**Supplemental File. BMI and body composition measurements**

Detailed instructions on anthropometric procedures can be found in the Anthropometry Procedures Manual National from the Health and Nutrition Examination Survey (NHANES) on the Centers for Disease Control and Prevention website: <https://wwwn.cdc.gov/nchs/data/nhanes/2017-2018/manuals/2017_Anthropometry_Procedures_Manual.pdf>

***Weight:*** Weigh clients with light indoor clothing but without shoes/socks/slippers using a digital chair or wheelchair scale. Ask the person to remove any heavy or excess clothing, braces and any heavy items from the wheelchair (if using a wheelchair scale).

***Height:*** Measure to the closest millimeter with a portable stadiometer or length measuring board. For infants, use an infantometer with a fixed head piece and horizontal backboard, and an adjustable foot piece.

For children under 4 years of age:

1. Ask the parent or guardian to remove the child’s clothes except for diapers or underpants.
2. Ask an assistant to support the child’s head while you position the feet and ensures that the head lies in the Frankfort horizontal plane.
3. Apply gentle traction to bring the top of the head in contact with the fixed head piece.
4. Secure the child’s head in the proper alignment by lightly cupping the palms of your hands over the ears.
5. Align the child’s legs by placing one hand gently but with mild pressure over the knees.
6. With the other hand, slide the foot piece to rest firmly at the child’s heels. The toes must point directly upward with both soles of the feet flexed perpendicular against the acrylic foot piece. To encourage the child to flex the feet, run the tip of your finger down the inside of the foot.

*If a person can stand unaided:*

1. Assist person to stand with his/her back against a wall mounted height scale (stadiometer) with heels together and eyes looking straight ahead (Frankfort plane)
2. Adjust the horizontal arm of the scale until it sits on top of the person’s head
3. The person’s height is indicated by the position of the scale arm
4. Record measurement in centimeters

*If a person cannot stand, measure the child’s length (recumbent):*

1. Ask the person to lie on a measuring board, face or front upward
2. Position the person so feet are touching the footboard together, shoulders are relaxed and touching baseboard, arms at sides, legs straight and knees together, and crown of head is touching headboard

Where a measuring board is unavailable and/or for people with severe contractures, measure segmental length:

1. Ask the person to lay on the measuring board (or examination table), face or front upward
2. Measure from head to neck (just above shoulder)
3. Measure from shoulder to hip
4. Measure from hip to knee
5. Measure from knee to ankle bone
6. And measure from ankle bone to bottom of foot
7. Add measurements together and record in centimeters
8. For people with scoliosis, measure both sides of the body

*Other methods to assess height*

Where height/length is challenging to assess, alternative methods have been shown to be useful, including arm span (1) and ulna length (2).

*Arm Span*

1. Extend both arms outward (each arm abducted to 90 degrees)
2. Measure from fingertip to fingertip using a metal rod across the area

of the Adams apple.

1. Record measurement in centimeters
2. To calculate BMI using arm span length, multiply by 0.95 for those with mid-lumbar lesions (i.e. those who lack gluteus medius and maximus function and/or those who lack foot dorsiflexion) and 0.90 for those with high lumbar/thoracic functional motor levels (i.e. those who lack quadriceps function) (3). Note that this refers to the functional level of lesion, not the anatomic level.

*Ulna Length Measurement (Segmometer)*

1. First, determine which forearm to measure. Measure the forearm that has been least affected by trauma, injury, or progression of weakness when compared to the opposite side. Measure the non-dominant arm if both arms are not affected
2. Support and position the arm in pronation with 90 – 110 degrees of elbow flexion
3. Palpate the distal tip of the ulnar styloid process (the prominent bone of the wrist) and mark lightly with a pen. Make sure to palpate superiorly on the wrist to avoid mistaking the tendon of the extensor carpi ulnaris for the distal tip of the ulna
4. Palpate the tip of the olecranon (the tip point of the elbow) and place one arm of the segmometer on the olecranon as pictured
5. Place the other end of the segmometer at the tip of the ulnar styloid
6. Measure in centimeters, to the nearest millimeter (e.g. 19.7 cm) to obtain ulnar length in centimeters
7. Complete the following calculation for height (2):

- Male: height (cm) = (4.605 x ulnar length in cm) + (1.308 x age in years) + 28.003

- Female: height (cm) = (4.605 x ulnar length in cm) + (1.315 x age in years) + 31.485

***Body Mass Index (BMI):*** BMI should be calculated using both height and length as kilograms per meter squared (kg/m2) and classified using Centers for Disease Control and Prevention cut-offs (85th–95th centile=overweight, above 95th percentile=obese) (4).

***Occipital head circumference*** *(up to two years of age)*(5)

1. Ask the parent/caregiver to hold the baby over their shoulder or sit with the baby in their lap
2. Place the head circumference tape around the child’s head so that the tape lies across the frontal bones of the skull; slightly above the eyebrows; perpendicular to the long axis of the face; above the ears; and over the occipital prominence at the back of the head
3. Move the tape up and down over the back of the head to locate the maximal circumference. Tighten the insertion tape so that it fits snugly around the head and compresses the hair and underlying soft tissues.
4. Measure the circumference to the nearest 0.1 cm.

***Waist circumference*:**

1. Ask the patient to place him/herself in the following manner:
   * Clear the abdominal region
   * Feet shoulder-width apart
   * Arms crossed over the chest
2. It is suggested to kneel down to the right of the patient in order to measure waist girth
   * Palpate the patient’s hips to locate the top of the iliac crest
   * Draw a horizontal line halfway between the patient’s back and abdomen
3. Place the measuring tape horizontally around the patient’s abdomen (\*to work comfortably, it is suggested to wrap the tape around the patient’s legs and then move up)
4. Align the bottom edge of the tape with your marked point
5. It is recommended to use a measuring tape with a spring handle, such as the Gulick measuring tape, to control the pressure exerted on the patient’s abdomen
   * Gently tighten the tape around the patient’s abdomen without depressing the skin
6. It is suggested to request the patient to relax and breathe NORMALLY (abdominal muscles should not be contracted)
   * Ask the patient to take 2 or 3 NORMAL breaths
   * Measure from the zero line of the tape to the nearest millimeter) at the end of a NORMAL expiration
7. Note the lesion level and/or any bulky masses, liposuction incision marks or spinal curvature.

***Waist circumference in supine***

1. Ask the patient to lay down and place him/herself in the following manner:
   * Clear the abdominal region
   * Arms crossed over the chest
2. Palpate the patient’s hips to locate the top of the iliac crest
   * Draw a horizontal line halfway between the patient’s back and abdomen
3. Complete steps 3-6 as indicated above

\*If iliac crest cannot be located, measure smallest part of abdomen

***Skinfold Thickness***

1. Ask the patient to remove their shirt if comfortable and clear the abdominal region
2. Begin with right arm placed at a 90 degree angle and request that the patient places his/her arm across the abdomen, with the palm facing inward

*Triceps*:

* + Along the midline on the back of the triceps of the right arm, determine the midpoint located between the top of the acromial process (top of shoulder) to the bottom of the olecranon process of the ulna (elbow)
  + Pinch the skin to create a vertical skinfold with the thumb and forefinger about 0.5 inches from the measurement site
  + Release the calipers on the skinfold three times for 1 second each and record the measurements

*Subscapular:*

* + Ask patient to place arm behind his/her back
  + The skinfold should angle 45 degrees from horizontal, in the same direction as the inner border of the scapula
  + Release the calipers on the skinfold three times for 1 second each and record the measurements

1. Use the Slaughter equation to calculate the estimated body fat (6).

References:

[1] Shurtleff D, Walker W, Duguay S, Peterson D, Cardenas D. Obesity and myelomeningocele: anthropometric measures. J Spinal Cord Med. 2010;33(4):410-149. doi: 0.1080/10790268.2010.11689720.

[2] Gauld L, Kappers J, Carlin J, Robertson C. Height prediction from ulna length. Dev Med Child Neurol. 2004;46:475-80. doi: 10.1111/j.1469-8749.2004.tb00508.x.

[3] Dosa N, Foley J, Eckrich M, Woodall-Ruff D, Liptak G. Obesity across the lifespan among persons with spina bifida. Disabil Rehabil. 2009;31(11):914-20. doi: 10.1080/09638280802356476.

[4] Ogden C, Carroll M. Prevalence of obesity among children and adolescents: United States, trends 1963-1965 through 2007-2008. 2010. [Cited 2020 Nov 22]. Available from: <https://pdfs.semanticscholar.org/ef0f/65c84678f7758ecdb4550a92b2ccabec5f99.pdf>

[5] Hagan J, JS S, Duncan P. Bright Futures: Guidelines for health supervision of infants, children, and adolescents. Elk Grove Village, IL: American Academy of Pediatrics; 2017.

[6] Slaughter M, Lohman T, Boileau R. Skinfold equations for estimation of body fatness in children and youth. Hum Biol. 1988;60(5):709-23.