The effect of different body positions on anthropometric measurements and derived estimates of body composition

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Abstract

Purpose: Measurement of cross-sectional lean limb area using physical anthropometry is usually performed in the standing position, but sometimes this may be impractical. Our aim was to determine the effect of different positions on cross-sectional lean area of the upper arm, calf and thigh derived from girth and skin-fold measurements.

Methods: Twenty healthy volunteers participated. Girth and skin-fold thickness of the upper arm, calf and thigh were measured in the standing, sitting and supine positions. We derived lean cross-sectional area (cm^2), and calculated the mean difference, its 95% confidence intervals (CI), and the 95% limits of agreement (LOA) between standing and the other two positions.

Results: For the upper arm, mean differences in lean cross-sectional area for the supine-standing and sitting-standing positions were $0.7cm^2$, (95% CI -0.6 to 2.0) and $-0.6cm^2$, (95% CI -1.4 to 0.3) respectively. Mean differences for thigh were $3.9cm^2$ (95% CI -2.3 to 10.1) and $-4.3cm^2$ (95% CI -8.6 to 0.0) for supine-standing and sitting-standing respectively. For the calf, mean difference for supine-standing was $-3.1cm^2$ (95% CI -5.3 to -0.9), while for sitting-standing it was $0.3cm^2$ (95% CI -1.8 to 2.4). The range of values expected to cover agreement for 95% of subjects (LOA) was widest for the thigh and narrowest for the upper arm.

Conclusion: In young healthy subjects, lean cross-sectional area differs according to measurement position, particularly for the lower limb. The same measurement method should be used in any one individual when monitoring change.

Key words: physical anthropometry, body position, muscle cross-sectional area

Introduction

Anthropometry is a non-invasive method for assessing nutritional status, growth and development and sports performance, including estimation of overall and limb-specific muscle mass. This was first done in a systematic way over 80 years ago [1]. Later, in the 1940s, pioneering work on nitrogen retention by adipose tissue spearheaded research into body fat estimation [2] and the subsequent use of densitometry to validate over a hundred equations which predict adiposity from surface anthropometry [3,4]. In the 1980s a standardized protocol for anthropometric measurements was proposed [5]. More recently, the International Society for the Advancement of Kinanthropometry (ISAK) [6], developed a series of standard anthropometric protocols and measurements which are quality assured (% technical error of measurement, intra and inter-tester) and include examinations and qualifications.

ISAK stipulates that anthropometric measurements should be carried out in the standing position, with the exception of the thigh skin-fold which is measured with the subject sitting unsupported on a box. This method may not always be practical. For example, in medical specialities such as stroke medicine and intensive care, where anthropometry could be used to monitor nutritional status and muscle wasting, many patients are nursed in bed and are unable to stand, necessitating anthropometric measurements in sitting or supine positions [7].

We have therefore adapted the ISAK technique for use in the sitting (supported) and supine positions (appendix). Our aim was to establish how well the adapted techniques agreed with the established methods, to determine whether the techniques could be used interchangeably, or whether one method could replace another. This method comparison study was analysed using Bland & Altman's method for calculating limits of agreement [8].

Methods

Healthy volunteers were recruited via advertisements on hospital notice boards, via the University staff email system and from among colleagues. Formal sample size calculations were not applicable for this type of method comparison study. The study received local Research Ethics Committee approval. Written informed consent was obtained from all volunteers. The study was performed at Lothian University Hospital Trust's Clinical Research Facility.

The rationale for the study involved predicting muscle circumference from girths and skinfold measurements which were made following 'landmarking' the body, ie, locating and marking an appropriate point on the skin surface which can be related to the underlying skeletal structure. Assuming limb cross-sections are circular and concentric, then the muscle circumference equates to the limb circumference from which the skinfold (multiplied by π) is subtracted [9,10]. All measurements were carried out by an ISAK qualified (level II) anthropometrist using Harpenden skinfold calipers (British Indicators, Burgess Hill, UK), an anthropometric metal tape measure (Lufkin, Cooper Industries USA), and a Segmometer (Rosscraft, Surrey, Canada).

The upper arm girth at the mid acromiale – radiale level, biceps and triceps skinfolds, mid thigh girth and skinfold (mid way between inguinal crease and anterior patella) and medial calf girth and skinfold were measured on the right side of the body in the three positions: 'standing ie. ISAK position', 'sitting' and 'supine'. These positions were chosen because of their functional relevance for important activities of daily living. The sites for the ISAK position were marked with a black pen. The sites for the ‘sitting’ position were marked with a blue pen, if different from previous site, and made while sitting supported on a wooden chair which had a horizontal seat, a vertical back and two arm rests. The sites for the ‘supine’ position were marked with a green pen, if different from previous two sites, and made while lying on a treatment couch (see Appendix). All sets of measurements were taken within 1 hour with no fluid intake allowed between sets. Measurements were taken to the last completed mm. Stature and body mass were measured using a Stadiometer (BodyCare, UK) and weighing scales (SECA 954 1309109, Germany). Stature was measured to the last completed mm and mass recorded in kg to 2 decimal places. The volunteers wore light weight shorts and a T-shirt.

Prediction equations [10] were used to calculate the lean cross sectional areas (i.e. muscle and bone)

$LA = (G-\pi S)^2 / 4\pi$

LA = lean cross-sectional area

S=skinfold

G=girth

The mean of the biceps skinfold and triceps skinfold was used to calculate the upper arm skinfold.

Mean differences between pairs of measurements were calculated to assess the overall bias of one method compared to the other. The 95% confidence intervals for the mean differences were also calculated. Bland & Altman's method for calculating limits of agreement [8] was used to estimate the level of agreement between measurements taken in the supine or sitting positions compared to the ISAK (standing) position.

Results

20 volunteers were recruited; their characteristics are shown in Table 2.

The Bland & Altman method for calculating level of agreement assumes that there is no relationship between the difference between the methods and the mean of the methods. It also assumes that the distribution of the differences is approximately Normal [8]. Both these assumptions were tested statistically for each comparison and no violations were found.

Table 2 shows the mean cross-sectional area (upper arm, thigh & calf) in the three positions and the mean difference and 95% confidence interval for each pair of comparisons. The range of values covering the agreement expected between the supine or sitting method and the ISAK method is expressed as the 95% limits of agreement.

The mean difference is an estimate of the average bias of the supine or sitting method relative to the ISAK method. Mean differences close to zero suggest that overall the methods agree well. The 95% confidence interval is an indication of the range within which the bias is likely to be, based on that set of data. It is a clinical judgement as to whether or not that range of bias is important and it depends on the particular measurement and the use to which it is to be put.

For the upper arm (Table 2) the mean differences were small in relation to the absolute mean area and the 95% confidence intervals were narrow. This suggests that there was little overall bias between the pairs of methods for the upper limb. This was also true for the calf for the comparison of the sitting and ISAK method. The mean difference was greater for the supine-ISAK comparison in the calf and for both method comparisons in the thigh. In the thigh, supine lean cross-sectional area was greater than ISAK. However, for the supine-ISAK comparison in the thigh, the 95% confidence interval was wide indicating that there could be a mean difference of as much as $10cm^2$ between the methods. The confidence interval for the supine-ISAK comparison in the calf did not include zero suggesting that there was an overall bias between these methods, the supine position producing the lower estimates of cross-sectional area. In the thigh, zero was at the upper margin of the confidence interval for the sitting-ISAK comparison indicating less bias, with the sitting position producing the lower results.

The 95% limits of agreement indicate how well the methods are likely to agree for an individual. They are calculated as the mean difference plus or minus 1.96 times the standard deviation of the difference. This gives a range within which the agreement between the methods will fall for 95% of observations. Again, acceptable agreement cannot be defined statistically as it depends on clinical circumstances.

The limits of agreement in Table 2 suggest that agreement between the methods for an individual is likely to be greatest in the upper arm and lowest in the thigh.

Discussion

The measurement of different segments of the body using anthropometric methods is an inexpensive, non invasive way of estimating body composition. The internationally accepted ISAK method of positioning and measurement is not suitable for those who cannot tolerate standing or sitting unsupported. Hence we modified the ISAK method for practical use in the supine and sitting positions. We found that the position influenced anthropometric measurements and therefore suggest that the same position should be used in one individual when attempting to monitor change over time.

It has been suggested that a sample size of fifty is desirable for method comparison studies [11], but we were unable for practical reasons to recruit more than twenty participants. Nevertheless this study is still an important contribution to the anthropometry literature because it is the first to evaluate the level of agreement between the ISAK method and both supine and sitting for lean cross-sectional area in healthy subjects. When we performed a subsequent study investigating longitudinal changes in muscle size and strength after stroke [12], we used the same body position when we repeated measurements.

The reasons why lean cross-sectional areas varied according to the position in which the measurements were taken are complex. The postural differences in measurements could be due to fluid movement and pressures (blood and extracellular fluid), which may respond to external hydrostatic influences. Also, the postural muscles are active when standing (and propriocepting), requiring altered length-tension relationships, relative to sitting or lying relaxed. This is true for both quadriceps and gastrocnemius, and therefore affects the front thigh and calf measurements. Contracting muscles may increase the adhesion of the surface between the muscle and the superficial adipose tissue, which would make a skinfold more difficult to raise.

What are the implications of this study? When anthropometry is performed in the supine or sitting position in healthy people, it is important to be aware that lower limb measurements, in particular lean cross-sectional area, may not be comparable to those that would have been obtained had the ISAK method been used. If a clinician or researcher is interested in monitoring changes in nutritional status or in muscle mass over time by using anthropometry, the same technique should be used whenever measurements are repeated. In the comparisons for which we found evidence of an overall bias, it may be possible to introduce a correction factor to standardise the new position in relation to the ISAK method.

This study was carried out in healthy young volunteers. Differences in plasticity of tissues and adiposity in older subjects or in those who are medically unwell may well have a greater influence on anthropometric measurements performed in different positions. Tothill and Stewart [10] concluded that the circular concentric model proved valid in estimating lean cross sectional area in the thigh, but acknowledged some wide individual variation, especially with increasing adiposity. In a non-athletic population with different resting muscle tone, and turgidity of overlying tissues, the results may display greater scatter.

We would urge researchers and clinicians to adhere wherever possible to the ISAK method and not to adapt its positioning without formally evaluating the effect of their modifications. Should it be impractical to use the ISAK position, researchers should ensure that the same method is used in individual patients to study changes over time. Further research is required in specific clinical groups to determine whether these findings can be generalized further.

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Competing interests: None

Table 1: Physical characteristics of participants

	Males (n= 6)	**Females (n= 14)**
Median Age (range)	34 (22-47)	30 (21-47)
Stature m (mean, SD)	1.80 (0.06)	1.66 (0.04)
Mass kg (mean, SD)	79.7 (14.0)	62.6 (8.0)
Body Mass Index (kg.m^{-2})	24.4 (2.6)	22.6 (2.2)
Sum of skinfolds*	42.3 (15.1)	54.9 (20.2)

* Sum of biceps, triceps, subscapular and iliac crest skinfolds, in the ISAK position.

Table 2: Differences between lean cross sectional area in cm^2 measured in three positions

Region	**Mean (SD) area (n=20)**		**Comparison**	**Mean difference (95% confidence interval)**	**95% Limits of agreement**
Upper arm	Supine	55.3 (13.4)	Supine - ISAK	0.7 (-0.6 to 2.0)	-4.9 to 6.3
	Sitting	54.1 (12.6)	Sitting - ISAK	-0.6 (-1.4 to 0.3)	-4.3 to 3.2
	ISAK	54.6 (12.8)			
Thigh	Supine	148.2 (34.5)	Supine - ISAK	3.9 (-2.3 to 10.1)	-22.6 to 30.5
	Sitting	140.0 (39.0)	Sitting - ISAK	-4.3 (-8.6 to 0.0)	-22.7 to 14.2
	ISAK	144.3 (38.4)			
Calf	Supine	86.8 (20.4)	Supine - ISAK	-3.1 (-5.3 to -0.9)	-12.4 to 6.3
	Sitting	90.1 (20.3)	Sitting - ISAK	0.3 (-1.8 to 2.4)	-8.7 to 9.3
	ISAK	89.8 (20.7)			

Appendix

Modifications of the ISAK positioning used for landmarking, girth and skinfold measurements in this study.

	Site	Landmarking	Girth	Skinfold
Supine	Biceps	Subject rolls onto side to aid landmarking.	Arm supported on bed in the anatomical position	Arm supported on bed in the anatomical position
	Triceps	As above	As above	Subject rolls onto side if possible. Ability/inability to turn in bed will be recorded. Elbow flexed at 90°. Arm medially rotated
	Thigh	Leg fully extended and supported by bed	Leg fully extended and supported by bed	Leg fully extended and supported by bed
	Calf	Thigh fully supported by rolled mat – calf not in contact with mat. Heel supported 45° flexion at knee. Toes aligned	Thigh fully supported by rolled mat or cushion - calf not in contact with mat. Heel supported 45° flexion at knee Toes aligned with knee at neutral	Thigh fully supported by rolled mat – calf not in contact with mat. Heel supported approximately 45° flexion at knee. Angle recorded using goniometer. Toes aligned with knee at neutral position

		with knee at neutral position	position	
Sitting	Biceps	Arm unsupported, in anatomical position to side of chair	Arm supinated Elbow supported on armrest of chair. 45° flexion at elbow	Arm supinated Elbow supported on armrest of chair. 45° flexion at elbow
	Triceps	Arm unsupported, in anatomical position to side of chair	Elbow flexed at 90° Elbow supported on arm-rest of chair Arm medially rotated	Elbow flexed at 90° Elbow supported on arm-rest of chair Arm medially rotated
	Thigh	Thigh fully supported by surface of chair	Thigh fully supported by surface of chair	Fully supported by surface of chair
	Calf	Foot supported on a box 90° flexion at knee	Foot supported on a box 90° flexion at knee	Foot supported on a box 90° flexion at knee