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Title: A simple equation to estimate body fat percentage in children with overweight or obesity: a retrospective study.

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ABSTRACT

Background. Dual-energy X-ray absorptiometry (DXA) provides separate measurements of fat mass, fat-free mass and bone mass, and is a quick, accurate, and safe technique, yet one that is not readily available in routine clinical practice. Consequently, we aimed to develop statistical formulas to predict fat mass (%) and fat mass index (FMI) with simple parameters (age, sex, weight and height).

Methods. We conducted a retrospective observational cross-sectional study in 416 overweight or obese patients aged 4 to 18 years that involved assessing adiposity by DXA (fat mass percentage and FMI), body mass index (BMI), sex and age. We randomly divided the sample into two parts (construction and validation). In the construction sample, we developed formulas to predict fat mass and FMI using linear multiple regression models. The formulas were validated in the other sample, calculating the intraclass correlation coefficient via bootstrapping.

Results. The fat mass percentage formula had a coefficient of determination of 0.65. This value was 0.86 for FMI. In the validation, the constructed formulas had an intraclass correlation coefficient of 0.77 for fat mass percentage and 0.92 for FMI.

Conclusions. Our predictive formulas accurately predicted fat mass and FMI with simple parameters (BMI, sex and age) in children with overweight and obesity. The proposed methodology could be applied in other fields. Further studies are needed to externally validate these formulas.

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INTRODUCTION

During childhood and adolescence, there is a balanced growth of the different body components: skeletal muscle, fat, bone and viscera. Obesity involves an increase in body weight combined with an imbalance between these components, with a higher proportion of body fat (Ballabriga & Carrascosa, 2006), and is defined as an excess of body fat relative to total body mass (Himes & Dietz, 1994). There is nearly universal consensus in defining overweight as a body mass index (BMI [kg/m^2]) between the 85th and 95th percentiles and obesity as a BMI at the 95th percentile or greater (Power, Lake & Cole, 1997; Prentice, 1998; Serra Majem et al., 2002; Cole & Lobstein, 2012). Determinants of body fat in children and adolescents include socioeconomic factors, education of the mother, physical activity, and physical fitness (Moliner-Urdiales et al., 2009; van Sluijs et al., 2010; Gómez-Martínez et al., 2012).

Age- and sex-specific BMI percentile values are easy to calculate and is strongly correlated with the body fat percentage, especially for high BMI values (Colomer, 2004; Koplan, Liverman & Kraak, 2005; Krebs et al., 2007). But in clinical practice, it may be more useful to combine age- and sex-specific BMI values with a body fat assessment capable of detecting a high degree of adiposity to avoid classifying individuals whose high BMI is attributable to a relatively greater fat-free mass or an athletic build as obese (Serra Majem et al., 2002; Whitlock et al., 2005). Since BMI does not follow a normal distribution in the pediatric age group, several indices have been proposed as alternatives. Of these, the recently described inverted BMI (iBMI [cm^2/kg]) has been referred to as the most useful and accurate proxy for body fat in adults (Nevill et al., 2011). A recent study in the pediatric age group that used the fat mass determined by dual-energy X-ray absorptiometry (DXA) as a reference found that the iBMI followed a normal distribution and was a good predictor of body fat, as was BMI, with iBMI accounting for a greater

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DXA enables the independent assessment of fat mass, boneless fat-free mass, and bone mass (Fields & Goran, 2000; Kehayias & Valtueña, 2001) and their distribution in each region of the body. DXA is considered a fast, accurate, and safe method for assessment of body fat (Ellis, 2001), as it is free of the drawbacks of computerized axial tomography and magnetic resonance imaging (Goulding et al., 1996). However, since it is not widely available, this technique is not suitable for large-scale and longitudinal studies. For this reason, several indices (BMI, iBMI, conicity index, etc.) have been proposed to estimate the value obtained by DXA. Other authors have constructed multivariable prediction models that estimate body fat from different skinfolds. These methods have been validated by contrasting the mathematical formula with DXA (reference standard) (Silva et al., 2013; Jensen, Camargo & Bergamaschi, 2016). Nonetheless, they present great difficulty in routine clinical practice because skinfolds are not as simple to measure or as reproducible as the weight and height of a child. For all these reasons, we aimed to develop and internally validate [intraclass correlation coefficient (ICC) and bootstrapping] a statistical model based on simple parameters (BMI, iBMI, sex and age) to predict body fat. Our goal was a simple tool that could be applied in clinical practice to assess adiposity in children and adolescents.

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MATERIALS & METHODS

Study Population

Patients referred for nutritional problems to the Nutrition, Growth and Metabolism Unit of the Department of Pediatrics of San Juan de Alicante University Hospital. This hospital covers an area of about 220,000 inhabitants in the province of Alicante, which is located in the southeast of Spain and has a total of 1,843,589 inhabitants (National Statistics Institute, 2016). The health system is universal and free for both children and adults. The prevalence of childhood obesity in the province of Alicante is approximately 13.5-18.8% (Ruiz Pérez et al., 2008). The criteria for referral by the primary care pediatrician are the lack of correlation between the height and weight of the child.

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Study design and participants

We conducted a cross-sectional observational study in patients aged 4 to 18 years who met the following inclusion criteria: having had an initial referred visit to the Nutrition, Growth and Metabolism Unit of San Juan de Alicante University Hospital and a DXA assessment prior to the implementation of dietary measures and lifestyle changes. The exclusion criteria encompassed excess weight secondary to causes other then high caloric nutrition, such as growth hormone deficiency with hormone replacement therapy, syndromic obesity, obesity secondary to other diseases such as hypothyroidism, protracted treatment with corticosteroids or other drugs that could influence energy intake or expenditure, precocious puberty, or neurologic or neuromuscular disorders preventing the patient from walking or exercising normally. The data were collected between July 2007 and July 2016, and all the study children were Caucasian.

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Variables and measurements

Our main outcome variables were body fat (% total body fat) and fat mass index (FMI, in kg/m^2). These were measured with a General Electric Lunar DPXN PRO™ DXA densitometer (GE Healthcare, Little Chalfont, Buckinghamshire, United Kingdom). The software of this device is able to obtain measurements for the total weight and percentage of body fat. These parameters were used as the reference standard measurements.

As secondary variables we used BMI (in kg/m^2), sex (male or female) and age (in years). To obtain the anthropometric measurements (weight and height), we followed a standardized protocol with a stadiometer accurate to 0.1 cm and a SECA scale accurate to 0.1 kg. Each value was measured twice by a single individual, and the mean of the two measurements was used in the analysis.

Sample size calculation

The sample collected during the study period was 416 children. This sample was randomly divided into two equal parts (n=208). The first group was used to construct a predictive model (multivariable linear regression) and the second group was used to validate it.

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Construction: To construct a multiple linear regression model we must look at the relationship between the number of subjects and the number of predictors (subject-to-variable ratio). As a heuristic rule, it was considered that this ratio should be at least 50, which allowed the introduction of four explanatory variables in the predictive model.

Validation: The sample consisted of the other 208 subjects. This sample size was very satisfactory in obtaining excellent predictions, since the constructed models had four predictors and coefficients of determination of 0.65 and 0.86 for fat percentage and FMI respectively (Knofczynski & Mundfrom, 2008). The coefficient of determination values were obtained in the construction sample and were used to determine the sample size of the validation.

Statistical analysis

Continuous variables (BMI, FMI, age and body fat) were summarized using means and standard deviations. To describe the sex variable, we calculated absolute and relative frequencies. To compare the homogeneity of the construction and validation samples, we

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performed the t-test and the Pearson's chi-squared test. We calculated the following exponentiations: bases (BMI and age) and exponents (-2, -1, 1 and 2). All the interactions between sex and the exponentiation variables were obtained. In the construction sample (n=208) we aimed to construct a linear regression model to predict body fat. Taking into account that we could only introduce 4 explanatory variables (subject-to-variable ratio: one per each fifty subjects) and had 17, we applied the following algorithm in order to select them: we obtained all the possible combinations of 1, 2, 3 and 4 elements from the total (17 variables): 3213 combinations. In each combination we estimated the linear regression model with them in order to predict the body fat and calculated its coefficient of determination. The combination/model with the maximum coefficient was then selected. The goodness-of-fit of the model was assessed with the ANOVA test. The model was internally validated using bootstrap methodology in the validation sample, calculating the intraclass correlation distribution [two fixed judges (the predicted and observed value) with absolute agreement in the ratings]. In addition, the scatter plot with the estimation and the real parameter was obtained. Finally, we also calculated the Bland & Altman limits of agreement (Bland & Altman, 1986). The same process was applied for FMI. We set the level of statistical significance at 0.05. The statistical software used was IBM SPSS Statistics 19 and R 2.13.2.

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Ethical considerations

This study adhered to the ethical principles of the Declaration of Helsinki, and only involved the performance of procedures used in everyday clinical practice. The data were processed safeguarding anonymity and confidentiality, and the study was approved by the corresponding Ethics Committee (Comité Ético de Investigación Clínica del Hospital Universitario de San Juan de Alicante, ref 16/305). Informed consent was not requested from the parents for this study, since it was part of routine clinical practice without any type of intervention. The Ethics Committee approved this procedure.

RESULTS

We analyzed a total sample of 416 children divided into two parts: 208 children in each group (construction and validation). Table 1 shows the descriptive analysis obtained for each group. Of note were a mean body fat of 43% and 11.7 kg/m^2 for FMI. No differences were observed in the groups, as all the p-values were greater than 0.05.

The optimal model for body fat had a coefficient of determination of 0.65 and the following formulas for the body fat estimation (Table 2):

A) Boys: $62.627-11245.580 \cdot BMI^{-2}-259.114 \cdot BMI^{-1}+2.310 \cdot Age-0.151 \cdot Age^2$.

B) Girls: $62.627-11245.580 \cdot BMI^{-2}$.

For FMI the optimal model had a coefficient of determination of 0.86 and the formulas for the estimation of this parameter were (Table 2):

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A) Boys: $18.655+0.007 \cdot BMI^2-293.601 \cdot BMI^{-1}+0.112 \cdot Age-0.018 \cdot Age^2$.

B) Girls: $18.655+0.007 \cdot BMI^2-293.601 \cdot BMI^{-1}$.

The intraclass correlation distribution is shown in Figure 1 (internal validation). Regarding the adjustment between estimations and real values, Figure 2 illustrates that both values were very similar. Finally, the Bland & Altman procedure was satisfactory (Fig. 3). So that our equations may be easily applied, they have been included in Supplemental Table S1.

DISCUSSION

Summary

We constructed and validated two predictive models to determine body fat and FMI in children with overweight and obesity, using the values obtained by DXA as the reference standard. Both models showed excellent accuracy (ICC>0.75) (Cicchetti, 1994).

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Strengths and limitations of the study

The main strength of the study is the easy and cost-effective calculation of body fat percentage and FMI based on the widely used standard anthropometric measurements (height and weight), age and sex. Although more complex techniques, such as DXA, consume little time and few resources and involve a very low radiation exposure, they are not widely available in health care settings and are more complicated and costly to implement. We also underscore the statistical methodology followed for its construction, which took into account the subject-to-variable ratio of about 6500 models. For validation, the sample size was adequate to obtain excellent predictions. Bootstrapping was applied (reference method to validate predictive models) and the intraclass correlation coefficient was determined instead of Pearson's, since the estimate and the value obtained by DXA referred to the same variable (body fat or FMI) (Steyerberg et al., 2001).

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Regarding limitations, the study was clearly lacking in normal-weight cases (selection bias), but due to ethical and cost-of-care considerations, body fat measurement using DXA was not justified in children of normal weight and was only performed for other clinical purposes, such as in patients that required a bone mineral density assessment. On the other hand, information bias was minimized through the use of fully validated and calibrated devices, and confounding bias was minimized through the estimation of multivariable models. Thus, our models can only be applied in children with overweight or obesity. Furthermore, although DXA is not considered the gold standard for the assessment of body

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fat because a four-component model is better (Sopher et al., 2004; Sopher, Shen & Peitrobeilli,2005; Williams et al., 2006), DXA is generally considered to provide the most valid estimates in clinical practice (Ellis, 2001). Finally, the models only included anthropometric parameters; that is they did not consider other factors associated with body fat (Moliner-Urdiales et al., 2009; van Sluijs et al., 2010; Gómez-Martínez et al., 2012). Nevertheless, even without these other factors our predictions were still precise.

Comparison with the existing literature

When comparing our predictive models with the existing literature, we find studies that evaluate a single anthropometric parameter and other authors who developed multivariable predictive models based on skinfolds (Silva et al., 2013; Jensen, Camargo & Bergamaschi, 2016). We must bear in mind that the studies evaluating a single anthropometric parameter (circumferences of the upper arm, waist, hip and others; ratios such as waist-to-height or waist-to-hip) (Freedman et al., 2004; Freedman et al., 2005; Freedman et al., 2012; Bergman et al., 2011; Goossens et al., 2012; Boeke et al., 2013; Weber et al., 2013; Craig et al., 2014) did not assess the power of this parameter, the interactions with other variables, or the use of a combination of factors to estimate body fat, which gives greater accuracy to the results obtained in our model. Multivariable models of using skinfolds have the clinical drawback of skinfolds being difficult to measure and the methodological drawback that they did not follow the statistical techniques that yield the highest power in the construction and validation of a multiple linear regression predictive model (interactions, powers, bootstrapping, ICC and testing of approximately 6500 models) (Silva et al., 2013; Jensen, Camargo & Bergamaschi, 2016). In light of the above, our model clearly provides greater accuracy with respect to the others published in the scientific literature.

Implications for research and practice

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The diagnosis, treatment and follow-up of obesity in the pediatric age group have become a global health priority. Consequently, there is great interest in the healthcare field in the development of quick and accurate tools that can be used in the follow-up of these patients. In this study, we developed formulas for the calculation of body fat percentage and FMI based on BMI, age and sex, which facilitate monitoring of adiposity in the management of these patients, reserving the use of more accurate methods such as DXA for extreme cases.

Regarding possible future lines of research, we encourage other authors to externally validate the equations developed in this paper. The methodology used in this work can be applied to create new equations for body fat or for other types of parameters, both anthropometric and non-anthropometric.

CONCLUSIONS

Body fat percentage and FMI measured by DXA can be accurately estimated in children and adolescents with overweight and obesity using our predictive models based on BMI, age and sex. Our models enable quick calculation of body fat percentage and FMI, thereby simplifying and reducing the use of resources in everyday clinical practice. We also highlight our methodology, which could be applied to obtain similar equations for the analyzed parameters.

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REFERENCES

Almeida SM, Furtado JM, Mascarenhas P, Ferraz ME, Silva LR, Ferreira JC, Monteiro M, Vilanova M, Ferraz FP. 2016. Anthropometric predictors of body fat in a large population of 9-year-old school-aged children. *Obesity Science & Practice* 2: 272-281.

Ballabriga A, Carrascosa A. 2006. Obesidad en la infancia y adolescencia. In: Ballabriga A, Carrascosa A, eds. *Nutrición en la Infancia y adolescencia*. Madrid, Spain: Ediciones Ergon, 667-703.

Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, Sebring NG, Xiang AH, Watanabe RM. 2011. A better index of body adiposity. *Obesity (Silver Spring)* 19: 1083-1089.

Bland JM, Altman DG. 1986. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1: 307-310.

Boeke CE, Oken E, Kleinman KP, Rifas-Shiman SL, Taveras EM, Gillman MW. 2013. Correlations among adiposity measures in school-aged children. *BMC Pediatrics* 13:99.

Cicchetti DV. 1994. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychology Assessment* 6: 284-290.

Cole TJ, Lobstein T. 2012. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatric Obesity* 7: 284-294.

Colomer J. 2004. Prevención de la obesidad infantil. Available at http://www.aepap.org/previnfad/pdfs/previnfad_obesidad.pdf (accessed May 2016).

Craig E, Bland R, Ndirangu J, Reilly JJ. 2014. Use of mid-upper arm circumference for determining overweight and overfatness in children and adolescents. *Archives of Disease in Childhood* 99: 763-766.

Duncan MJ, Martins C, Silva G, Marques E, Mota J, Aires L. 2014. Inverted BMI rather than BMI is a better predictor of DEXA determined body fatness in children. *European Journal of Clinical Nutrition* 68: 638-640.

Ellis KJ. 2001. Selected body composition methods can be used in obesity studies. *Journal of Nutrition* 131: 1589-1595.

Fields DA, Goran MI. 2000. Body composition techniques and the four–compartment model in children. *Journal of Applied Physiology* 89: 613-620.

Freedman DS, Thornton JC, Mei Z, Wang J, Dietz WH, Pierson RN Jr, Horlick M. 2004. Height and adiposity among children. *Obesity Research* 12: 846-853.

Freedman DS, Thornton JC, Pi-Sunyer FX, Heymsfield SB, Wang J, Pierson RN Jr, Blanck HM, Gallagher D. 2012. The body adiposity index (hip circumference ÷ height(1.5)) is not a more accurate measure of adiposity than is BMI, waist circumference, or hip circumference. *Obesity (Silver Spring)* 20: 2438-2444.

Freedman DS, Wang J, Maynard LM, Thornton JC, Mei Z, Pierson RN, Dietz WH, Horlick M. 2005. Relation of BMI to fat and fat-free mass among children and adolescents. *International Journal of Obesity* 29:1-8.

Gómez-Martínez S, Martínez-Gómez D, Perez de Heredia F, Romeo J, Cuenca-Garcia M, Martín-Matillas M, Castillo M, Rey-López JP, Vicente-Rodriguez G, Moreno L, Marcos A. 2012. Eating habits and total and abdominal fat in Spanish adolescents: influence of physical activity. The AVENA study. *Journal of Adolescent Health* 50: 403-409.

Goossens S, Bekele Y, Yun O, Harczi G, Ouannes M, Shepherd S. 2012. Mid-upper arm circumference based nutrition programming: evidence for a new approach in regions with high burden of acute malnutrition. *PLoS One* 7: e49320.

Goulding A, Taylor RW, Gold E, Lewis-Barned NJ. 1996. Regional body fat distribution in relation to pubertal stage: a dual-energy X-ray absorptiometry study of New Zealand girls and young women. *American Journal of Clinical Nutrition* 64: 546-551.

Himes JH, Dietz WH. 1994. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee: the Expert Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services. *American Journal of Clinical Nutrition* 59: 307-16.

Instituto Nacional de Estadística. 2016. Cifras de población y censos demográficos. Available at http://www.ine.es (accessed October 2016).

Jensen NS, Camargo TF, Bergamaschi DP. 2016. Comparison of methods to measure body fat in 7-to-10-year-old children: a systematic review. *Public Health* 133: 3-13.

Kehayias J, Valtueña S. 2001. Measurement of body fat mass in vivo: from two-compartment techniques to neutron activation analysis and DXA. *Medicina Clínica* 116: 590-597.

Knofczynski GT, Mundfrom D. 2008. Sample Sizes When Using Multiple Linear Regression for Prediction. *Educational and Psychological Measurement* 68: 431-442.

Koplan JP, Liverman CT, Kraak VI; Committee on Prevention of Obesity in Children and Youth. 2005. Preventing childhood obesity: health in the balance: executive summary. *Journal of the American Dietetic Association* 105: 131-138.

Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. 2007. Assessment of child and adolescent overweight and obesity. *Pediatrics* 120 Suppl 4: S193-228. Review.

Moliner-Urdiales D, Ruiz JR, Ortega FB, Rey-Lopez JP, Vicente-Rodriguez G, España-Romero V, Munguía-Izquierdo D, Castillo MJ, Sjöström M, Moreno LA; HELENA Study Group. 2009. Association of objectively assessed physical activity with total and central body fat in Spanish adolescents; the HELENA Study. *International Journal of Obesity (London)* 33: 1126-1135.

Nevill AM, Stavropoulos-Kalinoglou A, Metsios GS, Koutedakis Y, Holder RL, Kitas GD, Mohammed MA. 2011. Inverted BMI rather than BMI is a better proxy for percentage of body fat. *Annals of Human Biology* 38: 681-684.

Power C, Lake JK, Cole TJ. 1997. Measurement and long-term health risks of child and adolescents fatness. International Journal of Obesity and Related Metabolic Disorders 21: 507-526.

Prentice AM. 1998. Body mass index standards for children. Are useful for clinicians but not for yet for epidemiologists. *BMJ* 317: 1401-1402.

Ruiz Pérez L, Zapico Álvarez-Cascos M, Zubiaur Cantalapiedra A, Sánchez-Paya J, Flores Serrano J. 2008. Increase in the prevalence of overweight and obesity in the pediatric population of the province of Alicante (Spain) in the last 10 years. *Endocrinología y Nutrición* 55: 389-395.

Serra Majem L, Aranceta Bartrina J, Pérez Rodrigo C, Moreno Esteban B, Tojo Sierra R, Delgado Rubio A, Grupo colaborativo AEP-SENC-SEEDO. 2002. *Dossier de Consenso. Curvas de referencia para la tipificación ponderal. Población Infantil y Juvenil*. Madrid, Spain, IM&C.

Silva DR, Ribeiro AS, Pavão FH, Ronque ER, Avelar A, Silva AM, Cyrino ES. 2013. Validity of the methods to assess body fat in children and adolescents using multi-compartment models as the reference method: a systematic review. *Revista da Associação Médica Brasileira* 59: 475-486.

Sopher A, Shen E, Peitrobeilli A. 2005. Pediatric body composition methods. In: Heymsfield S, Lohman T, Wang Z, eds. *Human body composition, 2nd ed*. Champaign, IL: Human Kinetics, 129–140.

Sopher AB, Thornton JC, Wang J, Pierson RN Jr, Heymsfield SB, Horlick M. 2004. Measurement of percentage of body fat in 411 children and adolescents: a comparison of dual-energy X-ray absorptiometry with a four-compartment model. *Pediatrics* 113: 1285-1290.

Steyerberg EW, Harrell FE Jr, Borsboom GJ, Eijkemans MJ, Vergouwe Y, Habbema JD. 2001. Internal validation of predictive models: efficiency of some procedures for logistic regression analysis. *Journal of Clinical Epidemiology* 54: 774-781.

Truesdale KP, Roberts A, Cai J, Berge JM, Stevens J. 2016. Comparison of Eight Equations That Predict Percent Body Fat Using Skinfolds in American Youth. *Childhood Obesity* 12: 314-323.

van Sluijs EM, Page A, Ommundsen Y, Griffin SJ. 2010. Behavioural and social correlates of sedentary time in young people. *British Journal of Sports Medicine* 44: 747-755.

Weber DR, Moore RH, Leonard MB, Zemel B. 2013. Fat and lean BMI reference curves in children and adolescents and their utility in identifying excess adiposity compared with BMI and percentage body fat. *American Journal of Clinical Nutrition* 98: 49-56.

Whitlock EP, Williams SB, Gold R, Smith PR, Shipman SA. 2005. Screening and interventions for childhood overweight: a summary of evidence for the US Preventive Services Task Force. *Pediatrics* 116: e125-144. Review.

Williams JE, Wells JC, Wilson CM, Haroun D, Lucas A, Fewtrell MS. 2006. Evaluation of Lunar Prodigy dual-energy X-ray absorptiometry for assessing body composition in healthy persons and patients by comparison with the criterion 4-component model. *American Journal of Clinical Nutrition* 83: 1047-1054.