Short Communication:

Sources of Variability in Childhood Obesity Indicators and Related Behaviors

Peter T. Katzmarzyk[1], Stephanie T. Broyles[1], Jean-Philippe Chaput[2], Mikael Fogelholm[3], Gang Hu[1], Estelle V. Lambert[4], Carol Maher[5] Jose Maia[6], Tim Olds[5], Vincent Onywera[7], Olga L. Sarmiento[8], Martyn Standage[9], Mark S. Tremblay[2] and Catrine Tudor-Locke[10]

[1]Pennington Biomedical Research Center, Baton Rouge, LA
[2]Children's Hospital of Eastern Ontario Research Institute, Ottawa, Canada
[3]University of Helsinki, Helsinki, Finland
[4]Division of Exercise Science and Sports Medicine, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa
[5]School of Health Sciences/Sansom Institute, University of South Australia, Adelaide, Australia
[6]CIFI2D, Faculdade de Desporto, University of Porto, Porto, Portugal
[7]Kenyatta University, Nairobi, Kenya
[8]Universidad de los Andes, Bogota, Colombia
[9]University of Bath, Bath, United Kingdom
[10]University of Massachusetts, Amherst, MA

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Address for Correspondence and Offprints:
Peter T. Katzmarzyk, PhD
Pennington Biomedical Research Center
6400 Perkins Road
Baton Rouge, LA
70808-4124
Phone (225) 763-2536
Fax: (225) 763-2927
Email: Peter.Katzmarzyk@pbrc.edu

Abstract

The purpose of this study was to describe sources of variability in obesity-related variables in 6,022 children aged 9-11 y from 12 countries. The study design involved recruitment of students, nested within schools, which were nested within study sites. Height, weight and waist circumference (WC) were measured and BMI was calculated; sleep duration and total and in-school moderate-to-vigorous physical activity (MVPA) and sedentary time were measured by accelerometry; and diet scores were obtained by questionnaire. Variance in most variables was largely explained at the student level: BMI (91.9%), WC (93.5%), sleep (75.3%), MVPA (72.5%), sedentary time (76.9%), healthy diet score (88.3%), unhealthy diet score (66.2%), with the exception of in-school MVPA (53.8%) and in-school sedentary time (25.1%). Variance explained at the school level ranged from 3.3% for BMI to 29.8% for in-school MVPA, and variance explained at the site level ranged from 3.2% for WC to 54.2% for in-school sedentary time. In general, more variance was explained at the school and site levels for behaviors than for anthropometric traits. Given the variance in obesity-related behaviors in primary school children explained at school and site levels, interventions that target policy and environmental changes may enhance obesity intervention efforts.

Key Words: adiposity; pediatric; lifestyle; variance; multi-level models

Ecological models have been proposed to frame interventions to improve lifestyle behaviors such as physical activity and diet as well as the prevention of overweight and obesity.[1-3] A central tenet of these models is that obesity indicators and associated behaviors are influenced by factors at several levels, including individual influences, social environments, physical environments, and macro-level environments. Yet, the degree to which obesity indicators and related behaviors are influenced by these multiple levels has not been well documented using standardized research designs.

The purpose of this study was to estimate the percentage of the total variance in anthropometric measurements and obesity-related behaviors explained at the student, school, and study-site levels in a sample of children from 12 countries varying widely in level of socioeconomic and human development.

Methods

The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE), conducted at sites in 12 countries from every inhabited continent, allows a unique opportunity to estimate sources of variance in obesity indicators and related behaviors.[4] The sampling design included the recruitment of students (Level 1) nested within schools (Level 2), which were in turn nested within study sites (Level 3). A total of 7,372 children aged 9-11 years were sampled across the 12 countries, or which 6,022 remained in the analytic dataset after excluding those with incomplete data. The Institutional Review Board at the Pennington Biomedical Research Center (coordinating center) approved the overarching ISCOLE protocol, and the Institutional/Ethical Review Boards at each participating institution also approved the local protocol. Written informed consent was obtained from parents or legal guardians, and child assent was also obtained prior to participation in the study as required by local Institutional/Ethical Review Boards.

Body mass (kg), standing height (m) and waist circumference (cm) were measured using standard procedures, and the body mass index was computed (BMI; kg/m^2).[5] Nocturnal sleep duration (minutes/night) and time spent in moderate-to-vigorous physical activity (MVPA) and sedentary behaviors (minutes/day) were objectively assessed using 24-hour, waist-worn accelerometry as previously described.[6, 7] In addition, minutes per day of in-school MVPA and in-school sedentary time were assigned from the accelerometry files using school day schedules provided by each participating school; the in-school period was defined as the time between scheduled school start and end times.[8] Principal components analysis was used to compute healthy (HDS) and unhealthy diet scores (UDS) from a food frequency questionnaire.[9]

Multi-level models, as implemented in SAS using PROC MIXED, were used to estimate the variance components for the variables of interest. Intraclass correlation coefficients were computed from an unconditional model (a model with no predictors) as indicators of the variance accounted for by schools and sites.

Results

The percentage of the variance explained at the student, school, and site levels for several anthropometric and behavior variables are presented in Table 1. Overall, 91.9% and 93.5% of the variance in BMI and waist circumference was explained at the student level, respectively. The student-level variance in MVPA, sedentary time, sleep time, HDS and UDS were somewhat lower, ranging from 66.2% for UDS to 88.3% for HDS. The explained variance for the in-school MVPA and in-school sedentary time was different, with a greater proportion of the variance accounted for at the school and study site levels.

The percentage of the variance explained by the student and school levels within each site is presented in Table 2. Similar to the results for the overall sample, the variance explained at the student level across countries was high for both BMI (81.7% to 100%) and waist circumference (81.9% to 100%). Further, within sites, the variance explained at the student level was also high for UDS (72.6% to 99.7%), HDS (91.5% to 100%) and sleep (79.9% to 96.2%), with a lower contribution from the school environment. The sources of variance for MVPA and sedentary time were more variable across the sites, especially for in-school MVPA and in-school sedentary time.

Discussion

The results demonstrate that the major sources of variability differ among obesity indicators and related behaviors. The anthropometric measures of adiposity show the greatest contribution of student-level factors to the variability, and this suggests that these traits are not greatly influenced by the school or site-level environment. However, the school and study sites tend to contribute more to the variability in obesity-related behaviors such as diet and physical activity, especially for in-school MVPA and sedentary time. These results are consistent with earlier research that suggests that the effects of other "higher-order" environments such as neighborhoods tend to explain small amounts of variability in child outcomes (~ 5%).[10] However, the low school- and site-level variance components observed for most variables in the present study does not rule out the potential for significant effect sizes to be observed for differences across sites or schools. In fact, variance components exceeding ~14% suggest very large ($d \geq 0.8$) standardized effect sizes, [11] which warrants further research using multi-level interventions to test their impact on obesity-related outcomes.

Our results show that levels of in-school MVPA and in-school sedentary time cluster within schools, more so than BMI or waist circumference, which is expected when the context (i.e. schools) matches the setting in which the behavior occurs.[12] This suggests that interventions that modify the school environment to increase physical activity and reduce sedentary behavior might be effective at improving these behaviors within the context of the school environment. However, the extent to which these improvements during school hours might have an impact on overall lifestyle behaviors and obesity *per se* is not known. For example, the Healthy Study, which randomized 42 schools (4603 students) to either a multi-component intervention or assessment-only control group between the 6th and 8th grade, reported no significant differences between the groups in changes in the prevalence of overweight and obesity.[13] Similarly, in recent years there has been an increasing focus on including community-level intervention components in comprehensive obesity prevention programs.[14] However, community-based interventions have not been overly successful at reducing levels of childhood obesity.[15] For example, the 8-country IDEFICS childhood obesity prevention intervention targeted multiple levels of influence and was culturally adapted to each local population;[16] however, no significant differences in the prevalence of obesity were found after 2 years.[17]

The methods employed in this study modelled the variance components attributable to school- and site-level factors; the variance at the student level was obtained by subtraction. Given that all of the obesity indicators and related behaviors were measured at the student level, the variance attributable to the student level also contains measurement error, which varies across the variables used in this study. Further, this student-level variance also captures variability across other levels, like within families, households and neighborhoods, not accounted for in the study design and analysis.

Despite the lower amounts of variance explained by the site and school levels, it is important to control for these effects using multi-level models in order to better understand the independent effects of individual-level predictors across different higher-order environmental conditions. The search for common correlates of obesity can lead to common intervention targets for global health promotion. Despite the cross-sectional design of this study, the results of this study suggest that student-level (including household/family) factors may be important targets for obesity interventions. However, given that a significant fraction of the variance in obesity-related behaviors was indeed explained at the school and site levels, interventions that incorporate policy and environmental changes may enhance intervention efforts targeting improvement in these behaviors, and may be cost-effective due to the numbers of people reached. However, the statistical power to detect these effects is maximized when the outcome matches the context of the intervention. Further research using prospective and randomized designs is required to confirm the importance of different intervention targets at multiple levels.

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Conflict of Interest

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References

1. Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating active living communities. *Annu Rev Public Health* 2006; **27**: 297-322.

2. Davison KK, Birch LL. Childhood overweight: a contextual model and recommendations for future research. *Obes Rev* 2001; **2**(3): 159-71.

3. Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K. Creating healthy food and eating environments: policy and environmental approaches. *Annu Rev Public Health* 2008; **29**: 253-72.

4. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE): Design and methods. *BMC Public Health* 2013; **13**: 900.

5. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. Relationship between lifestyle behaviors and obesity in children ages 9-11: Results from a 12-country study. *Obesity* 2015; **23**(8): 1696-702.

6. Tudor-Locke C, Barreira TV, Schuna JM, Jr., Mire EF, Chaput JP, Fogelholm M, et al. Improving wear time compliance with a 24-hour waist-worn accelerometer protocol in the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE). *Int J Behav Nutr Phys Act* 2015; **12**(1): 172.

7. Barreira TV, Schuna JM, Jr., Mire EF, Katzmarzyk PT, Chaput JP, Leduc G, et al. Identifying children's nocturnal sleep using 24-hour waist accelerometry. *Med Sci Sports Exerc* 2015; **47**: 937-43.

8. Denstel K.D., Broyles ST, Larouche R, Sarmiento OL, Barreira TV, Chaput J-P, et al. Active school transport and weekday physical activity in 9-11 year old children from 12 countries. *Int J Obes Suppl* 2015; **5**(2): S100-S6.

9. Mikkila V, Vepsalainen H, Saloheimo T, Gonzalez SA, Meisel JD, Hu G, et al. An international comparison of dietary patterns in 9-11-year-old children. *Int J Obes Suppl* 2015; **5**(Suppl 2): S17-21.

10. Leventhal T, Brooks-Dunn J. The neighborhoods they live in: The effecst of neighborhood residence on child and adolescent outcomes. *Psychol Bull* 2000; **126**: 309-37.

11. Duncan GJ, Raudenbush SW. Assessing the effects of context in studies of child and youth development. *Educ Psychol* 1999; **34**: 29-41.

12. Gilles-Corti B, Timperio A, Bull F, Pikora T. Understanding physical activity environmental correlates: Increased specificity for ecological models. *Exerc Sport Sci Rev* 2005; **33**: 175-81.

13. Foster GD, Linder B, Baranowski T, Cooper DM, Goldberg L, Harrell JS, et al. A school-based intervention for diabetes risk reduction. *N Engl J Med* 2010; **363**(5): 443-53.

14. Institute of Medicine. Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation Washington, DC: Institute of Medicine; 2012.

15. Bleich SN, Segal J, Wu Y, Wilson R, Wang Y. Systematic review of community-based childhood obesity prevention studies. *Pediatrics* 2013; **132**(1): e201-10.

16. Baranowski T, Lytle L. Should the IDEFICS outcomes have been expected? *Obes Rev* 2015; **16 Suppl 2**: 162-72.

17. De Henauw S, Huybrechts I, De Bourdeaudhuij I, Bammann K, Barba G, Lissner L, et al. Effects of a community-oriented obesity prevention programme on indicators of body fatness in preschool and primary school children. Main results from the IDEFICS study. *Obes Rev* 2015; **16 Suppl 2**: 16-29.

Table Legends

Table 1. Percentage (%) of variance explained at the student, school and study site levels for several anthropometric and lifestyle traits in 6022 9-11 year old children from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE).

Table 2. Percentage (%) of variance explained at the student level and school level for several anthropometric and lifestyle traits across study sites in the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE).

Table 1. Percentage (%) of variance explained at the student, school and study site levels for several anthropometric and lifestyle traits in 6022 9-11 year old children from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE).

	Study Site (Level 3)	School (Level 2)	Student (Level 1)
BMI	4.8	3.3	91.9
Waist Circumference (WC)	3.2	3.4	93.5
Healthy Diet Score (HDS)	7.8	3.9	88.3
Unhealthy Diet Score (UDS)	24.9	8.9	66.2
Sleep Duration	17.1	7.7	75.3
MVPA	9.8	17.6	72.5
Sedentary Time (ST)	14.1	9.0	76.9
In-School MVPA	16.3	29.8	53.8
In-School Sedentary Time	54.2	20.7	25.1

BMI: body mass index; MVPA: moderate-to-vigorous physical activity.

Table 2. Percentage (%) of variance explained at the student level and school level for several anthropometric and lifestyle traits across study sites in the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE).

	BMI		WC		HDS		UDS		Sleep		MVPA		ST		IS-MVPA		IS-ST	
	School	Student	School	Student	School	Student	School	Student	School	Student	School	Student	School	Student	School	Student	School	Student
Australia	2.1	97.9	4.6	95.4	4.4	95.6	2.2	97.8	6.5	93.5	8.6	91.4	5.1	94.9	18.4	81.6	14.0	86.0
Brazil	5.8	94.2	3.6	96.4	0.0	100.0	5.9	94.1	12.9	87.1	8.7	91.3	6.2	93.8	60.8	39.2	71.6	28.4
Canada	4.4	95.6	4.6	95.4	8.0	92.0	13.3	86.7	20.1	79.9	5.7	94.3	13.3	86.7	9.3	90.7	18.4	81.6
China	0.0	100.0	1.0	99.0	4.7	95.3	0.3	99.7	4.9	95.1	7.0	93.0	2.9	97.1	28.3	71.7	4.6	95.4
Colombia	0.9	99.1	2.7	97.3	8.5	91.5	3.4	96.6	1.0	99.0	11.3	88.7	6.7	93.3	36.3	63.7	66.7	33.3
Finland	3.3	96.7	5.0	95.0	0.0	100.0	1.0	99.0	17.6	82.4	13.5	86.5	12.9	87.12	6.0	74.0	53.1	46.9
India	7.6	92.4	5.0	95.0	0.3	99.7	7.6	92.4	5.5	94.5	35.1	64.9	22.7	77.3	50.6	49.4	42.7	57.3
Kenya	18.3	81.7	18.1	81.9	1.8	98.2	7.0	93.0	5.2	94.8	49.9	50.1	21.5	78.5	43.0	57.0	51.6	48.4
Portugal	1.7	98.3	2.5	97.5	5.5	94.5	0.2	99.8	3.8	96.2	6.7	93.3	4.1	95.9	17.0	83.0	14.1	85.9
South Africa	0.0	100.0	0.0	100.0	3.6	96.4	17.9	82.1	12.5	87.5	17.1	82.9	16.2	83.8	19.8	80.2	24.3	75.7
United Kingdom	3.9	96.1	2.4	97.6	7.1	92.9	6.1	93.9	3.5	96.5	13.8	86.2	11.9	88.1	15.3	84.7	36.4	63.6
United States	2.3	97.7	1.5	98.5	4.6	95.4	27.4	72.6	8.6	91.4	10.9	89.1	8.4	91.6	40.9	59.1	19.7	80.3

BMI: body mass index; WC: waist circumference; HDS: healthy diet score; UDS: unhealthy diet score; MVPA: moderate-to-vigorous physical activity; ST: sedentary time; IS: in-school.