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SHORT REPORT

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Body proportionality and adiposity are not related in 6- to 8-year-old Yucatec Maya children

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Abstract

Objective: The aim of this study was to analyze the association between relative leg length (RLL) (leg length × 100/height) and adiposity in a sample of 6- to 8-year-old children of Maya ancestry from Motul and Merida, Mexico.

Methods: This cross-sectional study included 260 children (128 girls) measured between 2011 and 2015. The RLL was used as a measure of body proportionality. Linear regression models were performed to examine the association between RLL (predictor) and three adiposity indicators (outcome variables): fat mass index (kg/m^2), waist circumference (z-score), and sum of triceps and subscapular skinfolds (z-score).

Results: The prevalence of stunting was 12%, and a higher prevalence (19%) of short RLL (leg stunting) was found. The prevalence of overweight and obesity were 16% and 20%, respectively, but the highest prevalence was found for abdominal obesity (40%). None of the adiposity indicators were related to RLL ($P > .05$), even after adjusting for the influence of children's sex and age.

Conclusions: Our results suggest that the coexistence of short RLL and high body adiposity is not observed in all populations. Our findings do not discount the possibility that a negative association between RLL and adiposity is expressed at older ages.

1 | INTRODUCTION

The objective of this study was to analyze the relationship between relative leg length (RLL) and total, abdominal, and peripheral adiposity in a sample of 6- to 8-year-old children of Maya ancestry in the cities of Motul and Merida, Yucatan, Mexico. Having short legs for total height (short RLL) is one of the results of chronic poor nutritional conditions (Leitch, 1951). Suffering undernourishment in early life stages can induce metabolic adjustments that may lead to unhealthy outcomes in body composition, and this, in turn, increases the risk of future metabolic diseases (Wells, 2016). Some studies conducted in different countries, such as the United States (Frisancho, 2007), United Kingdom (Pliakas & McCarthy, 2010), and China (Zhang, Chu, & Zhao, 2016), have reported that children with generally lower RLL tend to accumulate more total adiposity or adiposity at different regions of the body compared with children with higher RLL. However, the last two of these studies used body mass index (BMI) to characterize body adiposity and the risk of overweight. Accordingly, in this study, we test the hypotheses that children's RLL will be negatively related to (a) fat mass index (FMI), (b) waist circumference (WC), and (c) sum of triceps and subscapular skinfolds (SumTS+SS). These hypotheses have not been tested in Maya children. Most of the Maya people from Yucatan live in conditions of poverty (Bracamonte y Sosa & Lizama Quijano, 2003), which contribute to the coexistence of stunting and overweight at both population and household levels (Varela-Silva et al., 2012), with a higher likelihood for leg stunting as well.

2 | METHODS

2.1 | Population study

A cross-sectional study was implemented between September 2011 and April 2015 involving 260 children (128 girls) of Maya ancestry living in the cities of Motul and Merida, in the state of Yucatan, Mexico. Three inclusion criteria used for children were that: (a) their mother had both maternal and paternal Maya surnames (Maya surnames were used as a proxy for Maya genetic ancestry), (b) their age was between 6.00 and 8.99 years, and (c) they had to attend public schools. In Yucatan, elementary school is compulsory; therefore, 97% of children attend school (INEGI, 2015). Participant recruitment procedures and selection criteria for the study population are described in detail in Azcorra Pérez (2014).

2.2 | Ethical considerations

The research project was reviewed and approved by the Bioethics Committee for the Study of Human Beings at Cinvestav (Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional) and the Loughborough University Ethics Advisory Group (R11-P133). Mothers provided informed consent for their child's participation in the study, and the children provided their verbal assent.

2.3 | Physical measurements

Height (cm), weight (kg), sitting height (cm), and triceps and subscapular skinfolds (mm) were measured following standardized protocols (Lohman, Roche, & Martorell, 1988), using a Seca 881 scale for weight, Martin type anthropometers for height and sitting height, and Harpenden HSB-BI calipers for skinfolds. Leg length (LL) and RLL were calculated using Equations (1) and (2).

$$LL_{cm} = height_{cm} - sitting\ height_{cm} \tag{1}$$

$$RLL_{\%} = (LL_{cm} \times 100)/height_{cm}. \tag{2}$$

WC was measured with a tape placed horizontally on the median line between the last floating rib and the highest portion of the iliac crest. Waist-to-height ratio ($WHR = WC_{cm}/height_{cm}$) was used as an indicator of abdominal level fat, and SumTS+SS was used as an indicator of peripheral fat. All measurements were taken in schools by standardized personnel, generally 2 hours after breakfast and before the recess and school physical education activities. A research assistant of the Laboratory of Somatology at Cinvestav-Mérida, with more than 20 years of experience in anthropometry, regularly trained five measurers for the duration of the project. There were three standardization sessions in which only <5% of interobserver technical error of measurement was acceptable.

For descriptive purposes, z-score values were calculated for height, LL, RLL, BMI, WC, and SumTS+SS based on Frisancho's Comprehensive Reference (Frisancho, 2008). This reference was selected, because it included Mexican-American children and because there are no anthropometry references available for Mexicans. To be under the fifth percentile was used to classify a child as (a) stunted, according to height-for-age, (b) LL stunted, according to LL-for-age, and (c) with short RLL, according to RLL-for-age.

Children were classified as at risk of overweight when their BMI-for-age was ≥85th percentile, and at risk of obesity when it was ≥95th percentile. Fat-free mass (Equation 3) was calculated by bioimpedance body composition analysis (Bodystat 1500 MDD) and the equation developed by Ramírez et al. (2012), which is the most reliable one for 6- to 12-year-old Maya children, since the sample from which the equation was developed included participants from this ethnic group. Fat mass (Equation 4) and the FMI (Equation 5) were then calculated. The latter value was used as an indicator of total adiposity, instead of body fat percentage or fat mass, because it is adjusted for height and the measurement unit is similar to that of the BMI (kg/m^2).

$$\begin{aligned} \text{Fat-free mass}_{kg} = 0.661 \times \left([height_{cm}]^2/resistance_{\Omega}\right) \\ + 0.200 \times weight_{kg} - 0.320 \end{aligned} \tag{3}$$

$$\text{Fat mass}_{kg} = weight_{kg} - \text{fat-free mass}_{kg} \tag{4}$$

$$FMI_{kg/m^2} = \text{fat mass}_{kg}/(height_m)^2. \tag{5}$$

2.4 | Statistical analyses

Fisher's exact test was used to examine the differences in the proportions of stunted/LL stunted children and stunted/short RLL children. To test the hypotheses, we performed three linear regression models to examine the relationship between RLL and adiposity indicators. We used RLL as the predictor variable and three adiposity indicators as the outcome variables: FMI (kg/m^2), WC (z-score), and SumTS+SS (z-score). The three models were adjusted for children's sex.

Only the model for FMI was additionally adjusted for age (years). All models satisfied the normality of the residuals. Significance level was set at $\alpha < .05$.

3 | RESULTS

Stunting was present in 12% (n = 31) of children, but the proportion of children with stunted LL (28%, n = 73) was significantly higher ($P < .01$). Near to one fifth (19%, n = 48) of children had short RLL, a proportion that significantly differed from that of stunting ($P < .01$) (Table 1).

Children in this sample showed higher adiposity levels than the reference population. Sixteen percent (n = 42) and 20% (n = 53) of children met the criteria for overweight and obesity, respectively. Forty percentage (n = 105) of children had a WHR >0.50, indicating risk for abdominal obesity.

The three regression models, however, showed no significant relationships between RLL and the three adiposity indicators ($P > .05$), even after adjusting for sex and age (Table 2).

4 | DISCUSSION

Our results do not support the hypotheses that lower RLL is associated with higher values of body adiposity. Some evidence indicates that children with lower RLL tend to have more BMI (Pliakas & McCarthy, 2010; Zhang et al., 2016); however, BMI has serious limitations as a proxy for fat (Bogin & Varela-Silva, 2012) because it is just an indicator of weight-for-height and individuals with the same weight could have different amounts of fat mass or fat free mass. As well, the variation in body proportionality results in different values in the prevalence of overweight using BMI classification, as Norgan (1995) clearly demonstrated in his study of Australian aborigines. Therefore, our analysis shows more accurate results about the relationship between body proportionality and adiposity.

Although not statistically significant, it might be relevant that slope coefficients in all three models (see Table 2) are positive, not negative, as expected from other studies (Frisancho, 2007; Pliakas & McCarthy, 2010; Zhang et al., 2016). Our results suggest that a negative association between RLL and body adiposity is not observed in all populations. We do not have a clear explanation for these discrepancies in results. However, it is possible that our results are explained by the fact that over-nutrition tends to accelerate growth (Vignolo, Naselli, Di Battista, Mostert, & Aicardi, 1988). In fact, overweight/obese children tend to be

TABLE 2 Regression models relating relative leg length to children's fat mass index, waist circumference, and sum of triceps and subscapular skinfolds

	B (SE)	95% CI	*P*-value
Fat mass index (FMI)$_{kg/m^2}$	0.135 (0.110)	−0.08 (0.35)	.221
Waist circumference$_{z\text{-score}}$	0.070 (0.038)	−0.01 (0.14)	.068
Sum of skinfold$_{z\text{-score}}$	0.093 (0.048)	0.00 (0.18)	.055

Note: Model for FMI was adjusted for children's sex and age (years); models for waist circumference and sum of skinfolds were adjusted for children's sex.

TABLE 1 Mean (SD) values of anthropometric and adiposity variables by sex and age (years) groups

	Male				Female			
Variable	6	7	8	z-score[a]	6	7	8	z-score[a]
n	36	49	47	132	38	44	46	128
Height$_{cm}$	115.1 (5.3)	119.8 (4.8)	126.4 (5.8)	−0.65 (0.88)	114.4 (4.2)	119.7 (6.1)	125.4 (6.3)	−0.53 (0.88)
Weight$_{kg}$	22.6 (4.3)	26.2 (6.2)	30.7 (7.6)	−0.15 (0.92)	22.7 (4.4)	25.8 (5.6)	29.1 (8.4)	0.15 (0.93)
LL$_{cm}$	52.4 (3.3)	55.2 (2.8)	59.2 (4.0)	−1.41 (0.88)	52.6 (2.9)	55.7 (3.5)	59.0 (3.7)	−0.80 (0.88)
RLL$_{\%}$	45.5 (1.3)	46.0 (1.8)	46.8 (1.4)	−0.96 (0.82)	45.9 (1.6)	46.5 (1.1)	47.0 (1.1)	−0.90 (0.76)
BMI$_{kg/m^2}$	16.9 (2.3)	18.1 (3.3)	19.0 (3.5)	0.91 (1.03)	17.3 (2.6)	17.8 (2.5)	18.2 (3.8)	0.71 (0.99)
FM$_{kg}$	6.6 (2.5)	8.1 (3.6)	10.0 (4.2)	N/A	7.3 (2.6)	8.7 (3.0)	10.2 (5.2)	N/A
FMI$_{kg/m^2}$	4.9 (1.7)	5.5 (2.2)	6.1 (2.2)	N/A	5.5 (1.8)	6.0 (1.7)	6.4 (2.7)	N/A
WC$_{cm}$	57.1 (6.3)	60.7 (8.4)	64.2 (8.8)	0.57 (0.81)	57.5 (6.5)	60.2 (7.2)	61.7 (10.2)	0.75 (0.77)
WHR	0.5 (0.1)	0.5 (0.1)	0.5 (0.1)	N/A	0.5 (0.1)	0.5 (0.1)	0.5 (0.1)	N/A
SumTS+SS$_{mm}$	17.7 (8.2)	20.5 (10.6)	22.9 (9.7)	0.34 (0.84)	21.2 (9.7)	23.9 (8.0)	24.7 (11.7)	0.66 (0.80)

Abbreviations: BMI, body mass index; FM, fat mass; FMI, fat mass index; LL, leg length; RLL, relative leg length; SumTS+SS, sum of triceps and subscapular skinfolds; WC, waist circumference; WHR, waist-to-height ratio.

[a]z-score of all age groups, based on Frisancho's Comprehensive Reference (Frisancho, 2008).

taller than their normal weight counterparts or above average (Papadimitriou, Gousi, Giannouli, & Nicolaidou, 2006). If excessive gain in fat tends to promote linear growth, as has been proposed, increments in lower body segments could be expected. In our sample, overweight/obesity is a widespread condition; 36% and 40% of children met the criteria for excessive BMI and WHR, respectively.

In their study with 2- to 20-year-old Mexican-American children and young adults, Frisancho (2007) found that individuals with low RLL (z-score < −1.036) had more subcutaneous fat compared to those who showed high RLL (z-score > +1.036). In contrast, we did not find in our sample a significant relation between RLL and SumTS+SS. However, Maya children are notably different, in terms of socioeconomic and biological conditions, from studied populations in the above-cited reports that come from the developed world; our sample seems to be poorer, implying limited access to safe water, health services, insanitary excreta disposal, and imbalanced diet. In addition, the nutritional dual-burden present in Maya households (Varela-Silva et al., 2012) could be promoting excessive adiposity early in life. This is a particular scenario, considering many ecological factors, from a human ecology perspective.

It is also possible that the studied children were still too young to manifest the influence of differentiated growth trajectories, and these would become significant after the pubertal growth spurt. The present results do not discount the possibility that the children will exhibit linear growth trajectories and body composition during adolescence and adulthood that influence the phenotype observed in the adult Maya population. Future research needs to include the use of biochemical markers for blood glucose, cholesterol, and triglycerides, or clinical markers, such as acanthosis nigricans, to estimate individuals' metabolic risk at early ages and to support adiposity indicator results.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

A.V.-G. and F.D. designed the study. A.V.-G. analyzed the data. A.V.-G. and F.D. wrote the manuscript draft. F.D., H.A., and M.V.S. designed the project of which this study forms a part. M.L.A.E., H.A., and M.V.S. revised and commented on the manuscript.

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