Chapter 2
Feasibility and reliability of body composition measurements in adults with severe intellectual and sensory disabilities

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Abstract

Background Anthropometric measurements are widely used to reliably quantify body composition and to estimate risks of overweight in healthy subjects and in patients. However, information about the reliability of anthropometric measurements in subjects with severe intellectual and sensory disabilities is lacking.

Objective The purpose of this study was to determine the feasibility and the test-retest reliability of body composition measures in subjects with severe intellectual and sensory disabilities.

Method The study population consisted of 45 subjects with severe intellectual and sensory disabilities. Body mass index, waist circumference, skinfolds and tibia length were measured. Reliability was assessed by Wilcoxon signed rank test, limits of agreement (LOA) and intraclass correlation coefficients. The outcomes were compared with values provided by the World Health Organization.

Results There were no significant differences between test and retest (P < 0.05). For the skinfold measurements, however, the LOA was insufficient. Intraclass correlation coefficients for all variables, except skinfold measurements, were 0.90 or above.

Conclusion Test-retest reliability and feasibility for all measurements are acceptable in subjects with severe intellectual and sensory disabilities. Skinfold measurements, however, could not be reliably performed in these subjects. Measuring tibia length and using the determined formula to calculate body height from tibia length is a reliable alternative for measuring body height. Although measuring the body height of subjects with severe disabilities was feasible, measuring tibia length was more feasible.
Introduction

Physical fitness and health are related according to the Toronto model [1], in the sense that a good physical fitness may reduce health risks [2, 3]. Health can be defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [World Health Organization (WHO) 4, 5]. In addition, health is considered a resource for everyday life, not the objective of living. Health is a positive concept emphasising social and personal resources, as well as physical capacities [6]. The American College of Sports Medicine [(ACSM), 7] gives the following definition of health-related physical fitness: ‘Health related physical fitness is defined as a set of attributes that people have or achieve that relates to the ability to perform physical activity’.

In the ACSM guidelines [8], body composition is defined as a component of health-related physical fitness; this implies that assessment of health-related physical fitness includes measures of body composition [8]. Higher body weights are associated with decrease in health [9]: being obese or overweight substantially increases the risk of morbidity of diseases, like heart and vascular diseases, type 2 diabetes, and respiratory problems [10]. In the Netherlands, over 40% of adults with an intellectual disability (ID) have been shown to be overweight [11]. This figure is similar in other countries [12, 13]. Reliable measurements are essential in order to prevent these individuals from becoming overweight or to reduce the weight of those already overweight.

Anthropometry provides techniques for assessing the size, proportions and composition of the human body; these techniques are universally applicable, inexpensive and non-invasive [14]. To assess an individual’s body composition, body length, body weight, waist circumference, skinfold measurement and bioelectrical impedance tests are used [15].

If height cannot be measured, it can be estimated with alternative height measurements such as tibia length, ulna length, knee height or demi-span, described by the ‘MUST’ Explanatory Booklet [16]. Hogan [17] described knee height, Madden [18] ulna length and Weinbrenner [19] demi-span as alternative measurements. Long bone length is known to be the best indicator of stature [20]. Moreover, ulna and tibia length are preferred, because measurements of knee height or demi-span may be influenced by deformation of the included joints: the ankle joint in measuring knee height and the shoulder, elbow, wrist and finger joints in measuring demispan. Because of ease of measurement and low cost, tibia length has been advocated by Stevenson [21] as the proxy measurement of choice in mobility-impaired subjects. Duyar & Pelin [20] advised when estimating height based on tibia length, the individual’s general stature category should be taken into consideration, and group specific formulae should be used for short and tall subjects.

Body mass index (BMI) provides a more accurate measure of total body fat than body weight alone [15]. The correlation between BMI and body fat content is fairly strong; however, this correlation varies according to gender, race and age [22, 23]. BMI has some limitations: BMI may overestimate body fat in very muscular people and underestimate body fat in some underweight people, who have lost lean tissue, such as the elderly [15].

Another means of assessing body fat content is through waist circumference. Waist circumference as an indicator of abdominal fat, is an important predictor of health risks [15] like heart and vascular diseases and type 2 diabetes [24, 25]. According to the study of Nadas [26], the intra-observer and inter-observer differences in repeated measurements of waist circumference are small when expressed in absolute values.

Some publications regard skinfold thickness as a better predictor of high body fat content.
in adults than BMI [27]. Thus, in addition to BMI and waist circumference, it is important to use an additional method to assess body composition, such as skinfold measurements. The reliability of waist circumference and skinfold measurements was examined by Bemben [28] in men aged 20-74. For lean, healthy individuals, most techniques appeared to provide accurate values, but as individuals age there is more discrepancy between the methods. If individuals are frail or not mobile, anthropometry can be used as long as its limitations are noted [28]. Stevenson et al [29] described the reliability of weight, tibia length and skinfold measurements. These authors described that reliability was comparable with other published reports [30] in children with CP. Body composition measurements are widely used in healthy subjects and in patients [31, 15, 32, 27, 26]. In subjects with mild ID, prevalence of overweight and obesity is described among others by Bhaumik et al, Emerson, Melville et al and, Merriman et al [33, 34, 35, 36], using BMI. Furthermore, validity of measurements of BMI, waist-to-hip-ratio and skinfolds in people with learning disabilities was examined by Rimmer [37].

To date, however, no available data exist on the feasibility and reliability of performing these measurements in persons with severe or profound intellectual and sensory disabilities (SIMD). The feasibility and reliability of measuring the body composition of these individuals, however, may be less than that in other subjects, because these persons with severe or profound ID may have an intellectual level of a young child [International Association for the Scientific Study of Intellectual Disabilities (IASSID); 38], may not understand much of their environment, and may be blind or partially sighted and thus cannot see their environment. They are completely dependent on their caregivers and not accustomed to the above-mentioned assessments. Other potential confounding factors include motivational problems, agitation, anxiety and misunderstanding. For example, some are unable to stand up against a wall, whereas others do not understand why they feel a pinch during skinfold measurements. Measuring body composition is very relevant, because these subjects may suffer from inactivity and have increased risk for obesity [39, 40].

The purpose of this study was (1) to determine the feasibility of performing body composition measurements on participants with severe intellectual and sensory disabilities; (2) to determine the test-retest reliability of measuring body composition variables in these participants; and (3) to describe the body composition of these participants.

**Materials and methods**

**Subjects**

Participants were classified according to an adapted Gross Motor Function Classification System [(GMFCS), 41], a five-level system used to classify the severity of motor abilities in people with mental and physical disabilities. For example, participants having a ‘level 1’ classification can generally walk without restrictions but tend to be limited in some more advanced motor skills. Participants with a ‘level 5’ classification have generally very limited mobility, even with the use of assistive technology. These participants always use a wheelchair. The original GMFCS was adapted for two reasons:

- In the study population, some participants had better motor skills than those outlined for GMFCS level 1. Thus, we added a level 0 to the classification system; and
- Most of the participants had to deal with impaired vision, and as a result they could not jump and run spontaneously. If a participant spontaneously increased his speed during walking, instead of jumping and running, the participant was classified as GMFCS level 1. The adapted version of the
GMFCS was presented to the investigator, who translated the original version of the GMFCS into Dutch [41] and he concluded that the adaptations did not influence the reliability of the system. The participants were recruited from ‘De Brink’, a residential care facility in the Netherlands, in which 200 persons with severe or profound intellectual and sensory disabilities live. Moreover, in 65% they are suffering from motor disabilities as well. We asked the representatives of 92 participants a written permission for the subjects to participate in this study. Eighty representatives gave permission. After informed consent was obtained, we screened these participants based on the examination findings of a physician specialized in mental disabilities and of a behavior scholar and excluded five participants. Another eight participants were excluded because they did not live at the centre for people with severe intellectual and sensory disabilities where the tests were performed. Twenty-two participants were excluded because they presented with exclusion criteria (see below) at the time the measurements were being performed (Fig. 1).

Figure 1. Inclusion steps

In all, 45 participants participated in this study: 17 were female and 28 were male. The mean (SD) age of the men was 38 (11) years and of the women was 44 (10) years. Five participants were classified as GMFCS level 0, 21 participants as GMFCS level 1 and 19 participants as GMFCS level 2. Eighty-nine percent (40) of the participants had severe ID and 11% (5) had profound ID, according to the classification scheme of the IASSID. Most of the participants also had impaired vision. According to WHO guidelines [42], 55% (25) of the clients were severely partially sighted, 38% (17) were partially sighted and 7% (3) were slightly limited in sight. Most participants had impaired motor abilities: 64% (29) had orthopaedic defects. In addition, 29% (13) of the participants had slight hearing problems, 9% (4) had loss of hearing and 4% (2) had severe loss of hearing or were completely deaf.
**Study design**
Forty-five participants were measured twice. There was 1 week between the test and the retest and both measurements were conducted at the same time of the day. Food before the test-retest, defecation before the test-retest and the attendant of the test-retest were noted so that we could check if these factors influenced whether the tests could not be reliably performed.

**Ethical statement**
The study was performed in agreement with the guidelines of the Helsinki Declaration as revised in 1975. Permission to carry out the study was obtained from a institutional ethics committee. Informed consent was obtained from representatives of the participants, because all participants were unable to give consent. The measurements were performed in accordance with the behavioral code section entitled ‘Resistance among people with an intellectual disability in the framework of the Act Governing Medical-Scientific Research Involving Humans’ [43]. Consistent distress or unhappiness was interpreted as a sign of lack of assent and further participation in the study was reconsidered.

**Measures and protocols**
All measurements took place around the swimming pool at the institution. This location was chosen because this was thought to be a relaxing environment for the participants. Three testers, a dietary therapist, a physical therapist and a physical therapy student took the measurements after an appropriate training (three times) with two together. Participants were excluded from the study if they exhibited any of the following exclusion criteria at the time of the measurements: psychoses, depression, or other severe psychological problems, or somatic diseases, which were defined as chronic diseases and/or diseases that do not resolve in the short term (e.g. osteoarthritis, osteoporosis, pneumonia, etc.). Participants were also excluded for the following reasons: general illness or fever; taking antibiotics; worsening of asthma, epilepsy (recent insult or epileptic fits), fresh wound(s)/bruise(s) or other factors causing pain during movement; or stress due to the participants’ behaviour just before the measurement date.

**Body height**
The participant was asked to remove his shoes, to stand with his back against a wall and to place his feet flat on the ground such that the back of his heels made contact with the wall. The participant had to stand straight and look forward. When the participant was standing correctly, we determined body length by sliding the measuring tape upward from the ground towards the participant’s head (Seca height meter 202, accurate at the 0.1 cm level, Hamburg, Germany). The length was noted in centimeters (cm). When a participant was unable to stand against the wall properly, he was asked to lie in a supine position or to lie on one side with stretched legs for body length to be measured. To measure a participant in a supine position, we drew two horizontal lines – one touching the top of his head and one touching the bottom of his heels – and measured the distance between the two lines. To measure a participant lying on his side, we measured the following distances: (1) top of head-to-cervical spine; (2) cervical spine-to-os sacrum; and (3) os sacrum-to-bottom of heel. We summed these three distances to obtain the body length measurement. For both positions, supine and lying on one’s side, it was important to follow the body lines instead of measuring the shortest distance. No protocols from previous studies measuring height in supine position are known. However, our measurer skills are based on 20 years dietary and physiotherapeutic experience in handling participants from this target group.
Body weight
To determine the body weight, we instructed the participant to remove his shoes, to wear only swimming clothes and to stand on an electronic calibrated gauged pair of scales (Weigh plateau for wheelchairs PM-9050, Lopital Nederland BV, Oisterwijk, the Netherlands). When a participant was unable to stand independently without moving (e.g. because of anxiety), the participant was weighed in a wheelchair. The weight (kg) of the participant was then calculated according to the following formula: body weight = measured weight - mass of wheelchair.

BMI
The following formula was used to calculate BMI:
\[ \text{BMI} = \frac{(\text{body weight, kg})}{(\text{body length, m})^2}. \]

Waist circumference
We used a measuring tape (Seca 201 tape measurer, accurate at the 0.1 cm level, Hamburg, Germany) to determine waist circumference. Waist circumference was measured at the point located halfway between the crista iliaca and the tenth rib. We took two measurements, one as the participant breathed in and one as he breathed out. The average of these two values was used for analysis. We deviate from The International Society for the Advancement of Kinanthropometry procedure, because in our participants a normal expiration in these circumstances may be difficult to recognize.

Skinfold measurements
Skinfolds were measured in mm at four sites according to the guidelines of the ACSM [8] and Harpenden Skinfold Calliper (Model: HSK-BI, Baty International, West Sussex, UK) was used. The participant was asked to stand straight for all measurements, and skinfolds on the right side were measured twice. The average of the two measurements was used for analysis. Triceps and biceps skinfolds were measured at the midpoint between the acromion border and the proximal border of the olecranon. Subscapular skinfolds were measured by palpating the participants’ angulus inferior scapulae and pinching the skinfold located just lateral to and under the angulus inferior at an angle of 45 degrees (with the spine). Suprailiac skinfolds were measured by palpating the crista iliaca of the pelvis and pinching the skinfold just before the top of the crista iliaca.

Tibia length
The participant was asked to sit in a chair with his knees flexed at 90 degrees. Next, we palpated the medial malleolus and the proximal end of the tibia, and then measured the distance (cm) between the distal border of the medial malleolus and the proximal end of the tibia with a measuring tape.

Data analysis
The data were analysed using spss 14.0.

Feasibility
To determine feasibility, we compared the number of successful measurements with the total number of measurements. The feasibility was considered to be sufficient when 95% of the measurements were successful.
Reliability
First, to determine whether significant differences between measurements 1 and 2 exist, we analysed the differences using the Wilcoxon signed rank test. Wilcoxon signed rank tests were used because the data were not normally distributed. The level of statistical significance was set at 5%. Limits of agreement (LOA) between two measurements of the same variables were calculated according to the procedure described by Bland & Altman [44]. The LOA is considered to be an indicator of reliability. LOAs are expressed in units and as a percentage of the mean of the first measurement. Measurements were considered reliable when the LOA was less than 10% of the mean of the first measurement.

Finally, the intraclass correlation coefficients (ICC two-way random, absolute agreement) of measurements 1 and 2 of the same variables were computed. Reliability is considered acceptable when the ICC value is greater than 0.80 and the 95% confidence interval is 0.04 or less. To compare the reliability determined in the present study with those from other studies, we made similar calculations of similar variables: the standard error of measurement (SEM = SD/√n); the coefficient of variation 1 (CV1 = SD/mean x 100%); the technical error (TE = √Sd²/2n, where d is the difference between paired measures of n subjects); and the coefficient of variation 2 (CV2 = 100 x TE/mean of measures taken).

Calculation of height
The long bone length/height ratio has been shown to vary among populations [45] and it is known that this ratio does vary to some degree with differences in stature [46, 47]. To address these differences, specific formulae have been generated for certain populations [48, 49, 50, 51, 52, 53]. For that reason, we used the formula to estimate a subject’s height from his tibia length of Stevenson [54]. The calculated height data were compared with the actual measured height using Wilcoxon rank tests and ICC (two-way random, total agreement). Also, LOAs between two measurements of the same variables were calculated according to the procedure described by Bland & Altman [44]. If necessary, a linear regression analysis was performed to determine the most appropriate equation for calculating a subject’s height from tibia length.

Body weight status
If feasibility and reliability were acceptable, the outcomes were compared with the normal WHO values [55, 56, 32].

Results
Reliability
Table 1 summarizes the means and standard deviations of body length, body weight, BMI, waist circumference, and skinfold measurements, the results of Wilcoxon signed rank test, LOA, ICC, and LOA expressed as a percentage of the means. There were no significant differences between measurements 1 and 2. The LOAs expressed as a percentage of the means for the skinfold measurements were more than 10%, whereas the LOAs for all the other variables were less than 10%. Intraclass correlation coefficients for all variables, except those for biceps, subscapular and suprailliac skinfold measurements, were 0.90 or above.
<table>
<thead>
<tr>
<th></th>
<th>Mean 1 (SD)</th>
<th>Mean 2 (SD)</th>
<th>p value</th>
<th>Wilcoxon</th>
<th>LOA</th>
<th>LOA of mean (%)</th>
<th>ICC* 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (in kg)</td>
<td>63 (12)</td>
<td>63 (12)</td>
<td>0.814</td>
<td>2 * 1.06939</td>
<td>3.2%</td>
<td>0.99</td>
<td>0.99-0.99</td>
</tr>
<tr>
<td>Height (in cm)</td>
<td>164 (14)</td>
<td>164 (14)</td>
<td>0.129</td>
<td>2 * 1.75123</td>
<td>2.1%</td>
<td>0.99</td>
<td>0.99-0.99</td>
</tr>
<tr>
<td>BMI (in kg/m²)</td>
<td>23 (3)</td>
<td>23 (3)</td>
<td>0.554</td>
<td>2 * 0.68659</td>
<td>5.8%</td>
<td>0.98</td>
<td>0.98-0.99</td>
</tr>
<tr>
<td>Tibia length (in cm)</td>
<td>36 (4)</td>
<td>36 (4)</td>
<td>0.527</td>
<td>2 * 0.94545</td>
<td>5.2%</td>
<td>0.99</td>
<td>0.98-0.99</td>
</tr>
<tr>
<td>Waist circumference (in mm)</td>
<td>85 (9)</td>
<td>85 (9)</td>
<td>0.372</td>
<td>2 * 2.27459</td>
<td>5.3%</td>
<td>0.97</td>
<td>0.95-0.98</td>
</tr>
<tr>
<td>Skinfold Biceps (in mm)</td>
<td>10 (5)</td>
<td>10 (6)</td>
<td>0.468</td>
<td>2 * 4.02861</td>
<td>80%</td>
<td>0.86</td>
<td>0.75-0.93</td>
</tr>
<tr>
<td>Skinfold Triceps (in mm)</td>
<td>15 (6)</td>
<td>16 (7)</td>
<td>0.957</td>
<td>2 * 3.56180</td>
<td>44%</td>
<td>0.91</td>
<td>0.85-0.96</td>
</tr>
<tr>
<td>Skinfold Sub scapular (in mm)</td>
<td>19 (8)</td>
<td>20 (7)</td>
<td>0.258</td>
<td>2 * 4.64008</td>
<td>46%</td>
<td>0.83</td>
<td>0.80-0.95</td>
</tr>
<tr>
<td>Skinfold Suprailiac (in mm)</td>
<td>20 (7)</td>
<td>20 (7)</td>
<td>0.957</td>
<td>2 * 5.52351</td>
<td>55%</td>
<td>0.89</td>
<td>0.68-0.91</td>
</tr>
<tr>
<td>Sum of skinfold measurements (in mm)</td>
<td>66 (22)</td>
<td>65 (21)</td>
<td>0.931</td>
<td>2 * 8.94375</td>
<td>27%</td>
<td>0.91</td>
<td>0.84-0.95</td>
</tr>
</tbody>
</table>

* Two way random, total agreement.
Table 2 shows SEM and CV1 values for waist circumference and for biceps, triceps, subscapular and suprailiac skinfolds. Table 3 lists TE and CV2 values for weight, tibia length, and triceps and subscapular skinfolds.

**Table 2** Standard error of measurement (SEM) and coefficient of variation 1 (CV1) values for waist circumference measurements and skinfold measurements*

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>CV 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waist measurement</strong></td>
<td>0.340</td>
<td>0.400</td>
</tr>
<tr>
<td>Skinfold biceps</td>
<td>0.622</td>
<td>6.212</td>
</tr>
<tr>
<td>Skinfold triceps</td>
<td>0.556</td>
<td>3.590</td>
</tr>
<tr>
<td>Skinfold subscapular</td>
<td>0.743</td>
<td>3.810</td>
</tr>
<tr>
<td>Skinfold suprailiac</td>
<td>0.863</td>
<td>4.300</td>
</tr>
</tbody>
</table>

* SEM = SD/√n; CV1 = SD/mean x 100%

**Table 3** Technical error (TE) and coefficient of variation (CV) values for weight, tibia length, and triceps and subscapular skinfolds*

<table>
<thead>
<tr>
<th></th>
<th>TE</th>
<th>CV 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight</strong></td>
<td>0.0005</td>
<td>0.0008</td>
</tr>
<tr>
<td>Tibia length</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Skinfold triceps</td>
<td>0.03</td>
<td>0.19</td>
</tr>
<tr>
<td>Skinfold subscapular</td>
<td>0.07</td>
<td>0.36</td>
</tr>
</tbody>
</table>

*TE = √∑d²/2n, where d is the difference between paired measures for n subjects; CV = 100 x TE/mean of measures taken
Calculation of height

The mean (SD) height calculated with the Stevenson formula [151 (35) cm] was significantly different (p < 0.01) from that of the mean (SD) of actual measured heights [164 (11) cm]. Because of this significant difference, we performed a linear regression analysis to identify a more accurate formula for calculating height from tibia length and arrived at the following formula (p < 0.01; R/R2: 0.926/0.857; Durbin/Watson: 1.945):

- For men, $74.008 + (1.841 \times \text{tibia length}) + (0.389 \times \text{weight}) - (3.787 \times 0)$;
- For women, $74.008 + (1.841 \times \text{tibia length}) + (0.389 \times \text{weight}) - (3.787 \times 1)$.

We used the Wilcoxon rank tests, ICC (2-way random, total agreement) and LOAs to compare height data calculated with the new formula to actual measured height data and found that height calculated with this formula was not significantly different from the actual measured height (p = 0.953). Moreover, the LOA was 10 cm, which is 6% of the mean, and the ICC was 0.96. Figure 2 shows that the standardized normal P-P plot of the regression analysis is acceptable.

Feasibility

Except for the measurements of skinfolds, which were 82% successful, at least 95% of the remaining measurements were successful.
Body weight status
Tables 4 and 5 show the results of the comparison of BMI and waist measurements according to the WHO [32, 55, 56].

Table 4. BMI interpretation according to WHO values: obese (BMI>30); overweight (25<BMI<30); healthy weight (18.5<BMI<25); underweight (BMI<18.5).

<table>
<thead>
<tr>
<th></th>
<th>Whole group</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>45</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>Underweight</td>
<td>4%</td>
<td>7%</td>
<td>0</td>
</tr>
<tr>
<td>Healthy weight</td>
<td>65%</td>
<td>79%</td>
<td>41%</td>
</tr>
<tr>
<td>Overweight</td>
<td>27%</td>
<td>14%</td>
<td>47%</td>
</tr>
<tr>
<td>Obese</td>
<td>4%</td>
<td>-</td>
<td>12%</td>
</tr>
<tr>
<td>Totaal</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

BMI, Body Mass Index, in kg/m².
WHO, World Health Organization.

Table 5. Waist circumference interpretation according to WHO values: abdominal obese (waist > 102 for men, waist > 88 for women); risk weight (96 > waist < 102 for men, 80 > waist < 88 for women); healthy weight (88 > waist < 96 for men, 76 > waist < 80 for women); underweight (waist < 88 for men, waist < 76 for women).

<table>
<thead>
<tr>
<th></th>
<th>Whole group</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>45</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>Underweight</td>
<td>16%</td>
<td>25%</td>
<td>-</td>
</tr>
<tr>
<td>Healthy weight</td>
<td>42%</td>
<td>61%</td>
<td>12%</td>
</tr>
<tr>
<td>Risk weight</td>
<td>24%</td>
<td>11%</td>
<td>47%</td>
</tr>
<tr>
<td>Abdominal obese</td>
<td>18%</td>
<td>3%</td>
<td>41%</td>
</tr>
<tr>
<td>Totaal</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Waist circumference in cm.
WHO, World Health Organization.
Discussion

The results of our study show that measurements such as body height, body weight, waist circumference and tibia length can reliably be performed in participants with severe intellectual and sensory disabilities (SIMD).

Feasibility and reliability of the measurements depended partly on the motivation of the attendant and participant. The environment and the attitude of the attendant can influence a participant's state of mind. However, when a participant is stressed and moves a lot, it is difficult to take a correct measurement. When a participant is relaxed, the attendant has more time to read the measurement value, and thus the measurement will be more accurate. To measure body height, the examiner has to determine whether a participant is standing correctly, because the participant is unaware of his stance. The measurement process must follow the protocol, so the attendant must check that the participant's feet are flat on the ground, that the back of his heels contact the wall and that he is standing straight and is looking forward. This process can be very difficult for the attendant, because it is often hard for a participant to stand still for a few seconds in the correct position. For this reason, we sought another way of determining participant's height by calculating body height from tibia length. To accurately measure tibia length, an attendant must have sufficient knowledge of human anatomy. We found that the feasibility of obtaining accurate measurements from tibia lengths is much better, because the participant is allowed to sit on a chair.

We experienced the most problems in performing skinfold measurements. During the measurement, the participant feels a pinch but does not understand why he or she is being pinched. Hence, at that moment, the participant becomes agitated and starts moving. This restricts measurement, because as soon as a participant feels the pinch, it takes 2 s before it is possible to read the correct value. When the subject is unable to stand still, it is almost impossible to take an accurate measurement. The skinfold measurement process also caused an unacceptable amount of stress to most of the participants. Furthermore, the LOAs expressed as a percentage of the mean skinfold values show that the skinfold measurement accuracy was unacceptable.

The reliability of body weight, body height, waist circumference, skinfolds and tibia length measurements of the present study is comparable to the reliability of similar measurements reported in other studies. This is considered to be a good result because of the complexity of obtaining measurements in this study population. In the study of Bemben et al. (1998), the reliability of waist circumference measurements and skinfold measurements was examined by determining the standard errors of measurement and coefficients of variation. Our waist circumference measurements (SEM/CV: Bemben et al. [28], 0.590/0.72; the present study, 0.340/0.400) and suprailiac skinfold measurements (SEM/CV: Bemben [28], 3.120/20.73; present study, 0.863/4.3) were more accurate than those reported by Bemben [28]. However, Bemben's [28] biceps, triceps and subscapular skinfold measurements are more accurate than our measurements (SEM: Bemben [28], 0.470, 0.420, 0.590, respectively; present study, 0.622, 0.556, 0.743, respectively).

In the study of Stevenson et al. (2006), the reliability of anthropometric measurements was examined by determining the technical error and the coefficients of variation. By comparing their calculations, we found that our weight, tibia length and skinfold (triceps and subscapular) measurements are more accurate (TE: Stevenson [29], 0.08, 0.22, 0.6, 0.51, respectively;
present study, 0.0005, 0, 0.03, 0.07, respectively). In the study of Prince [57], the ICC of waist circumference was 0.99 (p < 0.0001) and LOAs from -5.5 to 6.7 cm was 6.1 cm. In our study, the intraclass correlation was similar. However, LOA was 4.4 cm, indicating that our measures were somewhat more sensitive for monitoring individual changes. The study of Nadas [26] examined intra-observer and inter-observer variability in waist circumference measurements and BMI. In their study, the difference of the means of BMI measurement 1 and 2 was 0.02 kg/m², and the absolute average difference of the BMI was 0.292 kg/m². In our study, the difference of these two means of the BMI was 0.10 kg/m², and the absolute difference between BMI values was 0.687 kg/m², which is less reliable, but still acceptable, according to the LOAs expressed as a percentage of the means.

The results of the present study also demonstrated that a considerable number of participants with SIMD are overweight or obese, and are therefore at risk for developing health problems. According to the BMI and waist measurements, more of the men than women had a healthy weight. Thus, the women in the study population were at a higher risk for developing health problems compared with the men. Based on BMI values, 10% of the female subjects were obese and 39% were abdominal obese, while 0% of the male clients were obese and only 7% were abdominal obese.

Conclusions

Test-retest reliability and feasibility for all measurements are acceptable in participants with SIMD. However, skinfold measurements could not be reliably performed in these subjects. Measuring tibia length and using the determined formula to calculate body height from tibia length is a reliable alternative for measuring body height. Although the feasibility of performing body height measurements as outlined in our protocol was acceptable, the feasibility of performing tibia length measurements was much better. Assessing body fat composition in adults with SIMD through skinfold measurements is not recommended. Furthermore, our results indicate that this study population has a considerable number of participants that are overweight or obese.

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