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Caliper *vs.* Lipometer – Comparing Two Methods of Subcutaneous Body Fat Measurement by Bland-Altman Diagrams

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A B S T R A C T

Skinfold Calipers are widely used to obtain subcutaneous adipose tissue thickness because of its non-invasive, simple and inexpensive technique. Nevertheless, Caliper skinfold thicknesses have the disadvantage of measuring compressed adipose tissue and double layers of skin, which might reduce the precision of these results. In contrast, the computerized optical device Lipometer was developed to permit a quick, precise and non-invasive determination of non-compressed mono layers of subcutaneous adipose tissue thickness. In the present paper we investigate the hypothesis that Caliper skinfold thicknesses are significantly different from subcutaneous adipose tissue thicknesses in mm, which can be measured by Lipometer. Caliper and Lipometer results were obtained from 371 Estonian boys aged between 9.0 and 12.8 years. Measurements were performed at six different body sites: triceps, biceps, upper back, upper abdomen, hip and front thigh. Caliper measurements were systematically higher than Lipometer results in a range between 1.2 mm (hip) and 11.08 mm (front thigh). The limits of agreement analysis provided intervals from 7.5 mm (biceps) up to 30.14 mm (front thigh). Comparing Caliper and Lipometer results very low measurement agreement was found. The two methods provided very poor interchangeability.

Key words: *Caliper, Lipometer, subcutaneous body fat, children, subcutaneous adipose tissue*

Introduction

There exists a variety of different methods to assess subcutaneous body fat in children[1–3]. Until now, skinfold Calipers have been widely used to obtain subcutaneous adipose tissue thicknesses because they are non-invasive, simple-to-use and inexpensive[4,5]. The measurements of subcutaneous body fat gained by using skinfold Calipers are still a topic of high interest in science. A search in the ISI Web of Knowledge database resulted in 520 publications and 1500 citations in the last five years showing an increasing tendency from year to year. Nevertheless, the subcutaneous adipose tissue measurements obtained by using Calipers have the disadvantage of measuring compressed adipose tissue and double layers of skin[6], which might reduce the precision of these results. It also has been demonstrated that different Caliper types may bias skinfold estimates[7].

In contrast, the computerized optical device Lipometer was developed to permit a quick, precise and non-invasive determination of non-compressed mono layers of subcutaneous adipose tissue thicknesses. Its technical features and validation results were based on computed tomography (CT) as the reference system and have been presented before[8,9]. The Lipometer measures the thickness of subcutaneous adipose tissue (SAT) layers (in mm) at 15 well-defined body sites[10] and allows the specification of the typical fat distribution of a subject, the so-called subcutaneous adipose tissue topography (SAT-Top)[11,12]. The Lipometer has been applied and tested in many scientific areas in healthy[13] and diseased subjects[14–16].

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In the present paper we compare for the first time the measurement capacities of the two devices (Caliper and Lipometer) and we describe the deviation between both methods at different body sites. The general hypothesis is that Caliper skinfold thicknesses are significantly different from subcutaneous adipose tissue thicknesses in mm, which can be obtained by Lipometer. Furthermore, as a second hypothesis, we assume that Caliper skinfold thickness measurements are strongly influenced by the measured body sites (location, form, etc.) and consequently we expect significantly different values for Bias and limits of agreement at the different investigated body sites.

Subjects and Methods

Healthy subjects

In this study 371 healthy Estonian boys aged between 9.0 and 12.8 years (Table 1) were recruited from several schools in Tartu (about 100 000 inhabitants), Estonia. All children, parents and teachers were thoroughly informed about the contents and purposes of the study. A written informed consent was obtained from the parents or the adult caregivers before participation. This study was approved by the Ethics Review Committee (ERC) on Human Research of the University of Tartu (Protocol number: 179/T-4, 16.02.2009).

Body height was measured in standing position to the nearest 0.5 cm using a Martin metal anthropometer, and body mass was measured in kg with electronic scales (A&D instruments ltd, UK). BMI (kg/m^2) was calculated. In total, six skinfolds (triceps, biceps, subscalpular, abdominal, supraspinale, front thigh) were measured. A Slim Guide plastic skinfold Caliper, which is part of a Centurion kit (Rosscraft, Canada), was used. All anthropometric measures were determined according to the protocol recommended by International Society for the Advancement of Kinanthropometry (ISAK)[17]. Anthropometric measurements were performed by a well-trained anthropometrist (Level 1, ISAK anthropometrist).

Additionally, Lipometer measurements were taken at the six directly comparable body sites (triceps, biceps, upper back, upper abdomen, hip, front thigh). Information about the coefficients of variation of SAT thicknesses at these specific body sites was previously presented for children[18] and adults[19]. To determine SAT layer thickness (in mm), the sensor head of the Lipometer is held in perpendicular angle to the selected body site. Light-emitting diodes illuminate the SAT layer and a photodiode measures the back-scattered light intensities. These light patterns are converted into a SAT layer thickness[8]. The Lipometer is connected to a PC which stores the data measured. All subjects were measured in standing position. In each person, Lipometer measurements were done first, followed by the Caliper measurements shortly afterwards.

TABLE 1
PERSONAL CHARACTERISTICS OF 371 HEALTHY BOYS (MEDIAN, INTERQUARTILE RANGE (Q1 – Q3), [MIN – MAX])

371 Boys	Median	(Q_1 – Q_3)	[Min – Max]
Age (years)	11.0	(10.6 – 11.6)	[9.0 – 12.8]
Height (m)	1.49	(1.43 – 1.54)	[1.29 – 1.68]
Weight (kg)	39.1	(35.0 – 47.5)	[25.9 – 95.3]
BMI (kg/m^2)	17.8	(16.3 – 20.2)	[13.7 – 38.7]

TABLE 2
RESULTS OF LIPOMETER AND CALIPER MEASUREMENTS IN MM (MEDIAN (MIN – MAX)) OF 371 BOYS AT SIX BODY SITES. STATISTICAL SIGNIFICANCE WAS CALCULATED BY WILCOXON – TEST

	Lipometer	Caliper	p
1-Triceps	7.4 (1.6–16.6)	9.0 (3.0–32.0)	p<0.001
2-Biceps	3.6 (0.7–15.1)	4.0 (2.0–24.0)	p<0.001
3-Upper back	2.9 (0.6–22.0)	6.0 (3.0–34.0)	p<0.001
4-Upper abdomen	3.9 (0.7–27.3)	8.0 (2.0–43.0)	p<0.001
5-Hip	6.1 (0.8–28.9)	6.0 (2.0–45.0)	p=0.001
6-Front thigh	5.5 (0.9–13.4)	14.0 (5.0–51.0)	p<0.001

Statistics

Statistical calculations were performed by SPSS 16.0 for Windows (SPSS, Chicago, IL, USA). The hypothesis of variables being normally distributed was tested by the Kolmogorov-Smirnov test in which a p-value <0.05 was considered to be a significant deviation from normal distribution. All tested variables were non-normal, and thus the median, the quartiles and the range were calculated, and the Wilcoxon test was applied to test if the Lipometer and the Caliper measurements at the six body sites were significantly different.

To measure the strength of a relation between the Lipometer and the Caliper measurements at each body site, linear regression analysis was applied using the caliper results as the independent variable. However, the linear correlation coefficient R resulting from regression analysis is generally regarded to be inappropriate to judge whether the two measurement techniques agree sufficiently or not[20]. The use of correlation in this instance is misleading, because R measures only the strength of a relation between two variables, not the agreement between them. We will have perfect agreement only if the measurement points lie along the line of equality in a scatterplot, but we will have perfect correlation if the points lie along any straight line. To present a more informative solution of this problem, a plot of the difference between the methods against their mean was suggested (Bland-Altman diagram)[20]. Furthermore, the 'Bias' (the mean of the differences between the two methods) and the 'limits of agreement' (Bias ± 2 * standard deviation of the differences) were calculated and presented in a table and in Bland-Altman diagrams.

TABLE 3
RESULTS OF LINEAR REGRESSION ANALYSIS FOR ALL 371 BOYS AT SIX BODY SITES, USING THE LIPOMETER MEASUREMENT AS DEPENDENT VARIABLE AND THE CALIPER MEASUREMENT AS INDEPENDENT VARIABLE. INCLUDED ARE THE BIAS AND LIMITS OF AGREEMENT

Lipometer Body site	R	R^2	Caliper Independent variable	SEE	p	Bias (mm)	Limits of agreement (mm)
1. Triceps	0.847	0.717	triceps	1.74	p<0.001	–3.18	–9.88 to +3.52
2. Biceps	0.885	0.784	biceps	1.55	p<0.001	–1.37	–5.12 to +2.38
3. Upper back	0.925	0.855	subscapular	1.76	p<0.001	–3.21	–8.41 to +2.00
4. Upper abdomen	0.908	0.825	abdominal	2.66	p<0.001	–5.19	–13.74 to +3.36
5. Hip	0.743	0.552	supraspinale	3.70	p<0.001	–1.20	–11.69 to +9.29
6. Front thigh	0.696	0.485	front thigh	1.82	p<0.001	–11.08	–26.15 to +3.99

Results

Table 2 shows significant differences between Lipometer and Caliper measurements at all six body sites. Most Caliper medians are higher, ranging from 98.4% (hip) to 254.5% (front thigh), compared to Lipometer medians. Minimum values are higher in all Caliper results, showing a range between 187.5% (triceps) and 555.6% (front thigh). Furthermore, all Caliper maximum values are higher ranging from 154.5% (upper back) to 380.6% (front thigh). Notably, the body site of the front thigh provides the highest deviation between Lipometer and Caliper measurements in minimum, median and maximum values.

Concerning the strength of the relation between Lipometer and Caliper measurements for 371 boys, linear regression analysis at the six different body sites provided correlation coefficients ranging between R=0.696 (front thigh) and R=0.925 (upper back) (Table 3). We obtained negative Bias values for all body sites in a range between –11.08 mm (front thigh) and –1.2 mm (hip), indicating that Caliper measurements are systematically higher than Lipometer results. Finally, the limits of agreement were calculated, providing the smallest interval of 7.5 mm ([–5.12 to +2.38]) for the body site biceps and the largest interval of 30.14 mm ([–26.15 to +3.99]) for the body site front thigh (Table 3). Notably, Bias values and limits of agreement show great differences between the six investigated body sites.

Discussion

The greatest deviation between Lipometer and Caliper measurements was found at the body site front thigh: Minimum, median and maximum values were increased between 254.5% and 555.6% (Table 2), regression analysis provided the lowest R value of all six body sites (Table 3), and a regression line which showed the strongest deviation from the line of identity (Figure 1a). Additionally, we received the highest systematical deviation (Bias) also for the front thigh of –11.08 mm between the measurement devices with limits of agreement between –26.15 mm and

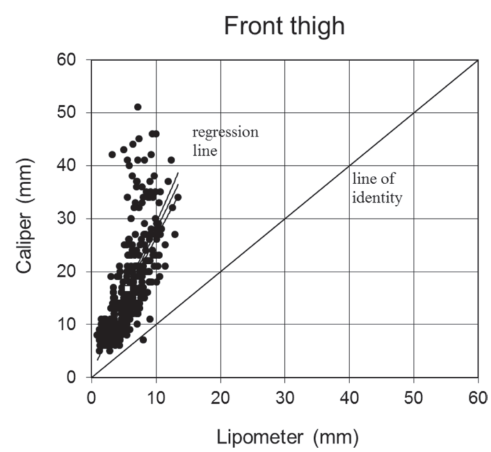

Fig. 1a. Scatterplot showing the Lipometer and Caliper measurement results in mm at the body site front thigh of 371 boys, including the regression line and the 95% confidence interval (R=0.696).

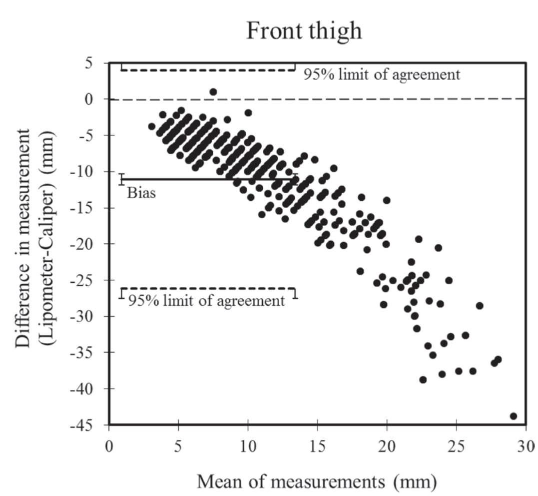

Fig. 1b. Bland-Altman diagram of the body site front thigh of 371 boys. As x-coordinate the mean value of each Lipometer and Caliper measurement is calculated, while the difference of these measurements (y = Lipometer – Caliper) is used as y-coordinate. The Bias line is situated at y=-11.08 mm, the limits of agreement reach from y=-26.15 mm to 3.99 mm.

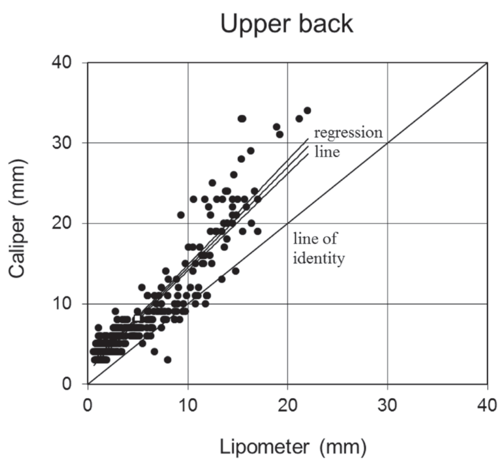

Fig. 2. Scatterplot showing the Lipometer and Caliper measurement results in mm at the body site upper back of 371 boys, including the regression line and the 95% confidence interval (R=0.925).

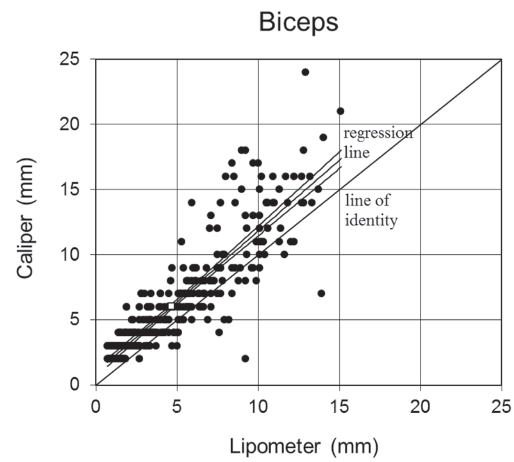

Fig. 3a. Scatterplot showing the Lipometer and Caliper measurement results in mm at the body site biceps of 371 boys, including the regression line and the 95% confidence interval (R=0.885).

+3.99 mm (Table 3), whereby increasing subcutaneous body fat thicknesses showed a tendency of greater differences between the two devices instead of measurement agreement (Figure 1b).

The strongest linear correlation between the two devices (R=0.925) was obtained at the body site upper back (Table 3), but, as mentioned in the Statistics section, the use of correlation to calculate measurement agreement is misleading. The scatterplots of upper back (Figure 2) and biceps (Figure 3a) show that the regression line for the biceps is even closer to the line of equality and therefore providing a better agreement, though the correlation coefficient is somewhat lower for biceps (R=0.885) (Table 3).

Although we find the lowest Bias of –1.2 mm at the body site hip (Table 3), which is slightly better than the Bias of –1.37 mm for biceps, a comparison of the limits of agreement provides a very much smaller interval (7.5 mm) for biceps than for hip (20.98 mm). Therefore, the best agreement between the two devices (Caliper and Lipometer) is probably at the body site biceps. Nevertheless, as Figure 3b shows, this result is not uniform throughout the measurement range. For instance, once the skinfold measurement is above approximately 10 mm, the level of agreement between the two devices starts to decrease.

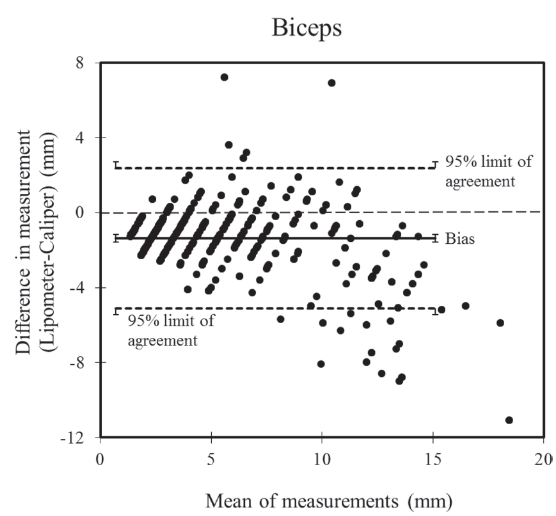

Fig. 3b. Bland-Altman diagram of the body site biceps of 371 boys. As x-coordinate the mean value of each Lipometer and Caliper measurement is calculated, while the difference of these measurements (y = Lipometer – Caliper) is used as y-coordinate. The Bias line is situated at y=-1.37 mm, the limits of agreement reach from y=-5.12 mm to 2.38 mm.

Conclusion

Previously, a good agreement between CT and Lipometer measurements of SAT thicknesses was published[8,19], providing a correlation coefficient of R=0.986, no systematically deviations between the two methods (Bias=0.00) and small limits of agreement ([–2.78 mm to +2.78 mm]) for SAT thicknesses between 0 mm and 50 mm. In this study, comparing Caliper and Lipometer measurements in 371 Estonian boys at six different body sites, very low measurement agreement was found. The two methods for measuring subcutaneous adipose thickness demonstrated very poor interchangeability, and, if using Caliper measurements, one has to bear in mind the methodical problems of the technique.

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KALIPER NASPRAM LIPOMETRA – USPOREDBA DVIJE METODE MJERENJA POTKOŽNOG MASNOG TKIVA PO BLAND-ALTMAN DIJAGRAMIMA

SAŽETAK

Kaliper za mjerenje kožnog nabora se uvelike koristi za izračun debljine potkožnog masnog tkiva, zbog svoje neinvazivne, jednostavne i jeftine tehnike. Ipak, kaliper za mjerenje debljine kožnog nabora ima nedostatak kod mjerenja komprimiranog masnog tkiva i dvostrukih slojeva kože, što može smanjiti preciznost rezultata. Za razliku od toga, računalni optički uređaj, lipometar, razvijen je kako bi se omogućilo brzo, precizno i neinvazivno određivanje debljine nekomprimiranog jednostrukog sloja potkožnog masnog tkiva. U ovom radu istražujemo hipotezu da se debljine kožnih nabora izmjerene kaliperom značajno razlikuju od debljine potkožnog masnog tkiva u milimetrima, koja se može mjeriti s lipometrom. Dobiveni su rezultati mjerenja i kaliperom i lipometrom od 371 estonskih dječaka u dobi između 9,0 i 12,8 godina. Mjerenja su provedena na šest različitih mjesta na tijelu: triceps, biceps, gornji dio leđa, gornji dio trbuha, kuk i prednje bedro. Mjere kalipera bile su sustavno veće od rezultata lipometra u rasponu između 1,2 mm (kuk) i 11,08 mm (prednje bedro). Granice analize usporedbe dale su intervale od 7,5 mm (biceps) do 30,14 mm (prednje bedro). Usporedbom rezultata kalipera i lipometra pronađena je vrlo mala podudarnost. Ove dvije metode dale su vrlo slabu međusobnu zamjenjivost.