Predicting Total Body Fat from Anthropometry in Latino Children

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Abstract

HUANG, TERRY T.-K., MICHAEL P. WATKINS, AND MICHAEL I. GORAN. Predicting total body fat from anthropometry in Latino children. *Obes Res.* 2003;11:1192–1199.

Objective: To develop prediction equations for total body fat specific to Latino children, using demographic and anthropometric measures.

Research Methods and Procedures: Ninety-six Latino children (7 to 13 years old) were studied. Two-thirds of the sample was randomized into the equation development group; the remainder served as the cross-validation group. Total body fat was measured by DXA. Measures included weight, height, waist and hip circumferences, and skinfolds (suprailiac, triceps, abdomen, subscapula, thigh, and calf).

Results: The previously published equation from Dezenberg et al. did not accurately predict total body fat in Latino children. However, newly developed equations with either body weight alone (intercept $\pm$ SE $=$ 1.78 $\pm$ 1.53 kg, $p >$ 0.05; slope $\pm$ SE $=$ 0.90 $\pm$ 0.07, $p >$ 0.05 against slope $=$ 1.0; $R^2 = 0.86$), weight plus age and gender (intercept $\pm$ SE $=$ 2.28 $\pm$ 1.20 kg, $p >$ 0.05; slope $\pm$ SE $=$ 0.91 $\pm$ 0.05, $p >$ 0.05; against slope $=$ 1.0; $R^2 = 0.92$), or weight plus height, gender, Tanner stage, and abdominal skinfold (intercept $\pm$ SE $=$ 1.47 $\pm$ 1.01 kg, $p >$ 0.05; slope $\pm$ SE $=$ 0.93 $\pm$ 0.04, $p >$ 0.05; against slope $=$ 1.0, $R^2 = 0.97$) predicted total body fat without bias.

Discussion: Unique prediction equations of total body fat may be needed for Latino children. Weight, as the single most significant predictor, can be used easily to estimate total body fat in the absence of any additional measures. Including age and gender with weight produces an equally stable prediction equation with increasing precision. Using a combination of demographic and anthropometric measures, we were able to capture 97% of the variance in measured total body fat.

Key words: anthropometry, fat, body composition, child, Latino

Introduction

The assessment of body composition in childhood often relies on skinfold measures or complicated and expensive techniques such as DXA (1–7). However, the accuracy and reliability of skinfold measures alone have been questioned, and DXA is expensive and often unavailable. Therefore, in many circumstances, it is desirable to have an easy prediction equation for estimating total body fat in children using a combination of widely available and simple demographic and anthropometric variables. This would allow quick determination of body composition without the need for specialized laboratories, radiation exposure, or expensive equipment.

Previously, Dezenberg et al. developed a prediction equation for total body fat in African-American and white children (8). However, this equation has not been tested in Latino children. No prediction equation is currently available for Latino children. Hence, it is the intent of this paper to evaluate the precision and accuracy of the previously developed equation by Dezenberg et al. in Latino children with a wide range of body fat and to develop new equations using demographic and anthropometric measures to predict total body fat specifically in Latino children.

Research Methods and Procedures

Subjects

Through newspaper, radio advertisements, flyers, and word of mouth, 96 Latino children 7 to 13 years of age (60 boys and 36 girls) were recruited from the Los Angeles, CA

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area. Children were excluded if they were <7 or >14 years old, taking medications known or suspected to affect body composition (e.g., methylphenidate, growth hormone, prednisone), or diagnosed with any major illness since birth. Children were of a range of body weight and not undergoing any weight-related intervention. Latino ethnicity was ascertained if all four grandparents of each child were of Mexican, Central American, or South American ancestry. Parents provided consent, and children provided assent before the study. The study was approved by the Institutional Review Board (University of Southern California, Los Angeles, CA).

Measurements

Equation by Dezenberg et al. (8). Using DXA as the reference, a prediction equation was developed for the determination of total fat mass in 202 African-American (n = 69) and white (n = 133) 4- to 10-year-old children with a wide range of fat mass and body composition (Tanner stages 1 and 2; 96 boys and 106 girls). The equation, including weight, triceps skinfold, and gender, achieved a model R^2 of 0.95. The equation is as follows:

$$0.342 \times \text{weight} + 0.256 \times \text{triceps} + 0.837 \times \text{gender} - 7.388$$

Anthropometric and Body Composition Measurements. Subjects wore a hospital gown without shoes at the time of testing. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Weight was measured to the nearest 0.1 kg using an electronic scale. Hip and waist circumferences were measured to the nearest 0.1 cm. Skinfold thickness (subscapula, triceps, abdomen, suprailiac, thigh, and calf) was measured to the nearest mm using a Lange caliper (Cambridge Scientific Industries, Inc., Cambridge, MD) and the procedures of Lohman et al. (9), with the average of three measurements at each site being used for analysis. DXA was used to measured total body fat (Hologic QDR 4500W, Waltham, MA). Measurements were made by trained and certified staff at the General Clinical Research Center.

Sexual Maturity. Sexual maturation was assessed by a physician using Tanner's criteria on a scale of 1 to 5, with 1 being prepubertal and 5 being adult.

Statistics

The Dezenberg et al. (8) equation was used in the total sample to generate predicted total fat mass values. Student's t tests were performed to test whether measured total body fat and predicted total body fat were significantly different from each other. Then, measured total body fat was regressed on predicted total body fat using linear regression models. The Dezenberg et al. equation was considered valid if Student's t tests revealed no significant differences and if the regression of measured total body fat on predicted total body fat suggested no significant deviation from the line of identity (i.e., intercept = 0 and slope = 1).

Subsequently, to develop new prediction equations of total body fat, two-thirds of the children in the sample were randomly assigned (stratified by gender) to a prediction equation development group (n = 64, 40 boys and 24 girls), and the remaining one-third (n = 32, 20 boys and 12 girls) were randomly assigned to a cross-validation group. Student's t tests were conducted to compare sample characteristics between children in the development group and children in the cross-validation group. A χ^2 test was used to detect differences in the proportion of those in Tanner stages 1 and 2 vs. Tanner stages 3 to 5 between the development and cross-validation groups.

Three equations were developed in the equation development group. The first equation included only weight as an independent variable. The second equation included weight and the two demographic measures—gender and age. The third equation included gender, age, height, weight, waist and hip circumferences, and several skinfold measures (suprailiac, triceps, abdomen, subscapula, thigh, and calf). Simple regression was used to generate the first prediction equation, whereas step-wise regression was used to derive significant predictors of total body fat for the second and third equations. These equations were then tested for accuracy in the cross-validation group by paired comparison Student's t tests and line of identity as described above. In addition, plots of measured minus predicted vs. measured total body fat were performed to examine possible bias in the prediction equations. All statistics were computed using SAS (version 8.2 for Windows: SAS, Cary, NC), with an alpha value of 0.05.

Results

Sample characteristics are shown in Table 1. No differences were found between the development group and the cross-validation group on any of these characteristics.

Fitting Existing Equations to Latino Children (Figure 1)

Total body fat mass predicted by the method of Dezenberg et al. (8) was significantly different from measured total body fat (mean difference ± SD = −3.43 ± 4.32 kg, $p < 0.001$). Regression of measured total body fat on total body fat predicted by the Dezenberg et al. method yielded an intercept not significantly different from 0 (−1.66 ± 0.87 kg, $p > 0.05$) but a slope significantly different from 1.0 (1.32 ± 0.05, $p < 0.001$). Therefore, the equation from Dezenberg et al. was not successfully cross-validated in the current sample.

Development of Prediction Equations with Anthropometric and Demographic Measures (Table 2)

To determine if total body fat in Latino children could be predicted by demographic and/or anthropometric measures,

Table 1. Sample characteristics ($n = 96$)

Variable	Statistics		
	Mean ± SD	Median	Range
Age (years)	10.6 ± 1.8	10.7	7.2 to 13.8
Weight (kg)	53.7 ± 19.0	51.2	21.9 to 121.9
Height (cm)	144.0 ± 12.0	143.9	121.4 to 174.8
BMI (kg/m^2)	25.2 ± 5.8	24.7	14.9 to 45.3
Waist circumference (cm)	79.2 ± 16.6	79.5	26.5 to 123.5
Hip circumference (cm)	86.8 ± 15.4	87.2	31.8 to 137.5
Abdominal skinfold (mm)	25.2 ± 11.1	25.0	5.0 to 57.3
Subscapular skinfold (mm)	18.1 ± 9.6	15.0	4.0 to 44.6
Triceps skinfold (mm)	14.1 ± 7.8	12.0	2.0 to 36.0
Total body fat (kg)	19.3 ± 10.5	18.3	3.7 to 60.2
Total lean tissue (kg)	32.2 ± 9.3	30.6	16.8 to 58.2
Gender	62.5% Boys		
	37.5% Girls		
Tanner stage	85.4% Stages 1 to 2		
	14.6% Stages 3 to 5		

we developed new equations in the development group and tested them in the cross-validation group of our sample. Table 2 shows the equations using: 1) weight alone as an independent variable, 2) weight plus two demographic measures—age and gender, and 3) a combination of anthropometric and demographic measures as derived from stepwise regression.

Weight Alone (Figure 2). Using weight, a simple regression was conducted to yield a univariate prediction equation for total body fat. Weight alone accounted for 86.3% of the variance in measured total body fat in the development group. Mean difference ± SD between measured and predicted total body fat was 0.35 ± 3.64 kg ($p > 0.05$). This equation was successfully validated in the cross-validation

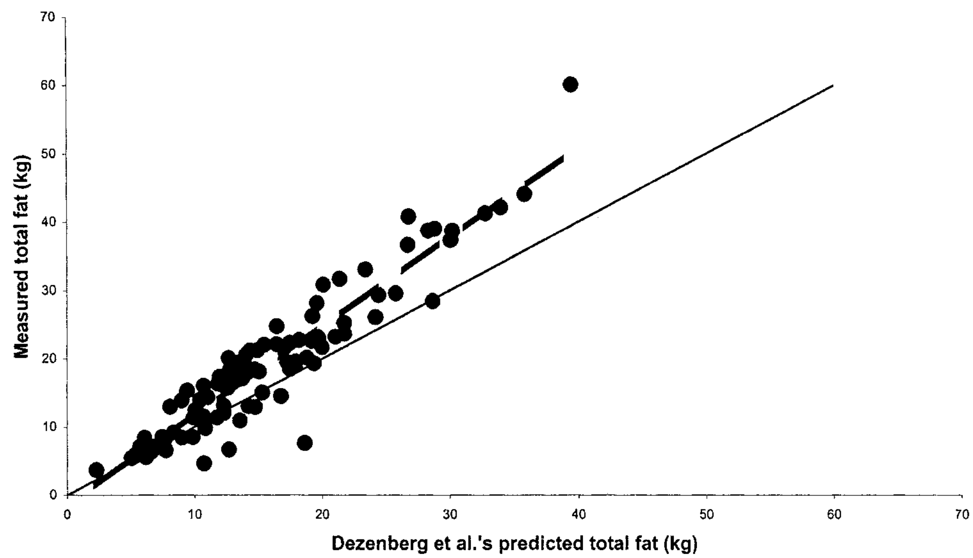

Figure 1: Measured vs. predicted total body fat using Dezenberg et al.'s prediction equation (8) ($n = 96$). Solid line represents line of identity; dashed line represents regression trend. The slope was significantly different from 1 ($p < 0.001$). The equation was not successfully cross-validated.

Table 2. Prediction equations for total body fat in Latino children in development group ($n = 64$)

Step variable	Regression equation for total body fat	Model R^2	p Value variable entered
Equation 1			
1. Weight	0.523 × Weight − 9.100	0.863 (0.859)	<0.001
Equation 2			
1. Weight	0.523 × Weight − 9.100	0.863	<0.001
2. Age	0.626 × Weight − 1.703 × Age + 3.457	0.917	<0.001
3. Gender	0.632 × Weight − 1.606 × Age − 1.882 × Gender + 3.330	0.924 (0.901)	<0.05
Equation 3			
1. Weight	0.523 × Weight − 9.100	0.863	<0.001
2. Height	0.764 × Weight − 0.471 × Height + 45.955	0.960	<0.001
3. Ab SF	0.682 × Weight − 0.409 × Height + 0.113 × Ab SF + 38.632	0.963	<0.05
4. Gender	0.665 × Weight − 0.377 × Height + 0.133 × Ab SF − 1.382 × Gender + 35.308	0.967	<0.05
4. Tanner stage	0.649 × Weight − 0.311 × Height + 0.132 × Ab SF − 1.837 × Gender − 0.962 × Tanner + 27.754	0.970 (0.956)	<0.02

Note: gender coded, 0 = girl, 1 = boy. Tanner stage coded 0 (prepubescent) to 4 (adult). Ab SF, abdominal skinfold.
Units: total body fat, kg; age, years; weight, kg; height, cm; Ab SF, mm. Final model R^2 for cross-validation sample indicated in parentheses.
In Equation 3, other entered but not selected variables were: age, waist and hip circumferences, and skinfolds of the suprailiac, triceps, subscapula, thigh, and calf.

group (intercept ± SE = 1.78 ± 1.53, $p > 0.05$; slope ± SE = 0.90 ± 0.07, $p > 0.05$; against slope = 1.0). Regression of measured minus predicted total body fat against measured total body fat revealed no bias in this equation (intercept ± SE = −1.26 ± 1.59, $p > 0.05$; slope ± SE = 0.04 ± 0.07, $p > 0.05$).

Weight Plus Age and Gender (Figure 3). The equation with weight ($p < 0.001$), age ($p < 0.001$), and gender ($p < 0.05$) accounted for 92.4% of the variance in total body fat in the development group. In the cross-validation group, mean difference ± SD between measured and predicted total body fat was 0.36 ± 3.03 kg ($p > 0.05$). This equation did not differ significantly from the line of identity (intercept ± SE = 2.28 ± 1.20, $p > 0.05$; slope ± SE = 0.91 ± 0.05, $p > 0.05$; against slope = 1.0). Regression of measured minus predicted total body fat against measured total body fat revealed no bias in the equation (intercept ± SE = 0.35 ± 1.34, $p > 0.05$; slope ± SE = 0.0002 ± 0.06, $p > 0.05$).

Combination of Anthropometric and Demographic Measures (Figure 4). Step-wise regression defined a prediction equation with weight ($p < 0.001$), height ($p < 0.001$), gender ($p < 0.01$), abdominal skinfold ($p < 0.01$), and Tanner stage ($p < 0.02$). This equation accounted for 97.0% of the variance in total body fat in the development group. In the cross-validation group, mean difference ± SD between measured and predicted total body fat was 0.0005 ± 2.47 kg ($p > 0.05$). This equation also did not differ significantly from the line of identity (intercept ± SE = 1.47 ± 1.01, $p > 0.05$; slope ± SE = 0.93 ± 0.04, $p > 0.05$; against slope = 1.0). No bias was detected in this equation (intercept ± SE = 0.16 ± 1.09, $p > 0.05$; slope ± SE = −0.01 ± 0.05, $p > 0.05$).

Discussion

The main findings of this study are as follows: the method of Dezenberg et al. (8), created in African-American and white children, was not appropriate in predicting total body fat in Latino children; weight alone was the most significant predictor of total body fat in Latino children, accounting for over 86% of the observed variance; equations that included weight, age, and gender or weight, height, gender, abdominal skinfold, and Tanner stage were equally cross-validated and explained a greater portion of the variance in measured total body fat. Dezenberg et al.'s equation was not successfully cross-validated in the current study, suggesting that unique equations may be needed for Latino children. Similar conclusions were reached when existing equations developed in white children could not be cross-validated in a combined cohort of African-American and white children (8). Using Dezenberg et al.'s method, the discrepancy between predicted and measured total body fat

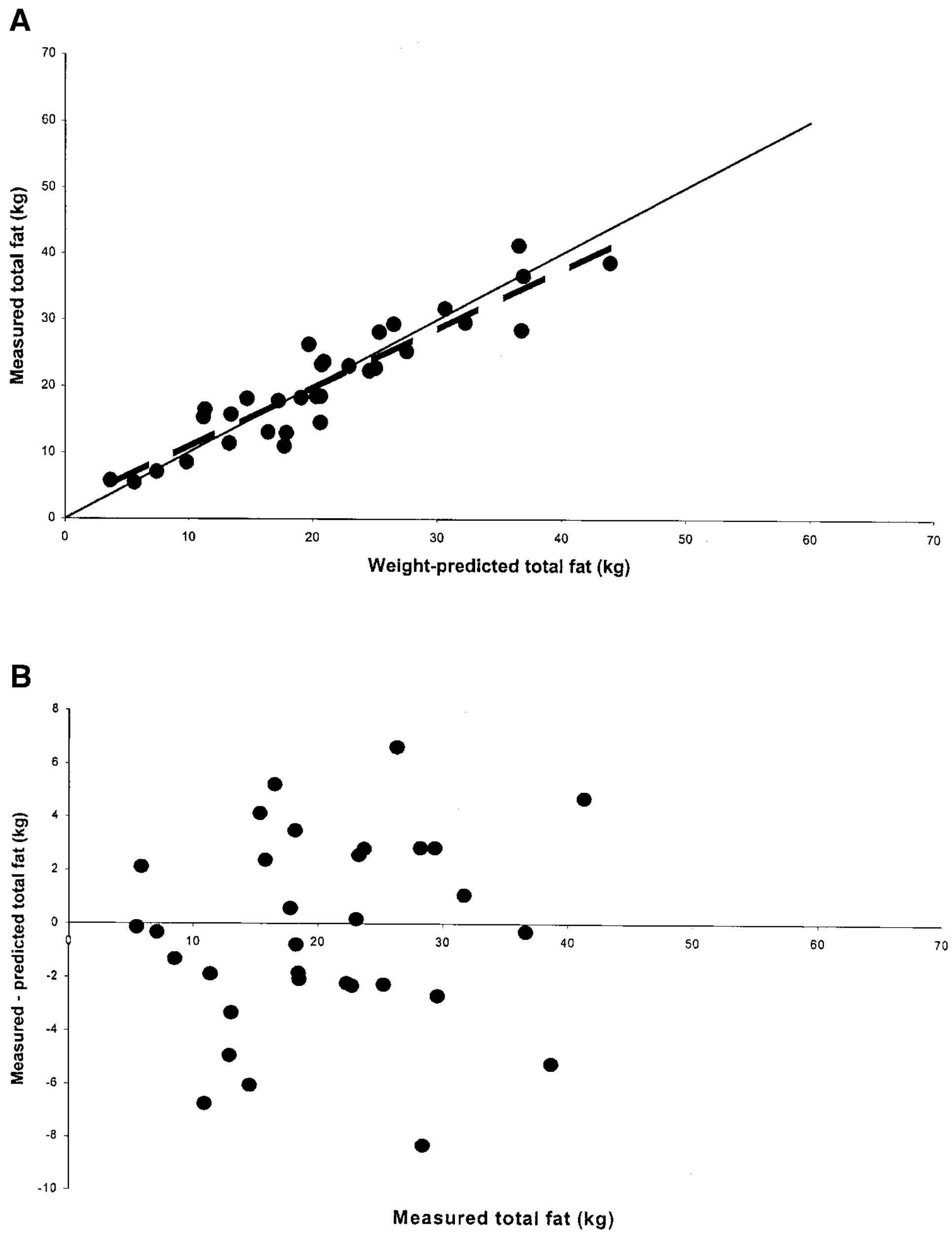

Figure 2: Cross-validation of prediction equation for total body fat using weight only (Table 2, Equation 1; $n = 32$). A, regression trend (dashed line) was not significantly different from line of identity (solid line), $p > 0.05$. B, no bias was present in the equation, $p > 0.05$.

became greater at higher levels of measured total body fat. The degree of underestimation of total body fat increased as measured total body fat increased. Ethnic differences in the relationship between anthropometry and total body fat may explain partially why these equations could not be cross-validated. In addition, differences between the Lunar DXA machine used by Dezenberg et al. and the Hologic DXA machine used in the current study may have also played a role.

To develop new equations that are appropriate for Latino children, we first examined weight as a univariate predictor (Table 2, Equation 1). Results suggested that weight explained a significant portion of the variance (86%) in measured total body fat. An equation with weight only predicted total body fat accurately, without any evidence of bias. In the absence of any additional anthropometric or demographic measures, this equation could be very useful and extremely easy to manipulate.

The addition of two available and relevant demographic measures—age and gender—to weight increased the explanatory power of total body fat by 6.1% (Table 2, Equation 2). This equation also predicted total body fat accu-

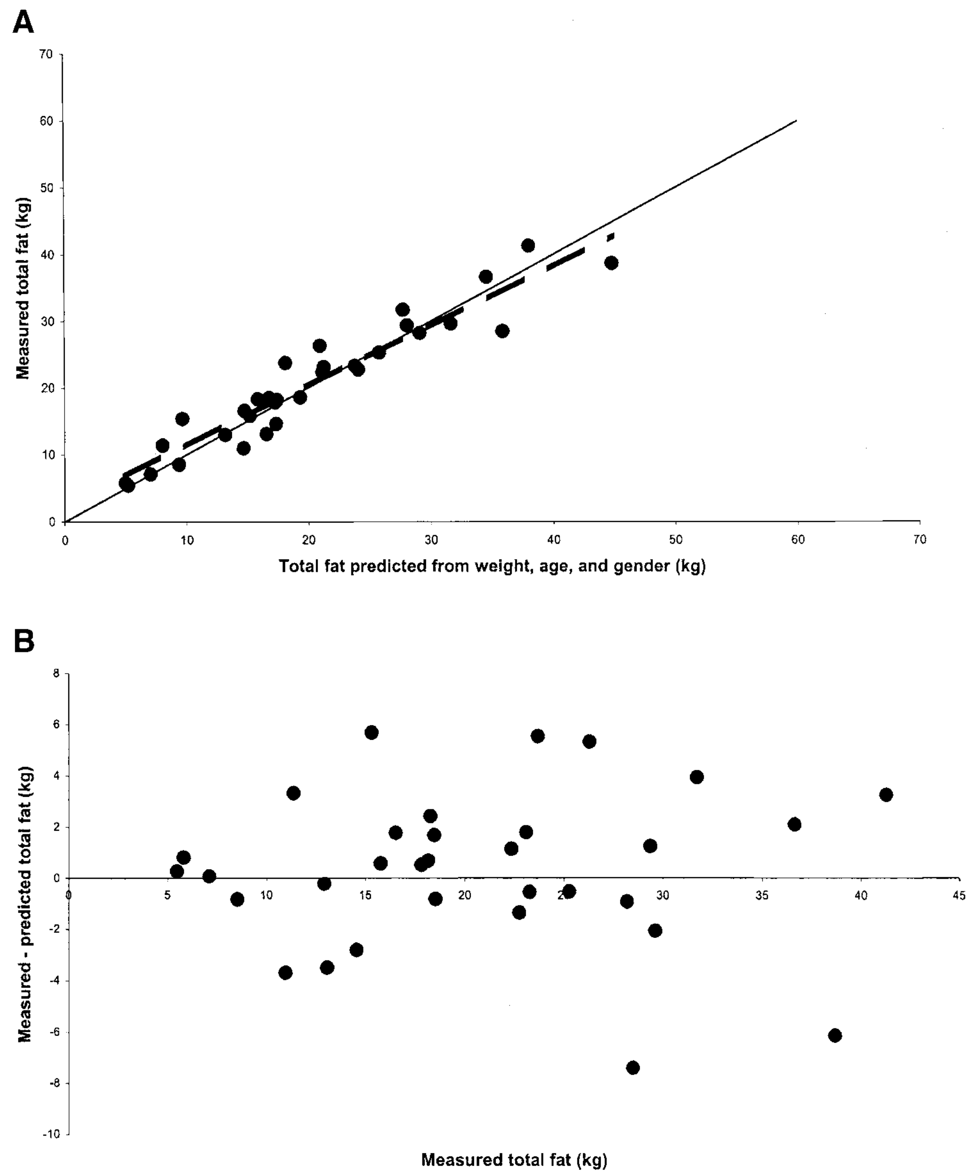

Figure 3: Cross-validation of prediction equation for total body fat using weight, age, and gender (Table 2, Equation 2; $n = 32$). A, regression trend (dashed line) was not significantly different from line of identity (solid line), $p > 0.05$. B, no bias was present in the equation, $p > 0.05$.

rately, without any bias. In most research settings, age and gender are easy to obtain. Therefore, this equation may be particularly cost-effective.

The third equation we developed and tested included weight, height, gender, abdominal skinfold, and Tanner stage (Table 2, Equation 3). This equation was equally valid in predicting total body fat in Latino children and, overall, had the greatest explanatory power. However, the use of this equation necessitates the difficulty of assessing abdominal skinfold and sexual maturity. In many settings, these measures may be too technically difficult and/or not conveniently accessible. Therefore, the limited increase in R^2 ($\Delta = 4.6\%$) compared with the equation with only weight, age, and gender may call into question its cost-effectiveness. Nevertheless, in complex research settings, the equation should be considered as the most precise of the three in this paper.

We have also tried using weight and height alone, BMI, and BMI percentile as predictors of total body fat in separate models. As shown in Table 2, weight and height alone yielded an R^2 of 0.96 in Equation 3. However, when tested in the cross-validation group, we found that the equation did not pass the test of the line of identity, where the intercept was significantly >0. BMI yielded a slightly higher R^2 (0.93 in development group and 0.90 in cross-validation

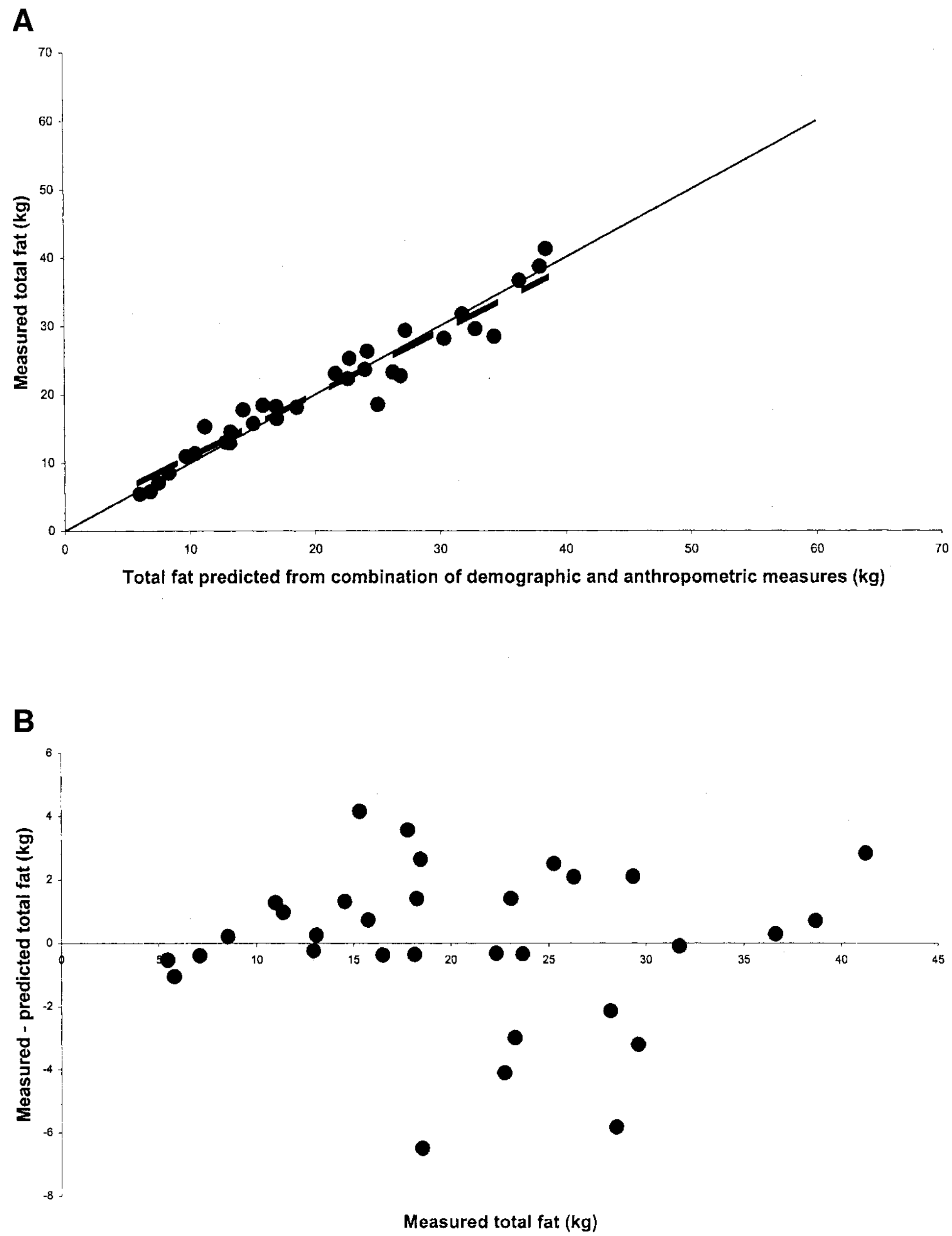

Figure 4: Cross-validation of prediction equation for total body fat using a combination of anthropometric and demographic measures (Table 2, Equation 3; $n = 32$). A, regression trend (dashed line) was not significantly different from line of identity (solid line), $p > 0.05$. B, no bias was present in the equation, $p > 0.05$.

group) than weight alone but also did not pass the test of the line of identity in the cross-validation group. BMI percentile accounted for only a small proportion of the variance in measured total body fat in Latino children ($R^2 = 0.32$ in development group and 0.35 in cross-validation group).

There are some limitations in the current study. First, the current study relied on a convenience sample of modest size. Therefore, generalization of study findings needs to be cautioned. Insufficient sample size may be a reason for the failure to cross-validate equations with weight and height alone or with BMI. Second, the majority of children in the current study are pre- or early pubertal. Findings may be limited to these early stages of sexual development. Third, most of the Latino children in our sample came from a Mexican background. It is not clear whether differences exist across different ethnicities within the Latino population. Fourth, our criterion method, DXA, has not been specifically validated in Latino children against a multicompartment model. Slaughter et al. had developed equations using the four-compartment model (10). Future studies need to compare the different approaches. However, given the complete lack of any anthropometric equation for Latino children, our results provide a preliminary way to predict total body fat from demographic and anthropometric measures using a reasonably strong criterion measure.

In summary, we were not able to cross-validate the equation of Dezenberg et al. (8), which suggests that separate equations may be needed for children of different ethnic background. Therefore, we developed new equations that were cross-validated using simple demographic and anthropometric measures. The use of weight alone is parsimonious and highly predictive. This method may be used where no additional information is available. The simple addition of age and gender, however, increased the explanatory power, with the prediction being equally stable. The third equation, however, possessed the greatest precision and required more technical expertise. Therefore, its use may be limited to more sophisticated research settings.

The current study is the first to develop simple ways to estimate total body fat in Latino children. In the absence of sophisticated techniques, our methods may be beneficial for future researchers. Future studies may still be needed to determine if combined data from different ethnic groups could generate a single equation for cross-cultural usage.

Acknowledgments

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