Review of Anthropometric Measures for Older Adults

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Background:

Older adults are the fastest growing segment of the world's population (1) and they are quite heterogeneous (2). As we age, there are many biological changes in body composition, although rate and consequences of changes vary greatly (3). Because of these changes, older adults have an increased susceptibility to several chronic diseases that may be prevented/ delayed through the provision of nutrition interventions (4). However, appropriate interventions are dependent on comprehensive assessment of nutritional status which includes diet, biochemical, clinical and anthropometric information. Nutritional status is difficult to measure in any population, but is especially difficult in older adults because:

- Dietary recalls may be inaccurate due to cognitive impairment (4)
- Biochemical lab values may be skewed due to the presence of chronic disease states (4), and;
- Clinical symptoms may be difficult to detect due to normal aging processes (4).

Thus, anthropometry is often heavily relied on to determine nutritional status of older adults as it is considered to be the most portable, inexpensive, simple and least invasive technique used to assess nutritional status (6,7). The purpose of nutritional anthropometry is to estimate or predict body composition (with a focus on the major nutritionally relevant components of body weight) based on weight, stature, body circumference and subcutaneous fat thickness measurements (4). Main advantages of these measurements include: the ability to reflect past, present and future events or processes, to predict functional impairment, morbidity and mortality (1, 5, 8) and sensitivity to the aging process (3).Due to age associated changes in physical function and body composition, collecting, interpreting and using anthropometric data from this population is very different from that of younger adults and techniques, estimation equations and standards for interpretation need to be specific to this group.

The purpose of this document is:

- To review and summarize current research and practice in the area of anthropometry and body composition specific to an older adult population,
- To highlight areas of best practice, and
- To describe the challenges that go along with collecting, interpreting and using data from this population.

How the literature was reviewed:

- A review of the literature was conducted from March to June, 2009.
- PubMed, Google Scholar and Ageline databases were searched.
  - Search terms included various combinations of the following key words: elderly, aged, geriatric, older adult, anthropometry, skin fold, body composition, Body Mass Index (BMI), height, weight, estimation, circumference, arm span, knee height, demi span, stature, sarcopenia, bioelectrical impedance analysis (BIA), dual energy x-ray absorptiometry (DEXA), bed scale, chair scale, immobile and bedridden.
  - The MeSH headings function of PubMed was also used to identify the relevant search terms “aged”, “aged, 80 and over” and “body weights and measures” which were used in addition to the above mentioned key words while searching the PubMed database.
- Several individual journals that focus on ageing were also manually searched. These include:
  - Journal of Nutrition for the Elderly, Gerontology, The Journal of Nutrition, Health & Ageing, and The Journal of the American Geriatrics Society

- Journal articles included in the review met the following inclusion criteria:
    - Sample population was aged 60 years or older OR sample population included adults aged 60 years or older as well as younger adults, but reported results for this population separately,
    - Research published between the years 1999 and 2009,
    - Research published in English, and
    - Study focused on methods of collection, interpretation or use of anthropometric data
- Reference lists of each of the included research articles were also scanned for resources that met the inclusion criteria.

Articles Identified:

- 85 journal articles met the inclusion criteria.
- The majority of this literature focuses on:
    - Estimating height, weight or body composition from simple anthropometric measures.
    - Recently published reference data
    - Validation of body composition assessment tools

How to use this document:

For ease of use by practitioners and research, the review of this literature is summarized into tables with sections that represent the most researched areas of anthropometry for an older adult population. Each subsection includes: key information on issues related to an older adult population, proposed cut off values and equations. In order to highlight best practices, methods of performing standardized measurements and newly developed or validated techniques for anthropometric assessment are addressed. This document provides a summary of the most current practices in anthropometry related to an older adult population and can be used as a guide by dietitians and others interested in anthropometry for this age group.

Table 1: Height

Parameter/Index	How to/ Method	Issues with older adults	Recommended equations/cut-off points	Published reference values
Standing height	• Using a free standing stadiometer (5) • Standing straight with head facing forward (5) • Shoulders relaxed (5) • arms hanging loosely at sides with palms facing forwards (5) • feet together and knees straight (5) • heels, buttocks and shoulder blades touching the vertical backboard of stadiometer (5) • shoes and socks removed, wearing a minimal amount of clothing (5) • while measurement is taken, subject should take a deep breath and stand tall, then the movable headboard can be lowered to touch the crown of the head (5) • measurement should be recorded to the nearest mm (5) • due to diurnal variations, time of day should be recorded, and subsequent measurements should be taken at the same time (5) • if possible, measurements should be taken in the afternoon (5)	• may be difficult to obtain due to inability or unwillingness to stand, spinal deformities such as kyphosis or chronic pain (15) • older adults lose stature as a result of vertebral compression, postural slump and loss of muscle tone (6, 17, 18) • Standing height represents current height affected by age, but not the individual's maximal height in young age (21) • Use of standing height may alter results of BMI calculations if loss of stature has occurred, resulting in a higher BMI without an increase in body weight (28,30)	N/A	• American (1) • Italian (11) • Chilean (12) • Irish (13)
Self reported height	• Ask participant to report their height verbally, or in writing	• Limited applicability in those aged 60 years and older (7) • Usually significantly over estimated in this age group, especially by those of short stature (7, 19, 20)	Equations for the estimation of standing measured height from self reported height for older American adults are as follows (7): • **Age 60-69 years:** Measured height (cm)= 11.4178 + 0.9216 (self reported height in cm)	N/A
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		• Reasons for over reporting may be the time lapsed from last height measurement, or stature decline with age (7) • Whenever possible, physical measurements should be used to assess the height of older individuals (7, 19)	• **Age 70-79 years:** Measured height (cm)= 7.2951 + 0.9384 (self reported height in cm) • **Age 80 years and older:** Measured height (cm) = 13.6880 + 0.8898 (self reported height in cm)	
Knee height (KH)	• Measured using knee height callipers on the left leg (5) • Left knee should be bent at a 90 degree angle, with participant in the supine position (5) • One calliper is placed under the heel of the foot, and the other on the anterior surface of the thigh, just above the femoral condyles and proximal to the patella (5) • Two measurements with an agreement within 5 mm should be averaged (5)	• Age does not affect the long bones of the legs (21) • May give a more accurate estimate of height unaffected by age (21) • May be more accurate than standing height in those with evident kyphosis (22) • Appropriate ethnicity specific prediction equations must be used (14, 15, 21, 23-26)	• **Joetsu City Japanese (15):** **Male:** Height (cm)=71.16 + 2.61(KH in cm) – 0.56 (age) **Female:** Height (cm)= 63.06 + 2.83(KH in cm) – 0.34(age) • **Mexican (23:** **Male:** Height (cm) = 52.60 + 2.17(KH in cm) **OR** Height (cm)= 53.2 + 2.17(KH in cm) - 0.005(age) **Female:** Height (cm)= 55.60 + 2.03(KH) **OR** Height (cm)= 73.70 + 1.99(KH) – 0.23(age) • **Chinese (26):** **Male:** Height (cm)= 51.16 + 2.24(KH in cm) **Female:** Height (cm) = 46.11 + 2.46(KH in cm) -0.12(age) • **Malaysian (25):** **Male:** Height (cm)= (1.924 x KH) + 69.38	• Italian (11) • Chilean (12)

			Female: Height (cm)= (2.225 x KH) + 50.25 • **<u>Hispanic (all) (24):</u>** **Male:** Height (cm) = 105.9638 + 1.2867(KH)- 0.1030(age) **Female:** Height (cm)= 106.0251 + 1.1914(KH)- 0.1539(age) • **<u>Hispanic Black (24):</u>** **Male:** Height (cm) = 115.5256 + 1.1543(KH) – 0.1312(age) **Female:** Height (cm) = 115.7813 + 1.0370(KH) – 0.1759(age) • **<u>Hispanic Mestizo (24):</u>** **Male:** Height (cm) = 70.9343 + 1.9198(KH) – 0.0799(age) **Female:** Height (cm) = 99.8957 + 1.3559(KH) – 0.1920(age) • **<u>Hispanic Mexican (24):</u>** **Male:** Height (cm) = 63.8510 + 2.0272(KH) – 0.0905(age) **Female:** Height (cm) = 74.1351 + 1.8150(KH) – 0.1690(age) • **<u>Hispanic Mulatto (24):</u>** **Male:** Height (cm) = 115.1857 + 1.0627(KH)	

			– 0.0764(age) **Female:** Height (cm) = 117.7919 + 0.9154(KH) – 0.1269(age) • **<u>Hispanic non-white (24):</u>** **<u>Male:</u>** Height (cm) = 92.5226 + 1.4845 (KH)- 0.0707(age) **Female:** Height (cm) = 91.6101 + 1.4258(KH) – 0.1191(age) • **<u>Hispanic White (24):</u>** **Male:** Height (cm) = 125.4438 + 1.0086(KH) – 0.1601(age) **Female:** Height (cm) = 126.1642 + 0.8513(KH)- 0.2011(age) • **<u>Hispanic American (14)</u>** **Male:** Height (cm) = 70.28 + 1.81(KH) **OR** Height (cm) = 76.02 +1.79(KH) - 0.07(age) **Female:** Height (cm) = 59.29 + 1.79(KH) **OR** Height (cm) = 68.68 + 1.90(KH) – 0.123(age) • **<u>Puerto Rican American (14):</u>** **Male:** Height (cm) = 53.42 + 2.13(KH) **OR** Height (cm) = 52.95 + 2.13(KH)- 0.006(age) **Female:** Height (cm) = 55.98 + 1.99(KH) **OR**	

			Height (cm) = 66.80 + 1.94(KH) – 0.123(age) • <u>**Frail Caucasian Canadian (21):**</u> **Male:** Current measured height (cm) = 63.336 + 2.184(KH) – 0.122(age) **OR** Reported maximal height (cm)= 63.469 + 2.091(KH) **Female:** Current measured height (cm)= 112.643 + 1.333(KH) – 0.248(age) + 0.254 (weight in kg) – 0.160 (hip circumference in cm) **OR** Reported maximal height (cm)= 79.693 + 1.610(KH) +0.0789(weight in kg)	
Arm span (AS) and demi-span (DS)	**Arm span:** • Against a flat wall with a fixed marker board at the zero end of a horizontal scale, and a vertical sliding board that can move along the scale (5). • The scale is best if positioned just above the shoulders of the subject (5) • Measurements are best taken with the subjects feet together and back against the wall (5) • Arms should be at shoulder height and extended laterally across the wall, with palms facing forward (5). • Measurements should be taken with the tip of the middle finger on the right hand in contact with the fixed marker board, and the tip of the middle finger on the left hand on the sliding board (5). • To ensure accuracy, two recordings of each measurement should be taken to the nearest 0.1cm (5).	**Arm span:** • Requires participant to stand, with full extension of arms which may be a challenge when working with older adults (5) **Demi-span:** • Can be measured with participant sitting in a chair or lying in bed (27) • Requires that participant outstretches their arms perpendicular to their body, which may be a challenge for some frail older adults (27) **Arm span and demi-span together:** • High correlations between measured and predicted heights (28-31) • Tend to overestimate standing height (28-31), however, this may be due to the fact that arm span measurements are representative of maximal	**Arm span:** • <u>**Malaysian (25):**</u> **Male:** Height (cm) = 0.681(AS) + 47.56 **Female:** Height (cm) = 0.851(AS) + 18.78 **Demi-span:** • <u>**Malaysian (25):**</u> **Male:** Height (cm) = 1.438 (DS) +51.28 **Female:** Height (cm) = 1.549 (DS) + 41.35 • <u>**Spanish (29):**</u> **Male:** Height (cm) = 77.281 -0.215(age) + 1.132(DS)	N/A

	Demi-span: • Participant must outstretch their arms perpendicular to their body (27) • A measuring tape can then be placed between the middle and ring fingers, and should run along the arm to the centre of the sternal notch (27) • Care should be taken to ensure that the arm is straight and horizontal, and that the wrist is naturally flexed and rotated (27) • Assistance from a second observer may be necessary	height, and are not affected by age(32) • When using such indices as BMI, arm span predicted height may be more appropriate than standing height, which is affected by aging (28, 30) • These measures have been shown to be the most easily completed by sick older adults (32) • Equations used to estimate stature from arm span and demi-span must be age and ethnicity specific (25, 29)	**Female:** • Height (cm) = 88.854 – 0.692(age) +0.899(DS)	
Arm length (AL) and fibula length (FL)	• Arm length is measured using measuring tape from the tip of the acromial process to the styloid process of the ulna (33) • Fibula length measured from the fibula head to the lateral malleolus (33)	• Arm length used because it excludes the shoulder and wrist joints, which make it less likely to be affected by joint deformities which can be common in older adults (33) • Fibula length is used as it is one of the longest bones in the body, is less likely to be affected by osteoporotic fractures than the femur, and has easy to access surface landmarks (33)	**Arm Length (AL)** • **<u>Chinese (33):</u>** **Male:** Height (cm) = 122.5 – 0.23(age) - 8.3(1) + 1.14(AL in cm) **Female:** Height (cm) = 122.5 – 0.23(age) – 0.83(2) + 1.14(AL in cm) **Fibula Length (FL)** • **Chinese (33):** **Male:** Height (cm) = 153.1 – 0.26(age) – 11.0(1) + 1.05(FL in cm) **Female:** Height (cm) = 153.1 – 0.26(age) – 11.0(2) + 1.05 (FL in cm)	N/A
Recumbent height using Luft Ruler	• Participant is lying in bed • Place the fixed arm of the ruler on the top of the patients head (34) • Retract the metric rod into the metal bar until it presses the bottom of the feet (34)	• This tool showed the least difference from standing height when compared to arm span, demi-span and various height prediction equations (34) • For patients who are	N/A	N/A

	• Read the height measurement at the end of the metallic bar scale (34)	bedridden, recumbent measurement may be the only way to obtain height (34) • Cost is $175 USD and is available by contacting the developers		

Table 2: Weight

Parameter/Index	How to/ Method	Issues with older adults	Recommended equations/cut-off points	Published reference values
Weight	• Should be done after the bladder has been emptied, and before a meal (5). • If possible, a beam balance with non- detachable weights should be used; however, spring balances and electronic scales are also acceptable (5). • The scale should be placed on a hard, flat surface and checked for zero balance before each use (5). • Subjects should stand on the scale looking straight ahead, relaxed and still, and be either nude or wearing light underclothing (which can later be weighed for subtracting) (5). • Measurements should be recorded to the nearest 0.1 kg. • Visible edema and time of weighing should be recorded to ensure consistency with subsequent measurements (5). • Scales should be calibrated at regular intervals throughout the year and whenever they are moved to a different location (5). • Type of scale and issues with measurement should be noted with recording.	• Regular, accurate measures of body weight are not easy to obtain, especially in those who are frail • Chair or bed scales can be used for those who cannot stand for measurement on an upright balance beam scale (4) and similar procedures to ensure accuracy and consistency should be followed. • Alternatively, other anthropometric measures may be used to estimate body weight in older adults. • Weight change represents recent changes in nutritional status and is thus sensitive, however it can also be due to fluid shifts which can be common with other older adults using diurectics • Weight change is proposed as a better indicator of nutritional status in older adults than BMI, however serial measures are required • In institutional environments a minimum of monthly weights is recommended to promote adequate monitoring of nutritional status	N/A	• American (1) • Italian (11) • Chilean (12) • Irish (13)
Self reported weight	• Ask participant to report their body weight verbally or in writing	• Accuracy is questionable • Generally, older adults underestimate their weight, especially women (20), and those who are considered to be	N/A	N/A

		overweight (19,20, 37, 38) • Difference between self reported and actual weight increases with age (7, 38) • Whenever possible, measured weight should be used		
Estimated from knee height (KH) and mid arm circumference (MAC)	• Knee height measured according to methods described above **Mid arm circumference (MAC):** • Participant should be standing if possible (92) • If laying down, arm should be propped up off the bed (92) • Arm should be bent at a 90 degree angle (92) • Sleeves should be rolled up (92) • Midpoint of the right arm (half way between the acromion and the olecranon) should be marked with a felt pen (92) • MAC is measured at this midpoint (92) • Measuring tape should not compress the skin below (92)	• Knee height calliper is light weight, portable and only requires one person to use (39) • Mid arm circumference is a non-invasive measurement; however sagging skin can make challenging to complete in older adults • May be useful when standing measured weight is not possible, and bed or chair scales are unavailable	** Caution should be taken when using these equations as they have not yet been validated** • **Hong Kong Chinese** **Male:** Weight(kg) = [KH(0.928) + MAC(2.508)-age(0.144)] – 42.543 ± 9.9kg of actual weight for 95% of Chinese males **Female:** Weight (kg) = [KH(0.826) +MAC(2.116)- age(0.133)]- 31.486 ± 10.1kg of actual weight for 95% of Chinese females	N/A

Table 3: Adiposity Indicators

Parameter/Index	How to/ Method	Issues with older adults	Recommended equations/cut-off points	Published reference values
Body mass index (BMI)	• Height and weight measurement methods as described above • BMI (kg/m²)= weight (kg)/height (m²)	• Cut-off values used to identify risk in younger adult populations may not be applicable (40,45,46) and may only be applicable for this age group at a population level (41) • Being underweight may be a better indicator of poor health outcomes (40,43) as the highest mortality rates seen in those with lowest BMI (47-52) • Obtaining accurate height and weight measurements may be difficult in the frail (40,44) • In past or current smokers, BMI not associated with increased risk of mortality (48,50) • Obese and underweight BMI in older adults has been found to be associated with increased risk of functional limitations and immobility (53,54)	• BMI <20.0 kg/m² good indicator of those at **high risk** of underweight (Italian population) (40) • BMI 20.0-22.0 kg/m² should be considered as **at risk** of underweight and be targeted for early intervention (Italian population) (40) • BMI 21.0 kg/m² and 25.0 kg/m² considered those that offer the **least mortality risk** in men and women respectively (Chinese population) (47) • BMI > 30 and >40 kg/m² associated with **impaired physical function** and immobility in comparison to those in the normal BMI range (53-55) • BMI < 20.0 kg/m² associated with reduced physical function limitations (53) • BMI < 19.0 kg/m² associated with increased mobility limitations (54)	• American (1) • Taiwanese (10) • Chilean (12) • Irish (13)
Waist Circumference (WC)	• WC can be measured at the natural waist (half way between the 10th rib and the iliac crest), or at the umbilicus, which is preferred in obese subjects when it is difficult to identify a natural waist (5). • During measurement, subjects should stand straight with their abdomen relaxed. • Weight should be distributed equally between both legs, feet should be together and hands should be relaxed at their sides (5).	• WC cut-offs used to identify risk in the general adult population may not be applicable to older adults (43,45,47) • High WC associated with hypertension, high cholesterol, diabetes and increased risk of functional limitation (47, 53, 56). • Some suggest that WC is a better indicator of risk than BMI (48), while others suggest that it offers no benefit (47) or that both should be examined	• WC of 80 and 85 cm shown to offer the lowest mortality and diabetes risk in Chinese older males and females, respectively (47) • Further work is needed to establish cut-points for risk in diverse populations of older adults	• American (1) • Italian (11) • Chilean (12)

	• If the measurement is being taken at the natural waist, the margins of the lowest rib and iliac crest should first be marked with a felt tip pen (5). An elastic tape can then be applied mid way between these two markings, tied firmly so that it stays in position, and used as a guide for measurement with a flexible, non-stretch fibreglass measuring tape (5). • The circumference should be measured to the nearest 0.5 cm, and be taken at the end of a normal expiration (42). • Measurements should be taken after an overnight fast, with the subject wearing limited clothing (5). • Care should be taken to make sure not to compress the skin underneath the measuring tape (5).	together (43). • Mortality risk greatest when high WC and BMI experienced together (43) • There is a limited amount of age specific WC reference data available		
Waist-to-hip ratio (WHR)	• WHR= waist circumference/hip circumference • Waist circumference measured according to methods (above) **Hip circumference:** • Subject standing straight with arms at the side and feet together (5) • Measurement should be taken at the level on the hips that gives the largest circumference around the buttocks (5) • Measuring tape should be touching the skin but not compressing the soft tissue (5) • Measurements should be made to the nearest mm (5) • Waist value is divided by the hip value to determine the ratio	• Some have suggested that WHR is superior to BMI or WC at predicting mortality in this population (49) • Associated with development of heart disease, diabetes and stroke (5) • WHR positively associated with mortality in this age group, especially when seen with high BMI or skin fold thickness (57) • Abdominal fat may be more important in predicting mortality than subcutaneous fat (57)	• WHR of >0.99 and >0.90 shown to be associated with the greatest risk of mortality in British men and women, respectively (49)	N/A

Mindex and Demiquet	• Mindex (for older women) = body weight (kg)/ demi-span (m) (58) • Demiquet (for older men) = body weight (kg) / demi-span (m^2) (58) • Methods of measuring body weight and demi-span as described above	• Strong relationship with measures of BMI and MAC, and body composition analysis (58) • May be easier to perform in those who are bed ridden as demi-span can be measured in bed (58) • May be more accurate in those who have clinically evident kyphosis (58)	• For a Thai population, cut-off values of 55.95, 69.55 and 75.60 kg/m have been suggested to identify underweight, overweight and obesity in women, and 75.60, 93.98 and 102.16 kg/m^2 to identify the same classifications in men (58)	N/A

Table 4: Body Composition Analysis

Parameter/Index	How to/ Method	Issues with older adults	Recommended equations/cut-off points	Published reference values
Skinfolds	**Skin fold thickness measurements:** • Best to use precision thickness callipers (5) • Callipers must be recalibrated at regular intervals, using a calibration block (5) • For all measurements, subject should stand straight, with weight distributed evenly on both feet and arms hanging at the sides (5) • Currently no consensus as to whether right or left side should be used for measurements (5), however, current practice suggests that measurements be made on the right side (5). **Triceps skin fold:** • Measured at the midpoint of the upper arm (5) • Fold taken from the back of the arm **Biceps skin fold:** • Measured on the front of the upper arm (5) • Directly above the cubital fossa, at the same level as the triceps skin fold (5) **Subscapular skin fold:** • Measured beneath and lateral to the angle of the shoulder blade (5) • Shoulder and arm should be relaxed (5) **Suprailiac skin fold:** • Measured in the midaxillary line, superior to iliac crest (5) **Midaxillary skin fold:** • Measured horizontally, on the midaxillary line	• Generally, equations underestimate fat percentage (63), especially in women (62) and those with a high body fat mass (62, 63). • Inclusion of skin fold thickness in the prediction of total body fat may result in an underestimation, as there is a redistribution of fat from the extremities to the trunk and from subcutaneous to intramuscular or abdominal with age(18) • Estimation of body composition using prediction equations may be accurate when equations are used in the populations from which they were derived, however, since great variability is seen when body composition is estimated by anthropometry, these methods should be used with caution (64). • The corrected arm muscle area (CAMA), has been shown to be a good predictor of 8 year mortality in subjects from this age group (59).	**Body Composition:** • **<u>Chinese (62)</u>** **Male:** Body fat %= -27.149 + 6.137(1) + 1.120(BMI) + 17.308(Log TSF +BSF) Body fat %=-25.572 + 6.348(1) + 1.125 (BMI x arm span) + 17.28(Log TSF +BSF) Body fat %= -30.702 + 6.572(1) + 0.774(MAC) + 23.653(Log TSF +BSF) **Female:** Body fat %= -27.149 + 6.137(2) + 1.120(BMI) + 17.308(Log TSF +BSF) Body fat %=-25.572 + 6.348(2) + 1.125 (BMI x arm span) + 17.28(Log TSF +BSF) Body fat %= -30.702 + 6.572(2) + 0.774(MAC) + 23.653(Log TSF +BSF) • **<u>Healthy Caucasian American Men (61)</u>** **Male:** Body Density = 1.0417 + 0.000988(WT) – 0.00107(MA) – 0.00186(WC) + 0.1092(WHR) Body fat %= 25.6639 – 0.4302(WT) + 0.4575(MA) + 0.8171(WC) – 49.2365(WHR) Fat free mass = 53.2723 + 1.0289	N/A

	• Level with the xiphoid process • Other methods as described above		(WT) – 0.2344(SI) – 0.2439(WC) – 0.5448(HC) Fat weight = 0.7707(HC)+ 0.3286(MA) – 0.7384(HT) – 56.7631 • **<u>Corrected Arm Muscle Area (91)</u>** **Male:** CAMA (cm)=[(MUAC-(π x TSF))²/ 4π] – 10.0 **Female:** CAMA (cm)= [(MUAC-(π x TSF))²/4π] – 6.5	
Bioelectrical Impedance Analysis (BIA)	• Spot or foil electrodes should be used (93) • Preparing skin with alcohol before applying electrodes has been recommended (93) • Current introducing and voltage sensing electrodes of the right foot and wrist (5, 93) • Variables that affect validity, reproducibility and precision of measurements include participants body position, hydration status and food and beverage consumption, skin temperature and recent physical activity (93) • Measurements best made with subject lying down (93) • Arms and legs should not be crossed (93) • Measurements should be taken after a minimum of 4 hour fast (93)	• Generally, when BIA equations to determine body composition are used outside of the population from which they were derived, large variations are seen, with under and overestimation of FM and FFM depending on the equation (63, 65-69). • Some have suggested that this variability is related to variations in the hydration of the FFM component often seen in older adults (66). • In some cases, equations developed from older adult populations were seen to be less accurate than those derived from the general adult population (65-67, 70) • Some suggest that ethnicity specific equations are more important than those matched for age, and that one equation may be used for all age groups if it is ethnicity specific (66, 67,70).	**Body Composition from BIA:** • **<u>Age 20-94 from Geneva, Switzerland (70)</u>** FFM= -4.104 + (0.518 x H²/Reactance) + (0.231 x weight) + (0.130 x reactance) + (4.229 x sex; men=1, women=0) • **<u>Age 75, from Goteborg, Switzerland (71)</u>** FFM (kg) = 11.78 + (0.499 x H²/R) + (0.134 x Weight) + (3.449 x Sex) where sex = 0 for females and 1 for males	• Swiss (71, 72)

	• It is essential that height and weight measurements used in equations are accurate (93) • Regular calibration of the BIA device is recommended (93)	• others have shown that when BIA equations are used for the specific age and ethnic populations from which they were derived, they produce the best estimations of FFM (69) • More reliable method of body composition analysis than skinfolds (76) • Unknown how changes in hydration affect results, which is a challenge in older adults where dehydration and edema are prevalent (67)		
Bioelectrical Impedance Vector Analysis (BIVA) and Phase Angle	• Standard methods similar to BIA as described above	• Can provide information on body cell mass and hydration without the use of regression equations (73) • Phase angle is generally smaller in women, increases with BMI and decreases with age (74) • Phase angle has been shown to predict poor survival from several chronic diseases (73) • Smaller phase angle and impedance vector displacement seen in those at nutritional risk or malnourished (73)	N/A	• German (74,75)
Dual Energy X-ray Absorptiometry (DEXA)	• According to standardized procedures described by the manufacturer	• Transportation to the DEXA site may pose a challenge • Validity for use with this population is still questionable, as mixed results have been reported • Some suggest that this method is comparable to CT, four compartment model (77) and MRI (79) • Others suggest that it is not sensitive enough to determine total body muscle mass (64), and age related changes in muscle mass (81).	N/A	N/A

Clinical Assessment of Sarcopenia	**Calf Circumference:** • Measurements are taken with subjects either sitting on a table so that the leg can be measured while hanging freely, or standing with feet 20 cm apart and weight distributed evenly (87). • A measuring tape is then positioned horizontally around the calf at the maximum circumference, with the zero end of the tape placed underneath the measurement value (87). • Measurements should be recorded to the nearest 0.1 cm, and care should be taken not to compress the skin (87).	• There is currently no consensus on the definition of sarcopenia (82) • Some suggest that sarcopenia is present when an older adult's muscle mass falls below two standard deviations of that of a young reference population (82, 83); others have defined sarcopenia according to the skeletal muscle mass index (skeletal muscle mass /body mass x 100) (43). • Calf circumference (CC) has been proposed as a possible anthropometric measure to predict sarcopenia (82, 85, 86). • Thigh girth may also be an indicator of sarcopenia (18). • Weight stability or increase may mask sarcopenia, as muscle mass, FFM and TBW may decrease, while FM may increase with age, resulting in a relatively stable body weight over time (88). • Sarcopenia may occur in conjunction with obesity, resulting in a condition termed "sarcopenic obesity" (83). This is associated with functional decline (18) • The waist- to- thigh ratio has been suggested as a possible screening tool for sarcopenic obesity (18)	**Calf circumference cut-off values:** • <30.5 cm best predicts malnutrition (85) • <31 cm best predicts sarcopenia (86)	• Irish (13)

Where BMI= body mass index in kg/m², TSF= triceps skin fold in mm, BSF= biceps skin fold in mm, WT= total body weight in kg, MAC = mid arm circumference, MA= midaxillary skinfold thickness in mm, HT= height in meters, HC=hip circumference in cm, SI= suprailiac skinfold thickness in mm, WHR= waist to hip ratio

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