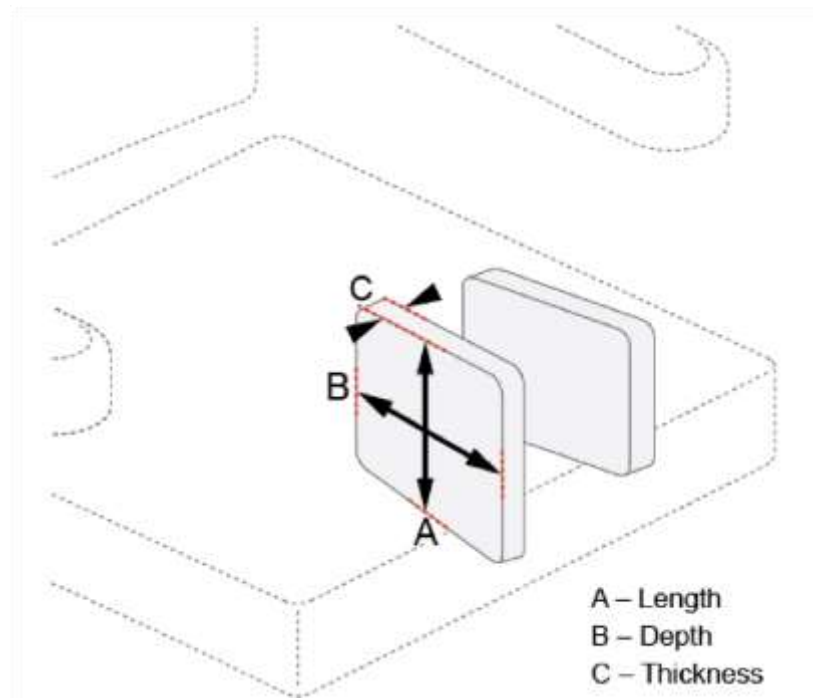
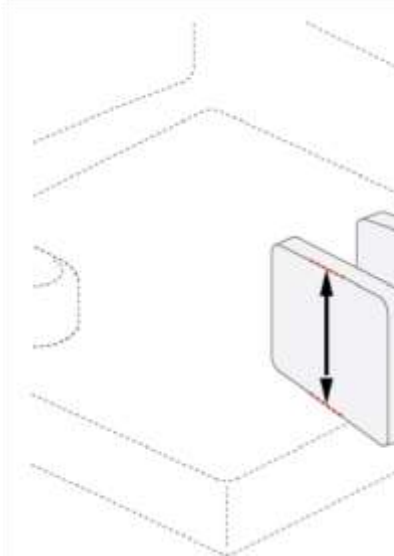


Fig. 5.40: Basic medial support dimensions

9.1 Medial support length



MEDIAL SUPPORT LENGTH

Type of Measurement: Support Surface Linear, right and left

Description: The length from the top to the bottom edges of the medial support.

End points used:

- Midpoint of the top edge of the contact surface side of the medial support.
- Midpoint of the bottom edge of the contact surface side of the medial support.

Definition: Linear distance between the top edge and the bottom edge of the contact surface side of the medial support, measured parallel to the support surface reference plane at centerline.

Fig. 5.41: Medial support length

Sample procedure:

1. Locate the midpoints of the top and bottom edges on the contact surface side of the medial support.
2. Measure the distance from the midpoint of the top edge to the midpoint of the bottom edge, along the centerline of the contact surface side of the support, staying parallel to the support surface reference plane.

MEDIAL SUPPORT DEPTH

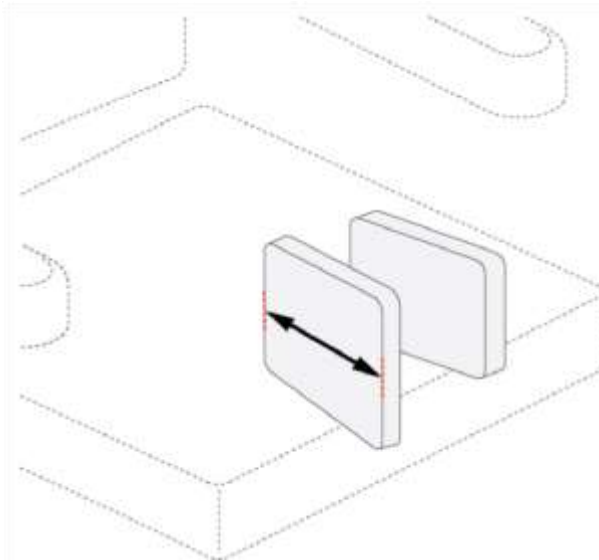
29 **Type of Measurement:** Support Surface Linear, right and left

Description: The distance from the back to the front edges of the medial support.

End points used:

- Midpoint of the back edge of the contact surface side of the medial support.
- Midpoint of the front edge of the contact surface side of the medial support.

Definition: Linear distance from the back edge to the front edge of the contact surface side of the medial support measured parallel to the support surface reference plane along the centerline.



Considerations:

- The above definition and procedure applies to any medial support that is attached as a component in the body support system, and can include medial thigh or knee supports, medial foot supports and medial forearm supports.
- Support of the medial aspects of both distal thighs is often accomplished with one support component having a right and left contact surface (often referred to as a “pommel”). If this type of medial thigh support is not symmetrical in shape, separate length measures may be necessary for the right and left contact surfaces.

9.2 Medial support depth

Fig. 5.42: Medial support depth

Sample procedure:

1. Locate the midpoints of the front and back edges on the contact surface side of the medial support.
2. Measure the distance from the midpoint of the rear edge to the midpoint of the front edge, along the centerline of the contact surface side of the medial support, staying parallel to the support surface reference plane.

Considerations:

- The above definition and procedure applies to any medial support surface that is attached as a component in the body support system, and can include medial thigh or knee supports, medial forearm supports or medial foot supports.
- Support of the medial aspects of both distal thighs is often accomplished with one support component having a right and left contact surface (often referred to as a ‘pommel’). If this type of medial thigh support is not symmetrical in shape, separate depth measures may be necessary for the right and left contact surfaces.
- The depth of a medial support needs to be taken into account so that there is adequate space for, and appropriate positioning of, the support hardware.

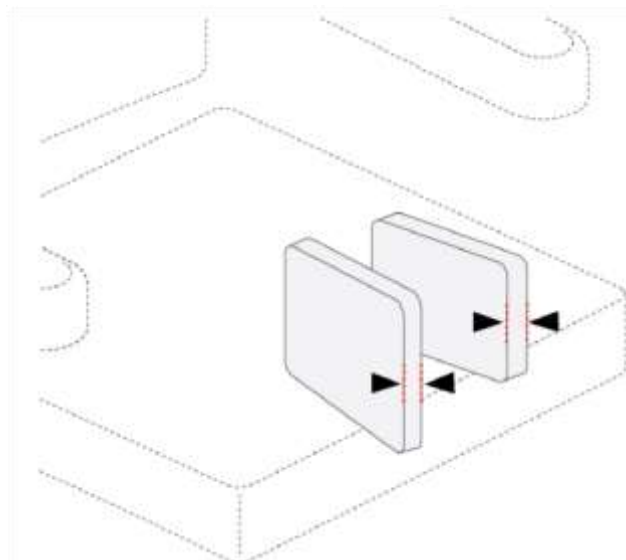


Fig. 5.43: Medial support thickness

MEDIAL SUPPORT THICKNESS

292 Type of Measurement: Support Surface Linear, right and left

Description: The thickness from the inside to outside surfaces of the medial support component.

End points used:

- Outside surface of the front edge of the medial support at centerline.
- Inside surface of the front edge of the medial support at centerline.

Definition: Linear distance from the inside to outside of the medial support, measured perpendicular to the support surface reference plane along the front edge at centerline.

9.3 Medial support thickness

Sample procedure:

1. Locate the midpoint of the front edge of the medial support.
2. Measure the distance between the inner and outer surfaces of the medial support component at the midpoint of the front edge, staying perpendicular to the support surface reference plane.

Considerations:

- The above definition and procedure applies to any medial support surface that is attached as a component in the body support system, and can include medial thigh or knee supports, medial forearm supports or medial foot supports.
- Support of the medial aspects of both distal thighs is often accomplished with one support component having a right and left contact surface (often referred to as a “pommel”). In this case, the thickness measurement would span between the right and left contact surfaces. If this type of medial knee support is not symmetrical in shape, thickness measurements at the front and back edges should be taken and noted.

10 Common Placement Measures

The figure below shows the six basic linear placement dimensions of a body support system which are included in this section.

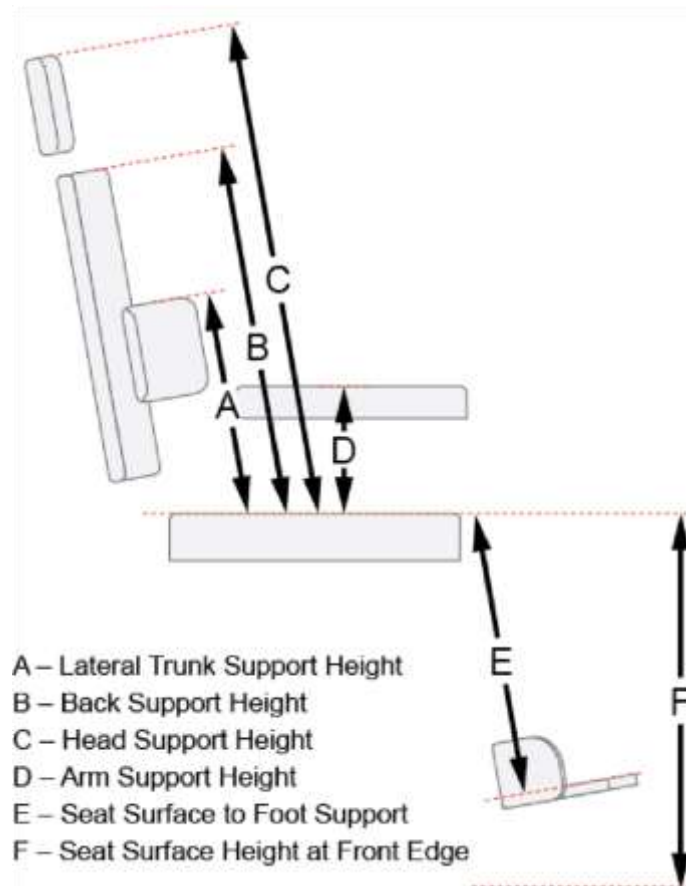
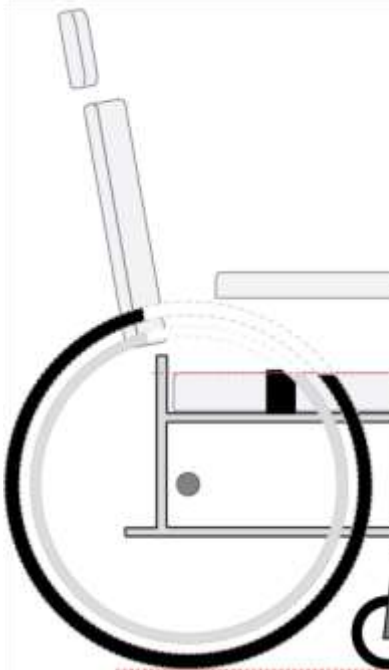


Fig. 5.44: Placement measures

10.1 Seat surface height at front edge



SEAT SURFACE HEIGHT AT FRONT EDGE

Type of Measurement: Support Surface Linear

Description: The distance from the floor to the top of the seat at front edge, in area intended for thigh loading.

End points used:

- Floor.
- Top surface of front edge of the seat, midway between lateral edge and the seat centerline.

Definition: Vertical distance from the floor to the top of the seat at its front edge, in the area intended for distal thigh loading.

Fig. 5.45: Seat surface height at front edge

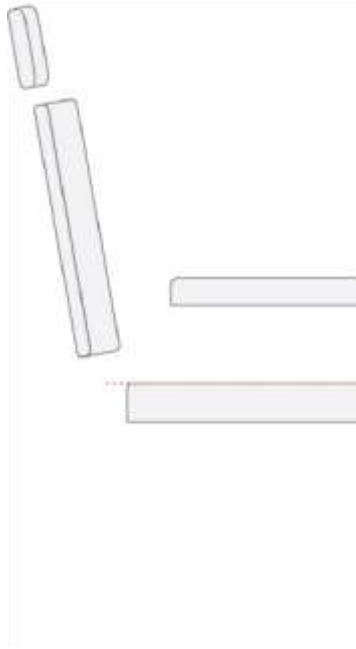
Sample procedure:

1. Locate one of the points on the front edge of the seat which is midway between the lateral edge of the seat and the seat centerline. (There will be two such points, representing the center of the concave regions intended to support the right and left thighs in a contoured seat.)
2. Measure the vertical distance from the floor to the top of the seat cushion at the location described above, keeping the tape measure perpendicular to the floor.
3. Note that if the front of the seat is flat (not contoured), then the measurement can be taken at any point along the top surface of the front edge of the seat.

Considerations:

- This measure is clinically relevant because it impacts the user's *overall* sitting height, clearance under tables, clearance of foot supports above casters or ground, and functional activities such as transfers.
- If the seat is part of a body support system with adjustable tilt, make sure that the system is brought to its fully upright position before taking this measurement.
- If significant compression of the seat at the front edge is noted during an initial assessment, it may be clinically useful to take this measurement with the seat loaded. This would provide a baseline measurement to document the current functional seat surface height, which can be related to the client's current transfer status or environmental access. In this case, note that the dimension was taken with seat loaded.
- In the case of a wheelchair with a fixed seat incline, commonly referred to as "dump", it is also useful to measure the distance from the floor to the top of the wheelchair seat pan or sling at both the front and rear, as this will determine the magnitude of the seat sagittal angle. It is recommended that these dimensions be reported as "seat pan/sling height at front edge" and "seat pan/sling height at rear edge", to differentiate these wheelchair frame measures from the seat surface height defined here.
- For example, wheelchair manufacturers will necessarily report the seat height to the top of the seat rail, seat pan or seat sling, as there is no seat cushion. You may also need to document a user's existing wheelchair seat pan/sling height if you are planning to provide a different seat cushion; this allows you to predict the subsequent seat surface height at front edge with a particular seat cushion thickness.
- The wheelchair seat pan/sling height at front edge, plus the inferior thigh support thickness will equal the seat surface height at front edge.

10.2 Seat surface to foot support



SEAT SURFACE TO FOOT SUPPORT

Type of Measurement: Support Surface Linear

Description: The distance from the top of the seat to the top of the foot support.

End points used:

- Top contact surface of front edge of the seat, midway between the lateral edge and the midpoint.
- Top contact surface of foot support, at back edge.

Definition: Linear distance from the top of the seat at its front edge to the back edge of the foot support contact surface, measured parallel to the lower leg support reference plane.

Fig. 5.46: Seat surface to foot support

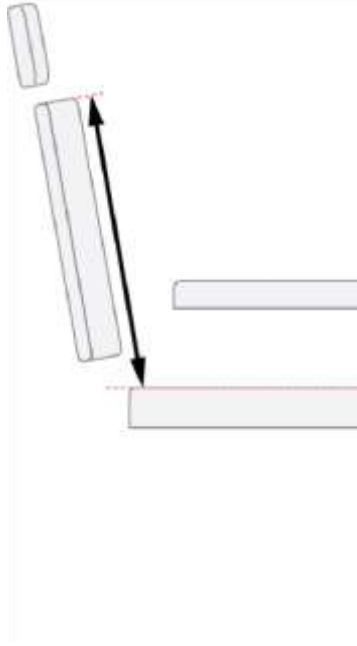
Sample procedure:

1. Locate the point on the front edge of the seat which is midway between the lateral edge and the midpoint. (There will be two such points, representing the center of the concave regions intended to support the right and left thighs).
2. Measure the distance from this point to the top of the foot support on the same side, at the back edge, staying parallel to the lower leg support reference plane (see Chapter 3, Section 1.5.3 for information on how to locate the lower leg support reference plane).

Considerations:

- The body measure that corresponds to the seat surface to foot support dimension is the lower leg length.
- This measure is clinically relevant because it can affect not only the degree of support provided to the user's foot, but also the user's three relative body segment angles (thigh to trunk angle, thigh to lower leg angle and lower leg to foot angle). Additionally, this dimension can impact the degree of contact and loading of the thighs on the seat cushion.
- In some situations, it may be necessary to measure and document the distance from the wheelchair seat rail or seat pan to the foot support. In this case, the dimension should be reported as "wheelchair seat pan to foot support".

10.3 Back support height



BACK SUPPORT HEIGHT

Type of Measurement: Support Surface Linear

Description: The distance from the top of the seat to the top of the back support.

End points used:

- Seat reference plane at centerline.
- Midpoint of top edge of the contact surface side of the back support.

Definition: Linear distance from the seat reference plane to the midpoint of the top edge of the back support contact surface, measured parallel to the back support reference plane along the centerline.

Fig. 5.47: Back support height

Sample procedure:

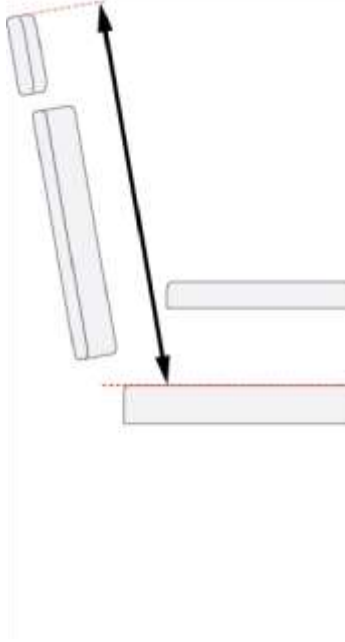
Note: A seat must be in place to measure the back support height.

1. Locate the point on the seat reference plane at the center of the back edge of the seat.
2. If the seat is contoured (making it difficult to identify the seat reference plane), use a point on the top surface of the back edge of the seat at centerline.
3. Locate the midpoint of the top edge of the contact surface side of the back support.
4. Measure the distance from the seat reference plane, or top of the seat at midpoint of back edge, to the top of the back support, along the back support centerline, keeping the tape measure parallel to the back support reference plane.

Considerations:

- The linear body measurements that correspond to the back support height and are typically used for its prescription are scapular height, axilla height, or shoulder height.
- It is important to note the difference between back support length and back support height. Back support length is the actual dimension of the back support cushion, whereas back support height represents the vertical location of the back support relative to the seat. Adjustment of the back support up or down will change the back support height, but not the back support length.
- In the case of a bi-angular back support, the upper back support portion's reference plane should be used for this measurement.
- With regard to interfacing with the wheelchair frame, it may also be helpful to measure the back support height from the wheelchair seat pan or rail, instead of from the seat surface as defined. In this case, the dimension should be clarified as "back support height from seat pan".

10.4 Head support height



HEAD SUPPORT HEIGHT

Type of Measurement: Support Surface Linear

Description: The distance from the top of the seat to the top of the head support.

End points used:

- Seat reference plane at centerline.
- Midpoint of top edge of the contact surface side of the head support.

Definition: Linear distance from the seat reference plane to the midpoint of the top edge of the head support contact surface, measured parallel to the back support reference plane and head support centerline.

Fig. 5.48: Head support height

Sample procedure:

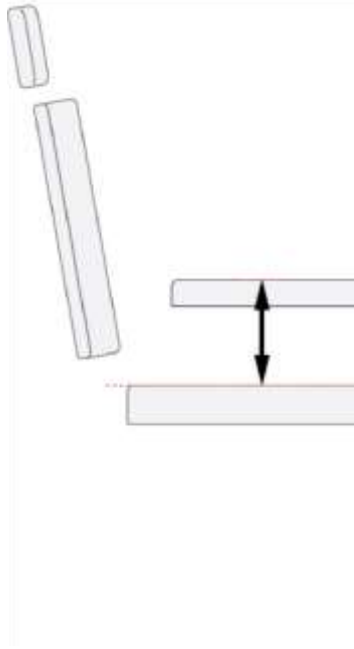
Note: A seat must be in place to measure the head support height.

1. Locate the point on the seat reference plane at the center of the back edge of the seat.
2. If the seat is contoured (making it difficult to identify the seat reference plane), use a point on the top surface of the back edge of the seat at centerline.
3. Locate the midpoint of the top edge of the contact surface side of the head support.
4. Measure the distance from the seat reference plane, or top of the seat at midpoint of back edge, to the top of the head support at centerline, keeping the tape measure parallel to the back support reference plane and parallel to the head support vertical centerline.

Considerations:

- It is important to note the difference between head support length and head support height. Head support length is the actual dimension of the head support from bottom to top edge, whereas head support height represents the vertical location of the head support relative to the seat. Adjustment of the head support up or down will change the head support height, but not the head support length.
- With regard to interfacing with the wheelchair frame, it may also be helpful to measure the head support height from the wheelchair seat pan, sling or rail, instead of from the seat surface as defined. In this case, the dimension should be clarified as “head support height from seat pan”.

10.5 Arm support height



ARM SUPPORT HEIGHT

Type of Measurement: Support Surface Linear, right and left

Description: The distance from the top of the seat to the top of the arm support surface.

End points used:

- Seat reference plane.
- Midpoint of lateral edge of the arm support contact surface.

Definition: Linear distance from the seat reference plane to the top contact surface of the arm support, measured perpendicular to the seat reference plane at the center of the arm support.

Fig. 5.49: Arm support height

Sample procedure:

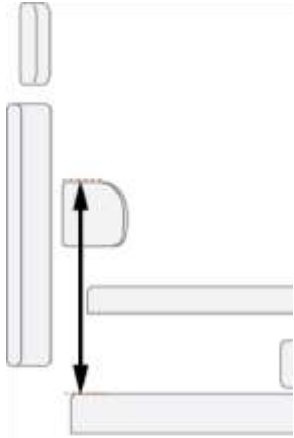
Note: A seat must be in place to measure the arm support height.

1. Locate the midpoint of the lateral edge of the contact surface side of the arm support.
2. Locate the point on the seat reference plane directly below this point.
3. If the seat is contoured (making it difficult to identify the seat reference plane), use a point on the top surface of the lateral edge of the seat below the arm support reference point.
4. Measure the distance from the top of the seat to the top of the arm support at its lateral edge midpoint, keeping the tape measure perpendicular to the seat reference plane.

Considerations:

- The body measure that corresponds to the arm support height and is typically used for its prescription is elbow height.
- This measure is clinically relevant because it can affect the degree of contact and weight bearing on the arm support, which can secondarily impact loading on the seat cushion. It can also impact the user's posture, comfort and function.
- In some situations it may be helpful to document the height of the arm support from the wheelchair seat pan or rail, instead of from the seat surface as defined. In this case, the dimension should be measured and reported as "arm support height from seat pan".
- In the case of a wheelchair with adjustable tilt or recline, adjust the seat and back support to their most upright position before taking the arm support height measurement.

10.6 Lateral trunk support height



LATERAL TRUNK SUPPORT HEIGHT

Type of Measurement: Support Surface Linear, right and left

Description: The distance from the top of the seat to the top of the lateral trunk support.

End points used:

- Seat reference plane at centerline.
- Most posterior point on top edge of the contact surface side of the trunk support.

Definition: Linear distance from the seat reference plane to the rear, top edge of the lateral trunk support contact surface, measured parallel to the back support reference plane and parallel to the back support vertical centerline.

Fig. 5.50: Lateral trunk support height

Sample procedure:

Note: A seat must be in place to measure the lateral trunk support height.

1. Locate the point on the seat reference plane at the center of the back edge of the seat.
2. If the seat is contoured (making it difficult to identify the seat reference plane), use a point on the top surface of the back edge of the seat at centerline.
3. Locate the most posterior point on the top edge of the contact surface side of the lateral trunk support. Using a straight edge or ruler, project this point medially over the centerline of the seat.
4. Measure the distance from the seat reference plane, or top of the seat at midpoint of lateral trunk edge, up to the top of the lateral trunk support (as represented by the straight edge), keeping the tape measure parallel to the back support reference plane and vertical centerline.

Considerations:

- The linear body measurements that correspond to the lateral trunk support height and are typically used for its prescription are scapular height or axilla height.
- It is important to note the difference between lateral trunk support length and lateral trunk support height. Lateral trunk support length is the actual dimension of the lateral trunk support device, whereas lateral trunk support height represents the vertical location of the lateral trunk support relative to the seat. Adjustment of the lateral trunk support up or down will change the lateral trunk support height, but not the lateral trunk support length.
- With regard to interfacing with the wheelchair frame, it may also be helpful to document the lateral trunk support height from the wheelchair seat pan or rail, instead of from the seat surface as defined. In this case, the dimension should be clarified as "lateral trunk support height from seat pan".

11 References

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APPENDIX A: PELVIC MOTION IN THE THREE REFERENCE PLANES

Conventional medical terminology for joint motion is defined by the plane in which the movement occurs. The axis of rotation around which a body segment moves is always perpendicular to the plane in which the movement occurs. For example, during hip flexion and extension motions, the thigh segment is moving in the sagittal plane and rotating around a medial-lateral axis which projects through the hip joint and is perpendicular to the sagittal plane of movement. If we use the pelvis as an example, pelvic movement in the sagittal plane is typically referred to as anterior/posterior pelvic tilt. Pelvic tilt is defined as rotation of the pelvis in the sagittal (XY) plane, about the Z axis (Fig A.1). The axis around which the segment is rotating is the one you do not see (since it is pointing straight towards you when you are viewing that plane).

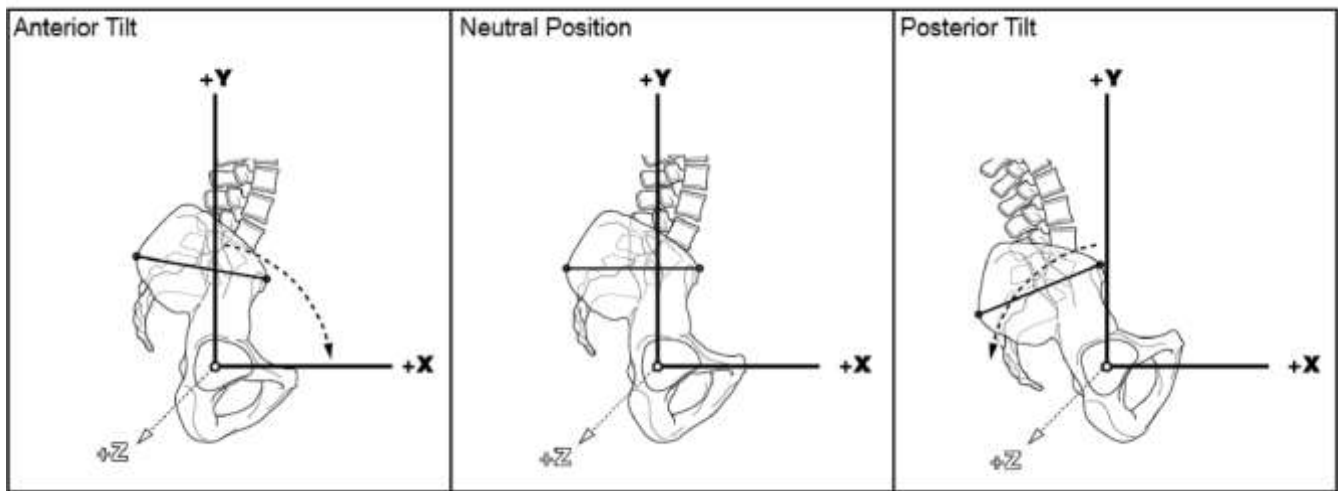


Fig. A.1: Pelvic movement in sagittal plane (side view)

Likewise, rotation of the pelvis in the frontal (YZ) plane gives rise to what is commonly called pelvic obliquity (Fig. A.2). Pelvic movement in this plane occurs around the X axis, which is the axis pointing straight toward you when you are viewing the person from the front.

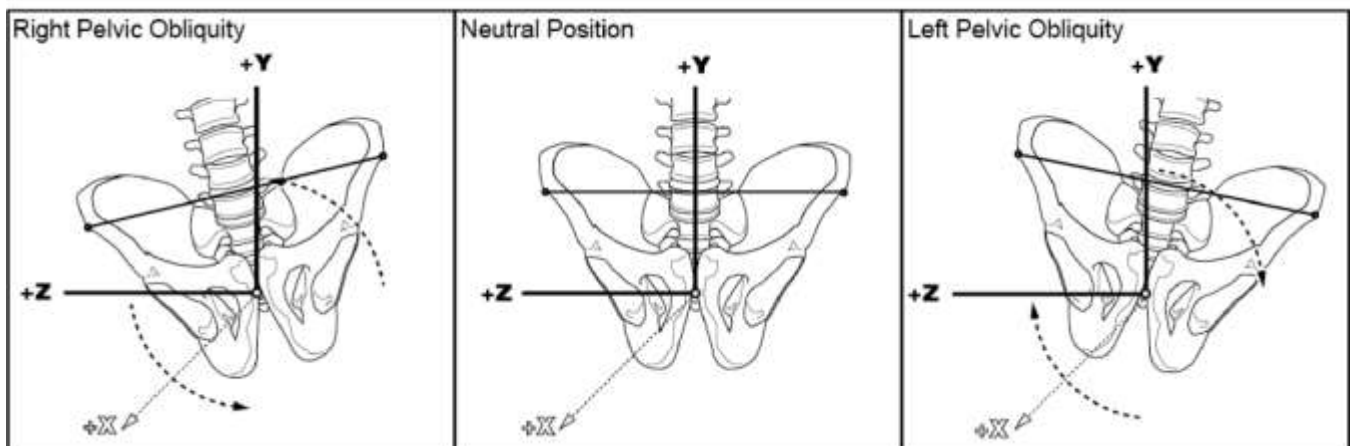


Fig. A.2: Pelvic movement in frontal plane (front view)

Rotation of the pelvis in the transverse plane, commonly described as pelvic rotation (Fig. A.3), involves movement in the transverse (XZ) plane around the Y axis, which is the axis pointing up towards you when viewing the person from above.

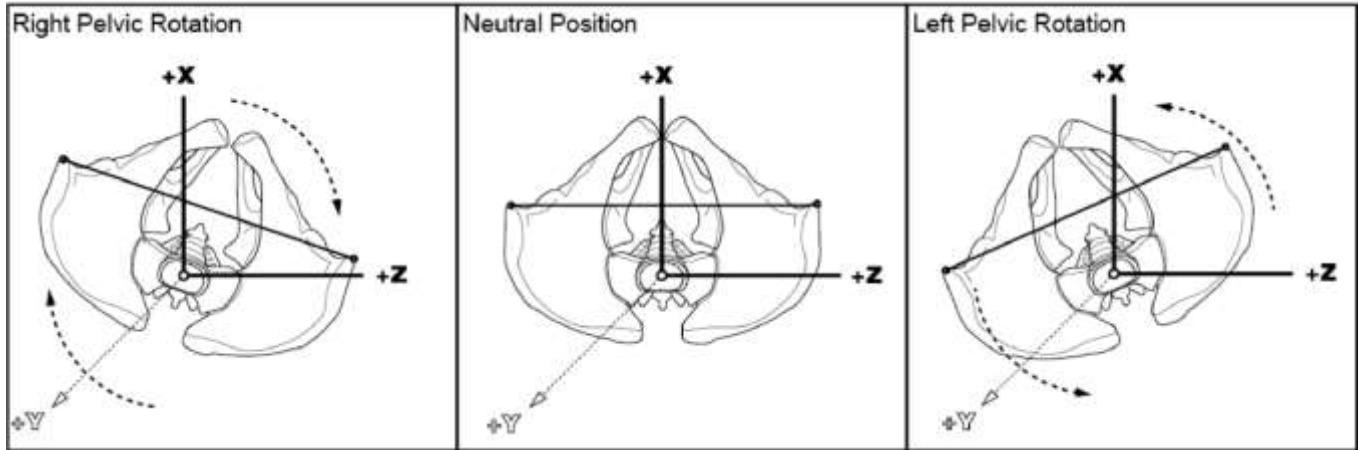


Fig. A.3: Pelvic movement in transverse plane (top view)

APPENDIX B: TERMS AND DEFINITIONS OF BODY SEGMENT LINES AND BODY LANDMARKS IN THE THREE REFERENCE PLANES

The following three tables include a complete list all of the body segment lines, the body landmarks that define the line, and an anatomical description of each body landmark. Table 1 lists body segment lines and landmarks in the sagittal plane/view, Table 2 lists body segment lines and landmarks in the frontal plane/view, and Table 3 lists body segment lines and landmarks in the transverse plane/view. These tables were adapted from the ISO 16840-1: 2006 standard [1]. The definitions of some body segment lines and descriptions of landmarks were updated according to the anticipated revisions to the standard and recent research ongoing in Japan and the U.S. regarding body landmark identification [2].

Table 1: Terms and definitions of body segment lines and body landmarks in the SAGITTAL PLANE
(Figs. B.1 and B.2)

Segment line term and definition	Body Landmarks defining the segment line	Figure	Anatomical description of landmark
Sagittal head line (Fig. B.2a) line passing through the tracion and the eye corner on same side	Tracion	Fig. B.1	The most anterior superior notch of the ear, located at the upper edge of the external auditory meatus
	Eye corner	Fig. B.1	Lateral corner of eye formed by the meeting of the upper and lower eyelids (ectocanthus)
Sagittal neck line (Fig. B.2a) line passing through the lateral upper and lower neck points on same side	Lateral upper neck point ^a	Fig. B.1	A point located by calculation [1] and projected to the lateral surface of the neck. <i>Location can be approximated by:</i> Lowest point on the lateral surface of the mastoid process
	Lateral lower neck point ^a	Fig. B.1	A point located by calculation [1] and projected to the lateral surface of the neck <i>Location can be approximated by:</i> The most anterior point on the acromion process if shoulder complex is well aligned with the trunk. The center point of a line between the C7 spinous process and the upper sternal notch
Sagittal upper trunk line (Fig. B.2c) line passing through the lateral lower neck point and the iliac crest point on same side	Lateral lower neck point ^a	Fig. B.1	See above
	iliac crest point	Fig. B.1	The point at which a perpendicular to the sagittal pelvic line (see below) crosses the iliac crest

Sagittal pelvic line (Figs. B.2a, B.2b and B.2c) line passing through the ASIS and PSIS on same side	ASIS	Fig. B.1	Most anterior inferior prominence of the right ASIS
	PSIS	Fig. B.1	The lowest point on the posterior surface of the PSIS
Sagittal trunk line (Figs. B.2a and B.2c) line passing through the lateral lower neck point and the lateral hip center point on same side	Lateral lower neck center point ^a	Fig. B.1	See above
	Lateral hip center point ^a	Fig. B.1	A point located by calculation [1] and projected to the lateral surface of the hip <i>Location can be approximated by:</i> The most anterior point on the lateral surface of the greater trochanter
Sagittal thigh line (Fig. B.2a) line passing through the lateral hip center point and the lateral femoral condyle on same side	Lateral hip center point ^a	Fig. B.1	See above
	Lateral femoral condyle	Fig. B.1	Point at most lateral aspect of the lateral femoral condyle
Sagittal lower leg line (Fig. B.2a) line passing through the lateral femoral condyle and the lateral malleolus on same side	Lateral femoral Condyle	Fig. B.1	See above
	Lateral malleolus	Fig. B.1	Point at most lateral aspect of lateral malleolus
Sagittal foot line (Fig. B.2a) line passing through the lateral heel and toe points of same foot	Lateral heel point	Fig. B.1	Intersection of sagittal leg line and plantar surface of the foot
	Lateral toe point	Fig. B.1	Lateral distal protuberance of 5th metatarsal
Sagittal upper arm line (Fig. B.2b) line passing through the lateral shoulder center point and the lateral humeral epicondyle on same side	Lateral shoulder center point ^a	Fig. B.1	A point located by calculation [1] and projected to the lateral surface of the humerus just below the acromion process <i>Location can be approximated by:</i> Most lateral aspect of the acromion process
	Lateral humeral epicondyle	Fig. B.1	Most lateral aspect of lateral humeral epicondyle
Sagittal forearm line (Fig. B.2b) line passing through the lateral humeral epicondyle and the lateral wrist point on same side	Lateral humeral epicondyle	Fig. B.1	See above
	Lateral wrist point	Fig. B.1	Inferior aspect of styloid process with forearm in full pronation
Sagittal hand line (Fig. B.2b)	Lateral wrist point	Fig. B.1	See above

line passing through the lateral wrist point and lateral hand point	Lateral hand point	Fig. B.1	Lateral point of fifth metacarpal-phalangeal joint
a Denotes landmarks located by calculation, all others are located by palpation.			

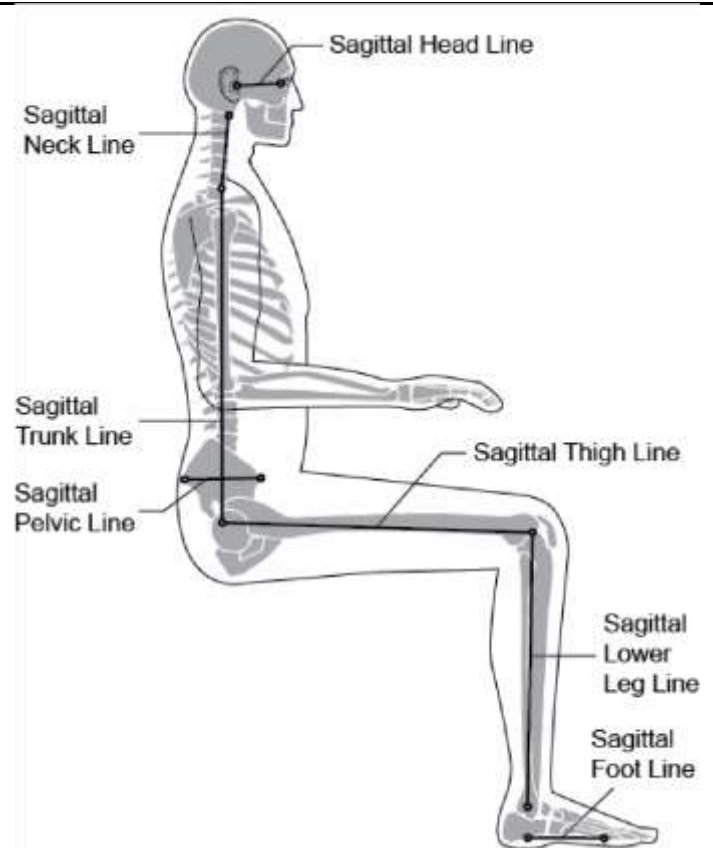
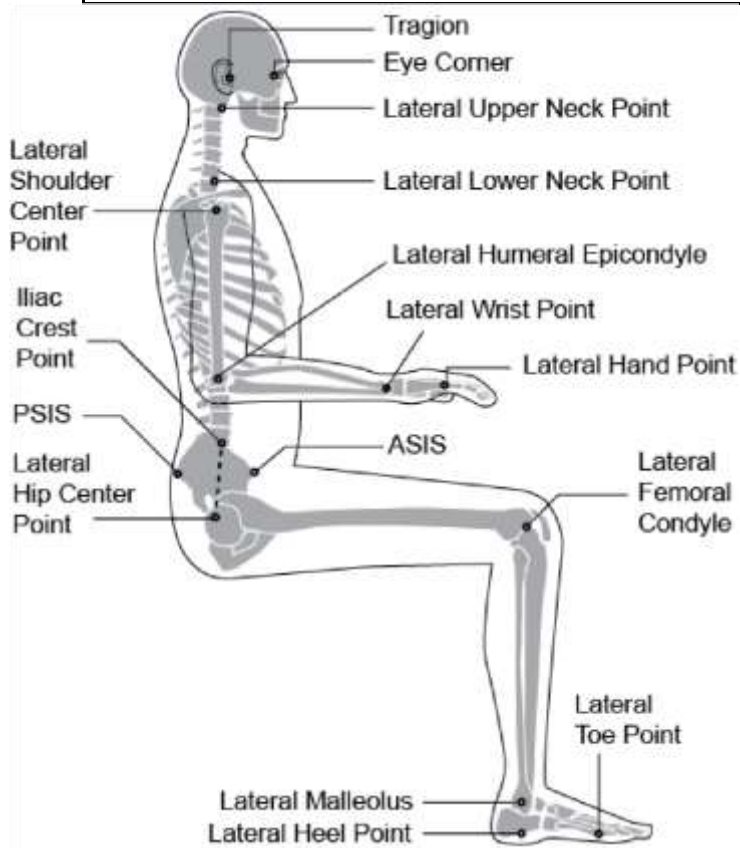


Fig. B.1: Sagittal body landmarks

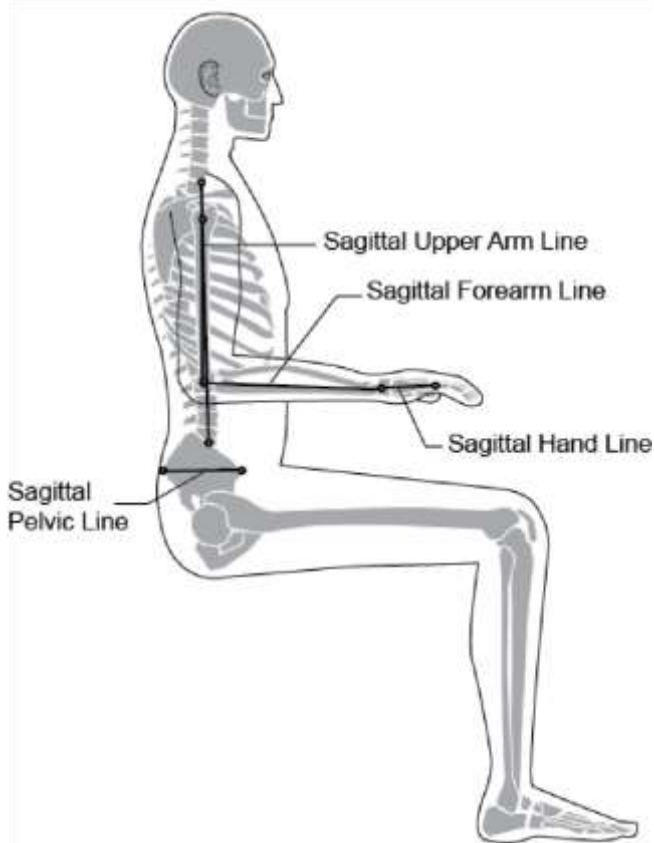


Fig. B.2a: Sagittal body segment lines

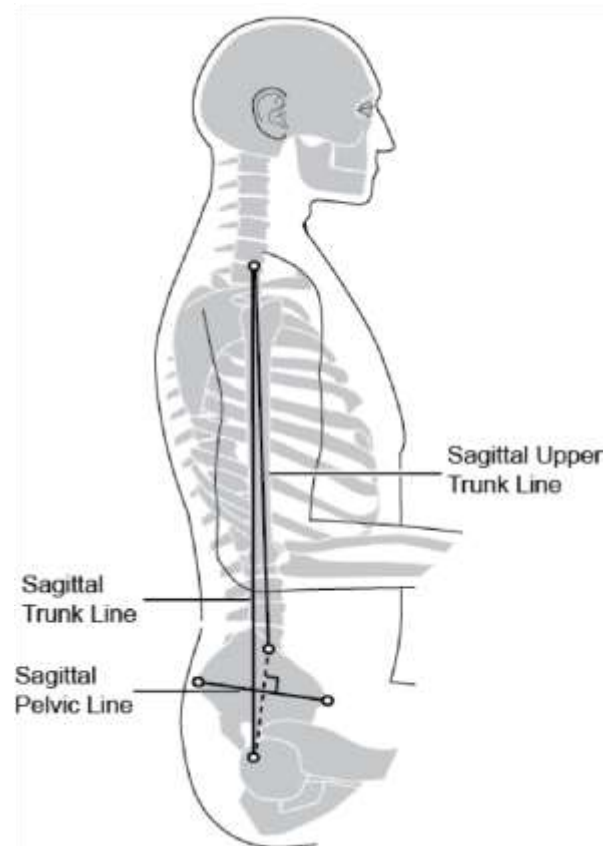


Fig. B.2b: Sagittal body segment lines, arms

Fig. B.2c: Sagittal body segment lines, trunk

Table 2: Terms and definitions of body segment lines and body landmarks in the FRONTAL PLANE (FIGS. B.3 AND B.4)

Segment line term and definition (Figs. B.4a and B.4b)	Body Landmarks defining the segment line	Figure	Anatomical description of landmark
Frontal head line (Fig B.4a) line passing between the right and left eye corners	Right eye corner	Fig. B.3a	Lateral corner of the right eye formed by the meeting of the upper and lower eyelids (ectocanthus)
	Left eye corner	Fig. B.3a	Lateral corner of the left eye formed by the meeting of the upper and lower eyelids (ectocanthus)
Frontal neck line (Fig. B.4a) line passing through the upper and lower neck points (approximately base of nose to suprasternal notch)	Upper neck point ^a	Fig. B.3a	The calculated upper neck center [1] projected to the anterior surface <i>Location can be approximated by:</i> the base of the nose
	Lower neck point ^a	Fig. B.3a	The calculated lower neck center [1] projected horizontally to the anterior surface (just above the suprasternal notch)

Frontal trunk line (Fig. B.4b) line passing through the upper sternal notch and the ASIS midpoint	Upper sternal notch	Fig. B.3a	Midpoint of the anterior surface at the top of the sternum (suprasternal notch)
	ASIS midpoint ^a	Fig. B.3a	Midpoint of the line between the right ASIS and left ASIS
Frontal sternum line (Fig. B.4a) line passing through the upper sternal notch and the lower sternal notch	Upper sternal notch	Fig. B.3a	Midpoint of the anterior surface at the top of the sternum (suprasternal notch)
	Lower sternal notch	Fig. B.3a	Midpoint of the anterior surface of the lower end of the sternum at the level of the base of the rib cage
Frontal pelvic line (Figs. B.4a and B.4b) line passing through the right ASIS and left ASIS	Right ASIS	Fig. B.3a	The most anterior inferior prominence of the right anterior superior iliac spine projected to the anterior surface of the body
	Left ASIS	Fig. B.3a	The most anterior inferior prominence of the left anterior superior iliac spine projected to the anterior surface of the body
	ASIS midpoint	Fig. B.3a	Midpoint of the line between the right ASIS and left ASIS
Frontal lower leg line (Fig. B.4a) line passing through the anterior knee and ankle points	Anterior knee point	Fig. B.3a	Midpoint between medial and lateral femoral condyles projected to anterior surface of the knee (approximately mid-patellae)
	Anterior ankle point	Fig. B.3a	Midpoint between lateral and medial malleoli projected to the anterior surface of the ankle
Frontal foot line (Fig. B.4a) line passing through the medial and lateral foot points (on plantar surface of the foot)	Medial foot point	Fig. B.3a	Inferior border of the head of the 1 st metatarsal
	Lateral foot point	Fig. B.3a	Inferior border of the head of the 5 th metatarsal

Frontal upper arm line (Fig. B.4b) line passing through the anterior shoulder and elbow points	Right and left anterior shoulder points	Fig. B.3b	Front of the shoulder at the bicipital groove, left and right arms
	Right and left anterior elbow points	Fig. B.3b	Midpoint between medial and lateral humeral epicondyles in the cubital fossa, left and right arms
Frontal hand line (Fig. B.4b) line passing through the lateral and medial hand points at the level of the superior hand points	Lateral hand point	Fig. B.3b	Lateral point of the fifth metacarpal-phalangeal joint
	Medial hand point	Fig. B.3b	Medial point of the second metacarpal-phalangeal joint
	Superior hand point	Fig. B.3b	Base of the third metacarpal-phalangeal joint (center of rotation for the hand segment)

^a Denotes landmarks located by calculation. All others are located by palpation.

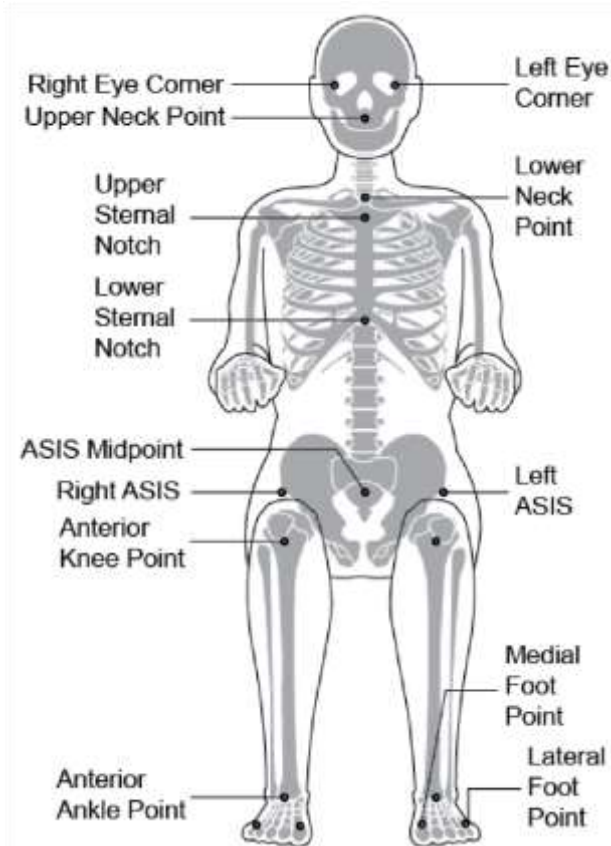


Fig. B.3a: Frontal body landmarks

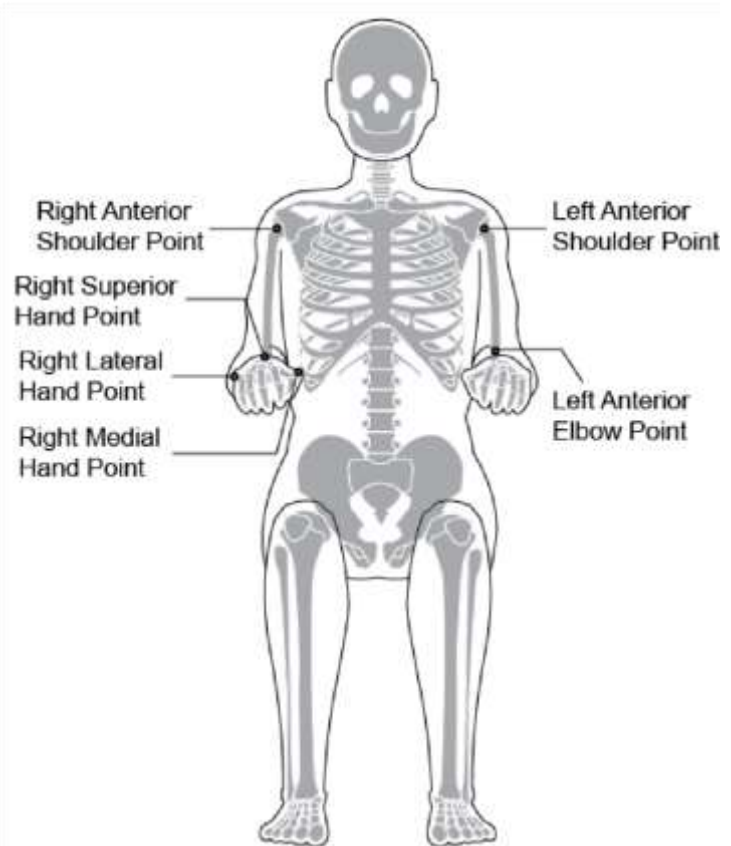


Fig. B.3b: Frontal body landmarks, arms

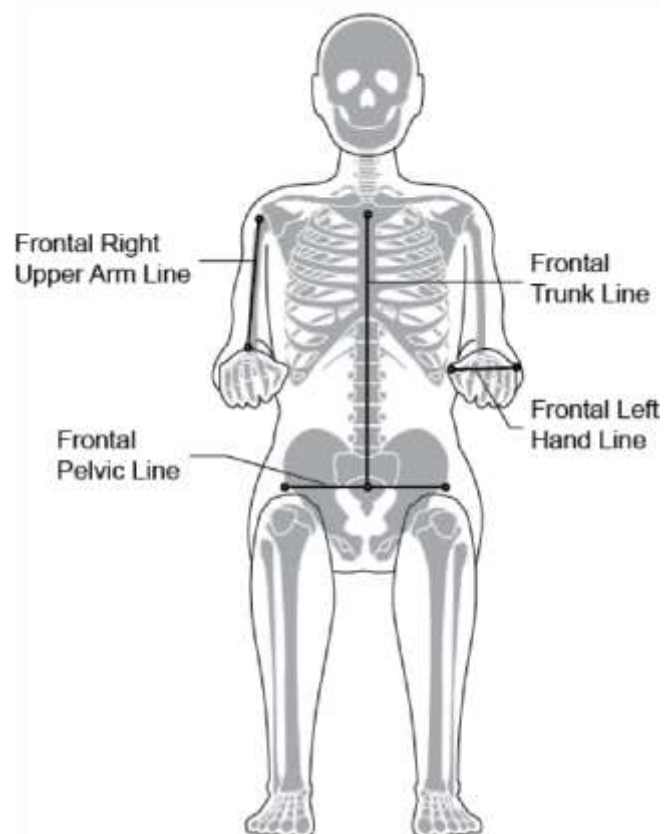
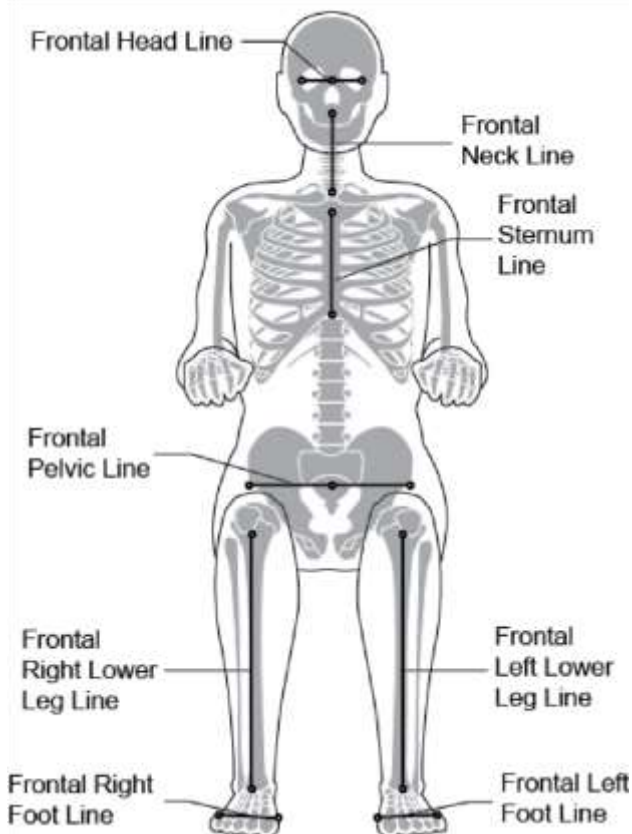


Table 3: Terms and definitions of body segment lines and body landmarks in the TRANSVERSE PLANE (Figs. B.5 and B.6)

Segment line term and definition (Figs B.6a and B.6b)	Body Landmarks defining the segment line	Figure	Anatomical description of landmark
Transverse head line (Fig. B.6a) line passing through the right and left tragions	Right tragon	Fig. B.5a	The most anterior superior notch of the right ear, located at the upper edge of the external auditory meatus
	Left tragon	Fig. B.5a	The most anterior superior notch of the left ear, located at the upper edge of the external auditory meatus
Transverse trunk line (Fig. B.6a) line passing through the right and left acromion points	Right Acromion Point	Fig. B.5a	The most anterior lateral prominence of the right acromion process
	Left Acromion Point	Fig. B.5a	The most anterior lateral prominence of the left acromion process
Transverse pelvic line (Fig. B.6b) line passing through the right and left ASIS's	Right ASIS	Fig. B.5b	The most anterior inferior prominence of the right anterior superior iliac spine
	Left ASIS	Fig. B.5b	The most anterior inferior prominence of the left anterior superior iliac spine
Transverse thigh line (Fig. B.6b) line passing through the ASIS and superior knee point on the same side	ASIS	Fig. B.5b	See above
	Superior knee point	Fig. B.5b	Midpoint between medial and lateral femoral condyles projected to the superior surface of the knee
Transverse foot line (Fig. B.6b) line passing through the anterior ankle point and the superior toe point	Anterior ankle point	Fig. B.5b	Midpoint of line between malleoli projected to anterior surface of ankle joint
	Superior toe point	Fig. B.5b	Midpoint between base of 2 nd and 3 rd metatarsal heads
Transverse forearm line (Fig. B.6a) line passing through the anterior elbow point and the superior wrist point	Anterior elbow point	Fig. B.5a	Midpoint on line between medial and lateral humeral epicondyles in cubital fossa
	Superior wrist point	Fig. B.5a	Midpoint between ulnar and radial styloids with fully pronated forearm projected to superior surface of wrist
Transverse hand line	Superior wrist point	Fig. B.5a	See above

(Fig. B.6a)

line passing through the
superior wrist and hand
points

Superior hand point

Fig. B.5a

Base of the third finger (3rd MCP joint)

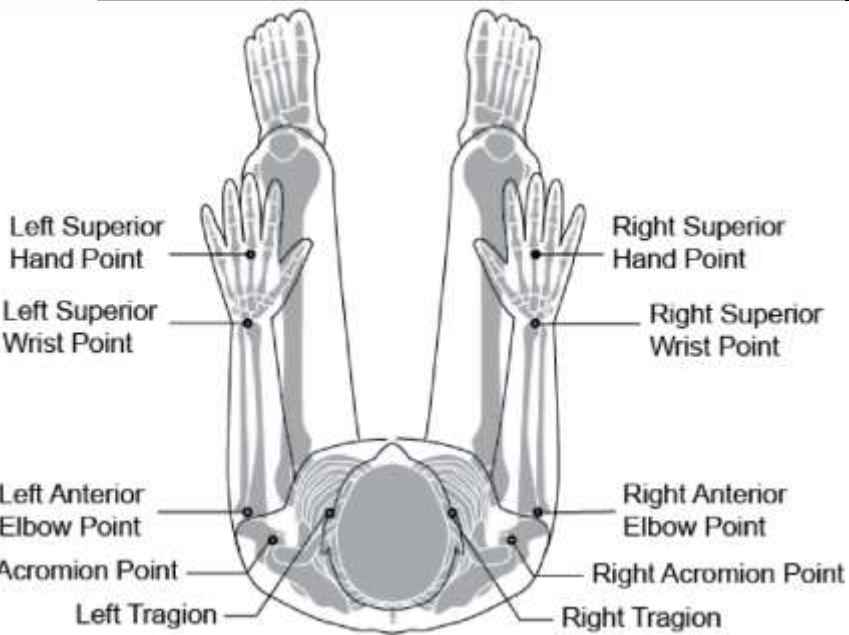


Fig. B.5a: Transverse body landmarks, upper body

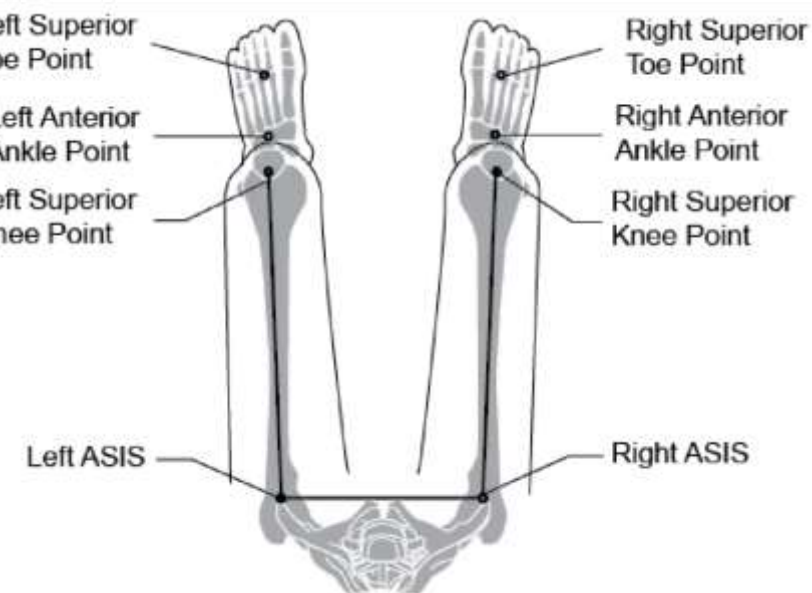


Fig. B.5b: Transverse body landmarks, lower body

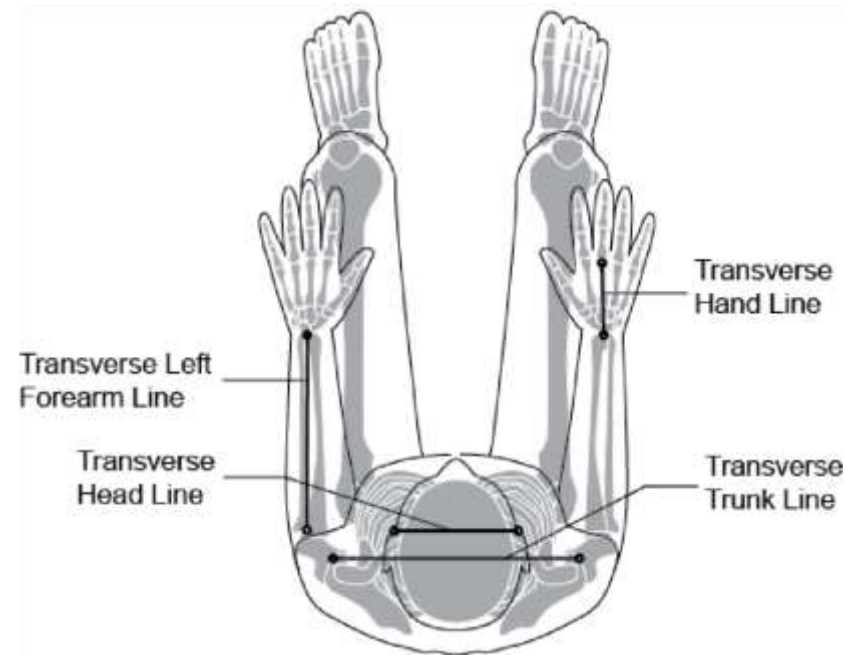


Fig. B.6a: Transverse body segments lines, upper body

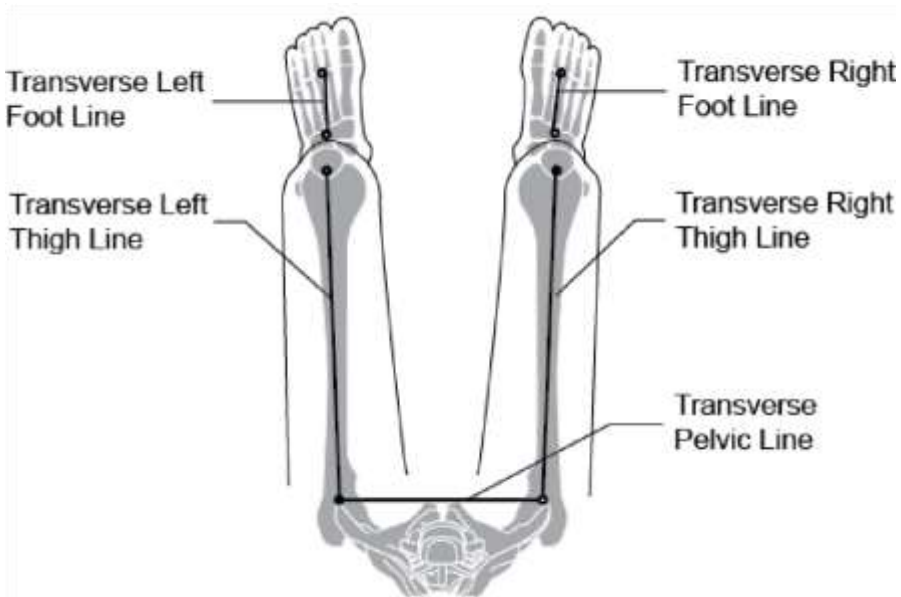


Fig. B.6b: Transverse body segment lines, lower body

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1. ISO 16840 (2006): *Wheelchair Seating, Section 1 - Vocabulary, reference axis convention and measures for body posture and postural support surfaces*, International Organization for Standardization, TC-173, SC-1, WG-11.
2. Handa, T., Hirose, H., Crane, B. and Furui, T. (2013). Refined Landmarks and Their Assessment for Seated Posture Measurement, ***Proceedings of the 29th International Seating Symposium: Building the Future***, 5-9 March 2013. Nashville, TN.

APPENDIX C: AUXILIARY GLOBAL REFERENCE SYSTEMS

In addition to the Wheelchair Axis System (WAS), the ISO 16840-1:2006 standard also defines two additional global coordinate systems: an axis system for the body support system as a whole – called a **Support Surface Axis System (SSAS)**, shown in Fig. C.1 and an axis system for the seated person's body as a whole – called a **Seated Anatomical Axis System (SAAS)**, shown in Fig. C.2. The direction of the X, Y and Z axes is the same in all three global axis systems. The only difference in the three systems is the location of the origins. Because each of these coordinate systems has a defined and different origin, this allows the linear location of the SAAS and SSAS to be compared to each other or to the WAS. This allows the positions of the wheelchair, support surfaces and person to be related to each other, if desired. However, the SSAS is used as a reference for determination of the location measures of support surfaces defined in the ISO 168401:2006 standard, but not included in this guide (see Appendix D). The SAAS and SSAS are not required for the determination of the angular and linear measures included in this guide.

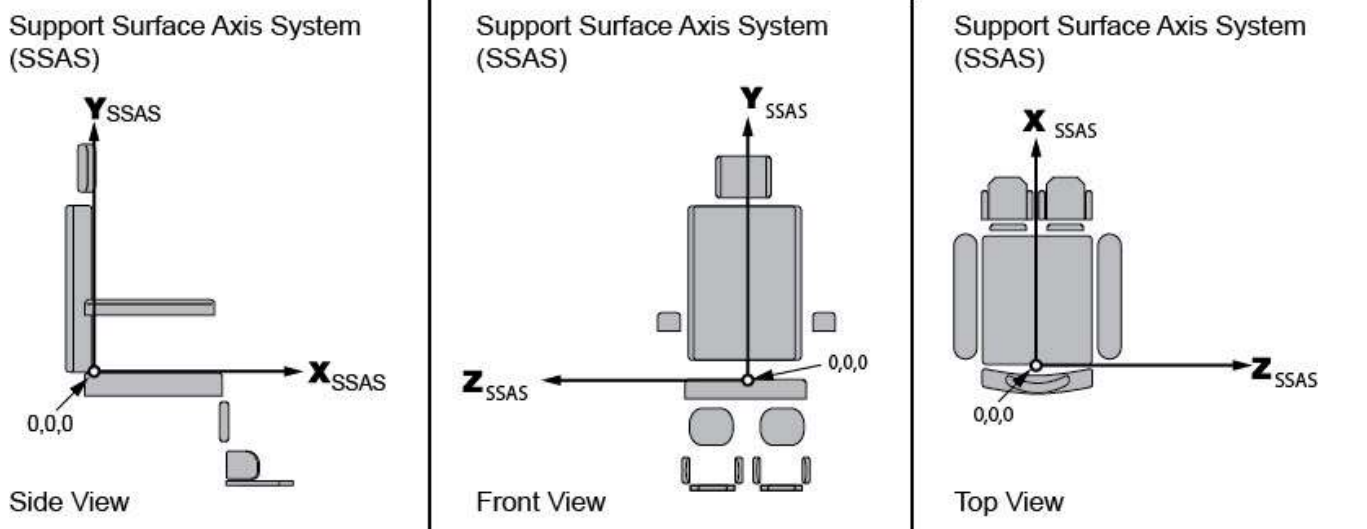


Fig. C.1: Support Surface Axis System (SSAS)

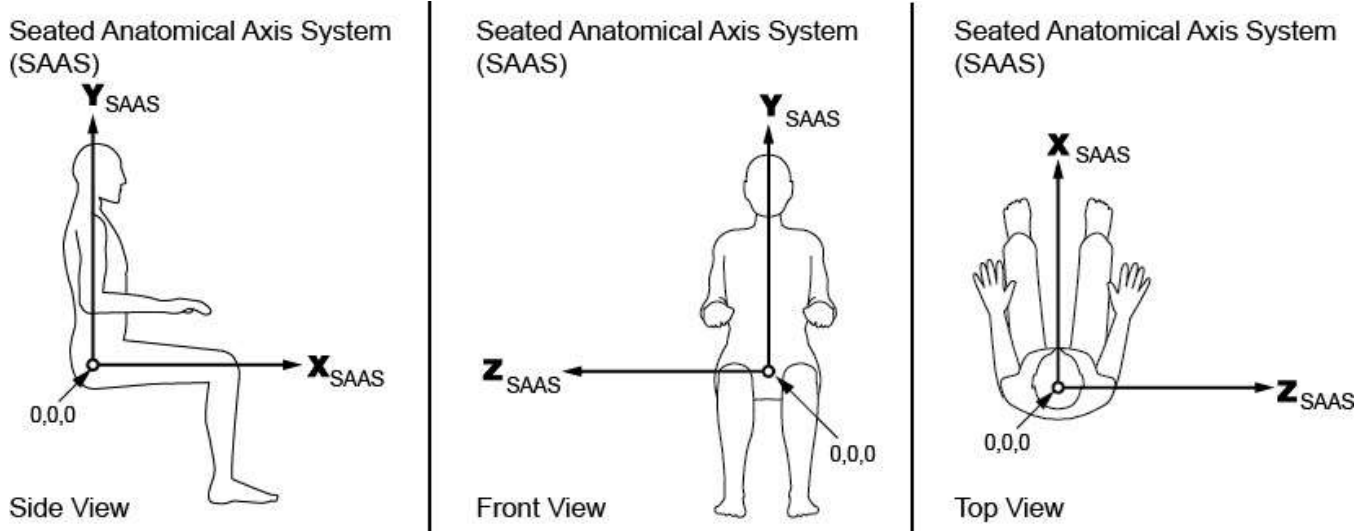


Fig. C.2: Seated Anatomical Axis System (SAAS)

APPENDIX D: LINEAR LOCATION MEASURES OF SEATING SUPPORT SURFACES

It is clinically necessary to be able to define and specify the location of support surfaces, especially secondary support surfaces, as this determines where the support is attached to the body support system and subsequently where it contacts the seated person's body. Individual practitioners, suppliers and technicians have developed their own terms and diagrams to communicate this information with each other because the field lacks a standardized method of defining the location of supports. For example, how does one specify the location of a medial knee support along the front edge of the seat if it is not at centerline, or the medial/ lateral location of a head support if it is not at centerline? How do you specify the vertical location of a lateral trunk support, and what do you call this measure? Note that these location measures are different than the linear size dimensions of length, width, depth and thickness defined in Chapter 5. In addition to these size dimensions, Chapter 5 also defines terms for six “placement” measures, which can be used to specify the vertical location of the seat, back support, head support, arm support, foot support and lateral trunk support. These measures are called *seat surface height at front edge*, *seat surface to foot support*, *back support height*, *head support height*, *arm support height*, and *lateral trunk support height*.

The ISO 16840-1: 2006 standard provides an alternative method for specifying the location of postural support devices, called “Location Measures”. These location measures allow one to specify the precise X, Y, Z coordinate location of a contact support surface relative to the fixed origin of the Support Surface Axis System (SSAS). (The SSAS is defined in Appendix C.) The rules for measuring the location of a support surface are generic, so that they can be applied to any support surface in the body support system. Using these principles established in the ISO standard, the location of any support surface is defined as the distance from the SSAS origin to the Support Surface Geometric Center (SSGC), along any of the X, Y or Z axes. Therefore, the location of a postural support device is expressed as three numbers, representing the distance along each of the three axes from the SSAS origin.

For example, the location of a lateral trunk support can be completely defined by X, Y, and Z values that represent the distance from the origin of the SSAS to the geometric center of the lateral support along the X axis (anterior-posterior placement), Y axis (superior-inferior placement), and Z axis (medial-lateral placement). Figure D.1 shows how this system is used to specify the location of a right lateral trunk support.

If you are using this system for determining the location of a support surface, you would use the terminology convention established in the standard. The term “sagittal location” would identify the placement along the X and Y axes, the term “frontal location” would identify the placement along the Y and Z axes, and the term “transverse location” would identify the placement along the X and Z axes (Fig. D.1). If you use just the term “location”, for example “right lateral trunk support location”, you would note the linear placement along all three axes with three values.

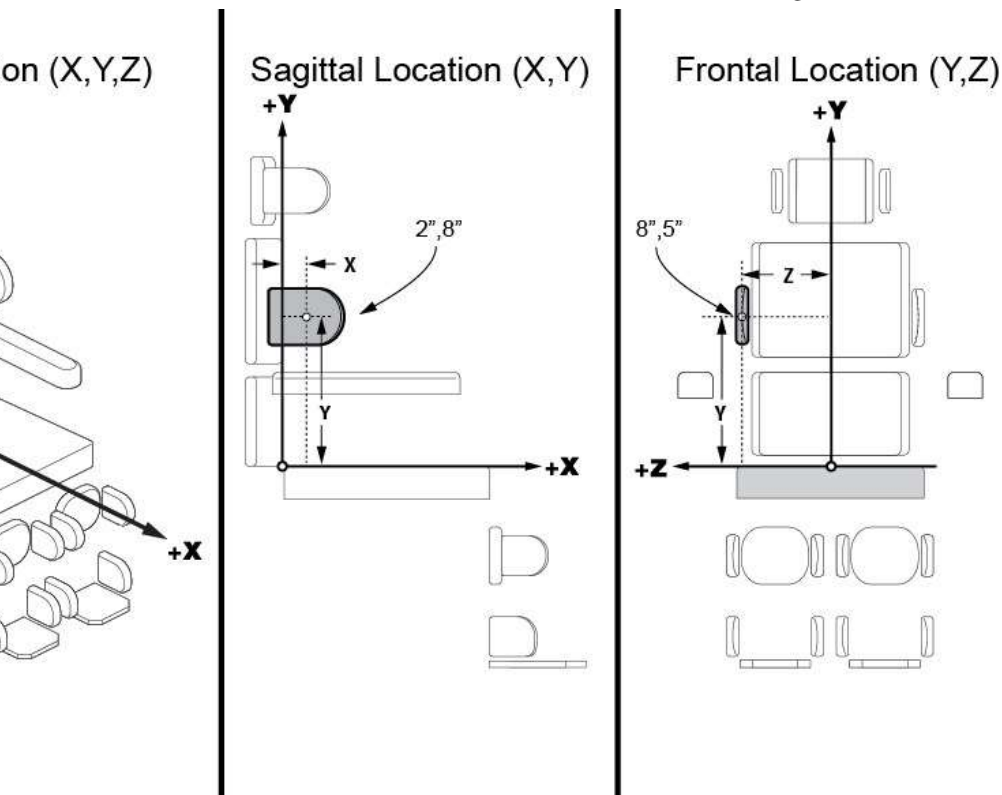


Fig. D.1: Right lateral trunk support location

GLOSSARY

Absolute angle

Angle which represents the orientation in space of a single body segment or support surface relative to the global axis system called the Wheelchair Axis System. (Chapter 1, Section 4.3)

Body segment line

A line defined by two designated body landmarks, either palpated or calculated, used in determining absolute angles of body segments (Chapter 1, Section 3.3)

Postural support device assembly

A postural support device and its attachment hardware, as a unit (Chapter 1, Section 1.2.3)

Body support system

All those parts of the wheelchair which are intended to directly contact the user's body, including the seat, back support, arm support, foot support and head support [1] (Chapter 1, Section 1.2.3)

Global axis system

A global axis system is an absolute coordinate system, meaning it is fixed in space and does not change its orientation; therefore it can be used as an external reference system. (Chapter 1, Section 3.5)

Local axis system

A local axis system is not fixed, and can move or rotate in space. This allows the orientation of a local axis system to be compared to a global axis system for measurement of angular deviations. (Chapter 1, Section 3.5)

Postural support device

A structure, attached to the body support system or wheelchair, which has a surface intended to contact the occupant's body. Examples of body support devices are the back support, seat cushion, or lateral trunk support. (Chapter 1, Section 1.2.3)

Pre-contoured

A type of body support device that has a generically shaped or curved contact surface when it is not loaded or being used. (Chapter 1, Section 1.2.3)

Reference position

A fixed hypothetical baseline position to which other positions may be referenced [2].

Relative angle

Angle formed between two body segment lines or two support surface reference planes_ (Chapter 1, Section 4.2)

Seated Anatomical Axis System (SAAS)

A global axis system used to define the location of a seated person's body relative to the body support system or wheelchair. (Appendix C)

Seated Reference Position (SRP)

A hypothetical seated position, where all body segments are at 90 degrees to one another, and all body segment lines align with one of the axes of the wheelchair axis system. When a body is in the Seated Reference Position, all absolute body segment angles are 0 degrees. The Seated Reference Position is also described as the "zero reference position" to which angular deviations of body segments can be compared and measured. (Chapter 1, Section 3.6)

Support surface

The part of the body support device which is intended to contact the user's body. This is also referred to as the "contact surface". (Chapter 1, Section 1.2.3)

Support Surface Axis System (SSAS)

A global axis system used to define the location of secondary support surfaces relative to the SSAS origin, or the location of the seating support system as a whole relative to the wheelchair. (Appendix C)

Support Surface Geometric Center (SSGC)

The geometric center of the contact surface side of a body support device (Chapter 1, Section 3.4.2)
ISO definition: Point of intersection of two or more lines joining the furthest points from the edges of a contact surface, measured along the surface [2].

Support surface reference line

A line lying on the support surface reference plane, and representing one of the local axes, used in determining absolute angles of seating support surfaces. (Chapter 1, Section 3.4.3)

Support surface reference plane

An imaginary plane that lies along the contact surface of a body support device used to represent the orientation of that support surface for measurement purposes. (Chapter 1, Section 3.4.1) *ISO definition:* The plane passing through the SSGC tangential to the surface curvature at the SSGC radius at the point of the SSGC [2].

Support Surface Reference Position (SSRP)

A hypothetical baseline position of support surfaces where all support surfaces are at 90 degrees to one another. In the Support Surface Reference Position, all absolute support surface angles are 0 degrees. The Support Surface Reference Position is also described as the “zero reference position” to which angular deviations of seating supports can be compared and measured. (Chapter 1, Section 3.7)

Wheelchair Axis System (WAS)

The global, gravitational axis system which is used to define the orientation of body segments and support surfaces for the measurement of absolute angles (Chapter 1, Section 3.5.1)

Acronyms

AKS = Anterior Knee Support

AS = Arm Support

ASIS = Anterior Superior Iliac Spine

BS = Back Support

FS = Foot Support

HS = Head Support

LLS = Lower Leg Support

LPS = Lateral Pelvic Support

LTS = Lateral Trunk Support

MKS = Medial Knee Support

PSIS = Posterior Superior Iliac Spine

SRP = Seated Reference Position

SSGC = Support Surface Geometric Center

SSRP = Support Surface Reference Position

WAS = Wheelchair Axis System

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