# HUMOSIM

# Anthropometric Measurements

Center For Ergonomics
University of Michigan
1205 Beal Avenue
Ann Arbor, Michigan 48109-2117

(734) 763-0570

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## Measurement Instructions

### General Instructions

All measurements are taken with shoes on unless otherwise noted. Linear measurements are in centimeters and weight and force measurements are recorded in pounds.

### Stature Related Measurements

Weight (Without Shoes)

Ask the subject to take his/her shoes off. Have the subject stand on the scale facing forward with both feet solidly on the scale and the weight evenly distributed between the feet. Record the subject's weight in pounds.

Body Mass Index

Calculate the BMI by dividing the body weight in kg by the square of the height in meters. Converting the weight into kilograms, lbs/2.2. Convert mm to meters then square. Divide $kg/m^2$.

Standing Height

Have the subject stand with his heels together and the weight evenly distributed between both feet. The subject should stand erect with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor. Take the measurement with an anthropometer from the ground to the highest point on the subject's head while firmly contacting the scalp. The measurement will be in cm (Figure 1).

Figure 1. Stature

Standing Height (Without Shoes)

Instructions are same as above although shoes will be off.

Nasion Height

For the hand orientation study, have the subject stand with his heels together and weight evenly distributed between the feet. With the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor, measure the distance from the floor to the nasion (indentation at the top of the nose between the eyes) using an anthropometer (Figure 2).

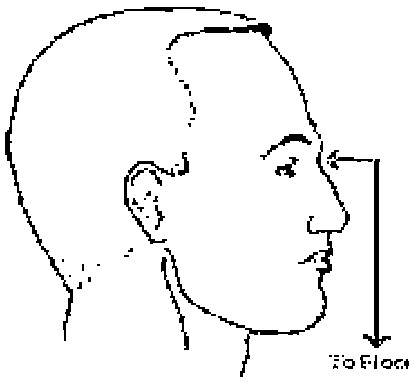


Figure 2. Nasion height

C7 Level Standing

Have the subject stand erect with his heels together and weight evenly distributed between his feet. To find the C7 vertebra, have the subject tilt his head forward and run your fingers from the hairline down the spine. The first palpable vertebra is C7. Measure the distance from the floor to the C7 vertebra using an anthropometer (Figure 3).

Figure 3. C7 level standing

Standing Acromion Height

Have the subject stand erect with his heels together and weight evenly distributed between his feet. Measure the vertical distance from the Acromion to the floor using an anthropometer.

Height to EM at Suprasternale

This measurement will be taken before placing the actual EM marker on the suprasternale. To find the marker location, the experimenter will run his fingers along the collarbone toward the midline of the body. There is a depression where the collarbone ends and the sternum begins. From there a mark will be placed at the uppermost point of the sternum between the end points of the right

and left collarbone. Measure from the ground to this mark with the subject standing erect with his heels together and weight evenly distributed between both feet. For back pain/paraplegia subjects measure from the ground to this mark with the subject sitting erect in the test fixture.

Floor to L5 Standing

The L5 vertebra can be found by having the subject lean forward at the waist. Coming up from the tailbone, L5 is the first vertebra you can feel. Once this point is found, have the subject stand erect with his heels together and weight evenly distributed between both feet. Measure from the floor to L5 in cm with an anthropometer. For wheelchair subjects, take this measurement in the fixture in the same way.

Standing Knee Height

Have the subject stand erect with their heels together and weight distributed evenly between both feet. Locate the patella (knee cap) on the front of the knee and find the center of that bone. Measure the distance from the floor to this location using a caliper (Figure 4).

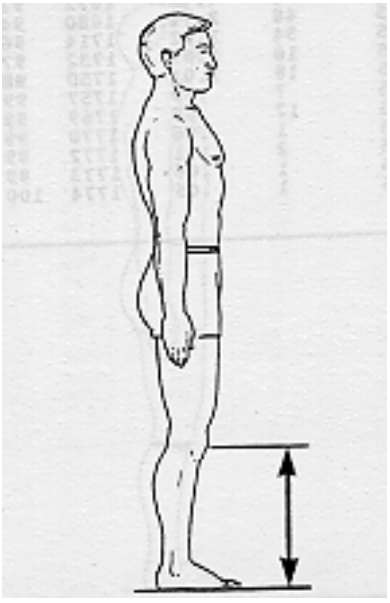

Figure 4. Knee height

Height of Seat

The height of the seat (reference point) was set at 74.7cm for all subjects.

Seated Height in Fixture

Have the subject sit in the test fixture used in the experiment. The feet should be placed on the footrest so that both the thighs and the feet are parallel and lie in the horizontal plane. The subject should sit erect with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor.

The measurement is taken with an anthropometer and is measured from the ground to the highest point on the subject's head with the anthropometer arm firmly contacting the scalp (in cm) (Figure 5).

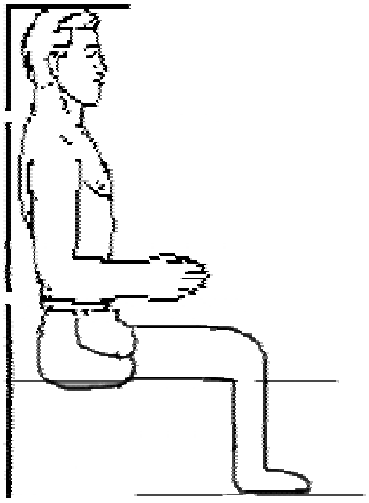

Figure 5. Seated height

Erect Seated Height from Seatpan

Measure from the seatpan to the top of head. The subject should sit erect with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor. Take the measurement with an anthropometer from the seatpan to the highest point on the subject's head while firmly contacting the scalp.

Seated Eye Height

Have the subject sit in the test fixture with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor. Measure the height from the floor to the subject's nasion (indentation at the top of the nose between the eyes) using an anthropometer (Figure 6).

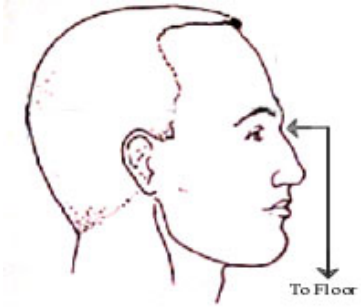


Figure 6. Seated eye height

Seated C7 Height

Have the subject sit in the test fixture. To find the C7 vertebra, have the subject tilt his head forward and run your fingers from the hairline down the spine. The first palpable vertebra is C7. Measure from the floor to the C7 vertebra using an anthropometer.

Seated Acromion Height

Measure from the seatpan to the acromion. The subject should sit erect with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor.

Seated Knee Height

Measure the vertical distance from the floor to the top of the Patella.

Seated Hip Breadth

Measure the lateral distance at the widest part of the hips.

Buttock-Knee Length (Seated)

Measure the distance from the buttocks to the Patella.

Seated Ankle Distance (Horizontal)

Have the subject sit in the industrial chair with their feet positioned comfortably on the footrest. Using a caliper, measure the horizontal distance from L5 to the lateral malleolus (Figure 7).

Seated Ankle Distance (Vertical)

With the subject seated in the same manner as above, measure the vertical distance from the floor to the lateral malleolus (Figure 7).

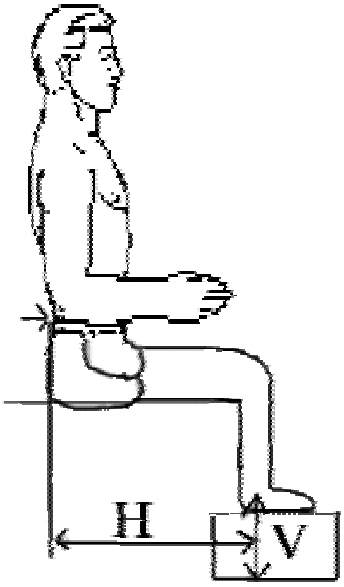


Figure 7. Seated ankle distance

## Head and Neck Related Measurements

C1 to C7 Distance

C1 can be located by having the subject tilt his head forward and feeling along the hairline for the point where the head rotates about the spine. Once this point is located, have the subject stand with the Frankfort plane of his head parallel to the floor and measure the distance from this point to C7 using a caliper.

Head Width

Using a spreading caliper, measure the maximum width of the head above the ears (Figure 8).

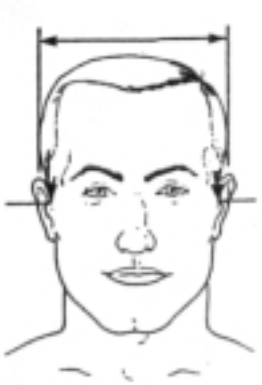

Figure 8. Head width

Head Depth

Using a spreading caliper, measure the distance from the nasion (indentation at the top of the nose between the eyes) to the most posterior point on the back of the head (Figure 9).

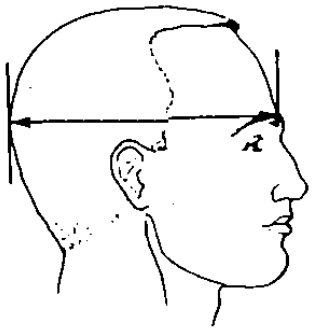

Figure 9. Head depth

Nasion to Top of Head

Have the subject stand or sit with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor. Using a caliper, measure from the nasion (indentation at the top of the nose between the eyes) to the top of the head (Figure 10).

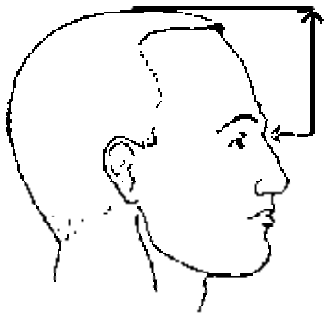

Figure10. Nasion to top of head

Head Length

Measure the linear distance from the bottom of chin to the highest point (vertex) on the top of the head.

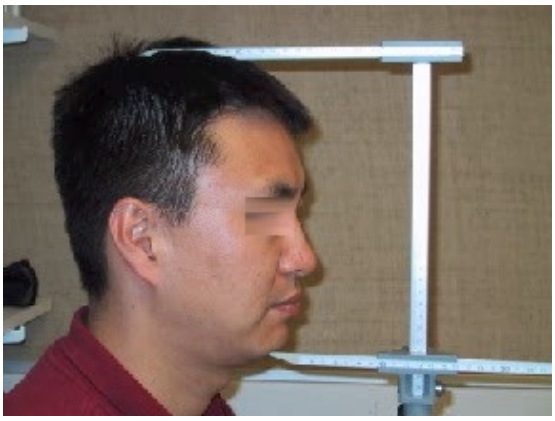

Figure 11. Head length measurement

Head Circumference

Measure with flexible tape. Place tape above ear and across brow. Hold tape firmly to compress hair as much as possible.

Figure 12. Head circumference measurement

## Torso Related Measurements

C7 to L5

The L5 vertebra can be found by having the subject lean forward at the waist. Coming up from the tailbone, L5 is the first vertebra you can feel. Place a mark here. To find the C7 vertebra, have the subject tilt his head forward. Run your fingers from the hairline down the spine until you can feel the first vertebra. This is C7. Have the subject return to an erect posture and measure the distance between these two vertebras. An alternate way to take this measurement is to measure from the ground to the L5 and from the ground to the C7 and subtract the distances.

Horizontal Distance from C7 to Suprasternal Notch

First measure the horizontal distance from the C7 to the front of the neck level with C7. From there, imagine a vertical line down from the front of the neck from C7 level to the height of the suprasternal notch. Measure the distance between the notch and this line. Assuming that the distance to the suprasternal notch is less than the depth of the neck, subtract the second number from the first and your resulting value will be the horizontal distance from C7 to the suprasternal notch (Figure 13).

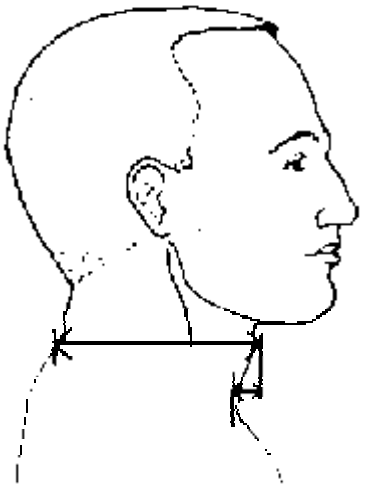

Figure 13. C7 to suprasternal notch

Vertical Distance from C7 to Suprasternal Notch

Have the subject stand in an anatomical position with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor. Measure the distance from the floor to C7 and the floor to the suprasternal notch and calculate the difference between these two values.

Suprasternal Notch to Right Acromion Process

Follow the scapula out to the right shoulder. The outermost point is the acromion process. Using a caliper, measure the distance between this point and the suprasternal notch (Figure 14).

Figure 14. Suprasternal notch to acromion process

Suprasternal Notch to Left Acromion Process

Follow the scapula out to the left shoulder. The outermost point is the acromion process. Using a caliper, measure the distance between this point and the suprasternal notch.

Bi-Deltoid Breath

Measure the distance between the outside of each upper arm at the largest point of the deltoid muscle.

Bi-Acromion Breadth

Have the subject sit erect on the measurement fixture. The feet should be placed on the footrest so that both the thighs and the feet are parallel and lie in the horizontal plane. The subject should sit erect with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor.

The measurement is taken with an anthropometer. Measure the horizontal distance from the right acromion to the left acromion

Wingspan

Have the subject stand with his heels together and arms abducted in the frontal plane, palms facing forward. Measure from 3$^{rd}$ fingertip to 3$^{rd}$ fingertip.

Torso Width at Nipple Height

Measure the linear distance across the torso at the level of the nipples.

Figure 15. Torso width at nipple level

Torso Circumference at Nipple Height

Using flexible measuring tape measure the circumference of the torso at nipple height.

Figure 16. Torso circumference at nipple height

Torso Width at Umbilicus

Measure the linear distance across the torso at the level of the umbilicus (belly button).

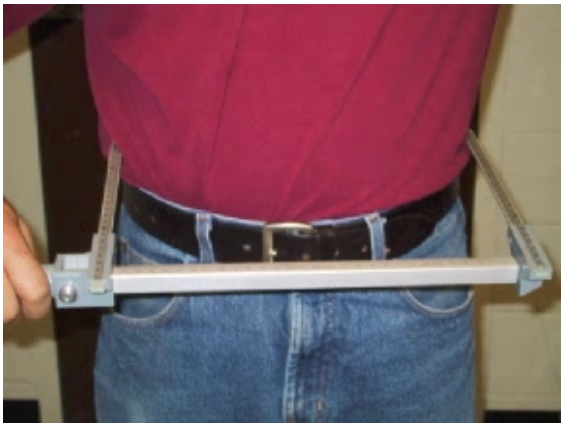

Figure 17. Torso width at umbilicus

Torso Circumference at Umbilicus

Using flexible measuring tape measure the circumference of the torso at umbilicus level.

Figure 18. Torso circumference at umbilicus

Torso Width at Hip

Measure the linear distance across the torso at the location of the hip joint centers.

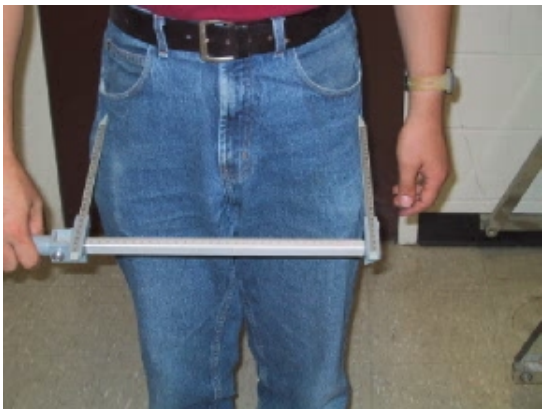

Figure 19. Torso width at hip level

Torso Circumference at Hip

Using flexible measuring tape measure the circumference of the torso at the level of the hip joint centers. Make sure to encircle both lower limbs when performing the measurement.

Figure 20. Torso circumference at hip

## Arm and Hand Related Measurements

Right Upper Arm Length (Acromion-Radiale Length)

Take this measurement using a beam caliper. Have the subject stand with the right upper arm hanging at the side and the elbow flexed at 90 degrees. Make sure the hand is straight and the palm is facing in. Follow the scapula out to the shoulder. Mark the outermost point, which is the acromion process. The olecranon process is the tip of the elbow when it is flexed at 90 degrees. While standing behind the subject, measure the distance from the acromion process to the olecranon process (Figure 21).

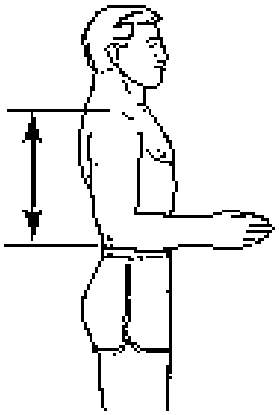

Figure 21. Upper Arm Length

Upper Arm Circumference at Axilla

Using flexible measuring tape, measure the circumference of the upper arm as proximally as is possible.

Figure 22. Upper arm circumference at axilla

Maximum Upper Arm Circumference

Locate and record the maximum circumference using the flexible measuring tape by measuring along the length of the upper arm.

Figure 23. Maximum upper arm circumference

Right Forearm Length

Have the subject stand with his arms straight at his side with his hands and fingers in line with the forearm. The measurement is taken from the right radiale (identified as the bony process on the outside of the elbow) to the stylion landmark (bone on the thumb side of the wrist) (Figure 24).

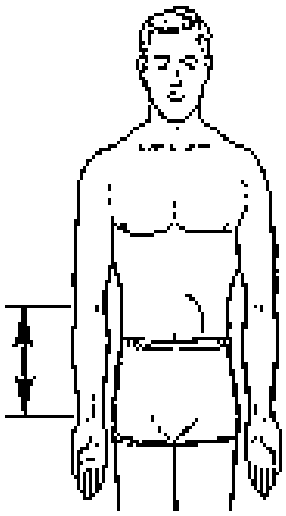

Figure 24. Forearm Length

Elbow Circumference

Using the flexible measuring tape, measure the circumference of the elbow, ensuring that the measuring tape passes through both the medial and lateral epicondyle of the humerus.

Figure 25. Elbow circumference

Maximum Forearm Circumference

Locate the maximum circumference using the flexible measuring tape by measuring along the length of the forearm.

Figure 26. Maximum forearm circumference

Right Elbow Width

This measurement will be taken using a beam caliper. Have the subject stand with the right upper arm hanging at the side and the elbow flexed at 90 degrees. Make sure the hand is straight and the palm is facing in. While standing behind the subject, measure the distance between the lateral and medial epicondyles of the humerus.

Elbow to Fingertip (3rd Finger)

Have the subject hold their elbow at 90 deg. Measurement is taken with a sliding caliper from the Olecranon Rear to Dactylion III.

Radial Styloid to Hand EM Distance (Right)

Find the radial styloid (wrist bone on thumb side) and draw a perpendicular line from there to the center of the wrist and mark. Measure the distance from this mark to the center of the EM marker.

Right Wrist Width

With a sliding caliper measure the distance between the outer edges of the wrist. Have the subject place his hand on a table for this measurement.

Right Wrist Depth

With a sliding caliper, measure the distance from the palm side of the wrist to the backside of the wrist. Place the calipers at the deepest point along the line of the wrist bones.

Wrist Circumference

Using the flexible measuring tape, measure the circumference of the wrist, at the same location as wrist width was measured.

Figure 27. Wrist circumference

Right Hand Length (Wrist to Tip of 3rd Finger)

Have the subject place his hand on a table with the fingers together and thumb abducted. The measurement is taken with a sliding caliper from the stylion landmark identified above to the tip of the middle finger (Figure 28).

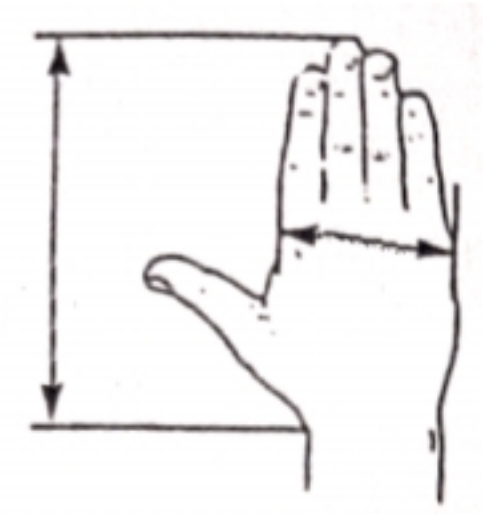

Figure 28. Hand length and width

Right Hand Width

This is measured as the width of the hand from metacarpal II to metacarpal V. Have the subject place his hand on a table with fingers together and thumb out to the side. With a sliding caliper measure the width of the hand at the knuckles as indicated in Figure 28.

Metacarpal-Phalangeal Joint Circumference

Using the flexible measuring tape, measure the circumference of the hand around the first set of knuckles (before the fingers begin). Have the hand placed on a flat surface to perform this measurement.

Figure 29. M-P joint circumference

## Leg Related Measurements

Horizontal Distance from ASIS to Greater Trochanter

The ASIS is located on the iliac crest (hip bone) at its most forward prominent point. The greater trochanter is the bony prominence of the femur that protrudes just below the meat of the hip. Measure the horizontal distance (in the sagittal plane; from rear of body to front of body) between these two points.

Right Thigh Length

This is measured as the linear distance between the joint centers of rotation of the hip and the knee

Gluteal Furrow Circumference

Using the flexible measuring tape once again, measure the thigh circumference just below the point at which the gluteal furrow contacts the upper thigh. This is usually characterized by a change in shape.

Figure 30. Gluteal furrow circumference

Mid-Thigh Circumference

This measurement is taken midway between the hip joint center and the center of the patella. Once again, use the flexible measuring tape to measure the circumference of the thigh at this location.

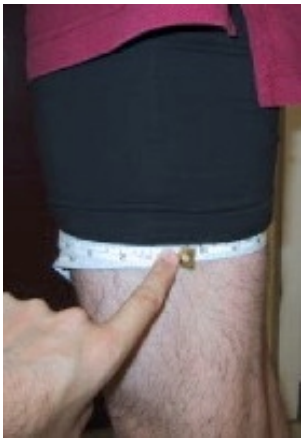

Figure 31. Mid-thigh circumference

Right Femoral Epicondyle (Knee) Width

Have the subject sit on a flat surface so the thighs are parallel and the knees are flexed 90 degrees. Thighs should be straight forward with lower leg straight down forming a 90° angle. With a caliper, measure the distance between the medial and lateral right femoral epicondyles (bones on the side of the knee).

Knee Circumference

For this measurement use the flexible measuring tape around the knee, using the center of the patella and the posterior knee crease to align the measuring tape.

Figure 32. Knee circumference

Right Shank Length

This is measured as the linear distance between the joint centers of rotation of the knee and the ankle.

Maximum Calf Circumference

Using the flexible measurement tape, locate the maximum circumference of the calf by moving the tape proximally and distally along the calf.

Figure 33. Maximum calf circumference

Minimum Distal Calf Circumference

Using the flexible measurement tape, measure just superiorly to the ankle.

Figure 34. Minimum calf/ankle circumference

Foot Length

This is measured as the linear distance between the back of the heel and the tip of the second toe.

Foot Arch Circumference

Measure the circumference of the foot halfway between the ankle joint and the ball of the foot using the flexible measuring tape.

Figure 35. Foot arch circumference

Ball Circumference

Measure the circumference of the foot at the ball with the flexible measuring tape. The tape should pass over the bony surface on the inferior side of the foot.

Figure 36. Ball of foot circumference

Right Malleolus Height

Have the subject stand erect with their heels together and the weight distributed equally on both feet. Measure the distance between the floor and the lateral malleolus (ankle bone) (Figure 37).

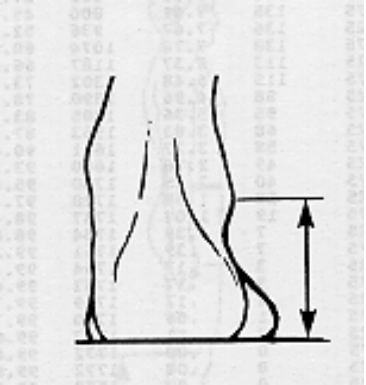

Figure 37. Malleolus height

Lateral Malleolus to First Metatarsal-Phalangeal

With the subject standing erect with their feet slightly apart, find the bone that marks the beginning of the first toe. If the subject if wearing shoes, this can be found by having them lift their heel and bend their foot forward. The first metatarsal-phalangeal is where the foot bends. From there, draw a perpendicular line to the lateral side of the foot. Draw another line from the lateral anklebone to the ground. Measure the horizontal distance between these two points.

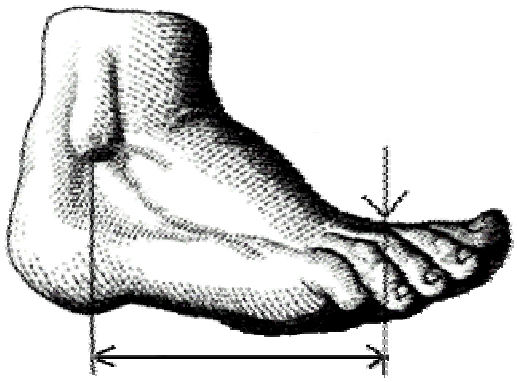

Figure 38. Malleolus to metatarsal-phalangeal

Malleolus Width

Have the subject stand erect with both feet firmly on the ground and slightly apart. Measure the horizontal distance between the two anklebones with a caliper (Figure 39).

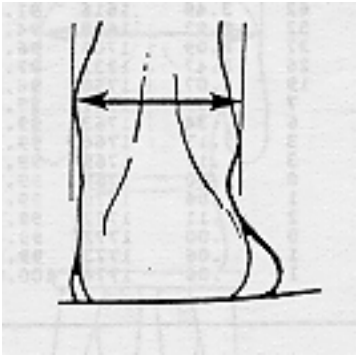

Figure 39. Malleolus width

## Object Related Measurements

### Cylinder Measurements

For the next five measurements have the subject hold the cylindrical object in the right hand. It is easiest to have them hold it near the top to facilitate in taking accurate measurements. Make sure that the wrist is in line with the forearm even if this isn't the subject's natural posture (Figure 40).

Wrist to First Knuckle (Grip Posture)

Have the subject grasp the cylinder in the vertical direction. Make sure the hand is in line with the forearm. Measure the distance from the stylion process (wrist bone on thumb side) to the first knuckle of the index finger while in this posture.

Cylinder L1

This measurement is taken from the radial stylion to a point in line with the center of the EM marker on the right hand.

Cylinder L2

This measurement is taken from the level of the radial stylion to the center of the EM marker in the direction of the fingers.

Cylinder L3

This measurement is taken from the center of the EM marker to the center of the cylinder in the direction of the fingers.

Cylinder L4

This measurement is taken from the center of the cylinder to a point in line with the center of the EM marker.

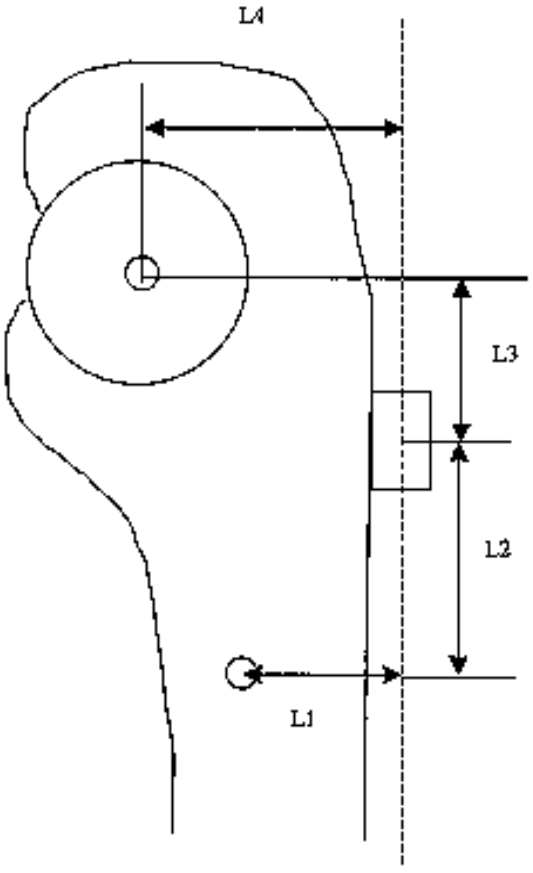


Figure 40. Hand grasping cylinder object

**Tote Measurements**

For the next four measurements have the subject hold the tote object. Make sure that the wrist is in line with the forearm and the wrist is in a neutral posture even if that means the box is not lying flat (Figure 41).

Tote L1

This measurement is taken from the radial stylion to a point in line with the center of the EM marker on the right hand.

Tote L2

This measurement is taken from the level of the radial stylion to the center of the EM marker in the direction of the fingers.

Tote L3

This measurement is taken from the center of the EM marker to the center of the tote in the direction of the fingers.

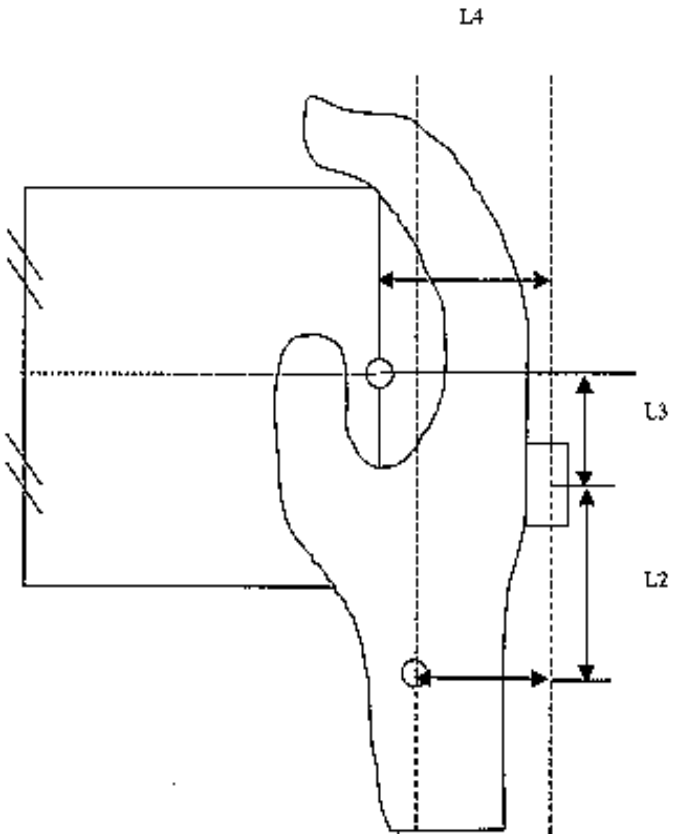


Figure 41. Hand gripping tote object.

Tote L4

This measurement is taken in two parts. A measurement will be taken from the center of the box to a point in line with the center of the EM marker. From this value, subtract 14.1cm (the distance from the edge of the box to the center of the box) to get a final value that represents the distance from the EM center to the edge of the box.

## Strength Measurements

General Instructions

Two repetitions of each exertion are measured using the Strength Test Monitor manufactured by Measurement Systems Inc. This device incorporates the three second average standard static strength test protocol recommended by Caldwell, et al., 1974. At least thirty seconds of rest should be given between trials. The maximum of the two average trial values are used as 100%MVC.

Shoulder Flexion Strength (lbs)

The subject will simulate an isometric lifting task in the following posture: seated erect with the right arm fully extended, parallel to the ground, and directly in front of the subject. The task will consist of pulling up on a handle attached to a force transducer (Figure 42).

Figure 42. Shoulder flexion strength

Shoulder Abduction Strength (lbs.)

The subject will simulate an isometric lifting task in the following posture: seated erect with the right arm fully extended, parallel to the ground, and directly to the right side of the subject. The task will consist of pulling up on a handle attached to a force transducer (Figure 43).

Figure 43. Shoulder abduction strength

Shoulder Strength at 45 Degrees (lbs.)

The subject will simulate an isometric lifting task in the following posture: seated erect with the right arm fully extended, parallel to the ground, and 45° lateral. The task will consist of pulling up on a handle attached to a force transducer (Figure 44).

Figure 44. Shoulder strength at 45 degrees

Wrist Flexion Strength (lbs.)

The subject will simulate an isometric pulling task in the following posture: seated erect with the right arm fully extended, parallel to the ground, and directly in front of the subject. The task will consist of pulling a handle attached to a force transducer horizontally toward the midline of the subject (Figure 45).

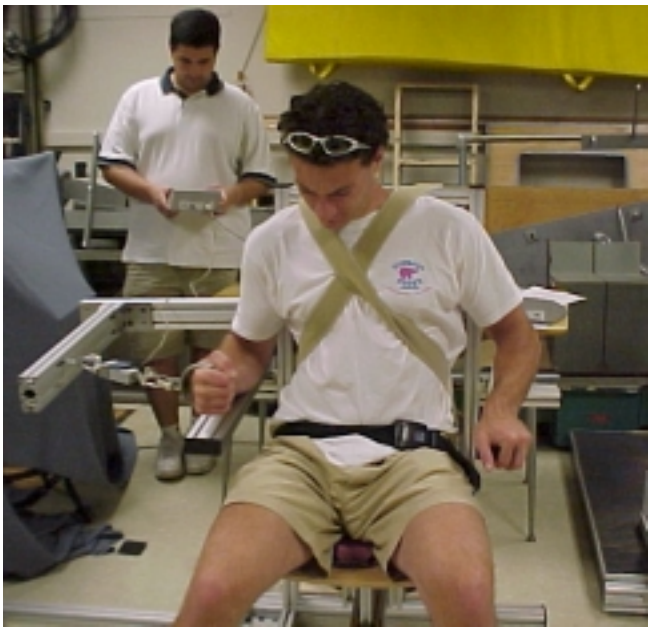

Figure 45. Wrist flexion strength

Low-Back Extension Strength, Standing (lbs.)

The subject will simulate an isometric lifting task (torso extension) in the following posture: standing, torso flexed at 30°, hips resting against a padded horizontal restrain bar, arms fully extended and at a 90° angle to the torso. To obtain this posture, have the subject stand with his arms extended at a 90° from the torso then ask him to bend at the waist maintaining the 90° angle. The angle between a horizontal line at the subject's shoulder and his arms should be 30°. The task consists of pulling with both hands on a horizontal bar attached to a force transducer (Figure 46).

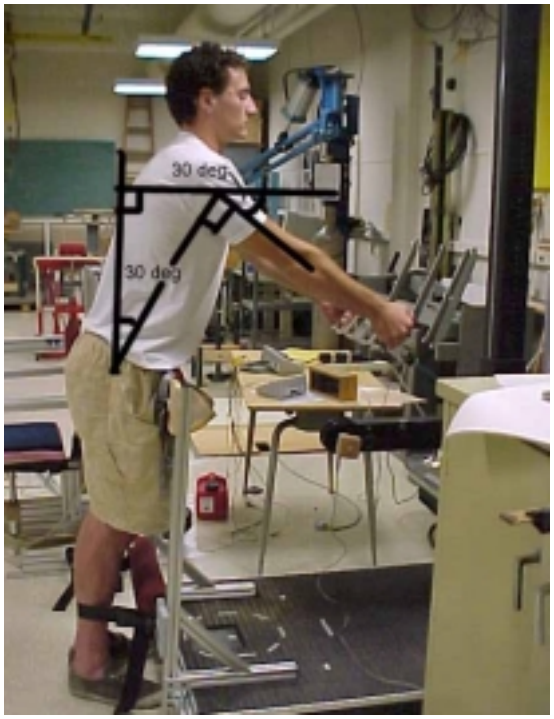


Figure 46. Standing low-back extension strength

Low-Back Extension, Seated (lbs.)

Have the subject sit in the strength testing fixture with his arms across his chest. The seatbelt should fit low and snug below the hips. The subject should push against the backrest to obtain the measurement (Figure 47).

Figure 47. Seated low-back extension strength

## Glossary of Terms

Acromial Height: Vertical distance between a standing surface and the right acromion landmark.

Acromial Height, Seated: Vertical distance between a sitting surface and the right acromion landmark

Acromion-Humeral Epicondylar Length: Distance between the right acromion landmark and the lateral humeral epicondyle landmark

Acromion-Olecranon Length: Distance between the right acromion and olecranon landmarks (shoulder to elbow when arm flexed)

Ankle Circumference Height: Vertical distance between the standing surface and the level of the minimum ankle circumference

Anterior Superior Iliac Spine Height R/L: Vertical distance between a standing surface and the ASIS landmark

Bi-Acromial Breadth: Distance between the right and left acromion landmarks

Bi-Spinous Breadth: Straight-line distance between the right and left ASIS landmarks

Bi-Trochanterion Breadth: Distance between the right and left trochanterion landmarks

Buttock-Knee Length: Distance between a vertical reference surface touching the buttock and the front of the right knee in line with the seated trochanter and lateral femoral epicondyle landmarks

Cervical Curvepoint Height: Vertical distance between a standing surface and the anterior curvepoint landmark on the neck

Elbow Height, Sitting: Vertical distance between a sitting surface and the lateral humeral epicondyle landmark on the flexed right elbow

Eye Height, Sitting: Vertical distance between a sitting surface and the right ectocanthus landmark (angle formed at junction of upper and lower eyelids). For our purposes this was measured from the floor to the nasion while sitting.

Foot Length, Total: Maximum length of the right foot

Foot Length, Anterior: Distance between the tip of the longest toe and the vertical line that intersects the medial malleolus landmark

Forearm-Hand Length: Horizontal distance between the back of the tip of the right elbow to the tip of the right middle finger

Frankfort Plane: The standard horizontal plane or orientation of the head. It passes through the right tragion (approximate ear hole) and the lower edges of the two orbits (bony eye sockets)

Hand Breadth (Width): Width of the right hand between the landmarks at metacarpal II and metacarpal V

Hand Depth: Depth of the hand is measured at the distal end of the third metacarpal

Hand Length: Length of the right hand between the stylion landmark on the wrist and the tip of the middle finger

Head Length: Distance from the glabella landmark between the browridges to the opisthocranion point on the posterior midline of the head

Hip Breadth, Seated: Distance between the lateral points of the hips or thighs, whichever is broader

Humeral Lateral Epicondyle-Radial Stylion Length: Distance between the lateral humeral epicondyle and the stylion landmarks

Knee Height at Lateral Femoral Epicondyle: Vertical distance between a standing surface and the lateral femoral epicondyle landmark on the right knee

Lumbar Curvepoint Height: Vertical distance between a standing surface and the lumbar curvepoint (sitting) landmark

Lumbar Curvepoint Height, Sitting: Vertical distance between a sitting surface and the lumbar curvepoint landmark

Malleolus Height, Lateral: Vertical distance between a standing surface and the lateral malleolus landmark

Sitting Height: Vertical distance between a sitting surface and the top of the head

Stature: Vertical distance from a standing surface to the top of the head

Suprasternale-Acromion: Distance between the suprasternale and the right acromion landmarks

Trochanterion Height: Vertical distance between a standing surface and the right trochanterion landmark

Trochanter-Lateral Femoral Epicondyle Distance, Sitting: Distance between the trochanter landmark and the lateral femoral epicondyle landmark

Weight: Weight of the subject is taken to the nearest tenth of a kilogram

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