Physical Growth and Nonverbal Intelligence: Associations in Zambia

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Objective To investigate normative developmental body mass index (BMI) trajectories and associations of physical growth indicators—height, weight, head circumference (HC), and BMI—with nonverbal intelligence in an understudied population of children from sub-Saharan Africa.

Study design A sample of 3981 students (50.8% male), grades 3-7, with a mean age of 12.75 years was recruited from 34 rural Zambian schools. Children with low scores on vision and hearing screenings were excluded. Height, weight, and HC were measured, and nonverbal intelligence was assessed using the Universal Nonverbal Intelligence Test, Symbolic Memory subtest and Kaufman Assessment Battery for Children, Second Edition, Triangles subtest.

Results Students in higher grades had a higher BMI over and above the effect of age. Girls had a marginally higher BMI, although that for both boys and girls was approximately 1 SD below the international Centers for Disease Control and Prevention and World Health Organization norms. When controlling for the effect of age, nonverbal intelligence showed small but significant positive relationships with HC (r = 0.17) and BMI (r = 0.11). HC and BMI accounted for 1.9% of the variance in nonverbal intelligence, over and above the contribution of grade and sex.

Conclusion BMI-for-age growth curves of Zambian children follow observed worldwide developmental trajectories. The positive relationships between BMI and intelligence underscore the importance of providing adequate nutritional and physical growth opportunities for children worldwide and in sub-Saharan Africa in particular. Directions for future studies are discussed with regard to maximizing the cognitive potential of all rural African children. *(J Pediatr 2014;165:1017-23)*.

Physical health indicators, such as height, weight, body mass index (BMI), and head circumference (HC), have been linked to intellectual development.[1-5] Correlations of height and intelligence have been found across broad age ranges, with mean intellectual performance increasing with height[6] and smaller children scoring lower on academic achievement tests compared with their taller counterparts.[7] Higher BMI has been linked to lower performance IQ[8] and lower nonverbal reasoning.[6] In contrast, in 5-year-old boys, BMI has been positively correlated with fluid intelligence, but negatively correlated with crystallized intelligence.[9] HC is one of the most important anthropometric indicators (ie, nutrition and brain volume index) associated with intellectual performance,[2-4,10] notwithstanding the associations of developmental disorders and microcephaly and macrocephaly.[11]

Most of the published research on developmental indices is from high-income countries. Comparatively less is known about these indicators in low-income countries. Reports from both suggest that inadequate physical growth represents a constant source of childhood underachievement. Worldwide, the largest percentage of young children living in poverty, a factor tied to underachievement and undergrowth, is in sub-Saharan Africa (54.3% of children aged <5 years).[12] A recent report described BMI trends in more than 9 million people in nearly 200 countries.[13] Contrary to the overall global trends toward increasing BMI and rates of obesity, in parts of Africa the trends are toward low and decreasing BMI, suggesting that many people are underweight. As in much of the relevant literature, African countries were underrepresented in this research.[13] In particular, Zambia was not included. Few studies of child nutrition have been completed in Zambia. Available data indicate worse nutritional status in children compared with adults,[14] as well as more underweight children in underprivileged communities.[15] Here we describe the connections between health and cognition in a large cross-sectional rural sample of students. The results provide a descriptive statement that emphasizes indicators of general health and explores their relationships with nonverbal intelligence.

Methods

A total of 4609 children were approached for participation in the Bala Bbala Project (*bala bbala* means "read the word" in Chitonga), a large-scale Institutional Review Board–approved (UNZA BREC #003-08-09) study of the manifestation, prevalence, and etiology of specific reading disabilities in rural Zambia.[16] After screening and enrollment, the following children were excluded from this analysis: those with missing data for BMI, intelligence, or HC; those age >19 years (ie, the upper age limit of

BMI	Body mass index
HC	Head circumference
KABC-II-T	Kaufman Assessment Battery for Children, Second Edition, Triangles subtest
UNIT-SM	Universal Nonverbal Intelligence Test, Symbolic Memory subtest

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the Centers for Disease Control and Prevention and World Health Organization BMI norms); and those with vision poorer than 20/30 in both eyes or hearing loss of >40 dB for at least 1 of the assessed frequencies (ie, 1000, 2000, and 4000 Hz) in both ears. A total of 628 children were excluded based on these criteria (**Figure 1**; available at www.jpeds.com). **Table I** (available at www.jpeds.com) present characteristics for the initial, excluded, and final samples. The final sample comprised 3981 students (50.8% male), grades 3-7, from 34 schools, with a mean age of 12.75 ± 2.03 years. The wide age range (7.40-18.78 years; mode, 14; median, 12.71) is typical in rural Zambia, where students often miss years of schooling because of financial difficulties or household responsibilities, or repeat grades because of absenteeism.[17]

Age, grade, and sex data were collected from school records. The Universal Nonverbal Intelligence Test, Symbolic Memory subtest (UNIT-SM)[18] and Kaufman Assessment Battery for Children, Second Edition, Triangles subtest (KABC-II-T)[19] were administered to assess nonverbal intelligence (ie, memory and simultaneous visual processing, respectively). These tests were chosen because they use manipulative materials thought to be as engaging as possible for children not familiar with Western testing modes. The UNIT-SM uses nonverbal instructions and comprises 30 items (Cronbach $\alpha = 0.82$) that require students to reproduce an array of 1-6 images of people from memory. The KABC-II-T comprises 27 items (Cronbach $\alpha = 0.86$) that require students to use physical foam and plastic shapes, mainly triangles, to reproduce images. Summed scores were computed and submitted to a principal components analysis (oblimin rotation) to extract factor scores from a 1-component solution (65.48% of variance explained) for further analyses. A stadiometer, scale, and measuring tape were used to measure height, weight, and HC of barefoot uniformed children. BMI was calculated as weight in kilograms divided by height in meters squared.

Once written informed consent was obtained from each subject's parent or guardian, trained research assistants individually administered the assessments and were monitored during data collection. The data collectors were not informed of the study hypotheses, group status (ie, at risk/not at risk for specific reading disabilities), or results. Assessments were performed in the local language, Chitonga.

Results

Zambian age expectations are based on school entry age (7 years for first grade). In this sample, the exact norm (eg, 9 or 10 years in grade 3) was achieved by approximately 50% of students in each grade (grade 3, 63.3%; grade 4, 52.5%; grade 5, 50.4%; grade 6, 51.1%; grade 7, 44.8%). The mean age for each grade was 10.49 years for grade 3, 11.76 years for grade 4, 12.86 years for grade 5, 13.95 years for grade 6, and 15.02 years for grade 7. The age–grade correlation was relatively high (Spearman rank-order correlation coefficient, $\rho = 0.79$; $P < .001$).

Table I presents descriptive statistics for the main study variables. Boys had larger HC ($M_{boys} = 52.87$, SD = 1.82; $M_{girls} = 52.62$, SD = 1.98; $t[3979] = 4.13$; $P < .001$), whereas girls had higher weight ($M_{boys} = 33.81$, SD = 7.83; $M_{girls} = 34.53$, SD = 8.69; $t[3979] = -2.73$; $P < .01$) and marginally higher BMI ($M_{boys} = 16.09$, SD = 2.07; $M_{girls} = 16.28$, SD = 2.51, $t[3979] = -2.51$; $P < .05$). There was no significant height difference by sex. To show the BMI value distribution, we used R to fit a generalized additive model for location scale and shape[20,21] to the data, with age as an explanatory variable and assuming a Box-Cox t distribution (**Figure 2**). As expected, these curves follow worldwide developmental trajectories, at least in the range of −2 to +2 SD below and above the mean. However, both boys and girls had comparatively lower BMI; for instance, in girls, BMI up to age 16 years is approximately 1 SD below global norms.

Correlates of General Health Indicators

Pearson product-moment correlations (Pearson r) were conducted. Partial correlations were computed to control for the effect of age. The 4 health indicators studied were significantly related to age ($r = 0.29$ for HC, 0.42 for BMI, and 0.69 for both height and weight) and grade ($r = 0.25$ for HC, 0.23 for BMI, 0.29 for height, and 0.32 for weight). Although the magnitude of association decreased when controlling for age, grade remained positively related to BMI ($r = 0.12$), indicating that greater level of schooling is related to higher BMI beyond biological maturation. Moreover, girls showed marginally higher BMI, attributable to higher weight. Given these BMI correlates, a multivariate model was specified to examine differential effects of grade by sex. Sex, grade, and the interaction between them were independent variables in ANCOVA, with age as a covariate. This model explained a significant proportion of variance in HC (adjusted $R^2 = 0.11$), height (adjusted $R^2 = 0.53$), weight (adjusted $R^2 = 0.53$), and BMI (adjusted $R^2 = 0.21$). Similar to the correlational analysis, the results showed significant main effects of grade on the 4 health indicators. However, significant interactions between sex and grade indicate that HC ($F_{Interaction} = 9.40$; $P < .001$; partial $\eta^2 = 0.009$), weight ($F_{Interaction} = 8.94$; $P < .001$; partial $\eta^2 = 0.009$), and BMI ($F_{Interaction} = 15.68$; $P < .001$; partial $\eta^2 = .016$) increased differentially by sex across grades.

Figure 3 displays age-adjusted means for health indicators as a function of grade and sex. Post hoc tests (P value adjustment using the Holm method) of differences in interaction means showed that girls in grades 3 and 4 had smaller HC than boys ($F = 25.97$, for grade 3, and $F = 21.38$, for grade 4; $P < .001$); however, the difference narrows after grade 5. Girls weighed significantly ($P < .001$) more than boys in grades 5 ($F = 17.33$), 6 ($F = 35.71$), and 7 ($F = 39.50$); however, weight did not differ between boys and girls in grades 3 and 4. The strongest effect size was found for BMI, with approximately 1.6% of the variance accounted for by the sex–grade interaction. The pattern of