MESTRADO INTEGRADO EM MEDICINA

DISSERTAÇÃO I ARTIGO ORIGINAL

ACCURACY AND FUNCTIONALITY OF A NEW DIGITAL SKINFOLD CALIPER FOR ESTIMATING BODY FAT IN OVERWEIGHT AND OBESE CHILDREN

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2021

U.PORTO
INSTITUTO DE CIÊNCIAS BIOMÉDICAS ABEL SALAZAR
UNIVERSIDADE DO PORTO

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ACCURACY AND FUNCTIONALITY OF A NEW DIGITAL SKINFOLD CALIPER FOR ESTIMATING BODY FAT IN OVERWEIGHT AND OBESE CHILDREN

Dissertação de candidatura ao grau de Mestre em Medicina, submetida ao Instituto de Ciências Biomédicas Abel Salazar – Universidade do Porto

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Porto, Junho de 2021

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AGRADECIMENTOS

Em primeiro lugar, gostaria de agradecer à minha orientadora, Dra. Helena Ferreira Mansilha por ter aceite orientar este projeto e, em especial, por todo o compromisso, confiança e disponibilidade demonstrados ao longo deste percurso. O seu apoio foi incansável e não poderia deixar de expressar a minha enorme gratidão por toda a sua ajuda.

À minha coorientadora, Prof. Doutora Esmeralda Martins, por ter aceite integrar este projeto.

Gostaria ainda de agradecer ao Dr. Tiago Andrade e à Professora Carolina Lemos pelas suas contribuições, essenciais para o desenvolvimento deste projeto.

Por fim, um enorme obrigada aos meus familiares e amigos por todo o seu apoio incondicional.

Resumo

INTRODUÇÃO: O excesso de peso e obesidade pediátrica são graves problemas de Saúde Pública, estando associados a complicações a curto e a longo prazo para a saúde física e mental das crianças afetadas. Atualmente, existem vários métodos para avaliar o excesso de gordura corporal associado a estas condições. No entanto, nenhuma destas técnicas é perfeita, sendo que todas apresentam as suas limitações. Recentemente, um lipocalibrador digital inovador, o *Lipowise®,* surgiu como um método antropométrico simples, prático e barato para avaliar a gordura corporal. Este estudo tem como objetivo avaliar a eficácia e a funcionalidade do *Lipowise®* na medição da espessura das pregas cutâneas e na determinação da percentagem de gordura corporal total em crianças pré-púberes.

METODOLOGIA: Foi realizado um estudo transversal com 134 crianças pré-púberes com excesso de peso e obesidade, com idades compreendidas entre os 5 e os 10 anos. Os dados antropométricos colhidos incluíram o peso, a estatura, o perímetro abdominal, o Índice de Massa Corporal (IMC), o rácio perímetro abdominal/estatura, a espessura das pregas cutâneas tricipital e subescapular, e a percentagem de gordura corporal total. O lipocalibrador digital *Lipowise®* foi utilizado para medir a espessura das pregas cutâneas e, a partir destas, foi aplicada a equação de *Slaughter et al* para o cálculo da percentagem de gordura corporal total. Esta percentagem foi igualmente estimada por bioimpedância com recurso ao aparelho *Inbody 270®.* Foi ainda avaliada a funcionalidade do método tendo em conta a colaboração das crianças e a exequibilidade da medição por *Lipowise®*.

RESULTADOS: Os resultados deste estudo revelaram uma correlação estatisticamente significativa entre a percentagem de gordura corporal total medida pelo lipocalibrador *Lipowise®* e pelo *Inbody 270®.* O mesmo foi observado entre a percentagem de gordura corporal estimada pelo *Lipowise®* e o IMC, bem como o perímetro abdominal e o rácio perímetro abdominal/estatura. Além disso, não foram observadas diferenças estatisticamente significativas destas percentagens entre sexos. Das 134 crianças que constituem a amostra total, apenas 3 não foram colaborantes com a mediação realizada com o *Lipowise®* (2,24%). Também foi observado que a amplitude de abertura deste lipocalibrador digital foi suficientemente ampla para acomodar as pregas cutâneas de todas as crianças colaborantes.

CONCLUSÃO: Este estudo demonstrou que o lipocalibrador digital *Lipowise®* parece ser um dispositivo preciso e funcional, representando um método simples e prático da avaliação da composição corporal em crianças com excesso de peso e obesidade, fazendo dele um recurso valioso para a prática clínica diária.

PALAVRAS-CHAVE:
Childhood Obesity, Childhood Overweight, Skinfold Thickness, Digital Skinfold Caliper, Bioelectrical Impedance Analysis, Body Fat

ABSTRACT

INTRODUCTION: Childhood overweight and obesity are serious public health challenges, as they are associated with short- and long-term compromise to the children´s physical and mental health. There are various methods to assess the excess adiposity that is related to these conditions. Recently, an innovative digital skinfold caliper, *Lipowise®,* has emerged as a simple, practical and inexpensive anthropometric method to evaluate the body´s adiposity. This study aims to evaluate the accuracy and functionality of the *Lipowise®* caliper for measuring skinfold thickness and determining the percentage of body fat in prepubertal children.

METHODS: A cross-sectional study was conducted among 134 overweight and obese prepubertal children, aged between 5 and 10 years old. The anthropometric measures included weight, height, waist circumference, BMI, waist circumference-to-height ratio, triceps and subscapular skinfold thickness and Total Body Fat percentage. The digital skinfold caliper *Lipowise®* was used to measure the skinfold´s thickness and, from these, the *Slaughter et al* equation was applied to calculate the Total Body Fat percentage. This percentage was also estimated by the BIA analyser device, *Inbody 270®*. The functionality of this method was also evaluated taking into account the children´s collaboration and the feasibility of the measurement with *Lipowise®.*

RESULTS: The results of this study revealed a statistically significant correlation between the total body fat percentage measured using *Lipowise®* skinfold caliper and the BIA analyser, *Inbody 270®*. The same was true between the total body fat percentage estimated by *Lipowise®* skinfold caliper and the BMI, as well as the waist circumference and the waist circumference-to-height ratio. Furthermore, there were not observed statistically significant differences in the total body fat percentage between boys and girls. Out of the total 134 children, only 3 were non-collaborative in the measurement with the *Lipowise®* skinfold caliper (2,24%), and it was also observed that the device´s opening range capacity was wide enough to accommodate to all the children´s skinfolds.

CONCLUSIONS: This study demonstrated that the *Lipowise®* digital skinfold caliper seems to be an accurate and functional device, representing a simple and practical method to assess the child´s body composition, making it a valuable asset to the daily clinical practice.

KEYWORDS:
Childhood Obesity, Childhood Overweight, Skinfold Thickness, Digital Skinfold Caliper, Bioelectrical Impedance Analysis, Body Fat

LIST OF ABBREVIATIONS

BIA – Bioelectrical Impedance Analysis
BMI – Body Mass Index
CDC – Centers for Disease Control and Prevention
CHUPorto – Centro Hospitalar Universitário do Porto
COSI – Childhood Surveillance Initiative
CT – Computed tomography
DXA – Dual Energy X-ray Absorptiometry
Kg – Kilograms
m – meters
mm – millimeters
NHANES – National Health and Nutrition Examination Survey
NMR – Nuclear Magnetic Resonance
SD – Standard Deviation
SPSS – Statistical Package for the Social Sciences
WHO - World Health Organization
µA – Microampere

INDEX

LIST OF TABLES

LIST OF FIGURES

Introduction

Childhood obesity is one of the most serious public health challenges of the 21st century [1]. WHO defines it as an abnormal or excessive fat accumulation that presents a risk to health [2]. Additionally, this excess adiposity is necessarily associated with adverse metabolic consequences, short- and long-term compromise to the individual's physical health [3-8], as well as non-negligible psychological effects [9,10]. Furthermore, childhood obesity is considered an independent risk factor for the development of numerous metabolic and cardiovascular diseases, such as Hypertension, type 2 Diabetes, Nonalcoholic Fatty Liver Disease, Polycystic Ovary Syndrome, Obstructive Sleep Apnea, among others, which were health conditions once thought applicable only to adults [11]. Moreover, up to 80% of the obese children and adolescents carry this condition to their adulthood [12], showing the extreme importance of the early detection of the ones at risk of developing it, and its timely prevention, of both the disease and its associated comorbidities.

In Portugal, a study conducted by COSI (WHO European Childhood Obesity Surveillance Initiative) in 2016 showed that there has been a stabilization, even a slight decrease, in both the prevalence of overweight and obesity in the past decade. However, it also concluded that 30,7% of the Portuguese schoolchildren from ages 6 to 8 were overweight, while 11,7% were obese, showing that it still represents a major public health issue [13].

Bearing in mind the consequences of overweight and obesity in one´s health, it is of paramount importance to rigorously assess adiposity in order to precociously hamper this hazardous progression.

Anthropometry is the most portable, universally applicable, inexpensive and noninvasive method available to assess the human body´s composition, helping us monitor the patient´s health and nutritional status. [14]

Amongst anthropometric measurements, the most widely used tool to assess overweight and obesity is Body Mass Index (kg/m^2), mainly due to its simplicity and practicality. Various studies have concluded that a high BMI-for-age is a moderate sensitive (70-80%) and specific (95%) indicator of excess adiposity among children[15].

Additionally, overweight (BMI-for-age superior to +1 Z-Score) and obesity (BMI-for-age superior to +2 Z-Score)[16] seem to correlate well with clinical outcomes, that is, children with these conditions are more likely to have adverse levels of multiple metabolic risk factors and to become obese adults, when compared to thinner children [17,18].

However, this index is a measure of weight relative to height rather than of adiposity, making it incapable of distinguishing between body fat, muscle mass and skeletal mass. Being so, it can serve solely as an indirect estimate of adiposity and can lead to crucial errors in the estimation of body fat [19]. This limitation is especially noticeable in the pediatric population, where the contributions of the different body compartments vary according to age, sex, ethnicity, pubertal maturity and other individual factors [20-22].

The waist circumference-to-height ratio has recently emerged as a good predictor of body adiposity, considered by some authors as being superior to BMI and waist circumference alone in identifying overweight and obese children.[23] A cutoff of 0.5 was determined as a means of indicating excessive body fat accumulation and risk to health [24]. However, similarly to the BMI, it serves only as an indirect measurement of the body adiposity [25].

There are currently various other methods available for evaluating body composition and estimating adiposity in the pediatric population, from simple techniques, such as skinfold-thickness measurements and BIA, as well as more elaborate instruments including CT, NMR, plethysmography and DXA[26]. However, none of these methods directly measures body fat and all of them present some limitations [14]. DXA has been considered the gold-standard for measuring the percentage of body fat in children with excess adiposity [27,28], but its clinical use is limited because it is expensive, impractical and exposes the patients to ionizing radiation, although in virtually insignificant doses (<10 microSieverts) [29].

One more convenient technique to estimate the percentage of body fat is the BIA analysers, which are considered ideal for routine practice in children and adolescents [30]. This method calculates body fat percentage based in correlating impedance and reactance values obtained by passing an alternating electric current through the patient´s body [31]. They are simple to use, low cost and require minimal subject collaboration, and are proven to provide acceptable quantification of the percentage of body fat in children from the general population [30].

Despite being increasingly sophisticated, the accuracy of the BIA analysers is still influenced by various factors, such as gender and age [32,33]. In fact, the relative proportion of the three main body components (water, protein and mineral) vary greatly with age and pubertal status. In order to address these variations, the BIA analysers assume constant lean mass characteristics for a given age and gender, which can be especially problematic in patients who have altered body composition[26], such as overweight and obese children, making it necessary for the development of wider studies demonstrating the accurate application of this method in these populations[34,35].

One of the largest studies ever made comparing measurements of body composition using BIA and DXA of children and adolescents concluded that there were significant correlations between the percentage of body fat measured using BIA analyser, *Inbody 720®*, and DXA in healthy children (r=0.940)[36]. Furthermore, it added that both techniques could be used as complementary methods, with BIA analyzers having an important role in the clinical field, due to its high precision, and on population study´s settings [36].

On the other hand, the measurement of skinfold-thickness with a caliper and subsequent application of the most suitable predictive mathematical equation for the population in study, from the many available, to calculate the total body fat percentage, is also an alternative screening tool to assess body composition of children in the clinical practice. It is highly informative, non-invasive and inexpensive, making it one of the most widely used anthropometric techniques in nutritional status and body composition assessment [37]. This technique is considered to be a better predictor of body fat percentage than other anthropometric variables and ratios, such as the BMI [38], and provides reliable results when compared with the gold standard, DXA [39].

However, a traditional caliper (*Harpender®*) is prone to the technician's subjectivity, which is associated with higher intrinsic errors and, consequently, limiting its use in the clinical practice. Furthermore, the use of the traditional caliper is quite restricted in the overweight and obese population due to its limited opening range capacity, which, not so infrequently, fails to accommodate to the skinfold thickness of the patient [40,41].

Recently, an innovative digital skinfold-thickness measuring system has emerged. *Lipowise®* allows for a rapid and precise measurement through the automatic recording and storage of data, with a software application with integrated database, which makes it less prone to subjectivity errors, such as thickness reading and measurement time counting.

Furthermore, it allows for a more rigorous assessment due to its higher measurement resolution (0.1 mm vs 0.20 mm with *Harpender®*) and a wider opening range capacity (up to 100 mm vs 80 mm with *Harpender®*), which allows for a better study of the overweight and obese pediatric population.[42]

In a nutshell, *Lipowise®*presents innovations that allow its use for fast and precise assessment of body composition by measuring skinfolds, while retaining the simplicity of any traditional caliper, making it a powerful tool for clinical practice, as well as for study and research purposes. To my knowledge, there are no studies testing this device in the overweight and obese pediatric population, making the present study even more relevant.

Objectives

The purpose of the present study is to evaluate the accuracy and functionality of a new digital skinfold system, *Lipowise®* caliper, for measuring skinfold thickness and determining the percentage of body fat in a cohort of prepubertal overweight and obese children. Additionally, a comparison will be made between the percentage of body fat estimated by *Lipowise®* and by BIA, and we´ll further analyze the overlaps and divergencies in the percentage of total body fat when the study´s cohort is divided into severity groups, based on their BMI. The functionality of this method was evaluated taking into account the children´s collaboration and the feasibility of the measurement with *Lipowise®.*

Methods

Cohort Selection and Sampling

The present cross-sectional study was conducted in Centro Materno Infantil do Norte (CMIN) in a cohort of 142 overweight and obese children aged between 5 and 10 years old, caucasian, during a 4 months' time period. A total of 8 children were excluded from the initial sample, as they were taking medication or had medical conditions that altered their body composition, leaving a total sample of 134 overweight and obese children. From these, only 49 had measurements made by the *Lipowise*® caliper (**Figure 1**). The protocol used for all participants was approved by the Ethics Committee of the CHUPorto. This age range was selected in order to eliminate the pubertal maturity bias, since the body composition varies significantly with the pubertal stage development [43, 44].

Measurement of Anthropometric Parameters

All the anthropometric data were obtained by two highly trained pediatricians, according to the US NHANES Anthropometry Procedures Manual [45]. Height (m) was measured using a stadiometer (*SECA*® 213) and weight (kg) using a calibrated digital scale *(Inbody® 270)*, with a range of 10-250 Kg. Children wore only their underwear. Afterwards, the Body Mass Index (BMI) was calculated using the standard equation: body mass(kg) / height (m) squared [46] and expressed in BMI-Z score. Overweight was defined as an BMI-for-age superior to +1 SD (Z-Score), while obesity superior to +2SD (Z-Score), concordant with WHO criteria [16].

The waist circumference was measured using a non-extendable tape measure, in the naval line, parallel to the floor, and the waist circumference-to-height ratio calculated using this measurement divided by height (m).

Measurement of Skinfold Thickness and Calculation of % Total Body Fat

The skinfolds evaluated were the tricipital and the subscapular, as they allowed to estimate the percentage of total body fat using the *Slaughter et al* mathematical equation, which has shown a good correlation with DXA in the body fat assessment of children and adolescents. [47,48]
The skinfold´s thickness was obtained using *Lipowise*® digital caliper, measured on the non-dominant limb with the child standing, for 3 seconds.
The tricipital skinfold should be measured in the posterior midline of the upper arm, while the subscapular skinfold 2 cm below the lower angle of the shoulder blade. Three measurements are made in each skinfold, presenting the median as a result. After measuring the skinfolds, the *Lipowise*® software converts the information obtained into the percentage of Total Body Fat, using the *Slaughter et al* predictive equation.

The percentage of Total Body Fat was also obtained using the *Inbody*® *270* device, which is an eight electrode segmental multi-frequency analyser. The measurement is made with the subject in an upright position with bare feet on the analyser footpads and both hands touching the top electrodes, while wearing only their underwear, after at least 3h of fasting and voiding before measurements. The total body fat percentage was calculated by passing and alternating current (∼ 200 μA) through the subject, in order to measure the water content.

Statistical Analysis

For all statistical tests, a 95% confidence interval was assumed. All continuous variables are presented through their mean ± standard deviation, or by their median, while categorical variables are presented through their frequency and proportion (%). The normal distribution of the variables was tested using the Kolmogorov-Smirnov test. As 2 of the variables (Waist/Height Ratio and % Total Body Fat using the *Lipowise*® caliper) did not fulfill the assumption of normality, the Spearman´s correlation coefficient (ρ) was applied when testing these variables.

The relationship between 2 continuous variables was evaluated using a simple bivariate correlation, using the Pearson (r) coefficient. For all of them, the cut-off points of 0.100, 0.300 and 0.500 were assumed for poor, moderate and strong agreement between variables, respectively. To compare means between 2 groups, a Student´s T test was performed for independent samples.

The study´s cohort was then divided into severity groups, based on their BMI-Z score (group 1: <2; group 2:≥2). The % Total Body Fat estimated by both BIA and *Lipowise*® devices were also divided in groups (group 1: <45%; group 2:≥45%). A crosstabulation was applied in order to analyze the overlaps and differences in the %Total Body Fat when the cohort is divided into severity groups based on their BMI-Z score. A Chi-Square test was also applied and the Fisher´s Exact Test analyzed in order to conclude the presence of a significant relation between the variables.

All analyses were performed using the SPSS® Statistical Package Software (version 27.0; SPSS, Chicago, IL, USA).

Results

Description and Initial Characterization of the study´s cohort

The study´s cohort consists of 134 children, with a median age of 8,8 years. There are 51 males and 83 females, the latter representing 62% of the population. In agreement with the selected population, the mean value of the Z-Score for the Body Mass Index (BMI-Z score) is +2,15. All the clinical characteristics of this cohort are described in **Table I.**

Relationship between Skinfold thickness, %Total Body Fat and Children´s Biometrics

I started by analyzing the existence of a significant correlation between the skinfold thickness and the children´s biometrics. There was a significant correlation between the thickness of both skinfolds with the BMI (tricipital: p<0,01; subscapular: p<0,01), the Waist Circumference (tricipital: p<0,01; subscapular: p<0,01) and the Waist Circumference-to-Height ratio (tricipital: p<0,01; subscapular: p=0,026). This analysis was also made according to sex, which results are further described in **Table II**. It was also observed that there are no significant differences in the skinfold thickness between both sexes (**Table III**).

Furthermore, I analyzed the existence of a significant correlation between the percentage of Total Body Fat using both BIA and *Lipowise®*, and the children´s biometrics. The study´s cohort consists of 134 children, but only 49 of these had their data regarding skinfold thickness and the percentage of Total Body Fat estimated by *Lipowise®* saved in the software, due to informatic error. There was a significant correlation between the Total Body Fat percentage with the BMI (BIA: p<0,01; *Lipowise®:* p<0,01), the Waist Circumference (BIA: p<0,01; *Lipowise®:* p<0,01) and the Waist Circumference-to-Height ratio (BIA: p<0,01; *Lipowise®:* p<0,01), in both methods. This analysis was further made according to sex, showing significant correlation with both methods, except when comparing the percentage of Total Body Fat using *Lipowise®* and Waist/Height ratio in males (p=0,07) (**Table IV**).

Afterwards, I analyzed the correlation between the percentage of Total Body Fat using BIA and *Lipowise®*.

There was a significant correlation between the Total Body Fat percentage measured by BIA and the Total Body Fat percentage measured using *Lipowise®* caliper ($p<0,01$), in both boys and girls (male: $p<0,01$; female: $p<0,01$).
More specifically it shows that *Lipowise®* caliper underestimated the Total Body Fat percentage in comparison with BIA analyser (**Table V**).

Overlaps and divergencies in the %Total Body Fat in different severity groups

Finally, the study´s cohort was divided into 2 severity groups based on their BMI-Z score (group 1: <2; group 2:≥2) and also by their Total Body Fat percentage (group 1: <45%; group 2:≥45%). For the Total Body Fat percentage using BIA, the Fisher´s Exact test concluded a significant correlation between the 2 groups ($p<0,01$), allowing for a crosstabulation to be made. This concluded that, in group 1 (BMI-Z score <2), 42% of the children had <45% and 58% had ≥45% of Total Body Fat. In group 2 (BMI-Z score ≥ 2), 2,9% of the children had <45% and 97,1% had ≥45% of Total Body Fat using BIA. This shows that, the bigger the BMI-Z score, the more overlaps there are between % Total Body Fat and the children´s BMI.

For the Total Body Fat percentage using *Lipowise®* digital caliper, the Fisher´s Exact test did not conclude a significant correlation between the 2 groups ($p=0,150$), thus a crosstabulation and further analyzes of the possible overlaps and divergencies of the percentage of Total Body Fat estimated by *Lipowise®* device could not be conducted. This happened mainly due to the short sample of subjects analyzed with this device (N=49), comparing to the bigger sample analyzed with the BIA device (N=134).

Functionality of the *Lipowise®* device

In terms of its functionality, only 3 out of the 134 subjects (2,24%) were non collaborative with the measurement with the *Lipowise®* digital caliper. In all the collaborative ones, the caliper fully accommodated to the children´s skinfold thickness.

Discussion

As previously discussed, overweight and obesity in the pediatric population are rising hazardous public health problems, taking into account the cumulative associated comorbidities that are prolonged and accentuated into adulthood. Thus, it is of cardinal importance to develop techniques that rigorously assess a child´s body adiposity, while being practical and innocuous for every-day clinical use, in order to promptly identify the problem and hamper its high-risk progression.

The main goal of the present study was to evaluate the accuracy and functionality of the *Lipowise*® digital caliper for measuring skinfold thickness and estimating the percentage of total body fat on overweight and obese prepubertal children.

The main findings of this study show that BIA analysers and *Lipowise*® digital caliper using *Slaughter et al* skinfold-thickness equation provide agreeable measurements of the Total Body Fat percentage in both male and female overweight and obese prepubertal children, although moderately underestimated by *Lipowise*® in comparison to BIA (**Table I**). This shows that these two methods are in close agreement (**Figure 2**), further supporting the accuracy of this new digital skinfold caliper.

The study also concluded that the percentage of Total Body Fat estimated by *Lipowise*® correlated strongly with the BMI (r=0,670) and the Abdominal Circumference (r=0,701), whereas moderately correlating with the Waist/Height ratio (r=0,457) (**Figure 3**). Knowing that these anthropometric measurements are used daily in the clinical practice to detect excess adiposity and are linked to increased metabolic risk [17,18,49], this results further support the validity of this innovative device.

When analyzing the overlaps and divergencies in the percentage of Total Body Fat calculated by BIA in different severity groups based on the subject´s BMI-Z score, we came to the conclusion that there was a strong association between increasing BMI-Z score and increasing percentage of Total Body Fat measured by the BIA analyser, especially in the more severe group (BMI-Z score ≥2).

Thivel D et al, in a study conducted among 196 obese adolescents with the mean age of 14 years old, showed that the accuracy of body composition assessment using BIA analysers decreases with increasing obesity (based on the subject´s BMI) [50]. In other words, the reliability of the calculated Total Body Fat percentage decreases as the BMI increases, which is the opposite we observed in our cohort of prepubertal children. Perhaps this divergency is due to the fact that the variation of the percentage of Total Body Fat depends greatly on gender and pubertal stage in this population of adolescents, which is not observed in our cohort of prepubertal children.

Another goal of this study was to evaluate the functionality of the *Lipowise®* skinfold caliper. As mentioned before, this new digital caliper has a wider opening range capacity when compared to the traditional caliper, which is an advantage when studying overweight and obese subjects, since it is not uncommon to be unable to evaluate them due to the thickness of the skinfold exceeding the opening range capacity of the caliper. Although non-invasive and painless, the measurement with this device can be intimidating, especially when used at such a young age. What we observed was that, from the total sample of 134 children, only 3 of them (2,24%) were non-collaborative in the measurement of skinfold thickness using the *Lipowise®* device, and that the caliper´s opening range capacity was wide enough to accommodate all the children´s skinfold thickness, supporting the hypothesis of the *Lipowise®* skinfold caliper as a highly functional and practical device, even in school-age children.

The strengths of this study include working with a homogeneous cohort of prepubertal children, ensuring the advantage of not having the variation in body composition during puberty as a confounding factor [43,44]. Actually, the absence of differences in the measurement of the skinfold thickness and total body fat percentage between the prepubertal boys and girls largely reduces the bias of gender, that is more strongly pronounced during adolescence [44], further reinforcing the homogeneity of this cohort and representing yet another advantage of this study.

Also, there were not included children with medical conditions that significantly alter body hydration status, fluid distribution or the ratio of extracellular to intracellular water, as well as those taking medication that altered the body´s composition [51]. Another strong point was that the anthropometric data was measured by only two experienced pediatricians, which is of great importance for the reliability of the results.

Limitations to the present study should also be noted. Firstly, we are not including the use of DXA, which is the accepted gold standard method for the measurement of the percentage of total body fat. Although Lim JS *et al* has shown that there was a significant correlation between the percentage of body fat measured using BIA analyser and DXA in a cohort of 166 healthy children aged 6-18 years old [36], there is still a lack of studies to further support the accuracy of this method, especially in the overweight and obese populations.

It is also important to mention that, although DXA is currently the accepted gold standard for body composition and its studies increasingly contribute to the evidence base for pediatric clinical practice, it does not represent a reference method and its results should be interpreted with caution [26]. Although DXA provides helpful insight on an individual´s relative fat and lean mass, these assessments are hampered by the lack of normal reference data [26]. Furthermore, a reduced validity of DXA has been reported for extreme body composition conditions, such as in obese individuals [52].

Another limitation of this study was the short sample of subjects that were analysed by the *Lipowise*® device*,* due to an unfortunate informatic error. This made it impossible to make a statistically significant analysis of the overlaps and divergencies in the percentage of Total Body Fat when the cohort was divided in different severity groups based on the subject´s BMI-Z score.

Conclusion

In conclusion, this study in a group of 5–10-year-old overweight and obese children demonstrates that the *Lipowise®* digital skinfold caliper seems to be an accurate and functional device and represents an innovation in the evaluation of skinfold thickness and body composition based on anthropometric measurements. As the skinfold thickness is rapidly measured and instantaneously recorded and analysed by the device´s software, any probable sources of measurement bias are avoided, solving some of the intrinsic problems of the traditional skinfold calipers. Therefore, it is an innovative device that allows for the objectification of parameters that were previously more prone to subjectity.

To my knowledge, there is still a lack of studies testing these digital calipers, *Lipowise®* being one of them, in the overweight and obese pediatric population, making this study even more relevant and its results ultimately successful. Nevertheless, it would be of paramount interest to compare the *Lipowise®* caliper´s accuracy with the gold-standard method, DXA, as well as in different age groups, in future studies.

Appendixes

Tables

Table I: Descriptive analysis and characterization of the study´s cohort

	Male	Female	All
Participants (N)	51 (38%)	83 (62%)	134
Age (IQR), years	8,7 (7,2-9,8)	8,9 (7,1-9,8)	8,8 (7,2-9,8)
Z-Score Height	0,97 (± 1,08)	0,85 (± 0,93)	0,89 (± 0,99)
Z-Score Weight	2,25 (± 0,74)	2,10 (± 0,64)	2,16 (± 0,68)
Z-Score BMI	2,24 (± 0,55)	2,10 (± 0,47)	2,15 (± 0,50)
Abdominal Circumference, cm	81,0 (± 9,8)	80,1 (± 9,6)	80,5 (± 9,7)
Waist/Height Ratio	0,79 (± 0,06)	0,80 (± 0,06)	0,80 (± 0,06)
Total Body Fat, Kg	18,4 (± 7,0)	18,4 (± 6,1)	18,4 (± 6,4)
%Total Body Fat using BIA	40,1 (± 6,8)	41,4 (± 5,7)	40,9 (± 6,2)
%Total Body Fat using *Lipowise*® [1*]	31,8 (± 16,0)	34,9 (± 10,4)	33,9 (± 12,3)

N (frequency in %), mean (± Standard Deviation), median (lower value-higher value). IQR - Interquartile range. BMI – Body Mass Index. BIA – Bioelectrical Impedance Analysis.

Total Body Fat (Kg) – calculated by Inbody 270® device.

1-Calculated using *Slaughter et al* equation [53]

*-Applied in 49 participants only.

Table II: Correlations between Skinfold Thickness and Body Mass Index values, Abdominal Circumference and Waist/Height ratio, according to gender.

Variables		Tricipital Skinfold			Subscapular Skinfold		
		Male	Female	All	Male	Female	All
Body Mass Index	Correlation (r)	**0,802**	**0,767**	**0,775**	**0,569**	**0,692**	**0,600**
	Sig. (p)	**<0,01**	**<0,01**	**<0,01**	**0,022**	**<0,01**	**<0,01**
	N	14	35	49	14	35	49
Abdominal Circumference	Correlation (r)	**0,698**	**0,698**	**0,694**	0,232	**0,648**	**0,449**
	Sig. (p)	**<0,01**	**<0,01**	**<0,01**	0,387	**<0,01**	**<0,01**
	N	14	35	49	14	35	49
Waist/Height Ratio	Correlation (r)	**0,749**	**0,452**	**0,561**	0,175	**0,372**	**0,299**
	Sig. (p)	**<0,01**	**0,006**	**<0,01**	0,518	**0,031**	**0,026**
	N	14	35	49	14	35	49

Significant correlations (p<0,05) in bold.

Table III: Mean value of Skinfold thickness according to gender.

		Male	Female	All	Statistical Analysis (Male vs Female)
Tricipital Skinfold	Thickness	24,0 (± 6,9)	23,8 (± 5,7)	23,9 (± 6,0)	p= 0,904
Subscapular Skinfold	Thickness	20,4 (±11,6)	25,1 (±10,1)	23,6 (±10,7)	p= 0,149

Significative correlation (p<0,050) in bold.

Table IV: Correlation between %Total Body Fat using both BIA and *Lipowise*®, and BMI values, Abdominal Circumference and Waist/Height ratio, according to gender.

Variables		% BF BIA			%BF *Lipowise*®		
		Male	Female	All	Male	Female	All
BMI	Correlation (r)	**0,637**	**0,712**	**0,655**	**0,595**	**0,719**	**0,670**
	Sig. (p)	**<0,01**	**<0,01**	**<0,01**	**0,025**	**<0,01**	**<0,01**
	N	51	83	134	14	35	49
Abdominal Circumference	Correlation (r)	**0,633**	**0,610**	**0,609**	**0,600**	**0,762**	**0,701**
	Sig. (p)	**<0,01**	**<0,01**	**<0,01**	**<0,02**	**<0,01**	**<0,01**
	N	51	83	134	14	35	49
Waist/Height Ratio	Correlation (r)	**0,430**	**0,299**	**0,353**	0,494	**0,442**	**0,457**
	Sig. (p)	**0,002**	**0,006**	**<0,01**	0,07	**0.008**	**<0,01**
	N	51	83	134	14	35	49

Significant correlation (p<0,05) in bold.

%BF *Lipowise*® - Percentage of Total Body Fat calculated using the *Slaughter et al* equation [53] with the *Lipowise*® caliper.

%BF BIA - Percentage of Total Body Fat calculated using Bioelectrical Impedance Analysis with Inbody 270® device.

Table V: Correlation between % Total Body Fat using BIA and % Total Body Fat using *Lipowise*®, according to gender

Variables		% BF BIA		
		Male	Female	All
%BF *Lipowise*®	Correlation ®	**0,863**	**0,790**	**0,810**
	Sig. (p)	**<0,01**	**<0,01**	**<0,01**
	N	14	35	49

Significant correlation (p<0,05) in bold.

%BF *Lipowise*® – Percentage of total body fat calculated using the *Slaughter et al* equation [53] with the *Lipowise*® caliper.

%BF BIA - Percentage of Total Body Fat calculated using Bioelectrical Impedance Analysis with Inbody 270® device.

Figures

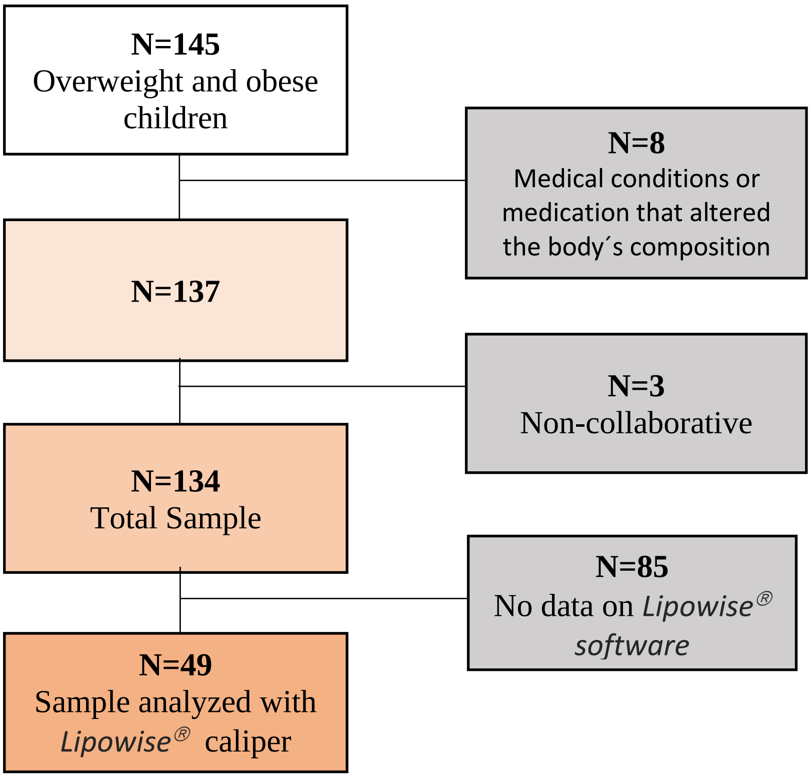


Figure 1: Sample Selection with exclusion criteria applied

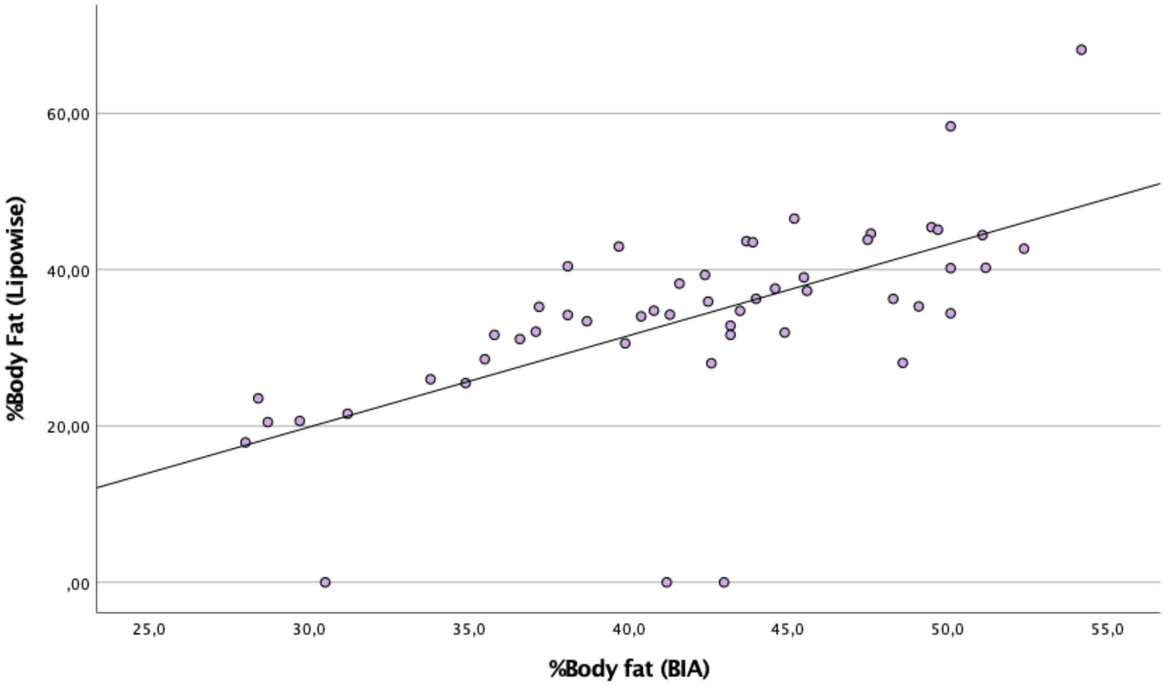
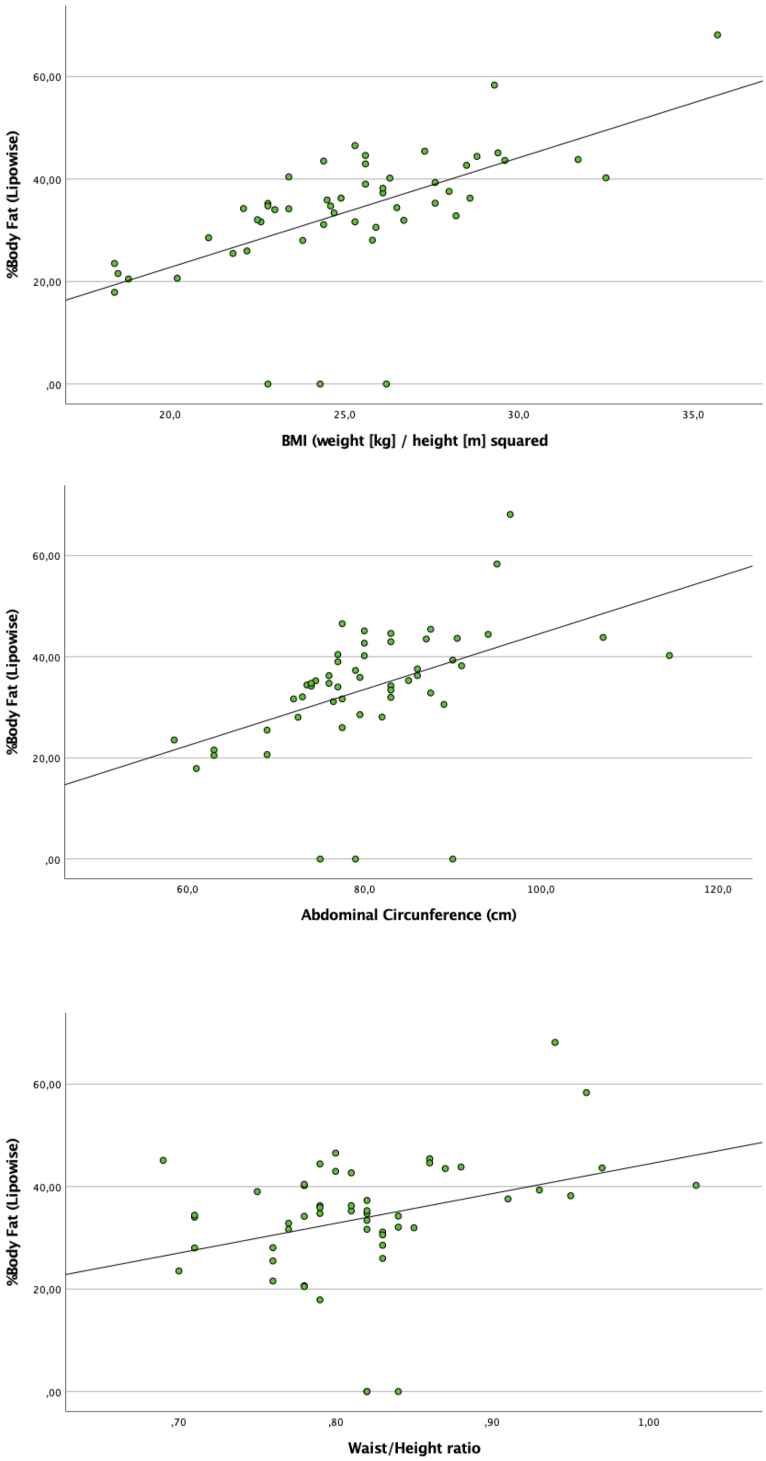


Figure 2: Correlation graph between % Total Body Fat using BIA and % Total Body Fat using *Lipowise*® caliper.

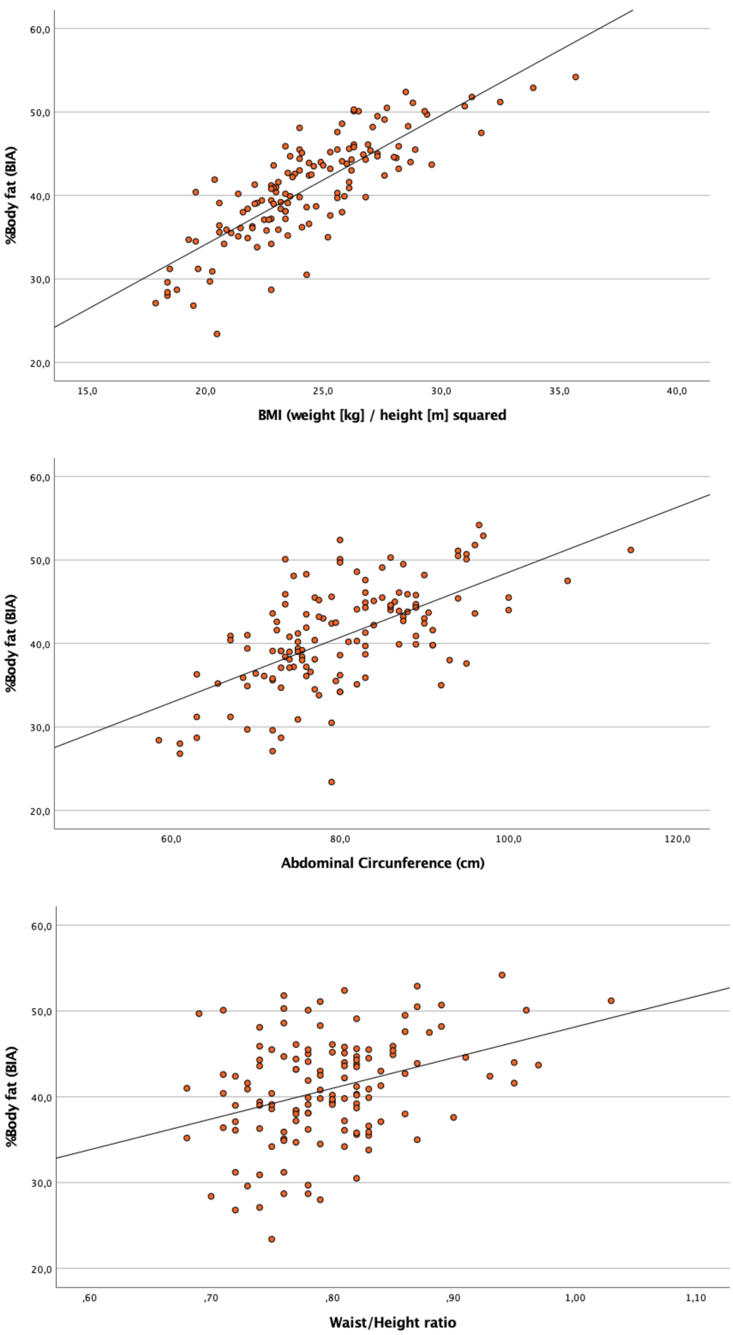
%Body Fat *Lipowise*® : Percentage of Total Body Fat calculated using the *Slaughter et al* equation[53] with the *Lipowise*® caliper.

%Body Fat BIA: Percentage of Total Body Fat calculated using Bioelectrical Impedance Analysis with Inbody 270® device.



Figures 3: Correlation graphs between Total Body Fat percentage using *Lipowise*® caliper and BMI values, Abdominal Circumference and Waist-to-Height ratio.

%Body Fat *Lipowise*®: Percentage of Total Body Fat calculated using the *Slaughter et al* equation[53] with the *Lipowise*® caliper.



Figures 4: Correlation graphs between % Total Body Fat using BIA analyser and BMI values, Abdominal Circumference and Waist-to-Height ratio.

%Body Fat BIA: Percentage of total body fat calculated using Bioelectrical Impedance Analysis with Inbody 270® device.

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