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SHORT COMMUNICATION

Utility of pedometer step recommendations for predicting overweight in children

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Objective: The purpose of this study was to examine the utility of pedometer-based physical activity recommendations in predicting childhood adiposity.
Design: Subjects ($n = 608$) (9.6 years) were from two Midwestern USA communities. Physical activity was assessed by a pedometer. The percentage of subjects meeting physical activity recommendations was determined using published recommendations. Overweight and obesity were determined based on reference values for the body mass index (BMI) developed by the International Obesity Task Force. An elevated waist circumference (WC) was determined based on age- and sex-specific reference values $>$75th percentile.
Results: Children who did not meet the pedometer recommendations were about two times more likely to be overweight/obese and have an elevated WC compared with those meeting recommendations. The BMI and WC were significantly different across pedometer step count groups in males and females.
Conclusion: Subjects not meeting the recommendations for steps per day were more likely to be classified with the overweight phenotype than those meeting the recommendation. A dose–response relationship between pedometer steps per day and adiposity is also apparent.
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Introduction

The pedometer has become a popular physical activity assessment tool.[1] Recently, two recommendations for the number of steps per day were suggested for children.[2,3] However, no studies have tested the utility of the current pedometer-based recommendations in predicting health outcomes. Furthermore, there is little evidence for a dose–response relationship from which physical activity guidelines can be obtained.[4] Therefore, the purpose of this study was to examine the utility of pedometer-based physical activity recommendations in predicting childhood adiposity and examine the dose–response relationship between pedometer steps per day and adiposity measures in children.

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Methods

Subjects

The subjects (mean age $= 9.6$ years) were from two Midwestern communities. Parental consent and child assent were obtained before data collection. The study protocol was approved by the University of Minnesota Human Subjects Review Board. A total of 1370 children were enrolled but owing to non-compliance for monitoring of physical activity or missing data for either physical activity, anthropometry or covariates, the sample size was reduced to $n = 608$ for this analysis.

Habitual physical activity

Habitual, free-living physical activity was assessed by a pedometer (Digiwalker 200 SW). The subjects were given instructions on wearing the pedometer during the school day and recorded the time on/time off, and number of steps accumulated over a 7-day period. Participants were included in the analysis only if they had at least 4 days (3 weekdays and 1 weekend), when the pedometer was worn for at least 10 h. From the total sample of subjects 826 subjects (63% of total sample) met the inclusion criteria. The classification of physical (in)activity was determined using two published recommendations. The first is a norm-referenced criterion[2] (13 000 and 11 000 steps/day for boys and girls, respectively) and the second is a criterion-referenced cutpoint[3] (15 000 and 12 000 steps/day for boys and girls, respectively).

Anthropometry

The body mass index (BMI, kg/m^2) was calculated from measurements of standing height and body mass. Overweight and obesity were determined based on age- and sex-specific reference values developed by the International Obesity Task Force,[5] which are anchored to adult values for overweight and obesity at the age of 18 years and back-extrapolated. Waist circumference (WC) was measured above the superior border of the iliac crest as an indicator of central adiposity using a Gullick tape to the nearest 0.1 cm. An elevated WC was determined based on age- and sex-specific reference values >75th percentile.[6]

Statistical analysis

Analyses were conducted on subjects with complete data for anthropometry, physical activity and covaritates ($n = 608$). Partial correlations, controlling for age, ethnicity and parental income, were determined. Logistic regression models controlling for age, ethnicity and parental income were used to calculate odds ratios (ORs) for those not meeting pedometer recommendations. To examine the dose–response relationship, the sample was stratified into physical activity groups based on quartiles of pedometer steps per day. Differences across physical activity groups for adiposity variables were assessed by analysis of covariance, controlling for age, ethnicity and parental income. ORs and 95% confidence intervals were calculated for each model in SPSS (SPSS Inc., Chicago, IL, USA).

Results

The mean (s.d.) number of steps per day for boys, girls and sexes combined were 12 709 (3384), 10 834 (2562) and 11 665 (3028), respectively. Approximately 25–30% of children are overweight or obese and have an elevated WC.

The partial correlation between pedometer steps and BMI was –0.22 in boys and –0.25 in girls, whereas the partial correlation between pedometer steps and WC was –0.28 in boys and girls. Results of the logistic regression analysis for PA and BMI are shown in Table 1. In general, children who did not meet the pedometer steps per day guidelines were about two times more likely to be classified as overweight/obese compared with those meeting physical activity recommendations. When analyzing boys and girls separately, an increased risk was still apparent but somewhat larger for boys, especially when utilizing the Tudor–Locke guidelines (boys$\approx$2.3 and girls$\approx$1.8). Similar results were found for children with a WC $\geqslant$75th percentile.

Adjusted means for adiposity measures within each physical activity group are shown in Table 2. BMI and WC were significantly different across pedometer step count groups in male subjects ($F = 4.28$, $P < 0.005$ and $F = 6.85$, $P < 0.0001$, respectively) and female subjects ($F = 5.99$, $P < 0.001$ and $F = 7.96$, $P < 0.0001$). The corresponding percentage of elevated BMI and WC also followed the same pattern.

Discussion

To our knowledge, this is the first report to examine the utility of these recommendations for predicting childhood overweight/obesity and central adiposity. The results indicate that those subjects not meeting pedometer-based physical activity recommendations had a two-fold increased

Table 1 ORs for BMI asssessed overweight and WC $\geqslant$75th percentile by step guidelines for boys and girls

Guideline	*BMI*				*WC*			
	Crude		*Adjusted*		*Crude*		*Adjusted*	
	OR	*95% CI*	*OR*	*95% CI*	*OR*	*95% CI*	*OR*	*95% CI*
Boys								
Vincent and Pangrazi	2.38	1.40–4.06	2.05	1.13–3.73	2.28	1.34–3.89	2.18	1.19–3.99
Tudor-Locke	3.26	1.55–6.80	2.46	1.13–5.32	3.11	1.48–6.52	2.36	1.09–5.10
Girls								
Vincent and Pangrazi	2.31	1.51–3.53	1.92	1.18–3.15	2.24	1.46–3.44	1.91	1.17–3.11
Tudor-Locke	2.00	1.25–3.19	1.76	1.03–3.02	1.98	1.23–3.19	1.88	1.09–3.23
Combined sexes								
Vincent and Pangrazi	2.30	1.65–3.20	1.95	1.34–2.85	2.22	1.59–3.10	1.98	1.36–2.89
Tudor-Locke	2.24	1.52–3.31	1.92	1.24–2.98	2.21	1.49– 3.27	1.97	1.27–3.06

Abbreviations: CI, confidence interval; BMI, body mass index; OR, odds ratio; WC, waist circumference. Adjusted for age, ethnicity and parental income. Vincent and Pangrazi Guideline (2002) = 13 000 steps/day for boys and 11 000 steps/day for girls. Tudor-Locke Guideline (2004) = 15 000 steps/day for boys and 12 000 steps/day for girls.

Table 2 Differences in adiposity measures across pedometer steps count groups among children

	<10000 steps	*10 000–12 000 steps*	*12 000–14 000 steps*	*>14 000 steps*
Boys (*n*)	52	65	65	87
BMI (kg/m^2)	19.7 (0.4)	18.5 (0.4)	18.1 (0.4)[a]	17.7 (0.3)[a]
WC (cm)	67.4 (1.2)	64.3 (1.1)	63.5 (1.1)[a]	60.8 (0.9)[a,b]
% Overweight/obese	40.4	29.2	23.1	13.8
% WC ⩾75th	36.5	29.2	24.6	12.6
Girls (*n*)	115	110	77	37
BMI (kg/m^2)	19.5 (0.3)	17.9 (0.3)[a]	17.8 (0.4)[a]	17.4 (0.6)[a]
WC (cm)	66.8 (0.9)	61.7 (0.9)[a]	62.4 (1.1)[a]	59.8 (1.6)[a]
% Overweight/obese	40.9	22.7	26.0	10.8
% WC ⩾75th	42.6	21.8	24.7	10.8

Abbreviations: BMI, body mass index; WC, waist circumference; s.e., standard error. Values are adjusted means (s.e.). [a]Significantly different from <10 000 steps/day. [b]Significantly different from 10 000–12 000 steps/day.

risk of being classified as overweight/obese. Furthermore, there appears to be a dose–response relationship between steps per day and adiposity measures.

In general, the impact of physical activity on adiposity has been studied extensively;[7] yet, results are mixed with regards to the strength of the association. Several other cross-sectional studies have shown that the correlation between physical activity and adiposity measures is <0.30,[8,9] which is consistent with the results obtained here. On the other hand, fewer studies have employed logistic regression to examine the relationship between physical activity and overweight among children.[10–14] In this study, we showed a two-fold increase in the risk of overweight/obesity or elevated WC among those not meeting step count recommendations, which is a stronger OR than previous studies.

This study is also unique in that it also examined if a dose–response relationship existed between pedometer steps and adiposity measures. It has been noted that to establish recommendations for an appropriate exercise prescription or general statement regarding physical activity and health requires empirical data to support some minimal, adequate or optimal level of physical activity.[15] Few studies have purposefully examined this issue in children or adolescents. Our results suggest a graded relationship between pedometer step groups, and BMI and WC. In the study by Vincent *et al.*,[16] there was a graded relationship across tertiles and prevalence of overweight/obesity for Swedish and US but not Australian youth.

It is important to understand that the findings of this cross-sectional study limits inference about the direction of causality. Indeed, it could equally be stated that overweight is associated with low levels of physical activity. Using an experimentally induced human obesity model, Sims *et al.*[17] showed that overfeeding normal-weight young men resulted in weight gain and decreases in physical activity. This finding along with the recent discoveries in adipocyte biology that some adipokines may regulate energy homeostasis[18] suggests that the results here should not been viewed as low levels of physical activity causing overweight. On the other hand, the mere purpose of this paper was to describe the practical/clinical importance of a physical activity recommendation using an instrument that is becoming increasingly popular – the pedometer – to establish the association between meeting or not meeting recommendations and risk of overweight. Future research should employ a prospective cohort and examine the association between baseline physical activity (meeting or not meeting recommendations) and risk of developing overweight.

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