Errors in Measuring Skinfold Thickness with Calipers Focusing on Deviation from the Standardized Site

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Abstract

The purpose of this investigation was to clarify the difference that would be found in skinfold thickness measured using the caliper technique between the standardized site and the 1-cm points deviating from the standardized point. The examined sites were 7 points and 6 points surrounding the standardized site on the triceps and subscapular, respectively. The revealed measurements with even a 1-cm deviation can lead to significant errors for the measurement and evaluation of percent body fat.

Key words: skinfold thickness, triceps skinfold, subscapular skinfold, measurement error, measurement site

BACKGROUND

The precision of measuring skinfold thickness with calipers owes a lot to the examiners' proficiency (Harrison GG, 1991; ACSM, 2006). There are various sites that are recommended to measure (Kirkendal et al., 1987; Golding, 2000; ACSM, 2006), but wherever they are, in order to keep the validity and reliability, those measuring procedures should comply with the standardized method and technique (ACSM, 2005; 2006). The first thing one must do for accurate measurement is to precisely identify the location to be measured, which may be not so easy. It is possible to gain errors by failing to identify an appropriate location due to the diversity of the human body and rushed trials that measure skinfold thickness without placing location marks on the skin.

If the condition of the skin and the adipose tissue are uniformly distributed around the standard point, it is not necessary to be seriously concerned with identifying the exact standard location recommended. If not, those measuring should be very careful not to deviate from the standardized site. The distribution of adipose tissue and its thickness are not well known, and it should be clarified as to how thick the skinfold thickness is at different locations around the standardized site as well as how those areas differ from the standardized site. This investigation aimed to clarify the above points.

For this study, two sites, the triceps and the subscapular were chosen and used from the various sites because they are common locations used to measure skinfold thickness in Japan (Kitagawa K, 1986; Kawasaki Y, 1990; Arimoto M, 2006). Nagamine and Suzuki (1964) developed an equation to estimate the body density of Japanese people using values of skinfold thickness at these two sites so that a percent body fat can be calculated using the equation proposed by Brozeck et al. (1963).

The standardized description of skinfold sites and procedures (ACSM, 2006) indicates the measurement for the triceps to be halfway between the acromion and olecranon processes on the posterior midline of the upper arm, and for the subscapular

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site at 1 to 2 cm below the inferior angle of the scapula while AAHPERD recommended 1 cm below the inferior angle of the scapula (Kirkendall et al., 1987) and Thompson (2003) suggested '2 cm below'. Without proper training and strict adherence to location accuracy, results will vary between examiners. In addition, it may be difficult to find the inferior angle of the scapula on subjects who are overweight or obese.

As the examiners' proficiency improves, the deviation will become less. However, errors may occur in the values of skinfold thickness derived from failing to sharply identify the measurement point. It is important to determine the extent to which these failed measurements will skew the results. As the maximum deviation from the standard point is within 1cm, which is considered through the authors' practice, a 1-cm deviation from the standard point on the triceps and subscapular sites were set to examine such errors in this investigation. In addition, the location of a 2-cm deviation from each standardized point was also set to further estimate the distribution of skinfold thickness.

METHOD

Participants

Forty-two male university students (19 to 22 years old, mean±SD: 21.4±0.96) were recruited as the participants in this research. Two students were excluded because their fat deposition made it problematic to effectively lift the adipose tissue and correctly measure. The maximum and minimum values, mean and standard deviation in physical features of the participants were 159-188 cm and 173.1±6.85 cm of height, and 50.0-94.0 kg and 68.5±9.48 kg of body weight.

Measurement procedure

Prior to the measurement, all locations to be measured in this investigation were marked. For the triceps measurement, the acromion and the olecranon processes were identified first, and then the halfway point on the posterior midline as the standardized point (STt) was identified using a tape measure and marked. Next, the locations 1-cm superior (SPt1), inferior (IFt1) deviating from the standard point along the midline, deviating lateral (LAt) and medial (MDt) on the same plane of the standard point were marked, and then the locations 2-cm superior (SPt2) and inferior (IFt2) deviating from the standard point were marked.

For the subscapular measurement, the inferior angle of the scapula was identified first. The standardized point (STs) was marked at 1.5cm inferior to the inferior angle of the scapula. The location (IFsS) 1-cm perpendicularly inferior to STs was also located with a tape measure and marked. The tape measure was placed on the standardized point and measured 1 and 2cm slightly superior and medially (SPs1, SPs2, respectively) and inferior and laterally (IFs1, IFs2, respectively) were also marked. These points are indicated in Figure 1.

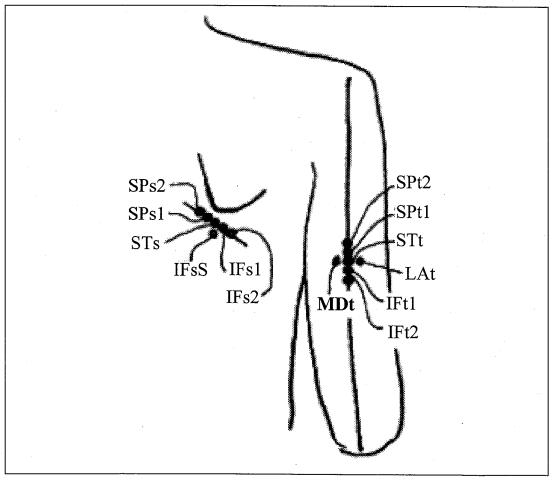

Figure 1. Measured locations and marked points

After marking the locations, the thickness of the skinfold at the seven locations on the triceps and the six points on the subscapular were measured. During the measurement, the participants remained

standing upright and naked from the waist up with their relaxed arm beside the trunk. Eiken-Shiki Calipers® were used in this investigation. All measurement procedures were in accordance with the standardized description (ACSM 2005; 2006).

Data analysis

Each skinfold thickness measured at the locations deviating from the standardized points were compared with the measurements from the standardized sites. Means and standard deviations were noted. Significant differences between each deviated point and the standardized point were identified by the Student's paired t-test and the probability (P) value of < 0.05 was considered statistically significant.

When percent body fat (%BF) was calculated using skinfold thickness, the equations by Nagamine & Suzuki (1964) and Brozek et al. (1963) were used. The equations are: Density (D) = 1.0913 − 0.00116 × (T + S), %BF = (4.57 / D − 4.142) × 100.

RESULTS

Table 1. The mean and standard deviation in skinfold thicknesses measured on the triceps and the subscapular (n = 42).

Triceps

Location	M ± SD (mm)	Average Difference from STt (mm)	Significance (P)
SPt2	13.6 ± 6.7	2.0	< 0.001
SPt1	12.1 ± 5.7	0.5	< 0.01
STt	11.6 ± 5.3	0.0	—
IFt1	11.1 ± 5.0	− 0.5	< 0.01
IFt2	10.3 ± 4.4	− 1.3	< 0.001
LAt	11.6 ± 5.5	0.0	n.s.
MDt	10.8 ± 5.0	0.8	< 0.001

Note: STt: the standardized site on the triceps; SPt1, SPt2: 1cm, 2cm superior to STt; IFt1, IFt2: 1cm, 2cm inferior to; LAt: 1cm lateral to, MDt: 1cm medial to STt.

Subscapular

Location	M ± SD (mm)	Average Difference from STs (mm)	Significance (P)
SPs2	12.7 ± 4.06	−1.5	< 0.001
SPs1	13.4 ± 4.76	−0.7	< 0.001
STs	14.1 ± 5.28	0.0	—
IFs1	14.3 ± 5.56	0.1	n.s.
IFs2	14.7 ± 6.25	0.6	< 0.05
IFsS	14.3 ± 5.63	0.2	n.s.

Note: STs: the standardized site on the subscapular; SPs1, SPs2: 1cm, 2cm superior to; IFs1, IFs2: 1cm, 2cm inferior to; STs, StsS: 1cm perpendicularly inferior to STs.

Each mean and standard deviation of the skinfold thicknesses measured at 7 points on the triceps and 6 points on the subscapular involving 42 participants is shown in Table 1. The difference in skinfold thickness between each deviated location and the standard site should be recognized as an error. Those errors are shown as the average differences in Table 1, which were gained through improper measurements.

In Figure 2, the skinfold thicknesses measured at the two standardized sites on the triceps and the subscapular are shown correlatively (r = 0.767). It shows that participants' skinfold thicknesses were between 5 mm and 30 mm at each site, and 13 mm and 54 mm as a sum of the two sites. Their percent body fat ranged between 10.4% and 30.1%. Seven of the participants had a percent body fat of 20% or more. The mean and standard deviation of the summed values of the triceps and the subscapular was 25.7±9.91 mm, and the average percent body fat of this group was 16.4±4.71%.

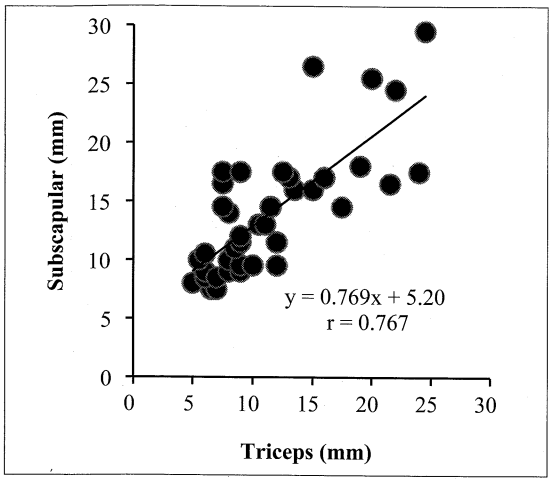

Figure 2. Correlative distribution of skinfold thickness measured with a caliper at the standardized site on the triceps and the subscapular. (n = 42).

Figure 3 shows the means and standard deviations of the skinfold thickness measured at the seven locations on the triceps. The results indicate that there was a tendency to increase skinfold thickness when deviating superiorly from the standardized site on the triceps, whereas the location which deviates inferiorly from the standardized site suggests the skinfold becomes thinner. Statistical significances were gained between the standardized site and each deviated point except for the lateral location.

Figure 4 shows the means and standard deviations of skinfold thicknesses measured at the six locations of the subscapular site. The skinfold thickness was found to be statistically significantly thinner on the superior-medial locations (SPs1, SPs2) as compared to the standardized site and tended to be slightly thicker at the locations 2-cm inferior and lateral (IFs2). However, the location diagonally 1-cm inferior (IFs1) and the location 1-cm straightly inferior (IFsS) from the standardized site have no statistically significant difference from the standardised site.

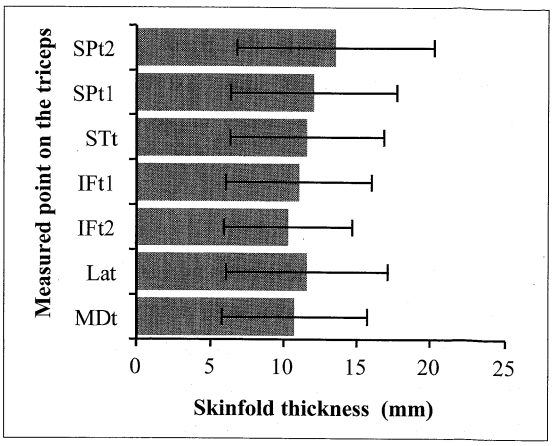

Figure 3. Skinfold thickness at different locations on the triceps.

Note: STt: the standard site on the triceps; SPt1 and SPt2: locations 1-cm and 2-cm superior to STt; IFt1 and IFt2: locations 1-cm and 2-cm inferior to STt; LTt and MAt: the locations 1-cm lateral and 1-cm medial to STt.

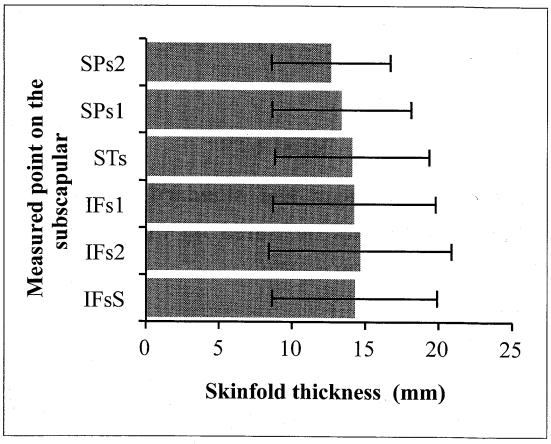

Figure 4. Skinfold thickness at the different locations on the subscapular site.

Note: STs: the standard site; SPs1 and SPs2: the location 1-cm and 2-cm superior and medial to STs on the diagonal line; IFs1 and IFs2: the location 1-cm and 2-cm inferior to and lateral to STs on the diagonal line; IFsS: the location 1-cm vertically inferior to STs.

The upper figure in Figure 5 correlatively shows distribution of the skinfold thickness measured at the locations 1-cm superior (SPt1) and inferior (IFt1) to

the standard site on the triceps. The lower figure in Figure 5 shows correlative distribution of skinfold thickness on the triceps measured at the standard site and the location 2-cm superior (SPt2) and inferior (IFt2) deviating from the standard site. These figures clearly show that on the triceps, a small deviation from the standardized site did not tend to cause large errors, but a larger deviation from the site caused noteworthy errors in participants who had a thicker skinfold thickness. This tendency was similarly observed in the case of the subscapular measurement although the degree of error was not as distinguishing.

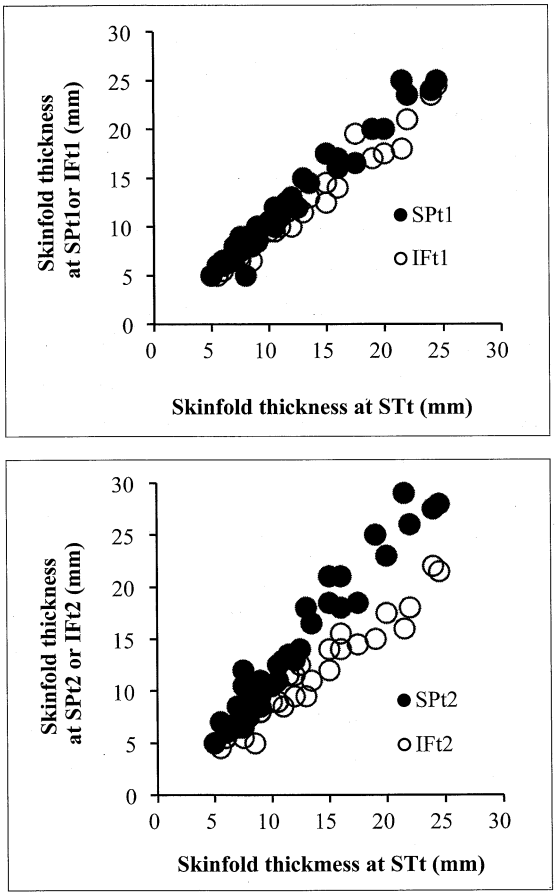

Figure 5. Correlative distribution of the skinfold thicknesses measured at the standardized site and the points 2-cm superior and inferior to the standard site.

When percent body fat is calculated, the sum of the two skinfold thicknesses at the triceps and the subscapular standardized (STt + STs) is summed up. In Figure 6, correlative distributions of [SPt1 + SPs1] and [STt + STs] (indicated by ○, and also [IFt1 + SPs1] and [STt + STs] (indicated by △) are shown. The regression equations reveal that the sum of STt1 and SPs1 is almost equal to the skinfold thickness measured at the standardised site while the sum of IFt1 and SPs1 tend to become significantly smaller than their standard values among participants who are in higher percent body fat.

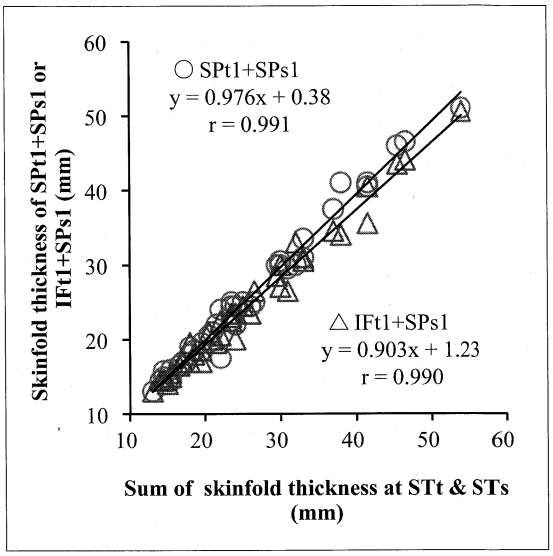

Figure 6. The skinfold thickness measured at the point 1-cm inferior to the standard site on the triceps and the point 1-cm superior to the standard site on the subscapular.

Note: STt: the standard site on the triceps, STs: the standard site on the subscapular, IFt1: the location 1-cm inferior to the STt, L1: the location 1-cm superior to STs.

DISCUSSION

Among young Japanese males aged 21 years, a norm of skinfold thickness at the triceps and the

subscapular regions are 11.3±5.0 mm and 13.6±6.3 mm, respectively (A Research Team at Tokyo Metropolitan University, 2000). The T-scores of the mean values of this participants' group are equivalent to 50.6 and 50.8 of skinfold thickness, respectively. Also, the norm of percent body fat is 16.0% and the average of this group is 16.3%. These scores and values suggest these participants made a typical sample group of young Japanese adults in terms of skinfold thickness. The means of their height and body weight were a little higher (T-score: 52.8 for height, 54.4 for body weight) than the Japanese norm (171.6±5.4 cm and 64.9±8.2 of 21 years of age). This gap may relate to the attributes of nearly half of participants who participate in athletic activities, especially regarding to their body weight.

This investigation revealed that skinfold thickness at the site surrounding the standardized point even at a 1-cm deviation tends to be not exactly uniform. At the location superior and medially to the standardized site on the subscapular, a smaller thickness tended to measure, but the location perpendicularly inferior to the standardized point read no significant difference. These results indicate that there may be no serious concern when measuring skinfold thickness on the subscapular site as long as examiners correctly identify the inferior angle of the scapula even though the ACSM doesn't sharply standardize the exact distance from the inferior angle (ACSM, 2005; 2006).

The investigation also revealed a seemingly small difference in the mean values from the standardized site. As a matter of fact, at the points 1-cm deviating from the standardized site, the average magnitude of error was 0.5 mm on the triceps and 0.7 mm on the subscapular (See Table 1). As a 1-mm of skinfold thickness is equivalent to about 0.5 %BF, 0.5 mm or 0.7 mm of the error may not be necessarily large. However, another point is that the magnitude of error may be larger among obese people as compared with non-obese people.

Moreover, regarding estimating percent body fat, in which two values of skinfold thickness gained at the triceps and the subscapular are used, cases failing to identify the correct point are likely to bring about two different results, which are typically no error and an amplified error, depending on measuring from different 1-cm deviating points.

As an example in which no error occurs, if skinfold thickness is measured at the superior point of the triceps (SPt1) and the superior point at the subscapular (SPs1), both which were wrong to measure, the summed value of the skinfold thicknesses of SPt1 and SPs1 will tend to be the same as or close to the correct value as if it were measured at both standardized sites. This is because the measured value at SPt1 tends to be larger and the value at SPs1 tends to be smaller than the one at the correct site. In fact, one of the regression lines in Figure 6, y=0.976x+0.38, is approximately y=x.

On the other hand, if the inferior point on the triceps (IFt1) and the superior point on the subscapular (SPs1) are measured, the magnitude of total error will tend to be large, especially among obese people. The following demonstrates these examples.

Allow the equations in Figure 6 to apply to the following cases. For the first case, if the sum of the skinfold thicknesses at the standardized points are 25.7 mm (11.6 mm + 14.1 mm) which is the same as the means of this investigation, an error that would most likely occur would result in a sum of 24.4 mm. These two site measurements are equivalent to 16.3%BF and 15.7%BF, respectively. In this case, an underestimation would occur, but only slightly. However, take someone whose percent body fat is 25%, which is the lowest rate within the moderate obesity category. The total skinfold thickness gained at the two standardized sites should be 43.7 mm, which can be, for instance, a sum of 21.2 mm for the triceps and 22.5 mm for the

subscapular. In this case, the skinfold thicknesses at the IFt1 and SPs1 are likely to be 40.7 mm (19.8 mm and 20.9 mm), which reflects 23.5%BF.

Accuracy of measurement of skinfold thickness using calipers is strongly expected not only because functional estimation of percent body fat is important, but also to observe and note skinfold thicknesses at specific sites (Plowman & Smith, 2011). Therefore, it is important to consistently identify and mark the appropriate points in order to keep score deviations to a minimum.

CONCLUSION

This investigation found that on the triceps, the locations 1- and 2-cm superior to the standard point are thicker than the standardized site for skinfold thickness, and those 1- and 2-cm inferior to the standardized site are thinner than the standardized site. Also, it found that the skinfold thickness deviating superior and medially tends to be thinner than the standard site on the subscapular location. Hence, to avoid measurement errors derived from deviating from the standardized site, those measuring with a skinfold caliper should carefully identify the standardized site using a tape measure and marking the proper location on the skin.

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