Reliability of anthropometric measurements in children with special needs

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ABSTRACT

Objective: To determine the reliability of anthropometric and body composition measurements in children with special needs.

Design: Observational study.

Setting: Specialist support schools (primary and secondary) in Manchester, UK.

Participants: 53 children with moderate to severe learning disability; 30 non-standers (14 boys) and 23 standers (15 boys). Mean ages were 11 years (range 3-20) for non-standers and 12.4 years (range 8- 19) for standers.

Measures: Anthropometric measures (height or length, segmental measures, weight, skinfold thickness, and body circumferences) and body composition estimated from bioelectrical impedance analysis (BIA) were measured twice, two to four weeks apart.

Main outcome measures: We assessed reliability based on the technical error of measurement (TEM).

Results: The TEMs for height and supine length were 0.55 cm for standers and 2.47 cm for non-standers, respectively. For non-standers, the TEMs for knee height and tibial length were 0.81 cm and 1.57 cm, respectively. The TEM for weight was 0.55 kg for standers and 0.75 kg for non-standers. For skinfold thickness, the TEM was smaller for non-standers than standers. The TEMs for the mid-upper arm circumference for standers and non-standers were 0.91 cm and 0.82 cm respectively. The TEMs for BIA in standers and non-standers were 34.7 Ω and 54.1 Ω, respectively. Some measurements, including waist circumferences, were difficult to obtain reliably.

Conclusions: Anthropometric and body composition measurements were feasible to obtain in children with special needs. However, the reliability of these measures differs between non-standers and standers and should be considered when choosing appropriate measures to use.

Short running title: Anthropometry in children with special needs

Key words: paediatrics, anthropometric measurements, bioelectrical impedance, special needs, reliability,

INTRODUCTION

Anthropometric measurements of children are important and form part of an overall clinical assessment. Weight, height, skinfold thickness, and body circumferences as well as body composition estimates from bioelectrical impedance analysis (BIA) are some of the measures that could be readily obtained in clinics and community settings. Reference values for these measurements are available to allow evaluation of individual nutritional status as well as for public health monitoring.[1-6] However, these measurements have been shown to have practical and theoretical difficulties in children with cerebral palsy.[7-8] Children with special needs, including those with learning difficulties, are a heterogeneous group who may present with poor nutritional status,[8] whereas others may present as being overweight or obese.[9,10] We therefore examined the reliability of anthropometric and body composition measurements of children with a variety of special needs who were able or unable to stand unassisted. The practical issues in taking these measurements are also described.

METHODS

Participants and setting

A convenience sample of children with moderate to severe learning disability was recruited from five specialist support schools in Manchester, UK. We identified children who were able to stand unassisted and usually ambulant ("standers") as well as children who were unable to stand ("non-standers"). Informed consent was obtained from parents/guardians. Ethical approval was obtained from the National Research Ethics Service Committee North West - Greater Manchester South (07/Q1403/68).

Measurements

Research investigators taking measurements (JH, DB and SC) underwent training, and obtained measurements following a specified protocol. All measurements were taken by the same investigator on two occasions, two to four weeks apart. DB measured primary school-aged standers and SC measured secondary school-aged standers. Measurements of non-standers were taken by JH. A school nurse provided assistance, and either DB or SC timed each measurement.

To reflect usual clinical and community settings, instruments available in each school were used to measure weight and height. Weight was measured to 0.1 kg on Seca digital scales (Seca Ltd, Birmingham, UK) for standers, and Marsden hoist (Marsden Weighing Machine Group Ltd, Rotherham, UK) or sitting scales (Weymed Scaleways, Leicester, UK) for non-standers. Standers' heights were measured using a wall-mounted ruler (rulers used included those from Raven Equipment Ltd, Essex, UK and from a number of different companies) or a Leicester height metre (Harlow Health Care, Tyne and Wear, UK). Supine length was measured using a Raven Rollameter (Raven Equipment Ltd, Essex, UK). Non-standers were measured on a gym mat or examination plinth. Upper arm length was measured from the acromion to the head of the radius using Holtain calipers (Holtain Ltd, Pembrokeshire, UK).[11] Tibial length was measured from the tibia to the sphyrion using a steel tape measure.[11] Knee height was measured with the knee and ankle at 90 degrees from the heel to the anterior surface of the thigh over the femoral condyle using Holtain calipers.[11] All height or length measurements were taken to 0.1 cm. All segmental measurements were taken on the child's right side. Supine length was estimated using Stevenson's equations[11] for all three segmental measurements. When feasible, body mass index (BMI) was calculated from weight/height^2.

Skinfold thickness was measured to 0.1 mm using Holtain calipers.[12,13] Two measurements were taken, and a third measurement was additionally taken if the difference between the first two measurements was >0.2 mm. Mid-upper arm circumference (MUAC) was measured to 0.1 cm using a Lasso-O Child Growth Foundation tape as described by Frischancho.[6] True waist circumference was measured midway between the tenth rib and the iliac crest to 0.1 cm using a vinyl coated polyester tape measure.[2] Umbilical waist circumference was measured at the level of the umbilicus to 0.1 cm.

Bioelectrical impedance analysis (BIA) was performed with the child supine using Bodystat 1500 (Bodystat Ltd, Isle of Man, UK). Wrist electrodes were applied between the bony prominences of the radial and ulna heads and foot electrodes between the bony prominences of the tibia and fibula at the ankle. Measurement of the raw impedance values was taken after the child had relaxed for 4 to 5 minutes. Fat-free mass was calculated from the raw impedance values using Houtkooper's equations.[1] Fat mass was calculated by subtracting fat-free mass from body weight. Fat-free mass and fat-mass indices were calculated as fat-free mass/height^2 and fat mass/height^2, respectively.[14] The hand-foot measurement using Bodystat 1500 was chosen, as this has performed better in validity studies than leg-leg impedance measurement.[15]

Reasons for not achieving a measurement or any specific difficulty in taking measurements were also recorded.

Statistical analysis

Data from 53 children formed the basis of our analysis. We analysed the characteristics of the children based on their ability to stand. We also analysed the feasibility and other practical issues of taking measurements in standers and non-standers, and noted some of the challenges and difficulties encountered. To assess reliability of repeated measures collected over time, we used paired t-test to compare the difference in measurements taken between the two different time points; to express the error margin we calculated the technical error of measurement (TEM). Measured and estimated supine length from supine measurements were compared using the Bland-Altman limits of agreement (LOA).[16] We also report the p-values and 95% confidence intervals, along with the coefficient of variability (CV) where appropriate. We reported standard deviation scores (SDS) for skinfold thickness. The triceps and subscapular SDS scores were used as a convenient method for expressing 'fatness' in both groups as they can be used serially for comparison.[17] We analysed our data using StatsDirect version 2.7.2 (StatsDirect, Cheshire, UK).

RESULTS

Subject characteristics

Twenty-three children (15 boys) were able to stand whereas 30 children (14 boys) were unable to stand. The mean (range) age of non-standers was 10.8 years (3 to 19.7) and standers was 12.4 years (8.3 to 19.3).

Diagnoses of the 30 non-standers included: cerebral palsy (n=13), undiagnosed severe neurological conditions (n=5), spina bifida (n=2), neuronal migration disorder (n=1), partial deletion of chromosome 13 (n=1), severe learning difficulties associated with severe epilepsy (n=1), and non-ketotic hyperglycinaemia (n=1). Six non-standers had no information available regarding their diagnoses. Of the non-standers, 12 had a gastrostomy and 10 had a scoliosis.

Diagnoses of 23 children who were able to stand included: Down syndrome (n=4), severe learning disability of unknown cause (n=9), SCN1 mutation with severe epilepsy (n=1), Klinefelter's syndrome (n=1), Cri du Chat (n=1), 16p11.2 microdeletion (n=1), and exposure to alcohol and anticonvulsants in utero (n=1). There was no information regarding the diagnoses of the remaining five children.

Feasibility of obtaining measurements

Measurement of weight and height was possible in all standers. Weight was obtained in 29 of 30 non-standers and supine length was possible in 28 of 30 non-standers. Among the 30 non-standers, segmental lengths including upper arm length, tibial length and knee height were obtained in 27, 30 and 28 children respectively. True waist circumference was obtained in 28 of 30 non-standers and 19 of 23 standers, and umbilical waist circumference in 26 non-standers and 17 standers.

Skinfold thickness measurement was feasible among non-standers, whereas standers tended to have poorer co-operation and did not like the calipers. Measuring the supra-iliac skinfold thickness was not feasible in the non-standers, and was measurable in less than half of the standers (10 of 23). Triceps skinfold thickness was achievable in 27 of 30 non-standers and 18 of 23 standers. Subscapular skinfold was achievable in 27 of 30 non-standers and 14 of 23 standers.

The time taken to obtain measurements in standers and non-standers is shown in *Supplementary table S1*. Measuring supine length in non-standers took twice as long as measuring height in standers. In contrast, it took longer to obtain subscapular skinfold thickness measurement in standers than in non-standers. It also took longer to measure weight in non-standers as they needed to be hoisted or transferred to sitting scales. The proportion of first 'successful' measurement are reported in *Supplementary table S2*.

Challenges encountered in taking measurements included: dystonic posturing, fixed flexion deformities, presence of an ileal conduit, difficulty locating landmarks in the obese or those with scoliosis, and distress or failure to cooperate (*Supplementary tables S3 to S6*).

Reliability of measurements performed

Table 1 shows the reliability of taking anthropometric measurements. Compared to standers, the TEM for non-standers was larger for height (or length), weight, and BMI but not for waist circumference.

The reliability of taking segmental measurements for non-standers is shown in Table 2.
The TEM for knee height was smaller than for tibial length or upper-arm length. The TEM for measured supine length in all non-standers was large. However, the TEM for both segmental and supine length in the <12 year olds was smaller. Excluding the participants with scoliosis from the analysis gave a TEM of 2.7, which was similar to the whole group (2.47).

Table 3 shows the limits of agreement (LOA) between measured supine length and that estimated from segmental measurements. Estimated supine lengths from segmental measurements compared with measured supine length showed wide LOA. Although the TEM for knee height was low compared with tibial length, the estimated supine lengths showed a wider LOA than for tibial length. The LOA for estimated length from upper-arm length were wide.

Table 4 shows the TEM for MUAC and skinfold measurements, which are presented in absolute measures as well as in standardised values. Non-standers had lower TEM for skinfold measures than standers, whereas the TEM for the arm circumference was similar for both standers and non-standers.

Taking BIA measurements was possible in 25 of 30 (83%) non-standers but only 17 of 23 (74%) standers *(Supplementary table S2).* Adiposity indices derived from BIA are shown in Table 5. The impedance values show larger TEM for non-standers than for standers.

DISCUSSION

In this study, we describe the reliability of obtaining anthropometric and BIA measurements in children with special needs. Our results show that the feasibility of taking measurements and the variability in repeated measurements depended on the specific condition of the child, particularly whether or not the child is able to stand unassisted.

Height, weight and body mass index

For both groups of children, particularly the non-standers, the reliability of weight measurements, taken two to four weeks apart, was somewhat poor. Possible reasons for this large variability may have been due to differences in the children's condition at that time, for example, timing of enteral feeds or meals, constipation, or fluid retention.

Poor co-operation or inability to lie still, particularly in those with dystonic movements, were some of the challenges involved in obtaining length measurement, as it involved placing a rollameter underneath the child and 'stretching' the legs. The presence of scoliosis did not appear to affect the repeatability of the measurement. However, the reliability of supine length was better in the under 12-year olds than the remaining older children. It is possible that knee and hip contractures may have reduced the reliability of supine length in the older children. Height measurement for those who can stand was achieved in all children with relatively good repeatability.

Measurements of height and weight were more difficult to assess and less reliable in non-standers than in standers. Poor repeatability of weight and supine length measurements in non-standers affected the reliability of their BMI.

Segmental height for non-standers

Segmental measurements as a means of estimating supine length showed poor repeatability using Stevenson's equations.[11] Estimation of length from segmental measurements depends on both the reliability of the measurement procedure and the prediction equation chosen.[18] Haapala *et al* investigated the agreement between total recumbent length of children with CP and that estimated from a number of different equations and they found only poor to moderate agreement.[18] The TEM for knee height in our study was larger than that reported by Stevenson[11] but that study only included children with the same condition (cerebral palsy) with a median age of 4.8 years. We found that the LOA between the measured supine length and that estimated from knee height for <12-year olds were much smaller, suggesting that this equation may be appropriate in this age group. Although the TEM for knee height in our study was considerably smaller than that for tibial length, this did not translate into better prediction of supine length, as the estimated supine length from tibial length showed narrower LOA. It is possible that the TEM was smaller for knee height because it involves using calipers resting on bony prominences, whereas tibial length involves locating a landmark and applying a tape measure. Knee height has been measured in a group of children with moderate to severe cerebral palsy (Gross Motor Function Classification System levels III- V) and has been used to produce growth curves that relate to severity of condition and health care use.[19] The population measured in our study was heterogeneous. Our results suggest that simply using serial measurements of knee height may be useful to assess individual trends in growth for those unable to stand.

Body circumferences and skinfold thickness

Waist circumference measurements (both true and umbilical) were difficult to achieve and showed poor reliability in both groups. This was mainly due to problems in locating landmarks in those who were overweight, in wheelchairs, wearing a spinal brace, or with ileal conduits.

MUAC has been used in combination with skinfold thickness to estimate cross-sectional fat and lean mass in the upper arm.[6] However, it correlates highly with skinfold thickness so the use of either measure may suffice. [20] In our study, MUAC seemed to provide moderate reliability.

The TEM for triceps, and subscapular skinfolds were smaller for the non-standers than the standers and this is likely to reflect the difficulty in taking skinfold measurements among standers.

Bioelectrical impedance analysis

The raw impedance values for non-standers showed a large error of measurement. This may be due to differences within the subject at different time periods, particularly hydration. For non -standers, the reliability of either weight or supine length could affect the reliability of the estimated body composition. For standers, the TEM for the raw impedance was smaller. However, obtaining body composition measures using BIA was easier to achieve than skinfolds, and may provide an alternative means of estimating body composition in this group of children.

Strengths and limitations

We studied the feasibility and reliability of measuring a heterogeneous group of children with special needs. There are very few studies reporting anthropometric measurements in these children. We replicated usual clinical or health care settings in the community by using locally available equipment in the school setting. Children were grouped according to their ability to stand which offers a practical approach. A strength of our study is that it describes measures likely to be feasible and identifies what challenges may need to be addressed to achieve these measurements.

For the standers, all the measurements were taken on two occasions by the same individual, but the primary school-aged standers were measured by one individual and the secondary school aged standers by a different individual. This approach may have introduced an element of bias as inter-observer TEMs could not be calculated.

CONCLUSION

Our study shows that a number of simple anthropometric measurements could be used to assess growth and body composition in children with special needs. However, the feasibility and reliability of obtaining these measures vary with the type of measurement and the ability to stand. Understanding the sources of variation in any choice of measurement for use in clinical or community settings may help reduce errors and improve reliability of these measurements. Future research may focus on how these measurements relate not only to growth and development but also on the metabolic health in children with special needs.

Acknowledgments

We would like to thank all the participants, their parents and carers for their willingness to be included in the study; to Andy Vail (R&D Support Unit Clinical Sciences Building Salford Royal NHS Foundation Trust) for statistical review and advice; to Lisa Kauffmann (Department of Community Paediatrics, CMFT) and Helen McCarthy (University of Ulster) for helpful discussions and support.

Disclosures None

Statements

What is already known on this topic?

- Anthropometric measures are widely used to assess nutritional status and as indicators of growth and development in children.
- Very little is known about the reliability of anthropometric or body composition measurements in children with special needs.
- Height predicted from segmental measurements has been assessed in children with cerebral palsy; the reliability of this method in children with special needs with a wide range of underlying conditions remains unclear.

What this paper adds

- Anthropometry and bioelectrical impedance body composition analysis were feasible to obtain in children with special needs in school settings.
- Reliability of measurements varied largely between children who could stand and those unable to stand unassisted.

REFERENCES

1. Houtkooper LB, Lohman TG, Going SB, *et al*. Validity of bioelectrical impedance for body composition assessment in children. *J Appl Physiol* 1989; 66: 814-21.

2. McCarthy HD, Jarrett KV, Crawley HF. The development of waist circumference percentiles in British children aged 5.0-16.9y. *Eur J Clin Nutr* 2001; 55: 902-7.

3. Norris B, Wilson JR. Child-data: the handbook of child measurements and capabilities – data for design safety. Department of Trade and Industry, UK. 1995.

4. Cole TJ, Freeman JV, Preece MA. Body mass index reference curves for the UK, 1990. *Arch Dis Child* 1995; 73: 25-9.

5. Tanner JM, Whitehouse RH. Revised standards for triceps and subscapular skinfolds in British children. *Arch Dis Child* 1975; 50: 142-5.

6. Frisancho AR. New norms of upper limb fat and muscle areas for assessment of nutritional status. *Am J Clin Nutr* 1981; 34: 2540-5.

7. Stallings VA, Charney EB, Davies JC, Cronk CE. Nutrition-related growth failure in children with quadriplegic cerebral palsy. *Dev Med Child Neurol* 1995; 35: 126-38.

8. Samson-Fang LJ, Stevenson RD. Identification of malnutrition in children with cerebral palsy: poor performance of weight -for -height centiles. *Dev Med Child Neurol* 2000; 42: 162-8.

9. Bandini LG, Curtin C, Hamad C, *et al*. Prevalence of overweight in children with developmental disorders in the continuous National Health and Nutrition Examination Survey (NHANES) 1999-2002 *J Paediatrics* 2005; 146: 658-62.

10. Marshall D, McConkey R, Moore G. Obesity in people with intellectual difficulties: the impact of nurse-led health screenings and health promotion activities. *J Adv Nurs* 2003; 43: 147-53.

11. Stevenson RD. Use of segmental measurements to estimate stature in children with cerebral palsy. *Arch Pediatr Adolesc Med* 1995; 149: 658-62.

12. Tanner JM, Whitehouse RH. Revised standards for triceps and subscapular skinfolds in British children. *Arch Dis Child* 1975; 50: 142-5.

13. Davies PS, Day JME, Cole TJ. Converting Tanner-Whitehouse reference tricep and subscapular skinfold measurements to standard deviation scores. *Eur J Clin Nutr 1993*; 47: 559-66.

14. Wells JCK. A critique of the expression of paediatric body composition data. *Arch Dis Child* 2001; 85: 67-72.

15. Reilly JJ, Wilson J, Durnin JV. Determination of body composition from skinfold thickness: a validation study. *Arch Dis Child* 1995; 73: 305-10.

16. Bland M, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; 8476: 307-10.

17. Wells JCK, Fewtrell MS. Measuring body composition. *Arch Dis Child* 2006;91:612-7.

18. Haapala H, Peterson MD, Daunter A, *et al.* Agreement between actual height and estimated height using segmental limb lengths for individuals with cerebral palsy. *Am J Phys Med Rehabil* 2015; 94: 539-46.

19. Stevenson RD, Conaway M, Chumlea WC, *et al.* Growth and health in children with moderate-to- severe cerebral palsy. *Pediatrics* 2006; 118: 1010-18.

20. Chomtho S, Fewtrell MS, Jaffe A, *et al*. Evaluation of arm anthropometry for assessing pediatric body composition: evidence from healthy and sick children. *Pediatr Res* 2006; 59: 860-865.

Table 1. Technical error of measurements between two repeat measurements for anthropometric measures for body sizes in children with special needs taken two to four weeks apart.

	Number of paired measurements n	Mean of paired measurements	Difference between 1st and 2nd measurement	P value	Technical error of measurement TEM (CV)
			Mean (95% CI)		
Non-standers (n=30)					
Supine length (cm)	25	126.0	0.3 (-1.1 to 1.8)	0.6	2.47 (1.96)
Weight (kg)	26	31.3	-0.2 (0.6 to 0.3)	0.5	0.75 (2.39)
Body mass index (kg/m^2)	23	19.3	-0.2 (-0.9 to 0.5)	0.6	1.38 (6.87)
True waist circumference (cm)*	26	70.0	0.05 (-1.0 to 1.1)	0.9	1.82 (2.6)
Umbilical waist (cm)	26	68.3	-6.3 (-1.4 to 0.8)	0.6	1.83 (2.7)
Standers (n=23)					
Standing height (cm)	22	144.9	-0.32 (-0.6 to 0.0)	0.04	0.55 (0.38)
Weight (kg)	23	50.6	-0.09 (-0.5 to 0.3)	0.6	0.59 (1.18)
Body mass index (kg/m^2)	22	22.0	0.04 (-0.2 to 0.2)	0.7	0.31 (1.44)
True waist circumference (cm)*	17	80.0	-0.02 (-1.4 to 1.4)	1.0	1.86 (2.33)
Umbilical waist (cm)	17	76.0	-0.7 (-2.2 to 0.8)	0.3	2.04 (2.68)

CI – confidence interval; Body mass index: for standers=weight/height^2, for non-standers=weight/supine length^2; Difference in means P value assessed by paired t test. TEM $=\sqrt{\sum d^2/2n}$, where d = difference between two measurements and n= number of measurements. CV = coefficient of variability: 100 x TEM/mean of measurements taken, expressed as a percentage.

Table 2. Technical error of measurement between two repeat measurements of segmental length for non-standers taken two to four weeks apart.

	Number of paired measurements	Mean of paired measurements	Difference between 1st and 2nd measurement	P value	Technical error of measurement TEM (CV)
	n		Mean (95% CI)		
Upper arm length (cm)	25	27.2	0.5 (-1.3 to 0.3)	0.2	1.37 (5.03)
Tibial length (cm)	27	29.4	0.2 (-0.7 to 1.1)	0.6	1.57 (5.35)
Tibial length (cm) <12 years	17	26.8	-0.23 (-0.97 to 0.51)	0.26	1.00 (3.74)
Knee height (cm)	27	37.3	0.1 (-0.6 to 0.4)	0.7	0.81 (2.18)
Knee height (cm) <12 years	17	33.6	-0.23 (-0.90 to 0.45)	0.24	0.91 (2.72)
Supine length (cm)	25	126.0	0.3 (-1.1 to 1.8)	0.6	2.47 (1.96)
Supine length (cm) <12 years	15	116.4	-0.058 (-1.19 to 1.08)	0.46	1.39 (1.20)

SD – standard deviation; CI – confidence interval; *Based on Stevenson's method[11] using the following equations: (4.35 x upper arm length) + 1.28, (3.26 x tibial length) +30.8, and (2.69 x knee height) + 24.2; Difference in means and significance (P value) assessed by paired t test;TEM = $\sqrt{\sum d^2/2n}$ where d = difference between two measurements and n = number of measurements. CV = coefficient of variability: 100 x TEM/mean of measurements taken, expressed as a percentage.

Table 3. Limits of agreement between mean measured supine length (1 and 2) and mean estimated supine length from segmental measures (1 and 2), with measures 1 and 2 taken two to four weeks apart.

	Number of paired measurements (n)	**Mean of measured supine length 1 and 2 (SD)**	**Mean of estimated length 1 and 2 (SD)**	**Difference between measured and estimated Mean (95% CI)**	**P value**	**95% Limits of agreement**
Estimated length from upper arm length	22	124.7 (19.7)	140.2 (24.5)	-15.5 (-20.2 to -10.7)	<0.001	-36.5 to 5.5
Estimated length from tibial length	25	126.0 (19.4)	126.3 (19.9)	-0.26 (-2.15 to 1.64)	0.8	-9.2 to 8.7
Estimated length from knee height	25	126.0 (19.4)	124.8 (19.8)	1.3 (-1.1 to 3.7)	0.3	-10.0 to 12.5
Estimated length from TL <12yrs	15	116.1(17.1)	116.3(18.09)	-0.13 (-2.7 to 2.4)	0.5	-9.2 to 8.9
Estimated length from KH <12yrs	15	116.1 (17.1)	113.95(17.22)	2.19 (0.02 to 4.36)	0.02	-5.5 to 9.9

Measurements 1 and 2 taken 2 to 4 weeks apart; CI – confidence interval; TL = tibial length; KH = knee height.

Table 4. Technical error of measurement between two repeat measurements of adiposity using skinfold thickness taken two to four weeks apart.

	Number of paired measurements (n)	Mean of paired measurements	Difference between 1st and 2nd measurement Mean (95% CI)	P value	Technical error measurement TEM (CV)
Non-standers (n=30)					
Mid-upper arm circumference (cm)	28	22.1	-0.5 (-0.9 to 0.1)	0.03	0.82 (3.72)
Triceps skinfold thickness (mm)	27	15.5	-0.5 (-1.6 to 0.6)	0.4	1.94 (12.5)
Triceps SDS	27	0.75	-0.13 (-0.36 to 0.11)	-	0.45 (59.43)
Biceps skinfold thickness (mm)	26	9.3	-0.0 (-1.5 to 1.5)	1.0	2.36 (25.6)
Subscapular skinfold thickness (mm)	26	12.1	-0.5 (-2.0 to 0.3)	0.2	1.28 (8.3)
Subscapular SDS	26	0.33	1.23(0.48 to 1.97)	-	0.34 (102.33)
Suprailiac skinfold thickness (mm)	-	-	-	-	-
Standers (n=23)					
Mid-upper arm circumference (cm)	22	26.1	-0.1 (-0.7 to 0.5)	0.7	0.91 (3.5)
Triceps skinfold thickness (mm)	17	17.2	1.4 (-0.7 to 3.5)	0.2	2.99 (17.4)
Triceps SDS	17	1.09	-0.17 (-0.45 to 0.12)	0.11	0.39 (36.3)
Biceps skinfold thickness (mm)	16	16.4	1.1 (-1.2 to 3.5)	0.3	3.11 (19.03)
Subscapular skinfold thickness (mm)	12	16.4	-2.6 (5.4 to 0.2)	0.06	3.49 (21.29)
Subscapular SDS	12	1.18	-0.12 (-0.3 to 0.06)	0.08	0.2 (17.5)
Suprailiac skinfold thickness (mm)	8	18.9	0.1 (-3.1 to 4.0)	0.8	2.79 (14.8)

SDS – standard deviation score using LMS method[13]; CI – confidence interval; Difference in means P value assessed by paired t test TEM $=\sqrt{\sum d^2/2n}$ where d=difference between 2 measurements and n= no of measurements. CV = coefficient of variability: 100 x TEM/mean of measurements taken, expressed as a percentage

Table 5. Technical error of measurement between two repeat measurements of body composition using bioimpedance analysis taken two to four weeks apart.

	Number of paired measurements (n)	Mean of paired measurements	Difference between 1st and 2nd measurement	P value	Technical error of measurement TEM (CV)
			Mean (95% CI)		
Non-standers (n=30)					
Impedance (Ω)	22	878.9	0.05 (-34.7 to 34.8)	0.99	54.1 (6.16)
Fat-free mass index (kg/m^2)*	21	12.9			0.67 (5.25)
Fat mass index (kg/m^2)**	21	6.46			0.8 (12.39)
Standers (n=23)					
Impedance (Ω)	16	635.6	2.6 (-24.4 to 29.5)	0.8	34.7 (5.45)
Fat-free mass index (kg/m^2)*	16	16.41			0.53 (3.23)
Fat mass index (kg/m^2)**	16	6.65			0.59 (8.93)

CI – confidence interval; Difference in means P value assessed by paired t test. TEM =$\sqrt{\sum d^2/2n}$ where d=difference between 2 measurements and n= no of measurements. CV = coefficient of variability %TEM = 100 x TEM/mean; *Calculated using Houtkooper's equation[1]: FFM = 0.61xht^2/impedance +(0.25 x weight) + 1.31; Fat-free mass index = Fat-free mass/supine length[2, 14]; **Fat mass=body weight – fat-free mass; Fat mass index = fat mass/supine length[2,1]