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Validity of Optical Device Lipometer and Bioelectric Impedance Analysis for Body Fat Assessment in Men and Women

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A B S T R A C T

The aims of this study were to validate different subcutaneous adipose tissue layers (SAT-layers) measured by lipometer for body fat percentage (BF %) assessment with dual-energy X-ray absorptiometry (DXA) and to compare the validity of lipometer and bioelectrical impedance analysis (BIA). The subjects were 21 male (18–60 years) and 19 female (23–54 years) healthy Estonian volunteers. SAT-layers were measured by lipometer using 15 standardized SAT-layers[1]. Sum of arms, legs and trunk SAT-layers were calculated and compared with arms, legs and trunk fat percentage measured by DXA. BF% was calculated by BIA using the equations of Lukaski et al.[4] and Chumlea et al.[6] for both genders and the equations of Segal et al.[3] for males and Van Loan and Mayclin[7] for females. BF % measured by DXA was significantly higher than calculated by Lukaski et al.[4] and Chumlea et al.[6] in both genders. The correlation was highest between the BF% measured by DXA and using Segal et al.[3] equation in males (r=0.94) and Van Loan and Mayclin[7] equation in females (r= 0.84). High relationship was observed between BF% measured by DXA and sum of 15 SAT-layers (r=0.88 in males and r= 0.91 in females). Stepwise multiple regression analysis indicated that two selected SAT-layers explained 85.9% and 86.7% (R^2 x 100) of the total variance in BF% measured by DXA in males and females, respectively:[BF% = 1.308 neck + 0.638 hip + 6.971 (males; SEE = 2.59) and BF% = 1.152 hip + 1.797 calf + 12.347 (females; SEE=3.46)]. In conclusion, lipometer and BIA give a similar mean estimation of BF% when compared with DXA. However, there is a wide range of variance for the upper and lower limits of agreement between the methods, and the methods are not interchangeable. Lipometer seems to be superior to BIA.

***Key words:** body composition, SAT-layers, DXA, BIA, adults, lipometer, Estonia*

Introduction

Computerized optical system lipometer has been developed for determination of the thickness of subcutaneous adipose tissue (SAT-layer)[1]. Previous results indicate good relationship between lipometer and total body electrical conductivity[2]. Lipometer data have not yet been validated using the dual-energy X-ray absorptiometry (DXA) which is a standard method and also has a potential to estimate regional body fat (i.e., hands, legs and trunk). Bioelectrical impedance analysis (BIA) is simple, quick, portable and non-invasive field method for body composition assessment[3]. Lukaski et al.[4] reported that the validity of the BIA is high. On the contrary, Segal et al.[5] indicated that the validity may not be very high. It was hypothesized that the lipometer validity is higher compared with BIA. The aims of the study were to: (1) validate different SAT layers measured by lipometer for body fat percentage (BF%) assessment with DXA; and (2) compare the validity of lipometer and BIA.

Methods

The subjects were 21 male (18–60 yrs) and 19 female (23–54 yrs) sedentary healthy Estonian volunteers. This study was approved by Medical Ethics Committee of the University of Tartu and written informed consent was obtained from participants. The height (Martin metal anthropometer) and body mass (medical electronic scale, A&D Instruments, UK) were measured and BMI (kg/m^2) was calculated.

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As a criterion method, the BF % was measured using DXA. Scans of the whole body were performed using a Lunar DPX-IQ scanner (Lunar Corporation, USA). Total BF% and separately the fat % of arms, legs and trunk were obtained. Measurement for the thickness of SAT-layers was performed by means of the lipometer at 15 original body sites[1]. The lipometer uses light-emitting diodes, which illuminate the interesting subcutaneous fatty layer (SAT-layer), forming certain geometrical patterns varying in succession. A photodiode measures the corresponding light intensities back scattered in the subcutaneous adipose tissue. These light signals are amplified, digitized, and stored on computer. Measurement for the thickness of SAT-layers in mm were performed at 15 body sites (neck, triceps, biceps, upper back, front chest, lateral chest, upper abdomen, lower abdomen, lower back, hip, front thigh, lateral thigh, rear thigh, inner thigh, calf) on the right side of the body in standing position. The sum of 15 SAT-layers and the sum of arms, legs and trunk SAT-layers were calculated.

Body impedance was measured with Multiscan 5000 (Bodystat Ltd, UK) at standard conduction current of 800 µA and 50 kHz, and the impedance index was calculated ($height^2$/impedance). BF% was calculated using the equations of Lukaski et al.[4] and Chumlea et al.[6] for both genders and equations of Segal et al.[3] and Van Loan and Mayclin[7] for males and females, respectively.

Standard statistical methods were used to calculate mean (X) and standard deviation (±SD). Statistical comparisons were made using independent t-tests. Pearson correlation coefficients were used to determine the relationships between dependent variables. The effect of different single SAT-layers and BF% calculated by BIA results to the BF% measured by DXA was analyzed using stepwise multiple regression analysis. Significance was set at $p<0.05$. Bland-Altman[8] plots were used to assess the agreement between BF% calculated by newly presented equations using specific SAT-layers or calculated by BIA and directly measured BF% by DXA.

TABLE 1
MAIN PHYSICAL CHARACTERISTICS AND BODY FAT % MEASURED BY DXA AND BIOELECTRICAL IMPEDANCE ANALYSIS (BIA) IN MALES AND FEMALES (X±SD, MINIMUM AND MAXIMUM IN BRACKETS)

	Males (N=21)	Females (N=19)
Age (years)	34.6±16.3 (18–60)	34.7±8.8 (23–54)
Height (cm)	183.8±7.2 (171–197)	167.3±6.1*** (159–181)
Body mass (kg)	83.7±11.4 (66.6–109.4)	64.2±9.9*** (49.5–93.0)
BMI (kg/m²)	24.81±2.99 (20.8±26.9)	22.86±2.76 (20.0±27.6)
BODY FAT PERCENTAGE (%)		
Dual-energy X-ray absorptiometry (DXA)	17.2±6.9 (5.0–27.2)	30.3±9.0*** (9.8–48.3)
BIA, Lukaski et al.[1]	12.9±7.2 (3.8–27.7)	22.7±8.7*** (8.7–44.5)
Chumlea et al.[6]	11.3±7.1 (3.3–26.1)	22.3±9.2*** (6.5–45.4)
Segal et al.[3]	18.7±6.0 (6.8–29.4)	–
Van Loan and Mayclin[7]	–	31.8±3.4 (14.4–37.3)

***p<0.001

Results

BF% measured by DXA was significantly higher than measured by BIA using Lukaski et al.[4] and Chumlea et al.[6] equations. Differences were not significant with Segal et al.[5] (males) and Van Loan and Mayclin[7] (females) equations (Table 1). Regression analysis indicated that the sum of 15 SAT-layers explained 88.9 % and 84.7% (R^2 ×100) of the BF% measured by DXA in males and females, respectively (Table 2). Neck and hip SAT-layers in males and calf and hip in females explained about the same amount of the total variance (85.9% and 86.7%, respectively). BF% values were predicted from the following equations:

$$BF\% = 1.308\ neck + 0.638\ hip + 6.971\ (males)$$

$$BF\% = 1.152\ hip + 1.797\ calf + 12.347\ (females)$$

The limits of agreement using Bland and Altman[8] plots were –4.9 to + 4.8% (males) and –6.5 to + 6.4% (females). The agreement of predicted and measured values was within 95% confidence limits and showed a mean bias of +0.1% (males) and 0.0% (females) for BF%. The influence of the SAT-layers measured separately in hands, legs and trunk to the fat% measured at the same regions by DXA was lower (Table 2). Correlation analysis indicated that body impedance or impedance index was not related to BF% measured by DXA, the sum of 15 SAT-layers or SAT-layers measured in hands, legs and trunk by lipometer. However, the correlation was highest using Segal et al.[3] equation in males (r=0.94) and Van Loan and Mayclin[7] equation in females (r=0.84) compared with DXA. These limits of agreement using Bland and Altman[8] plots were –6.8 to +3.0% (males) and –17.2 to +13.8% (females). The values were within 95% confidence limits and showed a mean bias of –2.1% in males and –1.9% in females. The limits of agreement were higher compared to lipometer.

Discussion

The results of our study add new information about the high validity of lipometer device using first time DXA as a prediction method. Compared to lipometer, the validity and especially the agreement between two methods of well-known BIA equations such as Segal et al.[3] in males and Van Loan and Mayclin[7] in females was slightly lower.

TABLE 2
REGRESSION SUMMARY BETWEEN DXA ANALYSIS AND SAT LAYERS

	Sex	R	Adjusted R^2	SEE	p
		BODY FAT % (DXA) *vs.* 15 SAT LAYERS			
Sum of layers	males	0.931	0.889	2.59	<0.000
	females	0.915	0.847	3.72	<0.000
Neck + hip	males	0.935	0.859	2.59	<0.000
Calf + hip	females	0.931	0.867	3.46	<0.000
		HANDS FAT % (DXA) *vs.* 2 SAT LAYERS			
Sum of layers	males	0.852	0.710	3.27	<0.000
	females	0.744	0.528	6.51	<0.000
Triceps + biceps	males	0.867	0.720	3.21	<0.000
Biceps	females	0.798	0.615	5.88	<0.000
		LEGS FAT % (DXA) *vs.* 5 SAT LAYERS			
Sum of layers	males	0.857	0.718	3.03	<0.000
	females	0.635	0.368	7.57	<0.000
Front thigh	males	0.787	0.596	3.63	<0.000
Rear thigh	females	0.658	0.399	7.38	<0.002
		TRUNK FAT % (DXA) *vs.* 8 SAT LAYERS			
Sum of layers	males	0.922	0.841	3.04	<0.000
	females	0.896	0.790	3.85	<0.000
Neck + hip	males	0.947	0.884	2.60	<0.000
Lower back + hip	females	0.908	0.802	3.74	<0.000

DXA – dual-energy X-ray absorptiometry, SAT – subcutaneous adipose tissue layers

Stepwise multiple regression analysis selected two SAT-layers – neck and hip in males, and calf and hip in females. The standard errors of estimate (SEE) for equations obtained were 2.59% (males) and 3.46% (females) (see Table 2). By Hayward's[9] scale, the SEE's are »very good« and »good«, respectively. In the original Möller et al.[2] study, the four different SAT-layers were selected. The correlation between this estimate and total body electrical conductivity was r=0.96, which is very similar to our results. The Bland-Altman plots indicate that a systematic difference in BF% values was not apparent between DXA measured and new equations calculated. However, the high values for the limits of agreement relative to the mean values for BF% in this study only partly support the conclusion of interchangeability between these two methods for estimating BF%. Dividing the whole body to the hands, legs and trunk indicates that the relationship between BF% measured by DXA on specific parts and specific SAT-layers are significant but lower than total body calculations (Table 2). This relationship was lowest in legs where the front thigh (males) and rear thigh (females) characterized only 59.6% and 39.9% of the fat percentage measured by DXA. Probably it depends on the fact that SAT-layers on the limbs are measured on fewer points than on the trunk.

Correlation analysis indicated that relationships between SAT-layers or BF% measured by DXA and body impedance or impedance index were not significant. BF% measured by DXA correlated highly with BF % calculated by Segal et al.[3] equation in males (r=0.94) and Van Loan and Mayclin[7] equation in females (r=0.88). The limits of agreement between BF% measured (DXA) or calculated were higher compared with lipometer. Several investigations have not confirmed the results of Lukaski et al.[4] study that SEE for BIA is 3%, but is closer to 5–6% of body fat[5,10]. The criteria of Lohman[11] suggest that the evaluation of a new method for predicting body fat % accurately should include a SEE within 3% of body mass. In our study using lipometer new equations the criteria were fulfilled in males (2.59%) but not in females (3.46%).

In conclusion, lipometer and BIA give a similar mean estimation of BF% when compared to DXA. There are wide variances for the upper and lower limits of agreement between the methods, and the methods are not interchangeable. Lipometer seems to be superior from BIA. However, further evaluation is required to clarify the validity of lipometer and BIA using larger sample size.

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VALJANOST OPTIČKOG UREĐAJA LIPOMETRA I ANALIZE BIOELEKTRIČNOM IMPEDANCIJOM U PROCJENI TJELESNE MASTI U MUŠKARACA I ŽENA

S A Ž E T A K

Cilj ovog istraživanja bio je usporediti metodu procjene postotka tjelesne masti (BF%) koja se temelji na mjerenju slojeva potkožnog masnog tkiva (SAT-slojevi) lipometrom s DXA (dual energy x-ray absorptiometry) i BIA (bioelektrična impedancija). Uzorak se sastojao od 40 zdravih Estonaca koji su dobrovoljno pristupili istraživanju – 21 muškarca (18–60 godina) te 19 žena (23–54 godina). Lipometrom je mjereno 15 standardiziranih SAT-slojeva. Zbroj SAT-slojeva ruku, nogu i trupa uspoređen je s postotkom masti dobivenim DXA mjerenjem ruku, nogu i trupa. Za izračun BF% na temelju BIA korištene su jednadžbe Lukaski et al. i Chumlea et al. za oba spola. Jednadžbe Segal et al. korištene su samo za muškarce, a jednadžbe Van Loan i Mayclin samo za žene. BF% mjeren metodom DXA bio je u oba spola značajno viši od onog izračunatog prema Lukaski et al. i Chumlea et al. za oba spola. Korelacija je bila najviša između BF% mjerenog metodom DXA i onog dobivenog izračunom prema jednadžbi Segal et al. za muškarce (r=0.94) te prema jednadžbi Van Loan i Mayclin za žene (r=0.84). Dobro podudaranje uočeno je između BF% mjerenog metodom DXA i onog dobivenog zbrojem 15 SAT-slojeva (r=0.88 za muškarce i r=0.91 za žene). Višestruka regresijska analiza (stepwise) pokazala je da dva odabrana SAT-sloja objašnjavaju 85.9% (za muškarce) i 86.7% (za žene) (R^2 x 100) ukupne varijance BF% mjerenog metodom DXA: [BF% = 1.308 vrat + 0.638 bokovi + 6.971 (muškarci; SEE = 2.59) i BF% = 1.152 bokovi + 1.797 list + 12.347 (žene; SEE = 3.46)]. Autori zaključuju kako lipometar i BIA daju slične procjene BF% u usporedbi s metodom DXA, ali uz širok raspon varijance donje i gornje granice podudaranja metoda. Međutim, navedene metode nisu međusobno zamjenjive, a lipometar se doima boljim od BIA.