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PREDICTING AGE DEPENDENT BODY COMPOSITION AND GENDER DIFFERENCES ON THE BASIS OF THE CORRELATION BETWEEN ANTHROPORMETRIC METHODS AND BIOELECTRICAL IMPEDANCE ANALYSIS

SUMMARY OF DOCTORAL DISSERTATION

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1. INTRODUCTION

Based on the uniform results of studies on obesity and being overweight, these conditions have been on the rise in welfare societies and have become one of the most frequent diseases of civilization in recent decades; consequently, as the risk factor of numerous diseases, they can be considered one of the greatest healthcare challenges of the 21st century (Branca 2007, Must et al 1999, Jermendy 2006).

The prevention of obesity during childhood, educating proper nutrition and physical activity all have a fundamental importance in the prevention of obesity in adulthood (Parsons és mtsai 1999, Power et al. 1997, Bodzsár 2003a, Branca 2007). To study the correlation between lifestyle and obesity and to screen children at risk of obesity and to take action to prevent obesity, it is required to evaluate the condition of the population, both in regard to body composition and nutritional status.

In my paper, I work on an increasingly popular method of body composition assessment, bioelectric impedance analysis (BIA). Over the course of the study, the BIA sensor, by measuring the impedance of the entire body versus gentle alternating electric current while knowing the conduction properties of the various tissues of the body measures the body's water, fat and fat free mass (Lukaski 1985). The limiting factor of the method is that the regressions with the aid of which the device estimates body fat content from the initially measured impedance had been developed for an unknown population, they were not published by the manufacturer, therefore they cannot be known to the user and cannot be edited. As there are ethnic differences in body composition and body proportions, the use of a prediction equation for a different population does not result in precise estimates (Deurenberg et al. 2002).

With population studies, by using the equations validated for the population, the BIA device is capable of estimating fat mass, lean body mass and total body water content (Kyle et al. 2004, Heyward 1996).

2. OBJECTIVES

On the one hand, our objective is to develop regressions valid for the Hungarian population with the aid of which the impedance data measured by the BIA device and with the use of anthropometric measurements, body fat content can be reliable estimated for all age ranges. On the other hand, with regard to the parameters of the representative subsample measured with bioelectric impedance analysis, we wish to provide such Hungarian references that can provide comperative data in future epidomological studies.

The necessity of developing new regression prediction equations is shown by the fact that in the Second National Growth Study (2003-2006, Bodzsár és Zsákai 2007, 2008, 2012; Zsákai és Bodzsár 2012), the differencce between the body fat mass predicted by the NutriGuard-M type BIA device and the reference method we use for predicting the body composition of the children – the Drinkwater-Ross anthropometric fractionation method – in both genders and in the majority of the studied age ranges, is significant. In certain age ranges, the error expressed in the percentile result of the Drinkwater-Ross method had been as much as 30% for boys and as much as 20% for girls.

We analyzed the nutritional status and body composition of the children according to the following factors:

1. We analyzed the age-dependent changes of the children's nutritional status and body composition.
2. We studied which body composition prediction method is the most suited to be used as a reference method to increase the precision of body-composition predictions performed by a BIA device.
3. We studied potential reasons for BIA device measurement errors.

4. We characterized the sample from the perspective of BIA measured and estimated parameters, describing age-dependant differences, and the connection between measured impedance and estimated absolute and relative body fat content alike.
5. We correlated the body fat content measured by the BIA device with the results of the reference method chosen, the Drinkwater-Ross prediction method.
6. We characterized the correlations between sexual maturity status and body composition/nutritional status.
7. We developed regression equations taking into account chronological age, gender and sexual maturity status to estimate body fat content by using impedance values measured by the BIA device and various anthropometric measurements.

We assume that in the age-dependent samples of predicted body fat content, a period characterized by a more active accumulation of fat will be typical of both boys and girls, followed by absolute and relative fat loss for boys in puberty and relative fat loss for girls. With boys, puberty is followed by a mild increase in absolute fat mass while relative body fat content does not change significantly. With girls, after puberty, both absolute and relative fat content rises (Bodzsár 2003a).

We expect that in the absolute and relative body fat mass of children, there can be differences in the cases of predictions made with certain anthropometric methods; with regard to median values, however, we are not anticipating significant variation in the age-dependant pattern of body fat changes.

With regard to erroneous predictions of body fat percentage values via bioelectric impedance analysis, we assume that there can be two fundamental reasons for these errors: a) due to various factors affecting the device, the device did not measure appropriate impedance values, b) the impedance values measured by the device are correct, but the prediction equation used by the device cannot be used in the case of a given age group or a group with certain body composition characteristics. The study of the group showing measurement error presumably provides data to generate new regression equations.

With regard to sexual development, body composition and nutritional status, we are expecting a deviation in body composition deriving from average sexual maturing. According to study results to date, age-dependent changes of body fat content are affected by maturation types: the body's fat content in both sexes is greater in early maturers than with late maturers. The reasons for this is that with early maturers, the fat accumulation prior to puberty had taken place during an earlier chronological period (Pápai et al. 1992, Bodzsár 2003b).

We expect that the progression of the age-dependent medians of body fat content measured by the BIA device may differ from the result of the body-composition prediction performed with the Drinkwater-Ross method. The reason for this is that the prediction of the BIA device was in some cases erroneous, therefore it is possible that although in the realistic range, but larger deviations in the median values of estimated body fact content with the two methods can be observed; these differences may even result in a significant dip in the curve. We are assumming that measurement with the BIA can be made even more precise if we use regression equations that were not developed for the unknown population integrated in the device for the prediction of body fat content, but rather we use regression equations generated for the Hungarian population using some anthropometric measurements and body fat content obtained with the Drinkwater-Ross method as dependent variables.

3. SUBJECTS AND METHODS

The basis of study-aim oriented analyses was comprised by the subsample comprised of 10–18 year old children selected with a random method from the also representative 1.5% national sample of the Second National Growth Study (2003-2006, Bodzsár és Zsákai 2007, 2008, 2012; Zsákai és Bodzsár

2012), on which we supplemented the anthropometric body development examinations with bioelectric impedance analysis of body composition.

We measured body composition with regression models: two-compartment Siri (1956), and Pařízková methods (1961) and Drinkwater-Ross four compartment body composition prediction (1980); and with bioelectric impedance analysis measurement.We estimated the nutritional status on the basis of body mass index (BMI) and the body fat percentage obtained through regression body-fat percentage predicting methods (McCarthy et al. 2006, Cole 2007).

We performed the prediction of sexual maturity on the basis of the occurance of the menarche/oigarche and the determination of the developmental stage of visible sexual characteristics. For both genders, we used the maturational status of pubic hair, for boys, we used the maturational status of external genitalia and for girls, we used the maturational status of the mammary glands. The latter we had performed with the Tanner (1962) method. We had assessed the maturational status of axillary hair in girls and facial hair in boys with the Zeller (1964) method.

As verified and used by our studies, the best approach to the relative body fat mass of children was the fat percentage predicted by the Drinkwater–Ross body composition estimation.

To generate the regression body fat prediction equations, the final prediction parameters were selected with resistance and reactance, the 23 anthropometric measurements used in the regression prediction equations and/or their relative values, of the indeces generated from the foregoing, the correlations estimated with the Drinkwater–Ross method and relative body fat mass, respectively, and the examination of the R^2 values, showing the accuracy of the prediction, also taking into account gender, age and sexual maturity.

The processing and analysis of the data was performed with the SPSS for Windows 17.0 program. We inserted the percentiles with the LMS method based (Cole 1990, Cole és Green 1992) LmsChartMaker Pro 2.3 software. We measured and compared the anthropometric measurements, differences in indeces and body composition differences of the sub-groups of children that were generated in accordance with various criteria with the aid of Scheffe's pair-wise comparison of means, in the case of abnormal distributions of variables, we performed the comparison with the Mann–Whitney-U test at a significance level of 5% (Hajtman 1971, Reiczigel et al. 2010). We performed the homogeniaty study of the subgroups developed in accordance with nutritional status with the χ^2-test at a 5% level of significance.

4. RESULTS AND DISCUSSION

4.1. The characterization of the nutritional status and body composition of studied children

In both genders, approximately 80% of the children (based on BMI) could be classified as being of average nutritional status. 2% of boys and 4% of girls belong to the undernourished category, 18% of boys were overweight or obese, with 14% for girls. The comparison of nutritional categories defined on the basis of body mass index or regression methods yielded the significant result that the two extreme nutritional categories (in the case of the undernourished and the obese) with the Siri and Pařízková methods – where the BMI-category medians in all age ranges were approximately on par with 10. or 95-97. percentile of body fat percentage – in the case of Drinkwater–Ross method categorization, there is no complete correlation to the categorization based on the BMI. The undernourished and the obese differed from the normal nourished group not only in their body fat mass but proportionally in their bone, muscle and residual mass as well. It was not primarily the fat mass but rather the muscle mass of the BMI defined undernourished group that was significantly lower than that of the normal category. In the case of the obese boys, the excess weight as defined under the BMI mostly derived from body fat

mass, while in girls the bone and muscle mass play a comparable role to fat in generating excess weight.

Based on these results, amont the regression anthropometric models, the Drinkwater–Ross method appeared to be the most appropriate to generate the regression equations to plug in the impedance values measured by the BIA device.

To further support the conclusions drawn from the study of nutritional status, we performed the comparison of the median and age-dependent progression of body fat content predicted by the Siri, Pařízková and Drinkwater–Ross anthropometric models. By examining the changes of the age-dependent changes in body-fat content, the trend of age-dependent progression is similar in the cases of the three anthropometric models we had used; however, significant variations had arisen in the median values of body fat content. For both genders, the median of body fat content predicted by the Siri method is significantly greater than those of the other two predictions (20-22% for boys, 27-32% for girls). The Drinkwater–Ross method's prediction value is the smallest for both boys (13-18%) and girls (20-22%).

The general trend of age-dependent changes in body fat content shows that the average body fat content of girls at the age of 8 is 17%, while that value in boys is around 13%; that value in girls, after a temporary relative fat loss during puberty, rises to appr. 25% after intensive fat accumulation by the time they reach adulthood, while in boys, after a relative and absolute fat loss during puberty, it rises to appr. 15% after some mild fat accumulation in adulthood (Bodzsár 2003a). We experience a deviation from this trend in girls: during post-puberty, presumably resulting from stronger body control and consequent cosmetic weight loss, of the age of 15 the body fat percentage median does not show significant variation in successive age ranges.

The mult-faceted comparison of the results of the three methods confirmed the findings described upon the nutritional status study, whereas the Drinkwater–Ross method should be used to generate the regression equations as the best prediction of actual body fat content. An additional argument is that on the basis of a great deal of anthropometric data, the Drinkwater–Ross method predicts three other components in addition to bodyfat content, therefore the total of predicted components can be verified with the total body mass value. After generating and using the correcting equations, however, the integration of large numbers of body sizes required to calculate Drinkwater–Ross type body compositions could be undertaken.

4.2. The study of body fat content data predicted by bioelectric impedance analysis in the interest of screening out erroneous predictions

Children who have had body fat content erroneously predicted by the BIA device possessed significantly smaller body size and body fat content than those with correct measurement results. The difference is most striking in the cases of body mass, body fat content, skinfolds, waist perimeter and upper arm perimeter. In the medians of measured impedance values, significant differences appear only at a few ages. In total body water (which is primarily predicted by the device) there is no significant difference in boys, but in girls, the absolute total body water predicted for those with an incorrect prediction is significantly lower in multiple age ranges, but simultaneously with this, their predicted absolute fat mass is also smaller. The results of the comparison of the two groups show that the two groups with regard to the measured impedance parameters differ slightly, but differ to a greater extent concerning certain body sizes and body composition. Based on the foregoing, it is warranted to generate new prediction equations, along with the use, as an independent variable, in addition to the measured impedance value, a few strongly body fat content correlated body sizes.

4.3. The study of parameters measured with bioelectric impedance analysis and predicted body fat content

Over the course of our studies we had tried to predict what equations the device uses on the basis of what criteria, whether it uses one or more equations. For this purpose, we examined the correlation between the values measured by the BIA device and the predicted physiological parameters and their age-dependent changes.

Our results showed that resistance and reactance were in strong correlation with absolute total body water content and body mass, with a weaker relationship shown for absolute body fat mass and an extremely weak correlation with the relative values of body components. In the case of both genders, a break can be observed with regard to both factors of BIA analysis, but mostly in the resistance curves. For boys, the value of the median significantly drops from the age of 13 to 14 and in girls from the age of 11 to 12. This break is reflected only on the median-curve of the total body water among the parameters predicted by the device. A significant drop in impedance means an increase in the primarily predicted absolute total body water, which we assume is in correlation with the significant increase in lean body mass, which at the same time does not exclude the simultaneous growth of body fat mass, either. This is verified by the study of the curves of body mass, total body water and absolute fat mass. For boys, in the entire age range, impedance is in inverse proportion with body mass and total body water alike. In the case of girls, among the parameters, inverse proportionality is only visible until the age of 13. The reason for this is that in both genders during the period of the adolescent growth spurt, the increase in body mass mostly derives from the increase of lean body mass, which contains the largest proportions of body water. While with boys successive body mass increase continues to mainly consist of increases in lean body mass, with girls, this increase is mostly attributable to increases in body fat mass, therefore with them, during the intensive body fat accumulation period following the adolescent growth spurt, impedance in strong correlation with the absolute total body water no longer shows significant variation.

The result of the correlation test imply that the device does not use different prediction equations by age, therefore, however, the danger persists that it does not take into account the age-dependent peculiarities in changes of body parts. According to the correlation test between impedance and the parameters measured by the BIA device as a function of body mass, it is improbable that the device would be working with separate equations on the basis of bodymass intervals.

4.4. The correlation of body fat content predicted by bioelectric impedance analysis and the results obtained via the Drinkwater–Ross anthropometric fractionation model

Studies to date supported the importance of our aim, whereas it is necessary to generate regression equations that take into account age to predict bodyfat content with the aid of impedance data measured by the BIA device. Our tests also supported the idea that to generate the equations, body fat percentage predicted by the Drinkwater–Ross anthropometric fractionation model could be viewed as the best approach to the total fat mass of the children.**Hiba! A hivatkozási forrás nem található.**

The median value of body fat content measured with bioelectric impedance analysis in boys only deviates significantly for the 10-14 age range from the prediction by the Drinkwater–Ross anthropometric fractiation method. As expressed in the body fat content obtained via the Drinkwater–Ross anthropometric fractionation, the difference is extremely significant, the extent of the median value of the body fact content predicted by the BIA is approximately 10-30% lower. For girls, until the age of 12 the median value of body fat content predicted by the BIA is significantly lower (15-25% lower percentile in the Drinkwater–Ross anthropometric fractionation method), and from the age of 15, it is 10-20% greater than the value of the medians predicted with the Drinkwater–Ross anthropometric fractionation model.

The age-dependent change of relative body fat content typical of boys is shown by predictions performed with both the BIA device and with the Drinkwater–Ross method; changes typical of boys with regard to absolute body fat mass is reflected better by the Drinkwater–Ross method, however. For girls, the progression of the median age-dependent relative body fat content predicted by the Drinkwater–Ross method most closely resembles the sample most typical of the gender. The BIA prediction does not reflect the temporary loss in relative body fat typical of the adolescent growth spurt. Each curve moderately reflects the intensive fat accumulation following the adolescent growth spurt; after the age of 16, neither method displays significant changes in relative body fat mass.

4.5. Study of the correlations of sexual maturity status, body composition and nutritional status

The study reflected in sexual maturity status as based on external genitalia, the developmental level of the mammary glands, spermarche and menarche, had proven that the body composition of children of identical chronological age can vary greatly as a function of sexual maturity. This means that in the equation predicting body fat content, we must take into account not only age and gender, but sexual maturity status as well. In the case of sexual maturity status as defined by both methods, the difference was not as markedly expressed in boys than in girls. In relative bodyfat content (both in the Drinkwater–Ross method and in the case of prediction performed with the BIA device), upon comparing maturation types determined on the basis of external genitalia and the developmental level of the mammary glands, neither early nor late maturers deviated significantly from those in the normal maturer group. We experienced a greater difference when categorizing on the basis of the existence of spermarche or menarche. In boys the group of late maturers mainly deviates from the group of normal maturers after the age of 14. In girls the two groups significantly vary in the entire tested age interval. There is a significant difference in the impedance values measured by the BIA within both sexual maturity assessment methods among the groups of varied sexual maturity. Based on the test results, we took into account categorization on the basis of menarche/spermarche in the generation of body fat content prediction equations.

4.6. *The development of regression equations taking into account chronological age, gender and sexual maturity level*

The study of the correlation tests and R^2 values showing the reliability of prediction variables also showed that absolute body fat mass can be predicted in a more reliable manner with prediction parameters than relative fat mass; additionally, in the case of girls, classification by sexual maturity further increased the accuracy of the prediction. We received the best predictions for bodyfat content for both boys and girls, with the same age group distribution (using a separate equation for both under and over the age of 12). Consequently, the equation for the prediction of body fat mass is identical until the age of 12 for boys and girls, after which one equation is required for boys and two for girls, on the basis of the existence/lack of menarche. The format of the prediction equation is as follows: BF = a + b * BM + c * BMI/R + d * relSSF/Re, where constants applicable to the appropriate age range are: (FM: body fat mass, BM: body mass, R: impedance, Re: reaction capacity, relSSF: the weighted relative value of sum of subscapular, tricpes and hip skinfolds). Each of the regressions and the prediction constants were signifcant.

We tested predictions with the new prediction equations on the entire sample which contains those children who were screened out at the beginning of the study because of the defective BIA predictions. The average deviation of the new regression equations from the prediction of the Drinkwater–Ross method in the case of body fat mass, studying all of the age ranges, does not exceed 0.6 kg, in the case of relative body fat content, 1.6%, while the Drinkwater–Ross percentage expressed average error of the new prediction method did not exceed 4% at any age.

NEW RESULTS AND FINAL CONCLUSIONS

1. Contrary to the results experienced with the Siri and Pařízková method, in the case of categorization on the basis of body fat content defined via the Drinkwater–Ross method, the median values of undernourished and obese individuals do not correlate with the categorization pursuant to the body mass index. As verified by the Drinkwater–Ross method, these nutritional groups differ from the normal group not just in their body fat mass, but also in their bone, muscle and residual mass. With the undernourished group it can be observed that in the case of both boys and girls, for the undernourished group under the BMI, it is not the body fat mass, but rather the muscle mass that is significantly lower than that in the normal category. In the case of obese subjects, the excess weight as defined under the BMI mostly derives from body fat mass; for girls, bone and muscle mass are comparable to fat in generating excess weight.

2. In the case of children with smaller body mass and body fat content, with a worse nutritional status, errors cropped up in the BIA device predictions. In the case of both genders, the device, mostly in the group of children categorized in the undernourished group on the basis of their body mass index, underestimated the body fat mass of the children as compared to the Drinkwater–Ross model. By studying the body fat content values predicted by the BIA, we showed that the device gives erroneous predictions in a varied manner for the two genders; it does so at all ages for boys and for girls, mostly under 14 years of age.

3. With boys, impedance measured by the BIA device in the entire age interval is inversely proportional to both body mass and total body water, as well as absolute fat mass. In the case of girls, however, inverse proportionality among the parameters can only be observed until the age of 13. The reason for this is that in the two genders, during the growth spurt and subsequently, the growth of certain body compartments takes place differently.

4. In both genders, compared to normal maturers, early maturers display a significantly lower and late matures a significantly higher BIA measured impedance value. In the case of boys, with early maturers, in parallel with lower impedance, total body water measured by the BIA device is higher. The difference in body mass between early and late maturers appears to derive equally from body fat content and lean body mass which comprises the largest proportion of the water mass. In the case of girls, it appears that the greater body mass of early maturers mostly derives from the higher absolute fat content. Consequently, the relative ratio of the two components is different in the case of different maturation type groups: early maturer girls have a higher relative fat mass, in parallel with which they have a lower relative water mass.

5. We provided data from our studies with regard to the physical parameters of 10–18 year old Hungarian children as measured by bioelectic impedance analysis.

6. A new finding among our results is that we have generated regressions for the 10–18 years of age population of Hungarian children that are dependent on age, gender, and sexual maturity level in girls, based on body fat prediction on the basis of impedance measured by bioelectic impedance analysis and on the measurements of a few anthropometric measurements. The age-dependent median values of absolute fat mass predicted with the new regression equations only showed an average difference of 1-4% in both genders during the entire studied age interval. When generating the equations, the accuracy of the prediction rose when we gave separate equations by age range, by gender from the onset of puberty, while providing separate equations for girls depending on the level of sexual maturity. This also shows that the relationship between the body composition of children and prediction parameters changes with both gender, age and level of sexual maturity. This means that the body fat content of

children of identical gender, possessing similar bodily dimensions, but of different ages or different leel of sexual maturity, even in the case of identical impedance parameters, is not necessarily identical. By using the new regression equations, correcting for the measurement results of bioelectic impedance analysis, the body fat content of Hungarian children between the ages of 10–18 can be more accurately estimated.

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