Inconsistency Between the Body Fat Percentages Estimated Through Anthropometric Measurements and Manual Bioimpedance in Children and Adolescents

Discordancia entre los Porcentajes de Grasa Corporal Estimados Mediante Medidas Antropométricas y por Bioimpedancia Manual en Niños y Adolescentes

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SUMMARY: The rate is assessed as per the body fat percentages (%BF) estimated through anthropometric measurements and manual bioimpedance, according to gender and adiposity rate within the paediatric population. The %BF is assessed by anthropometry using the Slaughter equation for cutaneous skinfolds and manual bioimpedance (Omron model HBF-306INTTM) to 321 students (160 females and 161 males) between 10-18 years. The association degree among the methods was measured using the Pearson correlation coefficient (r). The consistency among methods was analysed through the intra-class correlation coefficient (ICC) and the consistency correlation coefficient of Lin (CCC), grouping the population by gender and adiposity rate. The reference method was the cutaneous skinfolds assessed by the Slaughter equation. Optimum and high adiposity rates were recorded for the studied sample. The r between the bioimpedance and the anthropometry was 0.689, which corresponds to moderate. However, it decreased according to the gender and adiposity rate (females: optimum 0.409 and high 0.610; males: optimum 0.335 and high 0.507). The ICC was 0.668, which also decreased by gender and adiposity rate (females: optimum 0.323 and high 0.578; males: optimum 0.229 and high 0.506). CCC was poor (<0.90) by gender and adiposity rate. The study shows differences for both methods in this age range, which is accentuated by gender and adiposity rate. Therefore, the use of manual bioimpedance as an interchangeable method with the anthropometric measurements in children and adolescents is not suggested as it underestimates the %BF.

KEY WORDS: Anthropometry; Body composition; Body fat; Bioimpedance.

INTRODUCTION

Obesity determines different risks in the psychological, biological and social scope (Loaiza & Atalah, 2006). It leads children to isolation and self-esteem reduction, thus affecting the personal, family and academic sphere (De la Maza & Albala, 2000). Biological risks demonstrate in the short, medium and long run through orthopedic, respiratory, cutaneous pathologies, arterial hypertension, blood lipid increase, insulin resistance and eventually type 2 diabetes mellitus (Pérez & Albala, 2000; Muzzo, 2002).

The costs of children obesity for the family, the society and the health system are quite significant, not only associated to death and disease load, but also with disability and life quality of the population (Albala *et al.*, 2002; Rodríguez & Pizarro, 2006).

Consequently, there is an increasing concern in the body composition studies as a consequence of the new concepts on the body division into various compartments

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and the technological developments promoting its knowledge (Casanova Román *et al.*, 2004). Thus, the body mass index (BMI) has been suggested by the World Health Organization (WHO) as the indicator to anthropometrically assess the nutritional state of a population below 20 years, due to its simplicity, low costs and proper correlation with the total body fat (Rodríguez & Pizarro). Therefore, the BMI has been considered as the best anthropometric indicator to diagnose overweight and obesity in 2-18 year old children (Rodríguez & Pizarro). However, different researchers have resorted to cutaneous fold equations for more precise nutritional evaluations (Berral De La Rosa *et al.*, 2001), which require expertise of the assessors. According to the latter, electrical bioimpedance has risen, which has become quite relevant for the body composition measurements, both in the research and clinical areas (Sánchez & Barón, 2009). Among the advantages of this methods are: low costs, transport ease, safety, management simplicity, simple execution under any clinical context (from the clinic to the intensive surveillance unit), reproducible and adequate for the medical routine (Piccoli *et al.*, 2002). In this sense, this study aims to assess the consistency degree between the %BF evaluated through the manual bioimpedance and the cutaneous skinfolds in a child and adolescent population.

SUBJECT AND METHOD

The transversal study was carried out in 2009-2010, and involved the %BF estimation to assess the nutritional state through manual bioimpedance (Omron model HBF-306INT™) and anthropometric variables, using the Slaughter *et al.* equation (Slaughter *et al.*, 1998).

The sample consisted of 321 students (160 females and 161 males) between 10-18 years, who attended public, subsidized-private and private schools from three towns of the V region of Chile (Valparaíso, Viña del Mar and Concón). An informed consent of the parents and student was required, thus complying with the Ethical norms of the Pontificia Universidad Católica de Valparaíso and the Declaration of Helsinki.

In order to assess the manual bioimpedance, a fat loss monitor model -306INT™ was used, which shows the estimated %BF value along with the BMI (evaluated by first author). The bioimpedance monitor works through the emission of an extremely low electrical current (50 kHz and 500 mA) through the body to determine the fat tissue quantity. Such weak electrical current results safe and is not perceived when the monitor is used. Furthermore, the individuals are evaluated by anthropometry (by first author

of the present study), which considers name, sex, date of birth, date of evaluation, age in years, months and days, height in maximum inspiration, weight with minimum clothes and skinfolds (using a skinfold caliper: Slim Guide, Rosscraft Innovations Incorporated, Surrey, Canada, precision of 1 mm) such as triceps and medial calf in described and standardized scores (Norton & Olds, 1996). Measurements were taken at the right hemibody and at the schools during the morning.

The weight was assessed using a precision scale (SECA™) with a sensibility of 100 gr. Height was estimated using a stadiometer (SECA™) with a 0.1 cm precision. Individuals were evaluated standing, barefoot and with light clothes. All measurements were taken in triplicate, taking the mean as the final value.

The statistical analysis involved the sample description per age, gender and adiposity degree (men <20.5 low; 20-26 optimum; >26 high; women <15 low, 15-24 optimum and >24 high). Correlations between anthropometric and bioelectrical parameters were carried out using the Pearson correlation coefficient (*r*) to assess the lineal association degree between both measurements and the validity between the methods was done using the intra-class correlation coefficient (ICC) and the Lin consistency correlation (CCC; has the following ranges: almost perfect >0.99; substantial 0.95-0.99; moderate 0.90-0.95 and poor <0.90 (Lin, 1989)).

Statistical calculations were done using the SPSS program version 15.00 for Windows XP 2002. A *p*<0.05 was considered as significant.

RESULTS

The differences observed among males and females concerning the age, weight and height variables were not statistically significant (see Table I). When the complete sample is analyzed, in relation to the %BF estimated by the Slaughter equation and the manual bioimpedance, an underestimation of 0.63% is obtained for the latter method with respect to the values obtained by the cutaneous skinfolds ($27.58 \pm 7.48\%$) for the bioimpedance and ($28.21 \pm 9.63\%$) for the Slaughter equation. Notwithstanding such difference results irrelevant.

On the other hand, when an analysis by gender is carried out (Table I) the measures by manual bioimpedance are higher in men; like the global sample, the difference is not significant. In women, however, the mean obtained

through bioimpedance is significantly lower than that obtained by the Slaughter equation (Value $p=0.000026$). The r between the studied methods is 0.689 in the whole sample, which shows the data present a moderate colineality (see Figure 1). If the latter is analysed separated by gender, it is observed that women ($r=0.67$) are similar to men ($r=0.66$).

As the correlation results less predictive regarding the interchangeability evaluation of a method with respect

to another, it is then necessary to assess the consistency. In this study, therefore, the intra-class correlation coefficient (ICC) was used, which gives moderate consistencies for the complete population (0.668) and smaller as per adiposity rate. Consistent to such results, the Lin consistency correlation coefficient (CCC) also ascribes poor consistencies (<0.90 ; see table II) to the total results (0.666) and by adiposity rate.

Table I. Anthropometric data for the studied individuals. Mean $\pm$ standard deviation (SD).

Variable	Males (n=161)		Females (n=160)	
	Mean	SD	Mean	SD
Age	13.75	2.49	14.45	2.41
Weight	57.59	15.84	55.49	12.70
Height	1.60	0.14	1.56	0.09
%BF (Bioimpedance)	25.46	8.57	29.69	5.43
%BF (Slaughter equation)	24.65	9.71	31.68	8.23
BMI	22.12	3.57	22.70	4.04

Table II. Comparison between %BF estimated through cutaneous skinfolds (Slaughter equation) and manual bioimpedance, by age and adiposity rate. Pearson correlation coefficient (r), intraclass correlation coefficient (ICC), concordance correlation coefficient (CCC).

%BF	Optimum				High			Total	
Statistical methods	r	ICC	CCC	r	ICC	CCC	r	ICC	CCC
Male	0.335	0.229	0.169	0.507	0.506	0.498	0.656	0.655	0.652
Female	0.409	0.323	0.559	0.610	0.578	0.505	0.665	0.615	0.589

Fig. 1. Diffusion graph for the body fat percentage assessed through manual bioimpedance and cutaneous skinfolds (Slaughter equation). Males on black spheres; females in grey spheres.

DISCUSSION

The methods analyzed in this study make an indirect estimation of the %BF; thus, in absence of a pattern such as hydrodensitometry, DEXA or tomography, it is impossible to determine which contributes with a more reliable %BF. Cutaneous skinfolds, present in most studies on body composition as a comparison technique with the analyzed and/or reference method, show a high consistency and correlation with the %BF obtained through different techniques, such as: densitometry (Lean *et al.*, 1996), DEXA (López *et al.*, 1997), dilution methods (Rush *et al.*, 1997), which along with their low costs and accessibility justify their wide use in this type of studies, thus being considered as a golden pattern among anthropometric measurements (Gómez *et al.*, 2001). Regarding children and adolescents, the Slaughter equation represents the method recommended by diverse authors (Sopher *et al.*, 2007; Alvero *et al.*, 2009a; Alvero *et al.*, 2009b) thus, the cutaneous fold measurement was considered as the golden pattern.

On the other hand, monitors of manual bioimpedance (such as the one used in this study: Omron model HBF-306INT™) represent an alternative in the %BF assessment, showing some advantages compared to cutaneous skinfolds, such as: less time consumption, less unpleasant for the patient, less training required and a lower intra and inter-observer variability (Valtueña *et al.*, 1996), although during use it is necessary to know its basis and limitations (Brodie *et al.*, 1998). Consequently, the sample height variability, gender and age groups of some researchers make this monitor still incomparable with the reference patterns (Santos *et al.*, 2008).

A reflection of the latter is that some authors have recorded the monitors of similar characteristics (hand by hand bioimpedance) significantly underestimate the %BF in young and thin people (Fernández *et al.*, 2000) and even though the capacity of skinfolds to assess the %BF is limited in this situation, as the skin thickness may pose a bias in the final result, and the subcutaneous fat-inner fat relation may differ, such difference supports the execution of complementary studies with this monitor in other groups (thin, obese and elderly; Rush *et al.*). Consequently, the analysis was performed dividing the sample by adiposity rates (%BF), thus finding optimum and high rates within the sample, and where the latter was significantly higher in women (83.74%) than in men (60.2%). The results are due to a transition towards an adiposity excess, which had already been recorded by the authors in similar populations (Lizana *et al.*, 2011). Likewise, a poor CCC was found. Interestingly, all three studied coefficients considerably decrease after segmenting the sample by gender and adiposity rate (Table II), which shows these monitors involve certain limitations at the individual and gender level

(Santos *et al.*). Other authors have found an adequate consistency between bioimpedance and anthropometry at the pediatric age. However, the equipment used in such investigations was tetrapolar (Casanova Román *et al.*), which have been validated through reference patterns and used in epidemiological studies, such as NHANES III (Chumlea *et al.*, 2002).

Regarding the statistical analysis, some investigations (Ostojic, 2006; Utter *et al.*, 2005) have used the Pearson correlation coefficient for determining the measurement consistency. This methodology may be adequate to reflect the intensity of the linear association between two variables, but it does not result in proper information on the produced agreement, as the generated systematic difference is disregarded (Portao *et al.*, 2009). In this case, a moderate correlation is shown through the *r* in the total group, as a direct linear association is shown, where it is proven that while one of the variables increases the other does the same, thus producing only a variation in the extent of such increase. This results quite predictable as both methodologies assess the same variable. Therefore, the assessment of the consistency was done through ICC and CCC, which allow assessing the consistency between the employed techniques; both statistical methods involve incomparable results in this study, as in this population group the agreement degree reached in the consistency level between the estimated %BF through the Slaughter equation and the monitor is evaluated as poor (CCC) in all categories, due to the fact all the values are lower than 0.90, although the higher values were observed in the total population, like in the ICC.

These varied observations by gender and adiposity rate do not allow interchangeability between the anthropometric method and the manual bioimpedance. Such differences in the adiposity rate (through the body mass index) have been observed in adults by other authors (Pimentel *et al.*, 2010).

Another variable that should have improved the body fat estimation precision through the manual bioimpedance was that this monitor incorporates weight, age and gender. Notwithstanding, it does not seem to improve the consistency between these two methods for the estimation of the %BF, as the manual bioimpedance underestimates the 0.63% of the body fat.

The investigators involved in this study have observed that educational institutions in the region (Valparaíso, Chile) have purchased manual bioimpedance monitors, which are being used in pediatric population due to their easy handling. However, this use is not appropriate, since their programming corresponds to adult equations (Gallagher *et al.*, 2000). Besides, the bioimpedance monitor utilizes a standard equation, something that is not recommended, because

it must be categorized regarding the ethnic origin of the studied population (Dehghan & Merchant, 2008). Likewise, the fact that these monitors operate at a unique frequency (monofrequency equipment) must be considered; it is recommended to use multifrequency equipments because of the variation individuals show (Cornish *et al.*, 1993), especially during this growing and development stage (Wells *et al.*, 2007).

Manual bioimpedance results to be an unreliable indicator for the estimation of the %BF in the pediatric

population for this monitor, an aspect consistent with other authors for 9-11 year-old girls, which also found different data between bioimpedance and anthropometry (Urrejola *et al.*, 2001).

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RESUMEN: Se analiza el grado de acuerdo entre los porcentajes de grasa corporal (%GC) estimados mediante medidas antropométricas y por bioimpedancia manual, por género y grado de adiposidad en población pediátrica. Se valora por antropometría el %GC utilizando la ecuación de Slaughter para pliegues cutáneos y por bioimpedancia manual (Omron modelo HBF-306INT®) a 321 estudiantes (160 mujeres y 161 hombres) comprendidos entre las edades de 10 a 18 años. El grado de asociación entre los métodos se midió mediante el coeficiente de correlación de Pearson (r). La concordancia entre métodos se analizó mediante el coeficiente de correlación intraclase (CCI) y coeficiente de correlación de concordancia de Lin (CCC), agrupando a la población por género y grado de adiposidad. El método de referencia fueron los pliegues cutáneos evaluados por la ecuación de Slaughter. En la muestra estudiada se registró grados de adiposidad óptimo y alto. El r entre bioimpedancia y antropometría fue de 0,689 lo que corresponde a moderado. Sin embargo, disminuye por género y grado de adiposidad (mujeres: óptimo 0,409 y alto 0,610; hombres: óptimo 0,335 y alto 0,507). El CCI es 0,668 el que igualmente disminuye por género y grado de adiposidad (mujeres: óptimo 0,323 y alto 0,578; hombres: óptimo 0,229 y alto 0,506). El CCC en todos fue pobre (<0,90) por género y grado de adiposidad. El estudio indica discrepancias de estos dos métodos en este rango etáreo, lo que se acentúa por género y grado de adiposidad. Por lo tanto, no se sugiere utilizar la bioimpedancia manual como un método intercambiable con las medidas antropométricas en niños y adolescentes, pues subestima el % GC.

PALABRAS CLAVE: Antropometría; Composición corporal; Grasa corporal; Bioimpedancia.

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