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Pedometer step count and BMI of Irish primary school children aged 6–9 years

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ABSTRACT

Objective. (1) To assess step count and Body Mass Index in Irish children, (2) to examine variation in (i) weekday and weekend activity, (ii) during-school and after-school activity, and (3) to evaluate the utility of pedometer based PA recommendations for health in predicting Body Mass Index.

Methods. Three hundred and one Irish primary school children aged 6–9 years wore a sealed pedometer for seven consecutive days in 2008, had their height and weight measured, and completed a short Physical Activity questionnaire.

Results. The majority of children were classed as of normal weight, and met the age and sex specific pedometer recommendations for health. Children took significantly more steps at weekends than on weekdays, and after school than during school. A child being classed as normal or overweight/obese based on Body Mass Index did not predict the likelihood of them meeting the pedometer recommendations.

Conclusions. The majority of children were achieving sufficient steps/day for health but interventions to target those falling short should be considered. Further research examining the relationship between steps per day and Body Mass Index is warranted.

Introduction

Despite the increasing recognition of the health benefits associated with PA participation (Pate et al., 1995; Strong et al., 2005; Department of Health and Children, 2005), high proportions of youth in Europe and the United States do not meet current PA guidelines highlighting the importance of promoting a physically active lifestyle among youth (Riddoch et al., 2004; Sallis and Owen, 1999). It is a much stated belief that PA levels in childhood and adolescence have long term effects which influence health into adulthood (Malina and Bouchard, 1991; McManus, 2000; Van Beurdan et al., 2003). It has also been suggested that many of the behavior patterns that impact on PA experiences are established in early childhood (Telama et al., 1997; Hands et al., 2006), further amplifying the need for the accurate measurement of PA in children from an early age.

There are difficulties with all measures of PA (Freedson and Miller, 2000; Tudor-Locke et al., 2004a), and no one measure is suitable for all purposes (Sallis et al., 1993). Pedometers offer a practical and affordable objective method of assessing PA levels in varying populations; although pedometers are not able to discriminate between intensities of PA, they do provide a simple means of tracking daily PA expressed as a summary output of steps/day (Tudor-Locke et al., 2008). In a review of 25 articles Tudor-Locker et al. (2002) found that pedometers correlated strongly with both accelerometers (median $r = 0.86$) and time in observed activity (median $r = 0.82$). In order to achieve health benefits from PA, Tudor-Locke et al. (2004b) established that the average age and sex specific pedometer cut points should be 12,000 steps/day for girls and 15,000 steps/day for boys. These criterion-referenced cut points were derived as optimal cut points separating normal-weight and overweight/obese students (aged 6–12 years), with children averaging fewer steps than the cut-off point per day deemed more likely to be labeled as overweight or obese.

Results of a study carried out by Eisenman et al. (2007) indicated that US children (aged 9.6 years) not meeting the Tudor-Locke et al. (2004b) pedometer-based PA recommendations were twice as likely to be classed as overweight/obese. Cox et al. (2006) compared during-school step count and after-school step count in an effort to gather more information on the habitual PA patterns of New Zealand children (aged 5–11 years). It was found that boys were significantly more active than girls and that for the overall sample, steps taken out of school made up 52.4% of total daily steps. Duncan et al. (2006) examined the PA levels of 208 British children (aged 9.6 ± 0.9 years) via pedometer. Children were found to have significantly higher mean steps/day on weekdays than weekends, with boys achieving significantly higher mean steps/day than girls. When the Tudor-Locke et al. (2004b) cut points were applied to the data only 28.7% of boys and 46.7% of girls met or exceeded the thresholds. The authors highlighted a lack of studies examining children's step patterns across weekday and weekend days, and identified the need for more such studies examining the number of children meeting the Tudor-Locke

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et al. (2004b) BMI referenced cut-points for health. In addition the importance of more studies, such as that carried out by Cox et al. (2006), distinguishing between in school and after-school activity was identified.

The aims of the current study were (i) to provide information on the number of Irish school children, aged 6–9 years, meeting the Tudor-Locke et al. (2004b) pedometer cut points, (ii) to examine any differences in step count across weekday and weekend day, and in the during school and after-school periods, and (iii) to further examine the relationship between step-count and BMI.

Methods

Participants and recruitment

Four mixed gender primary schools (representing urban, suburban and rural) across the greater Dublin area were selected for participation in this study (approximately 430 primary schools in this area). All children from second and third class within each school were invited to take part in the study; 301 children from a possible total of 311 volunteered to participate. Fifty one percent of participants were boys ($n=153$), and 49% were girls ($n=148$). Participants were aged between 6 and 9 years (7.8 ± .58 years). Informed consent for participation was granted by each child and their parent/guardian; all children were free to withdraw from participation in the research at any stage. Full approval for this study was given by the institutional research ethics committee.

Procedures

PA was assessed using a Yamax Digiwalker SW200 pedometer (with a tamperproof cover) worn over 7 days. On the first day of monitoring children were instructed on how to attach the pedometer (midline of the thigh at waist level), and how to remove it. Children were asked to wear the pedometer during all waking hours unless showering, swimming or taking part in a contact activity for which an adult deemed it unsafe to wear. The child's parent/guardian and class teacher were given a recording sheet on which to record the step counts of each child—teachers recorded each child's step count at the start and end of each school day, while parents recorded step count first thing in the morning on each weekend day. Parents or teachers noted on the record sheet if the child had forgotten to wear the pedometer for a significant period of the day (more than 1 h) outside of swimming/taking part in a contact activity etc. The investigator collected each monitor from the school on the morning of the eighth day. Body mass (kg) and height (m) were directly measured using a SECA Leicester Portable Height Measure and SECA heavy duty scales on the morning of the first day of monitoring.

BMI for each child was calculated using the formula weight/(height^2) and the International Obesity Task Force cut-off points derived by Cole et al. (2000) were applied to the data to classify weight status. The first days pedometer monitoring was omitted from analysis to allow for differing administration times, and any reactivity to wearing the pedometer (Rowe et al., 2004). Average pedometer counts were calculated from the data for the following time periods—(i) Overall week: average step count for at least three weekday's data plus one weekend day's data. (ii) Weekday: average step count for at least three weekdays data. (iii) Weekend: average step count for Saturday or Sunday data, or average step count for Saturday and Sunday. (iv) During school: average step count for at least three weekdays during school hours. (v) After school: average step count for at least three weekdays excluding school hours.

For a variety of reasons (child forgetting to wear the pedometer, teacher or parent forgetting to record steps, loss of monitor, and monitor failure) full pedometer data was not available for all children for all time periods. If a child did not have, for example, three weekdays plus one weekend days data they were eliminated from the 'Overall week average' calculation. In addition if it had been noted on the record form that the child had forgotten to wear the pedometer for a significant portion of any time period the data from that time period was similarly excluded from analysis. This did not however preclude the child from contributing pedometer data to the other time periods where it was available. For this reason there is large variation in the sample sizes for the different time periods. The proportion of normal weight, overweight and obese children meeting the Tudor-Locke et al. (2004b) cut off points were calculated using the overall week average for each child.

Statistical analysis

Independent samples t-tests were used to identify any significant gender differences for BMI and pedometer steps in each of the five time periods. Independent sample t-tests were also used to identify significant differences in terms of height, weight, BMI and age between children that had pedometer data included and excluded from the five time periods. Paired sample t-tests were used to compare the step counts in the Weekday and Weekend periods, and the During school and After school periods. A logistic regression with meeting pedometer cut point as the dependant variable, and age (in years), gender (male or female) and BMI category (normal or overweight/obese) as predictor variables was used to examine the relationship between meeting pedometer recommendations and BMI, gender and age. To examine the relationship between step count in the five time periods and BMI, gender and age, multiple regression analysis was carried out with the average steps taken in each of the five time periods as dependant variables, and BMI, gender and age as predictor variables. The alpha level for analysis was set at $p<0.05$. A series of one-way ANOVA's with a conservative alpha of $p<0.01$ (due to multiple comparisons) were further used to explore variation in step count in each of the five time periods across BMI category (normal, overweight and obese).

Results

The mean (SD) for children's anthropometric characteristics and average step counts in each of the time periods are shown in Table 1. No significant gender differences were found for BMI, but boys were found to take significantly more steps than girls in the Overall week ($p=0.005$), the Weekday ($p=0.010$) and the During school periods ($p=0.000$). No significant difference between children included/excluded in any of the five time periods was found for height, weight, BMI or age, with the exception of a significant age difference ($p=0.032$) in the 'during school' period. Mean (SD) for step counts according to weight status are shown in Table 2; 68.5% achieved the age and sex specific BMI referenced pedometer cut off points derived by Tudor-Locke et al. (2004b) (62.2% male, 74.7% female). Children had a mean BMI of 16. 9 kg/m^2 ± 2.55. When the Cole et al. (2000) cut off's were applied 79.4% were of normal weight, 14.6% were overweight, and 6% were obese.

Paired samples t-tests showed that children took significantly more steps on weekends than on weekdays ($p=0.00$), and after school than during school ($p=0.00$). Logistic regression showed a small increase in the overall percentage of correctly classified cases (from 68.2% to 69.3%) when the predictors (age, gender and BMI)

Table 1
The anthropometric characteristics and mean (SD) values for step counts of Irish primary school children in 2008.

	Height (m)	Mass (kg)	BMI (kg/m^2)	Overall week	Weekday	Weekend	During school	After school
	($n=148$)	($n=148$)	($n=148$)	($n=91$)	($n=132$)	($n=116$)	($n=141$)	($n=130$)
Girl ($n=148$)	1.28 (.07)	28.0 (6.7)	16.9 (2.7)	14710 (4276)	10434 (3268)	32768 (15762)	3665 (1077)	6756 (2903)
	($n=153$)	($n=153$)	($n=153$)	($n=90$)	($n=132$)	($n=114$)	($n=147$)	($n=128$)
Boy ($n=153$)	1.31 (.06)	29.2 (6.1)	17.0 (2.4)	16821 (5575)	11463 (3129)	37009 (17663)	4223 (1156)	7229 (3123)
	($n=301$)	($n=301$)	($n=301$)	($n=181$)	($n=264$)	($n=230$)	($n=288$)	($n=258$)
Total ($n=301$)	1.29 (.07)	28.7 (6.4)	16.9 (2.6)	15760 (5062)	10948 (3234)	34870 (16829)	3950 (1150)	6991 (3018)

Table 2
The mean (SD) values for step counts according to weight status of Irish primary school children in 2008.

Cole et al. cut offs		Overall week	Weekday	Weekend	During school	After school
Normal weight ($n=225$)	n	143	206	177	225	199
	Mean (SD)	16281 (5095)	11391 (3162)	36327 (16990)	4040 (1146)	7374 (3096)
Overweight ($n=43$)	n	29	42	37	43	41
	Mean (SD)	13859 (4308)	9622 (2801)	30508 (14623)	3781 (1030)	5820 (2117)
Obese ($n=17$)	n	7	13	12	17	14
	Mean (SD)	12937 (5864)	7757 (2567)	27637 (16386)	3229 (1297)	4814 (2282)

were entered into the model. Further analysis of results shows that both age ($p=0.007$, B = 0.817, OR = 0.454) and gender ($p=0.021$, B = -.791, OR = 2.265) contributed significantly to the predictive ability of the model, but that BMI did not. Results of the five multiple regression analyses carried out are given in Table 3 and show that very little of the variation in step count in any of the five time periods can be explained by BMI, age or gender. The highest R^2 found was 0.104, with Weekday average step counts as the dependant variable; BMI made the strongest unique contribution to explaining Weekday average step count ($p=0.256$). Using one-way ANOVA's significant differences were found in normal and overweight, and normal and obese children's step counts in the Weekday and the After school periods.

Discussion

The high average daily step counts, and large percentage of children meeting the Tudor-Locke et al. (2004b) cut off points (identified as the minimum needed in order to achieve health benefits) in this study are encouraging (62.2% male, 74.7% female) but it must be noted that they are in contrast to the findings of similar studies in other countries including England (Duncan et al., 2006), and the United States (Laurson et al., 2008). This variation in step count across countries does not appear to be unusual as documented by Vincent et al. (2003). The averages detailed in the current study are most consistent with those reported in a cohort of Swedish children aged 6–12 years (Vincent et al., 2003), and of Cypriot children aged 11–12 years (Loucaides et al., 2003). Children in the current study were also found to be significantly more active on weekends than on weekdays which again is in contrast to the findings of Duncan et al. (2006). This disparity in findings adds to the growing body of literature on either side of the weekday versus weekend PA debate (Duncan et al., 2006). The large standard deviations for average weekend step count in the current study are worth noting as they reflect the large variation in different children's physical activity patterns over the weekend period.

The findings in the current study in relation to during school and after school activity are consistent with those of Loucaides et al. (2003), where it was reported that the cohort of Cypriot children accumulated significantly more mean steps after school than during school. The study carried out by Cox et al. (2006) also reflects this finding to a lesser extent. The during and after school average step counts for both males and females were considerably lower in the current study however than those reported in the Loucaides et al. and the Cox et al. research. Within school children are seated for large periods of the day, and opportunities for physical activity are limited to the two break periods (10 and 30 min) and school physical education lessons (61.7 ± 20.3 min/week; Broderick and Shiel, 2000). Targeted interventions to help maximize physical activity participation during these periods could have a significant effect on the average step count of lesser active children, and particularly females who were shown to be less active than males in the during school period.

Results of logistic regression analysis indicate that boys were .454 times less likely than girls to meet the pedometer cut points, and that older children were approximately twice as likely to meet these recommendations than their younger counterparts. Independent sample *t*-tests showed that boys took significantly more steps than girls in three of the five reported time-periods; it is important to note however that due to the lower cut-point for girls, girls were significantly more likely to accumulate the quantity of steps identified as necessary for health benefits.

Results of multiple regression analysis in the current study showed that very little of the variation in step count in any of the five time periods can be explained by BMI, age or gender. A child being classed as normal or overweight/obese based on BMI was not found (using logistic regression) to predict the likelihood of them meeting the pedometer-based PA recommendations. This is in contrast to a recent study (Eisenman et al., 2007) which found that children (aged 9.6 years) not meeting the Tudor-Locke et al. (2004b) pedometer recommendations were twice as likely to be classed as overweight/obese. This contrast in findings is possibly a result of the higher proportion of children meeting the pedometer recommendations (69%), and classed as normal weight (79%) in the current study. It is worth noting however a recent study carried out by Beets et al. (2008) who found that the utility of these pedometer step counts in a US sample was minimal due to their inability to differentiate between children of a healthy or unhealthy weight. Further research examining the utility of these recommendations with larger samples, across a broader span of age groups, and across different countries is warranted.

Study limitations and strengths

The small age range of this study (6–9 years) is a limiting factor. Also as the sample of participants were all drawn from schools in the greater Dublin area caution should be taken when generalizing these results to the 6–9 year old Irish population. The long monitoring period (7 days, minimum of 4 days used in overall average calculations) is strength of the study, but the fact that the full 4 days monitoring were not available for all participants should be noted.

Conclusion

Findings of this study add to the growing body of literature on step counts and PA patterns of children. Although findings in relation to step count are positive in terms of international comparisons, concern is warranted for those children not meeting the pedometer or BMI cut points. Findings support the need for specific interventions targeting children's during school and after school activity participation in an effort to improve these figures.

Table 3
Results of multiple regression analysis examining variation with BMI, age and gender as predictor variables in Irish primary school children in 2008.

Independent variables (average step count)	R^2	ANOVA (sig)	Predictor variables (Beta (sig))		
			BMI	Gender	Age
Overall week	0.087	0.001	-0.144 (0.05)	0.189 (0.010)	0.173 (0.020)
Weekday	0.104	0.000	-0.256 (0.000)	0.145 (0.015)	0.153 (0.011)
Weekend	0.046	0.015	-0.127 (0.056)	0.112 (0.093)	0.137 (0.041)
During school	0.081	0.000	-0.148 (0.011)	0.247 (0.000)	-0.009 (0.879)
After school	0.077	0.000	-0.217 (0.000)	0.063 (0.306)	0.184 (0.003)

Conflict of interest

The authors declare that there are no conflicts of interest.

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