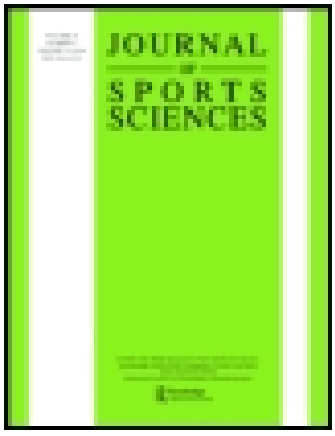

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The importance of accurate site location for skinfold measurement

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Abstract
We assessed the importance of accurate site location for skinfold measurement in ten healthy males in a cross-sectional quantitative study. Nine measurements, in a 1-cm grid pattern, centred on each of eight ISAK-specified skinfold sites, were taken three times at each grid point by each of two ISAK Level 4 practitioners using Harpenden skinfold callipers. The presence of significant systematic discrepancy between reliability measures of different skinfold sites and grid points for each of the two testers was determined using P-values. Effect sizes were calculated to show the magnitude of effects. Skinfolds taken at the eight peripheral grid points were generally different from the skinfolds taken at a central ISAK grid point and there was an effect by direction away from the central ISAK point (anterior, posterior, superior or inferior). The subscapular skinfold had the least number of differences (three) and the abdominal had the most (eight). All other skinfold sites showed some variation with most care needed in marking the biceps and triceps skinfold sites. Adherence to identifying, marking, and measuring at the defined site is essential.

Keywords: *Anthropometry, skinfolds, measurement reliability*

Introduction

Anthropometric measurement has a long history extending back over at least two millennia and is now practised universally (Marfell-Jones, Olds, Stewart, & Carter 2006a). Other than height and weight, arguably the most measured anthropometric variables today are skinfolds. To minimize technical error of measurement differences between repeat skinfold measures, measurement sites and measurement techniques have been defined. One example of such definitions can be found in the International Standards for Anthropometric Assessment (Marfell-Jones *et al.*, 2006a), which sets out the measurement standards approved by the International Society for the Advancement of Kinanthropometry (ISAK). For each of the eight skinfold sites that the ISAK standards define, the measurement site at which the skinfold is picked up is clearly specified as being on, or a specific distance from, an identifiable anatomical landmark. Before taking skinfold measurements, ISAK-qualified anthropometrists mark all skinfold measurement sites so that repeat measures can be taken at the same place for each site during that particular measuring occasion and at, or as close as possible to, the same site on separate measurement occasions. This marking process takes time, but has long been intuitively considered an important factor in minimizing the technical error of measurement.

Few studies, however, have investigated the magnitude of any errors likely to derive from not measuring at exactly specified points. Ruiz and colleagues (Ruiz, Colly, & Hamilton, 1971) reported that skinfold thickness varied by an average of 2.5 mm when the calliper was placed 2.5 cm from the correct site. The reality of a location error of that magnitude, however, is not easy to credit. It is more reasonable to question whether a much more realistic margin of error, say 1 cm, would still result in significantly different skinfold values being obtained. If, at that distance, variability of skinfold measurement values about specific ISAK skinfold sites was not significant, then quicker estimation marking methods might be possible.

A reliable test is considered to be one with small changes in the mean, a low standard error of measurement, and a high test–retest correlation

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between repeated trials (Hopkins, Schabort, & Hawley 2001). The purpose of this cross-sectional quantitative study, therefore, was to determine the reliability of skinfold measurements across a range of different positions placed on a 1-cm grid surrounding the usual ISAK skinfold sites. The results of this study will have clear implications for training certified anthropometrists internationally.

Methods

When assessing the reliability of a test procedure, it is important that the assessment is as specific as possible to actual clinical conditions, as there may be a number of factors that alter the level and consistency of tester performance in obtaining the skinfolds. Therefore, all testing was conducted in the J. E. Lindsay Carter Anthropometry Laboratory at Auckland University of Technology, which is frequently used for body composition testing of both athletic and non-athletic populations.

All procedures used in this study complied with the guidelines of the Auckland University of Technology Ethics Committee (approval number AUT/06/59).

Participants

Ten healthy male university students and staff participated in the study. The participants' characteristics are summarized in Table I. Each participant attended a one-hour appointment. An informed consent form that included demographic information (age, gender, and ethnicity) was completed.

Measurers

All sites were identified and all skinfolds were measured by two ISAK-accredited Level 4 anthropometrists as defined by Marfell Jones and colleagues (Marfell-Jones, Olds, Stewart, & Carter, 2006b), using the same instrument for any given individual. Participants were measured by one tester and then, after a 10-min rest period, by the second tester. Since the average time for measuring all skinfolds on a single individual was 20 min, the time between any variable being measured by the first tester and the second tester on the same individual was approximately 30 min.

Table I. Participant characteristics (mean $\pm$ *s*).

Participants (all males)	10
Height (m)	1.78 $\pm$ 0.06
Mass (kg)	79.8 $\pm$ 12.4
Age (years)	27.9 $\pm$ 6.9
Sum of eight skinfolds (mm)	93.4 $\pm$ 29.9

Equipment

A Lufkin tape, Rosscraft segmometer, and a 1-cm grid template were used to identify skinfold sites. All skinfold measures were taken with Harpenden callipers (10 g $\cdot$ mm^{-2} constant pressure).

Procedures

All participants were measured for standing height, body mass, and eight skinfolds using ISAK protocols (Marfell-Jones *et al.*, 2006a). Data were recorded onto an adapted ISAK restricted-profile recording sheet.

Eight ISAK skinfold sites (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, and medial calf) were marked on the participant's body using standard ISAK procedures. Eight measurement dots in a 1-cm grid were marked surrounding each ISAK skinfold mark (see Figure 1). The grid pattern was aligned perpendicular to the ISAK pick-up direction for each skinfold (see Figure 2). For each ISAK skinfold site, nine skinfold measurements were assessed three times at each grid point by each of the two anthropometrists. The skinfolds were picked up at each site using the standard ISAK procedure with the dot point representing the intersection of the cross marked in the normal ISAK landmarking protocol. ISAK Level 3 recorders called the site and grid dot to be measured and checked the correct grid position was used.

Data analyses

Descriptive statistics for all variables were calculated as means and standard deviations. Plots of residuals were calculated for each tester for each grid point to

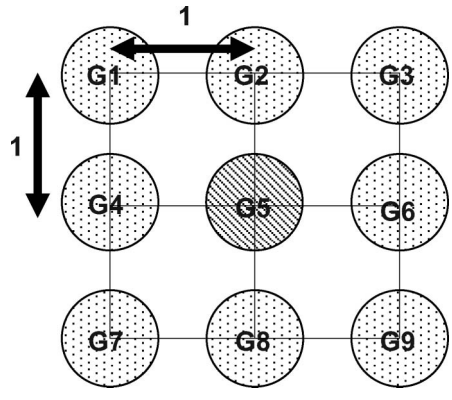

Figure 1. Central ISAK grid point 5 (G5) and peripheral grid sites (G1–G4, G6–G9) used for skinfold grid point selection.

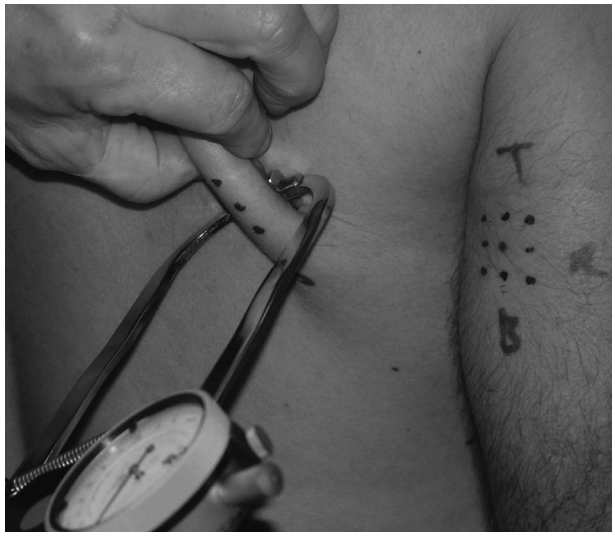

Figure 2. Measurement of the subscapular skinfold at grid point 2.

identify outliers due to incorrect data recording. Reliability statistics determined using Proc Mixed in SAS were differences of least-squares means (%), standardized errors (Cohen), fixed effect estimates (%), standardized fixed effects (Cohen), random effects expressed as coefficients of variance (%), and 95% confidence limits. The presence of significant systematic discrepancy between reliability measures of different skinfold sites and grid points for each of the two testers was determined using *P*-values. Effect sizes (ES) were calculated to show the magnitude of the effects, with the thresholds for trivial, small, moderate, and large effects being 0.2, 0.6, 1.2, and 2.0, respectively (Hopkins, 2002).

Results

Descriptive statistics

The descriptive statistics for the sample are shown in Table I. The average sum of eight skinfolds for the participants indicated they were relatively lean.

Influence of one-centimetre variation from standard ISAK skinfold sites

Each of Tables II–IX represents one skinfold site with nine locations – that is, eight peripheral grid sites surrounding the central ISAK site (G5). Therefore, each table consists of nine cells, a central cell (G5) and eight peripheral cells. The numbers in each of the eight peripheral cells describe the relationship with the G5 cell for the average of the two testers. In each cell, the top number is the absolute difference in millimetres, the middle number is the *P*-value for the *t*-test comparison, and the bottom number is the Cohen effect size. If the top number within a cell is grey and bold, then that number is more than 0.5 mm greater than G5. If the middle number within a cell is grey and bold, then that number is significantly different to G5. If the bottom number within a cell is grey and bold, then that number indicates a non-trivial difference to G5.

Given that skinfolds are greater at some sites than others, it is not only the absolute error that is important, but also the effect size. The standardized Cohen effect size provides the magnitude of differences with any effects less than 0.2 considered trivial, and those between 0.2 and 0.6 considered small.

Triceps. Table II shows the triceps skinfold site had 7 of 8 grid points significantly different from G5. There was a clear diagonal trend, with a more medial skinfold (G1, G4, G7) producing a larger skinfold than G5 (with the largest deviation being inferior and medial at 1.27 mm) and a lateral skinfold (G3, G6, G9) producing a smaller skinfold than G5 (with the largest deviation being superior and lateral at −1.06 mm). The standardized Cohen effects were small, with the largest effect of 0.4 in the superior and medial direction at G1.

Subscapular. Although Table III shows the lateral points G3 and G9 were significantly larger than G5 for the subscapular skinfold site, while the medial point G7 was significantly smaller, the standardized Cohen effect sizes were trivial for all peripheral sites with all effects below 0.2. All mean differences were less than 0.3 mm.

Biceps. Table IV shows the biceps skinfold. Six of eight grid points were significantly different from G5. A more lateral skinfold (G1, G4, G7) produced a smaller skinfold than G5, with the largest deviation being inferior and lateral at −0.8 mm. A more medial skinfold (G3, G6, G9) produced a larger skinfold than G5, with the largest deviation being superior and medial at 0.61 mm. The standardized Cohen effects were small, with the largest effect of 0.34 found in both the superior mid-direction at G2 and the inferior lateral direction at G7.

Iliac crest. Table V shows the anterior grid points (G3, G6, G9) were significantly larger than G5 for the iliac crest site, with the largest deviation being inferior and anterior at 2.12 mm. A more posterior midline skinfold (G4) produced a smaller skinfold than G5, with a −0.6 mm deviation. The standardized Cohen effects were all trivial.

Supraspinale. Table VI shows the supraspinale site had all points except G1 significantly different from

Table II. Triceps skinfold site.

Grid point key: mm / p value / effect size

	Superior		
Medial	0.33 **0.018** **0.40**	-0.40 **0.000** **0.26**	**-1.06** **0.000** **0.25**
	0.82 **0.000** **0.24**	**ISAK** **Triceps**	**-0.67** **0.000** **0.22**
	1.27 **0.000** **0.26**	0.16 0.079 **0.25**	-0.34 **0.033** **0.28**
	Inferior		Lateral

Table III. Subscapular skinfold site.

	Superior		
Medial	-0.08 0.425 0.11	0.15 0.119 0.11	0.25 **0.023** 0.18
	0.10 0.524 0.09	**ISAK** **Subscapular**	0.19 0.056 0.11
	-0.23 **0.023** 0.11	-0.00 0.986 0.11	0.30 **0.004** 0.10
	Inferior		Lateral

Table IV. Biceps skinfold site.

	Superior		
Lateral	**-0.55** **0.000** **0.30**	-0.22 0.455 **0.34**	**0.61** **0.000** **0.32**
	-0.38 **0.001** **0.27**	**ISAK** **Biceps**	**0.54** **0.000** **0.23**
	-0.80 **0.010** **0.34**	0.07 0.127 **0.30**	0.48 **0.000** **0.29**
	Inferior		Medial

Table V. Iliac crest skinfold site.

	Superior		
Posterior	-0.34 0.152 0.18	0.33 0.111 0.15	**1.84** **0.000** 0.15
	-0.60 **0.015** 0.15	**ISAK** **Iliac Crest**	**1.91** **0.000** 0.16
	-0.28 0.166 0.18	0.40 0.103 0.12	**2.12** **0.000** 0.16
	Inferior		Anterior

Table VI. Supraspinale skinfold site.

	Superior		
Lateral	-0.08 0.509 **0.21**	**-0.66** **0.000** 0.16	**-0.84** **0.000** 0.19
	0.48 **0.000** 0.18	**ISAK** **Supraspinale**	**-0.57** **0.000** 0.16
	0.95 **0.000** 0.16	0.50 **0.000** 0.17	-0.44 **0.009** 0.17
	Inferior		Medial

Table VII. Abdominal skinfold site.

	Superior		
Lateral	**1.03** **0.000** 0.11	**0.69** **0.001** 0.09	**1.62** **0.000** 0.13
	0.39 **0.047** 0.07	**ISAK** **Abdominal**	**1.09** **0.000** 0.11
	0.93 **0.000** 0.12	**0.84** **0.006** 0.09	**1.00** **0.000** 0.10
	Inferior		Medial

Table VIII. Thigh skinfold site.

	Proximal		
Lateral	-0.50 **0.003** 0.19	-0.13 0.305 0.16	0.23 0.105 0.17
	-0.14 0.354 0.17	**ISAK** **Front thigh**	**0.55** **0.001** 0.16
	-0.00 0.976 0.17	0.39 **0.006** **0.23**	**0.76** **0.000** **0.24**
	Distal		Medial

Table IX. Calf skinfold site.

	Superior		
Anterior	0.02 0.870 **0.30**	-0.25 **0.004** **0.22**	-0.33 **0.005** **0.29**
	0.36 **0.045** 0.17	**ISAK** **Medial calf**	0.10 0.305 **0.22**
	0.23 **0.028** **0.20**	0.26 **0.002** 0.18	0.32 **0.003** **0.25**
	Inferior		Posterior

Note: In each cell, the top number is the average difference in millimetres and the middle number is the *P*-value compared with the central ISAK site. The bottom number is the standardized Cohen effect size. See Table II for grid point key.

G5. There was a shift from the smallest skinfolds at the G3 (superior and medial) position moving on the diagonal to the largest skinfolds at the G7 (inferior and lateral) position. The standardized Cohen effects were trivial at all grid points except for G1, which had a small effect of 0.21.

Abdominal. Table VII shows that all abdominal grid points were significantly larger than G5, with the differences ranging from 0.39 to 1.62 mm. However, the standardized Cohen effects were trivial for all grid points.

Thigh. Table VIII shows there was a small directional trend with three thigh points (G6, G8, G9) significantly larger than G5 (with differences of 0.39–0.76 mm) and G1 significantly smaller (by −0.5 mm). The standardized Cohen effects were trivial for six of the eight grid points, with only G7 and G8 having small effects (of 0.23 and 0.24, respectively).

Calf. Table IX shows the calf had all grid points except G1 and G6 significantly different from G5, with differences of up to 0.36 mm. The standardized Cohen effects were small for six of the grid points and trivial for the other two points.

Table X summarizes the absolute difference ranges, the number of significant mean differences, and the number of trivial and small effects. Each skinfold had a number of significantly different grid points compared to G5, with the subscapular skinfold having the least number of differences (three) and the abdominal having the most (eight). The triceps, biceps, supraspinale, and calf also had six or more grid points significantly different from G5. The abdominal and supraspinale had the most grid point differences above 0.5 mm.

The biceps and triceps had small effects at all grid points and absolute differences were over 0.5 mm for half the grid points. Although the calf had six small effects, and six significant differences, the absolute differences were all less than 0.5 mm (0.02–0.36 mm). Measurements lateral to G5 on the thigh resulted in small effects. The subscapular, iliac crest, and abdominal only had trivial effects, with only the subscapular having absolute differences less than 0.5 mm (0–0.3 mm). Therefore, the subscapular was a relatively stable skinfold measure with trivial effects, small absolute differences, and few significant differences with deviation away from the central ISAK point. All other skinfold sites showed some variation, with most care needed in marking for the biceps and triceps sites.

Overall, there were significant differences between G5 and the average of the other grids grouped by direction (e.g. anterior, posterior, superior, inferior, medial or lateral) for the average of three trials per grid for two testers. Direction differences can be identified for each skinfold site in Tables II–IX and have been highlighted in their associated comment.

Influence of different testers

The variability of the 27 measures (when taking all the nine grid measures × the three repeated trials) within a skinfold site, as shown by least-squares means (%) for Tester A and Tester B at each of the eight skinfold sites (see Table XI), showed that Tester A had significantly more variability for each skinfold site than Tester B, except for the subscapular (10.2% vs. 10.4%). Tester A's skinfolds were always larger than Tester B's except for the subscapular, which was 1.7% smaller. Three sites (biceps, calf, and thigh) had percentage differences

Table X. Absolute difference ranges (mm), the number of significant differences, and the number of trivial and small effects for peripheral grid points compared with a central ISAK point.

Skinfold	Range of absolute difference for peripheral grid points compared with a central ISAK point	Number of differences over 0.5 mm for peripheral grid points compared with a central ISAK point	Number of significant differences for peripheral grid points compared with a central ISAK point	Number of effects for peripheral grid points compared with a central ISAK point	
				Small	*Trivial*
Triceps	0.16 to 1.27	4	7	8	0
Subscapular	0.00 to 0.30	0	3	0	8
Biceps	0.07 to 0.80	4	6	8	0
Iliac crest	0.28 to 2.12	4	4	0	8
Supraspinale	0.08 to 0.95	4	7	1	7
Abdominal	0.39 to 1.62	7	8	0	8
Front thigh	0.00 to 0.76	2	4	2	6
Medial calf	0.02 to 0.36	0	6	6	2

greater than 10%. The Cohen standardized effects expressed as a percentage change indicated that there were small within-participant effects for both testers for triceps (0.26 and 0.28), calf (0.2 and 0.25), and abdominal (0.29 each), while the other skinfold sites had trivial wiuthin-participant effects (<0.2).

Summary of results

The key finding was that the skinfolds taken at the eight peripheral grid points in a 1-cm grid pattern were different from the skinfolds taken at a central ISAK grid point. Forty-five of 64 (70%) peripheral skinfold sites were significantly different from a central ISAK grid point. There was a direction effect and this differed between skinfolds.

Discussion and implications

For an assessment test to be of any value, it must be specific enough to be measuring the performance variable of interest, but also reliable enough to detect the relatively small differences in performance that are beneficial to elite athletes (Schabort, Hawley, Hopkins, & Blum, 1999).

Table XI. Least-squares means for Tester A and Tester B, and differences of least-squares means (%) between Tester A and Tester B, for each group of 27 measures (9 grid points × 3 trials) at each of the eight skinfold sites.

	Tester A LSmean ± *s* in mm (min:max in mm) [% estimate] {Cohen standardized effect}	Tester B LSmean ± *s* in mm (min:max in mm) [% estimate] {Cohen standardized effect}	Tester A vs. Tester B where A > B = +ve LSmean % difference (lower and upper CL%) [probability]
Triceps	8.1 ± 2.2 mm (3.4:13.1 mm) [7.7%] **{0.26}**	7.6 ± 2.2 mm (3.2:12.6 mm) [7.3%] **{0.28}**	6.0% (4.8:7.3%) **[0.0000]**
Subscapular	10.6 ± 3.3 mm (6.7:17.6 mm) [10.2%] {0.12}	10.8 ± 3.3 mm (7.1:19.6) [10.4%] {0.11}	−1.7% (−2.2:−1.2%) **[0.0000]**
Biceps	4.0 ± 1.4 mm (2.1:9.9 mm) [3.8%] {0.10}	3.6 ± 1.5 mm (1.8:9.2 mm) [3.4%] {0.10}	13.2% (11.6:14.8%) **[0.0000]**
Iliac crest	19.2 ± 7.4 mm (6.6:39.2) [17.8%] {0.16}	18.4 ± 7.5 mm (6.2:39.0 mm) [16.9%] {0.14}	5.1% (4.1:6.1%) **[0.0000]**
Supraspinale	10.3 ± 3.9 mm (4.5:21.0 mm) [9.6%] {0.19}	10.3 ± 4.5 mm (4.4:22.6 mm) [9.4%] {0.17}	2.0% (0.9:3.2%) **[0.0034]**
Abdominal	20.6 ± 10.6 mm (6.8:46.9 mm) [18.1%] **{0.29}**	20.4 ± 10.7 mm (5.9:46.0 mm) [17.9%] **{0.29}**	1.4% (0.6:2.3%) **[0.0043]**
Thigh	14.0 ± 4.2 (7.4:22 mm) [13.4%] {0.16}	12.7 ± 4.7 mm (5.4:22.1 mm) [11.8%] **{0.20}**	13.1% (11.7:14.6%) **[0.0000]**
Calf	8.5 ± 2.5 mm (4.7:14.4 mm) [8.1%] **{0.20}**	7.5 ± 2.5 mm (3.2:13 mm) [7.1%] **{0.25}**	14.3% (12.9:15.6%) **[0.0000]**

Note: Effect sizes <0.2 are trivial, 0.2–0.6 are small.
Cohen standardized effects are expressed as a percentage change (with lower and upper confidence limits).

Influence of one-centimetre variation from standard ISAK skinfold sites

This study found significant differences in skinfold measurement values for 45 (70%) of the peripheral grid points (compared with the value for a central ISAK-specified site). Of those 45 differences, however, 20 had a trivial effect. Therefore, of the 64 comparisons, 25 (39%) were both significant and non-trivial.

For three appendage skinfolds (triceps, biceps, and medial calf), 22 of 24 were significant and non-trivial. In other words, for these three skinfolds no matter which direction you deviate from the ISAK-specified site, measured values may differ simply due to individual fat-patterning differences rather than any change in the adiposity status of the individual, so accurate identification of the defined measurement site is essential. For the fourth appendage site (front thigh), only two of the eight effect sizes were non-trivial and these were in the medial/distal direction.

Of the four central skinfolds (subscapular, iliac crest, supraspinale, and abdominal), only one of the 32 peripheral sites was both significant and non-trivial. This result implies that pin-point accuracy of these sites is less crucial.

The least variable site was the subscapular skinfold, where measuring exactly on the defined site appeared less crucial, as the eight absolute differences were all small, with only three being significant. The largest absolute variation was found (not unexpectedly due to the larger skinfold values) in the central part of the body, with 0.28–2.12 mm for the iliac crest skinfolds (most pronounced when taken lateral/anterior to the G5 site) and 0.39–1.62 mm for the abdominal skinfold site (most pronounced when taken lateral/medial to the G5 site).

Although we found variation at all eight ISAK skinfold sites between peripheral and G5 measures, some sites showed differences of larger magnitude than others. The explanation for this may be due to variability in skin thickness, fat density, fat distribution, and fat compressibility as previously identified by Brozek (1965) and Martin and colleagues (Martin, Ross, Drinkwater, & Clarys, 1985), further emphasizing the need for correct marking of skinfold sites.

Influence of tester

The differences identified between the two experienced testers highlighted the importance of using the same tester wherever possible for comparative measurements for any given participant. Additionally, the specific site measurement variability (technical error of measurement) for each tester should be known to allow for an adequate evaluation of potential test–retest variability due to measurement alone, rather than an actual change in the participant's body composition. The abdominal, triceps, and calf had small within-participant effects (see Table XI), so care needs to be taken in interpreting the skinfold change at these sites due to the increased variability at these sites. Previous testing established that the inter-test technical error of measurement scores of the testers were well within the ISAK criteria (Marfell-Jones *et al.*, 2006b). Nevertheless, the real differences between the two experienced testers in this study highlight the importance of using the same tester where possible.

Conclusions

Measuring one centimetre away from a defined ISAK site produced significant differences in the majority of skinfold measurement values obtained. No site was totally free from this variation. Therefore, adherence to identifying, marking, and measuring at the defined site is essential.

Practical implications

The results of this study can be used to reinforce the importance of strict adherence to a measurement protocol (in this case the ISAK protocol) when taking skinfolds. Given the variation about the central skinfold sites reported in this study, anthropometry practitioners should note the possible measurement error due to error in landmarking in their reports to clients. To reduce error, the same practitioner should be used where possible for repeat measurements.

The findings of the study could be exacerbated if the measurements had been conducted on participants with larger skinfolds. In addition, anthropometrists who are not ISAK trained could be using a protocol that fails to specify exactly the location, accounting for differences of greater than one cm.

References

Brozek, J. (Ed.) (1965). *Human body composition: Approaches and applications.* Oxford: Pergamon Press.

Hopkins, W. G. (2002). A new view of statistics. Retrieved 13 April 2003, from http://www.sportsci.org/resource/stats/effectmag.html

Hopkins, W., Schabort, E. J., & Hawley, J. A. (2001). Reliability of power in physical performance tests. *Sports Medicine*, *31*, 211–234.

Marfell-Jones, M. J., Olds, T., Stewart, A. D., & Carter, L. (2006a). *International standards for anthropometric assessment.* Potchefstroom, South Africa: International Society for the Advancement of Kinanthropometry (ISAK).

Marfell-Jones, M. J., Olds, T., Stewart, A. D., & Carter, L. (2006b). *ISAK accreditation handbook.* Potchefstroom, South Africa: International Society for the Advancement of Kinanthropometry (ISAK).

Martin, A. D., Ross, W. D., Drinkwater, D. T., & Clarys, J. P. (1985). Prediction of body-fat by skinfold caliper: Assumptions and cadaver evidence. *International Journal of Obesity*, *9*(suppl.1), 31–39.

Ruiz, L., Colly, J. R. T., & Hamilton, P. J. S. (1971). Measurement of triceps skinfold thickness: An investigation of sources of variation. *British Journal of Preventive and Social Medicine*, *25*, 165–167.

Schabort, E. J., Hawley, J. A., Hopkins, W., & Blum, H. (1999). High reliability of performance of well-trained rowers on a rowing ergometer. *Journal of Sports Sciences*, *17*, 627–632.