Measuring physical fitness in persons with severe or profound intellectual and multiple disabilities
Waninge, Aly

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Chapter 3
Measuring waist circumference in disabled adults.

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Abstract

To date, it is unknown whether waist circumference can be measured validly and reliably when a subject is in a supine position. This issue is relevant when international standards for healthy participants are applied to persons with severe intellectual, sensory, and motor disabilities. Thus, the aims of our study were (1) to determine the validity of waist circumference measurements obtained in a supine position, (2) to formulate an equation that predicts standing waist circumference from measurements obtained in a supine position, and (3) to determine the reliability of measuring waist circumference in persons with severe intellectual, sensory, and motor disabilities. First, we performed a validity study in 160 healthy participants, in which we compared waist circumference obtained in standing and supine positions. We also conducted a test-retest study in 43 participants with severe intellectual, sensory, and motor disabilities, in which we measured the waist circumference with participants in the supine position. Validity was assessed with paired t-test and Wilcoxon signed rank test. A prediction equation was estimated with multiple regression analysis. Reliability was assessed by Wilcoxon signed rank test, limits of agreement (LOA), and intraclass correlation coefficients (ICC). Paired t-test and Wilcoxon signed rank test revealed significant differences between standing and supine waist circumference measurements. We formulated an equation to predict waist circumference ($R^2=0.964$, $p<0.001$). There were no significant differences between test and retest waist circumference values in disabled participants ($p=0.208$; Wilcoxon signed rank test). The LOA was 6.36 cm, indicating a considerable natural variation at the individual level. ICC was .98 ($p<0.001$). We found that the validity of supine waist circumference is biased towards higher values (1.5 cm) of standing waist circumference. However, standing waist circumference can be predicted from supine measurements using a simple prediction equation. This equation allows the comparison of supine measurements of disabled persons with the international standards. Supine waist circumference can be reliably measured in participants with severe intellectual, sensory, and motor disabilities.
Introduction

Children and adults with severe generalized cerebral palsy (CP) and intellectual disability have an increased risk for malnutrition [1]. This is a consequence of an altered energy metabolism [2] in combination with feeding difficulties such as gastro-esophageal reflux and dysphagia [3]. Many of these subjects need to be fed by stomach tube. Malnutrition is associated with poorer health status and limitations in societal participation [4]. On the other hand, 40% of the adults with intellectual disability in the Netherlands [5] and in other countries [6, 7] have been found to be overweight. These adults have increased risk for developing obesity [8, 9] and associated degenerative diseases such as type 2 diabetes.

Anthropometry provides techniques for assessing the size, proportions, and composition of the human body; these techniques are universally applicable, inexpensive, and non-invasive [10]. To assess an individual’s body composition, body mass index (BMI, kg/m²) can be used. The correlation between BMI and body fat content is fairly strong; however, this correlation varies according to gender, race, and age [11, 12]. Furthermore, BMI has some limitations, as it 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 [13].

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 [13] such as heart and vascular diseases and type 2 diabetes [14, 15]. BMI and waist circumference are widely used measures in healthy participants and in patients [13, 16, 17, 18]. Pischon et al [19] described that ‘both general adiposity and abdominal adiposity are associated with increased morbidity and mortality and support the use of waist circumference in addition to BMI in assessing the risk of death’.

De Brink is a residential care facility in the Netherlands, housing 200 persons with severe or profound intellectual, sensory, and in several cases, motor disabilities (PIMD). In a pilot study, we found that the female residents of De Brink appeared to be at a higher risk for developing health problems compared to male residents [20]. In that study, BMI as well as waist circumference were measured. According to BMI values, 10% of the female participants were obese, while none of the male participants were obese. However, when waist circumference was used as a criterion, 39% of the female and 7% of the male participants were classified as being obese. Other authors also conclude that, if waist circumference is used as the criterion, then the prevalence of obesity among these adults may be significantly greater than as indicated by BMI [21, 22].

Reliable measurements are critical for assessing the nutritional status of patients with intellectual disabilities. Reliable measurements are also required to obtain reliable data on prevalence and to identify participants at risk of becoming overweight or developing malnutrition.

We determined that measuring waist circumference with a tape measure halfway between the tenth rib and the hipbone is feasible and reliable in participants with intellectual and sensory disabilities who are able to stand upright [20]. However, due to severe generalized CP and motor disabilities, e.g., spasticity, many participants with intellectual and sensory disabilities are unable to stand straight or stand at all [23]. In these participants, waist circumference can only be measured with the subject lying in a supine position. This raises the question of whether waist circumference can be measured reliably and validly in a supine position. This issue is particularly relevant when international standards for healthy individuals are applied to disabled persons. Therefore, the purpose of this study, was as follows:
(1) in healthy participants, to determine the validity of waist circumference measurements obtained in participants lying in a supine position (supine waist circumference) by comparing these measurements with waist circumference measurements obtained in the same participants in a standing position (standing waist circumference);
(2) to formulate an equation that predicts standing waist circumference based on supine waist circumference and based on covariates that can influence waist circumference, such as gender, age, BMI, or past pregnancy; and
(3) in participants with severe intellectual, sensory, and motor disabilities, to determine the reliability of measuring waist circumference using a test-retest study design.

Methods

Validity study

Study design
The waist circumference of 160 healthy participants was measured while persons were in a standing position and in a supine position.

Participants
One hundred sixty healthy persons without disabilities served in the validity study, in which we compared waist circumference measurements obtained while the participants were in standing and supine positions. Participants were recruited from a nursing school (students and teachers) and from a research organization where people receive medical examinations. All potential participants received written and spoken information about the study. They were included in the study if informed consent was obtained. The participants had to be able to stand and to lie down. Exclusion criteria were pregnancy and having scars, because these situations might alter the shape of the waist.

To ensure that all ages were represented in the study population, we included both men and women from three age categories: 20-35 years, 35-50 years, and 50-65 years. Similarly, all BMI categories were included in the study.

Ethical statement
The participants of this study gave informed consent.

Measurements
A non-stretchable tape measure (Seca 201 tape measure; Seca, Hamburg, Germany), accurate to the 0.1 cm level, was used to determine waist circumference. Waist circumference was measured at the point located halfway between the crista iliaca and the tenth rib. In healthy participants, measurements were obtained while the participants were in a standing position and in supine position. We took two measurements, one as the participant breathed in and one as he/she breathed out. The average of these two values was used for analysis.

Data analysis
The number of participants required was based on a power analysis using data from a pilot study. In order to detect a statistically significant difference of 1.5 cm between the standing and supine measurements, assuming a standard deviation of 9 cm, the study needed to include at least 160
participants. These calculations assume a type I error (alpha) of 0.05, two-tailed, and a type II error (beta) of 20%; that is, a statistical power of 80%. The data were analyzed using SPSS 14.0.

To determine whether significant differences between supine waist circumference and standing waist circumference exist, we analyzed the differences using both a paired t-test and Wilcoxon signed rank test. Wilcoxon signed rank tests were also used to get a better impression of the distribution of the data. The level of statistical significance was set at 0.05.

Furthermore, limits of agreement (LOA) between supine and standing waist circumference measurements were calculated according to the procedure described by Bland and Altman [24].

**Predicting standing waist circumference**

To determine whether standing waist circumference can be predicted by using supine waist circumference and to determine the influence of the covariates gender, age, BMI, or past pregnancy, first we performed a simple linear regression analysis of standing waist circumference on each variable separately. Significance (p<0.05) and $R^2$ were estimated for each variable. The normality and the homogeneity of variance of the residuals were checked with a normal P-P plot and a plot of the variance.

Subsequently, a model was built with multiple linear regression by first adding all the significant variables and then removing insignificant variables, starting with those having the highest p-value (backward method). Significance and $R^2$ were estimated from the model, and the normality and the homogeneity of variance of the residuals were checked with a normal P-P plot and a plot of the variance.

**Reliability study**

**Study design**

Forty-three disabled persons were measured at two different times, initially at the test and 1 week later at the retest. For each participant, both measurements were conducted at the same time of the day. We recorded information about food intake before the test and retest measurements, defecation before the test and retest, and the attendant of the test and retest.

**Participants**

For the reliability study, we asked the representatives of 54 persons with severe or profound intellectual, sensory, and motor disabilities (PIMD) written permission for these persons to participate in our study. Forty-eight representatives gave permission. After informed consent was obtained, we screened the 48 persons based on the examination findings of a physician specialized in mental disabilities and a behavior scholar. The screening exclusion criteria were severe psychological problems or somatic diseases, which were defined as chronic diseases and/or diseases that do not resolve in the short term. Three persons were excluded from the study because they had one of these problems or diseases. The exclusion criteria at the time the measurements were being performed were 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 behavior just before the measurement date. Two persons were excluded because they exhibited one of these criteria.

Figure 1 presents the sampling scheme of persons included in the reliability study.
The participants with PIMD were classified according to the Gross Motor Function Classification System (GMFCS) [25], a five-level system used to classify the severity of motor abilities in people with physical disabilities. For example, persons having a Level I classification can generally walk without restrictions but tend to be limited in some more advanced motor skills. Persons with a Level V classification generally have very limited mobility, even with the use of assistive technology. These persons always use a wheelchair.

Ethical statement
This 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 the 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 Governing Medical-Scientific Research Involving Humans Act” [26]. This is a behavioral code for doctors to help them assess the resistance of people with an intellectual disability. The code was drafted by the Dutch Society for Doctors in the Care of People with an Intellectual Disability (NVAZ). Consistent distress or unhappiness was interpreted as a sign of lack of assent, and further participation in the study was reconsidered.

Measurements
A non-stretchable tape measure (Seca 201 tape measure; Seca, Hamburg, Germany), accurate to the 0.1 cm level, was used to determine waist circumference. Waist circumference was measured at the point located halfway between the crista iliaca and the tenth rib, while the disabled participants were in a supine position. We took two measurements, one as the participant breathed in and one as he/she breathed out. The average of these two values was used for analysis. Three testers—a dietary therapist, a physical therapist, and a student—took the measurements after appropriate training (three times).
Data analysis
The data were analyzed using SPSS 14.0. First, to determine whether significant differences between test and retest measurements exist, we analyzed the differences using the Wilcoxon signed rank test. The level of statistical significance was set at 0.05. Limits of agreement (LOA) between two measurements of the same variables were calculated according to the procedure described by Bland and Altman [24]. 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. Afterward, the intraclass correlation coefficients (ICC; two-way random, absolute agreement) of test and retest measurements of the same variables were computed. Measurements were considered reliable when the ICC values were greater than 0.80 and the 95% confidence interval (CI) was 0.30 or less. Finally, the test-retest was considered reliable if (1) there were no significant differences between test and retest measurements; (2) LOA was acceptable, as described above; and (3) ICC was acceptable, as described above.

Results
Validity study
The characteristics of the subjects that participated in the validity study are shown in Table 1.

Table 1. Validity study: subject characteristics

<table>
<thead>
<tr>
<th>Gender</th>
<th>BMI category</th>
<th>&lt;25</th>
<th>≥25</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>Age category</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-35 y</td>
<td>20-35 y</td>
<td>23</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>35-50 y</td>
<td>35-50 y</td>
<td>7</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>50-65 y</td>
<td>50-65 y</td>
<td>13</td>
<td>16</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>43</td>
<td>37</td>
<td>80</td>
</tr>
<tr>
<td>Women</td>
<td>Age category</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-35 y</td>
<td>20-35 y</td>
<td>24</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>35-50 y</td>
<td>35-50 y</td>
<td>13</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>50-65 y</td>
<td>50-65 y</td>
<td>15</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>52</td>
<td>28</td>
<td>80</td>
</tr>
</tbody>
</table>

In all, 160 healthy persons participated in our study, 80 female and 80 male. The mean (SD) age of the men was 42 (15) years and that of the women was 40 (15) years. The mean (SD) BMI of the men was 25 (4) and that of the women was 24 (4).

There were significant differences between standing and supine waist circumference in healthy subjects (p<0.001; paired t test). The mean (SD) standing waist circumference was 89.3 (13) cm and the mean (SD) supine waist circumference was 87.8 (12) cm. The Wilcoxon signed rank test (p<0.001) showed that in the majority of subjects (n=112) supine waist circumference was lower than standing waist circumference. In 48 subjects (11 men and 37 women),
supine waist circumference was higher than standing waist circumference. In zero subjects, there was no difference. The LOA was 5.34 cm (Figure 2.).

![Figure 2. Bland and Altman plot of the differences between standing and supine waist circumference measurements. The mean difference is 1.48±5.34 (LOA) (-3.86; 6.82).](image)

**Predicting standing waist circumference**

A simple linear regression analysis was performed on standing waist circumference, supine waist circumference, age, BMI, gender, and past pregnancy (Table 2). The normal P-P plots and the plots of the homogeneity of variance residuals showed that there was a normal distribution and homogeneity of variance of the residuals.
Table 2. Simple regression analysis of standing waist circumference using supine waist circumference, gender, age, BMI, and past pregnancy as predictors.*

<table>
<thead>
<tr>
<th>Simple regression analysis</th>
<th>Model</th>
<th>Beta</th>
<th>95% CI</th>
<th>p-value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Waist circumference (supine)</td>
<td>1.044</td>
<td>1.010 to 1.078</td>
<td>&lt;0.001</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>-10.184</td>
<td>-13.871 to -6.496</td>
<td>&lt;0.001</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.319</td>
<td>0.192 to 0.446</td>
<td>&lt;0.001</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>BMI category</td>
<td>17.439</td>
<td>4.399 to 20.478</td>
<td>&lt;0.001</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td>Past pregnancy</td>
<td>-5.205</td>
<td>-9.814 to -0.596</td>
<td>0.027</td>
<td>3%</td>
</tr>
</tbody>
</table>

*R², p<0.05, beta, and 95% confidence interval (CI).

A multiple linear regression model showed that BMI (p=0.632), age (p=0.525), and past pregnancy (p=0.084) had no significant influence on waist circumference. Thus, they were removed from the model (Table 3).

Table 3. Multiple regression analysis of standing waist circumference using supine waist circumference, gender, age, BMI, and past pregnancy as predictors.*

<table>
<thead>
<tr>
<th>Multiple regression analysis</th>
<th>Model</th>
<th>Beta</th>
<th>95% CI</th>
<th>p-value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constant</td>
<td>0.437</td>
<td>-3.049 to 3.996</td>
<td>0.791</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waist circumference (supine)</td>
<td>1.022</td>
<td>.972 to 1.073</td>
<td>&lt;0.001</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>-1.459</td>
<td>-2.447 to -0.470</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.10</td>
<td>-0.21 to 0.41</td>
<td>0.525</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BMI category</td>
<td>-0.271</td>
<td>-1.385 to 0.843</td>
<td>0.632</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Past pregnancy</td>
<td>-1.017</td>
<td>-2.171 to 0.137</td>
<td>0.084</td>
<td></td>
</tr>
</tbody>
</table>

*R², p<0.05, beta, and 95% confidence interval (CI).

Standing waist circumference can be predicted by supine waist circumference with a simple correction using the following formula (p < 0.001; R²/R²: 0.982/0.964): corrected standing waist circumference = 1.017 - 1.961 x gender + 1.016 x supine waist circumference. The normality and the homogeneity of variance of the residuals were checked with a normal P-P plot and a plot of the variance. The variance of the residuals was found to be homogeneous.
Reliability study
Forty-three individuals in this study. The characteristics of these persons are shown in Table 4.

Table 4. Reliability study: characteristics of the participants

<table>
<thead>
<tr>
<th>Gender</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age category</td>
<td>20-35</td>
<td>35-50</td>
</tr>
<tr>
<td>Intellectual disability</td>
<td>Severe</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Profound</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8</td>
</tr>
<tr>
<td>Visual impairments</td>
<td>Blind/Severe</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Partially</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8</td>
</tr>
<tr>
<td>Orthopedic defects</td>
<td>Yes</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8</td>
</tr>
<tr>
<td>Cerebral palsy</td>
<td>Yes</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8</td>
</tr>
<tr>
<td>GMFCS level</td>
<td>Level 3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Level 4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Level 5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>8</td>
</tr>
</tbody>
</table>

GMFCS, Gross Motor Function Classification System.

There were no significant differences between test and retest measurements of waist circumference in disabled subjects (p=0.208; Wilcoxon signed rank test). The mean (SD) of the test measurement was 84 (12) cm, whereas the mean (SD) of the retest measurement was 83 (12) cm. The LOA was 6.36 cm, which is 8% of the mean (Figure 3). ICC was .98; 95% CI, 0.97-0.99 (p<0.001).
Figure 3. Bland and Altman plot of test and retest supine waist circumference measurements. The mean difference is $0.73 \pm 6.36$ (LOA) (-5.63; 7.09).

**Discussion**

The purpose of this study was (1) to determine the validity of waist circumference measured in a supine position (supine waist circumference) by comparing these measurements with waist circumference measured in a standing position (standing waist circumference) in healthy participants; (2) to develop an equation to predict standing waist circumference based on supine waist circumference and taking into consideration covariates that can influence waist circumference measurements, such as gender, age, BMI or past pregnancy; and (3) to determine the reliability of measuring waist circumference in participants with severe or profound intellectual, sensory, and motor disabilities using a test-retest study design.

The results of our study show that the validity of supine waist circumference is poor, with higher values (1.5 cm) for standing waist circumference in the majority of healthy participants. This implies that international standards based on unmodified standing measurements from healthy participants cannot be used in disabled persons in whom measurements are conducted in a supine position. We found that age, BMI, and past pregnancy did not influence differences between supine and standing measurements. However, because gender did influence the difference between these two measurements, we formulated a simple equation enabling us to compare the supine measurements obtained from disabled persons with the international standards. Furthermore, we found that measuring waist circumference in a supine position can be reliably performed in participants with PIMD.

Reliable measurements are critical for the assessment of nutritional status in persons with PIMD. These individuals are at risk of becoming either overweight [8, 9] or developing malnutrition [1]. As shown at De Brink, as well as in other studies, women are at higher risk than men for developing health problems caused by overweight [7, 20, 27, 28, 29]. The reliability of the waist circumference measurements obtained in our reliability study is comparable to those
reported in another study [30]. This is considered to be a good result because of the complexity of obtaining measurements in this study population. In the study of Prince et al. [30], the ICC for waist circumference was 0.99 (p < 0.001) and LOAs ranged from -5.5 to 6.7 cm, with a mean of 6.1 cm. In our study, the ICC and LOAs were similar: .98 (p<0.001) and LOAs ranging from -5.63 to 7.09 (with a mean of 6.36 cm), respectively.

Children and adults who have severe generalized Cerebral Palsy (CP) and intellectual disabilities are often fed by stomach tube [1]. However, tube feeding may improve body weight mainly through fat deposition [31]. Sullivan et al. [32] demonstrated that children with severe CP have relatively low energy expenditure and high body-fat content and highlighted the potential risk of overfeeding with available enteral feeds administered via gastrostomy tube. Therefore, it is necessary to determine the validity of waist circumference measured in a supine position. As far as we know, the validity of these measurements was unknown until now.

A limitation of our study is the fact that the validity study was performed in persons without disabilities. This may influence the outcomes of the equation we formulated for predicting standing waist circumference based on supine waist circumference. However, our results can be applied to a larger group of people, not just persons with PIMD. The equation can also be used to predict standing waist circumference in persons with motor disabilities who are unable to stand.

Another limitation of our study is that the reliability study involved a relatively small number of participants. However, because of the exclusion criteria, there was only a small group of persons with PIMD who were able to participate in the research.

In conclusion, although supine waist circumference can be reliably measured in people with severe or profound intellectual, sensory, and motor disabilities, these measurements cannot be compared with standard waist circumference measures, which are obtained in subjects who are standing. Therefore, a correction equation, such as the one proposed in the present study, is required if such comparisons are to be made.

**Acknowledgements**

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References


