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Running Title: Daily step count targets for the early years

ABSTRACT

Purpose: New physical activity guidelines recommend that children aged 3 to 4 years should accumulate at least 180 min of physical activity at any intensity spread throughout the day, including progression toward at least 60 min of energetic play by 5 years of age. Step count targets corresponding to these recommendations will help practitioners and researchers monitor physical activity.

Methods: One hundred and thirty-three preschoolers were instructed to wear accelerometers for 7 consecutive days. Activity and step count data were recorded in 3-sec epochs. Step count targets equivalent to physical activity recommendations were derived using prediction equations from regression analyses. Receiver operating curve analyses were conducted to compare the sensitivity and specificity of the derived thresholds as well as a range of other targets.

Results: The daily step count target derived for 180 min of physical activity of any intensity was 6013 ± 88, while the target for 180 min of physical activity of any intensity including at least 60 min of MVPA was 6191 ± 103. The smallest discrepancy between days meeting physical activity guidelines and step count targets was found with a 6000 steps per day target. Receiver operating curves confirmed a balanced sensitivity and specificity of this target.

Conclusion: Based on our data we suggest a new step count target of 6000 steps per day should be used to determine if 3- to 5-year old children are meeting physical activity recommendations.

Keywords: preschool, pedometer, stepping, accelerometry, health, child

INTRODUCTION

Canadian physical activity guidelines for the early years have recently been developed, based on the best available evidence, expert opinion, and a rigorous and transparent guideline development process (16). These new guidelines recommend that children aged 3 to 4 years should accumulate at least 180 min of physical activity *at any intensity* spread throughout the day, including progression toward at least 60 min of energetic play by 5 years of age. Energetic play in this context refers to moderate-to-vigorous physical activity (MVPA). Other countries have released similar, evidence-based guidelines specific to the early years (1,5)(1,5). In light of these recent efforts to provide evidence based physical activity recommendations for the early years, surveillance is required to evaluate the proportion of children meeting the guidelines, which are designed to promote healthy growth and development.

Accelerometry is the instrument of choice for many physical activity researchers as it objectively measures the frequency, intensity, and duration of movement. However, because this tool is expensive and requires complex software for data analysis, it may be less suitable for use in a clinical or public health setting. Pedometry, on the other hand, is a comparatively simple and inexpensive tool that objectively assesses step counts. Daily step count thresholds coinciding with recommendations for minutes of physical activity are necessary to add meaning to pedometry measurements. Currently, no such thresholds specific to the new physical activity recommendations for the early years exist. Step count thresholds corresponding to 60 min of MVPA were recently reported for 6-19 year olds (4). However, it is not known if the proposed recommendation of 12,000 steps per day (4) is also appropriate for children under the age of 6 years.

The purpose of this study was to determine thresholds for daily step counts for 3- to 5-year old children meeting 180 minutes of physical activity at any intensity and 180 minutes of physical activity at any intensity, including at least 60 min of MVPA. As many physical activity recommendations differentiate between children under 5 years of age and children 5 years and older, a secondary objective of this study will investigate if different step count thresholds are appropriate for 3- to 4-year olds and 5-year olds.

METHODS

Sample

The HOPP (Health Outcomes and Physical activity in Preschoolers) Study is an ongoing longitudinal project, collecting data from children age 3 to 5 years at baseline (15). One hundred and thirty-three preschoolers (70 boys, 63 girls) from the HOPP Study and an earlier cohort (7,10) participated in this retrospective study. Participants were recruited from the South-central region of the largest Canadian province, Ontario, using a community-based sampling procedure. All participants were free of medical conditions (e.g. heart disease, diabetes, epilepsy) or physical limitations that might limit them from engaging in physical activity or exercise. The Hamilton Health Sciences/Faculty of Health Sciences Research Ethics Board approved this study. Parents or guardians provided written informed consent prior to their child's participation in the study.

Anthropometric Assessment

We performed standard anthropometric measurements of height to the nearest 0.1 cm using a calibrated stadiometer. Weight was measured to the nearest 0.1 kg using a digital scale (BWB-800, Tanita Corporation, Japan) while wearing light clothing. The average of two measures was taken for both height and weight. BMI was calculated as kg/m^2. The Centre for Disease Control (CDC) data were used to identify overweight or obese participants (8).

Physical Activity Assessment

Data were collected from June 2009 to December 2011. Physical activity and step counts were measured concurrently using the ActiGraph GT3XE or GT1M accelerometers (Fort Walton Beach, FL, USA), as previously described (7,10)(5; 8). Physical activity and step counts were recorded in 3-sec epochs. Step counts measured with these accelerometers are strongly related to those assessed by a common pedometer (Yamax Digi-Walker SW-200) (6). Accelerometers were instructed to be worn during all waking hours, except when engaging in water activities. Parents were given a logbook to record the times of the day the accelerometer was put on and removed.

Accelerometer data were visually inspected to ensure the time recorded in the activity logbook matched the accelerometer output. Any activity or step counts during reported times of non-wear, as indicated in the logbook, were deleted. All remaining zero counts were treated as sedentary time. The data were uploaded to a Microsoft Excel-based Visual Basic for Applications data reduction program to determine physical activity. Physical activity was defined using common cut-points (13) from a previous validation study in a healthy sample of 3-

to 5-year olds (12,19). Because Pate et al. (12) used 15-sec epochs, we divided their cut-points by five to use with our 3-sec epochs, as in our previous work (7,10). Total physical activity (light physical activity + MVPA) was indicated as ≥8 counts/3-sec and MVPA as ≥84 counts/3-sec. Minutes of physical activity and step counts were summed for each day of wear. All days the participants wore the accelerometer for ≥10h were considered 'valid days' and were included in physical activity analyses. Meeting physical activity guidelines was defined as having met or exceeded the activity recommendations on every valid day of accelerometer wear.

Statistical Analyses

All data are presented as mean ± standard deviation (SD), unless otherwise noted. Statistical significance was set at $p \leq 0.05$. Step count thresholds corresponding with 180 min of physical activity of any intensity and 180 minutes of physical activity of any intensity including at least 60 min of MVPA were derived using prediction equations developed from regression analyses. Comparisons were made between the proportion of days meeting physical activity recommendations and step count targets. Receiver operating curve (ROC) analyses were conducted to determine the sensitivity and specificity of the derived thresholds, as well as a range of other possible thresholds at 500 step intervals. In preliminary analyses, age, but not sex was a significant predictor of physical activity and step counts. To assess our secondary objective, all analyses were conducted in 2 age groupings (3- to 4-year olds and 5-year olds). All analyses were performed in SPSS for Windows 18.0 (SSPS Inc, Chicago, IL, USA).

RESULTS

Seven hundred and twenty-five days of physical activity and step count monitoring were included in the analyses. Accelerometers were worn by participants for an average of 5.5 ± 1.3 days and for a minimum of 3 days. Participant characteristics, including average daily physical activity and step counts are presented in Table 1.

Daily step counts were positively correlated with total min of physical activity ($r = 0.76$, $p < 0.001$) and min of MVPA ($r = 0.76$, $p < 0.001$). The strength of the relationship was similar among age groupings (Table 2). Monitoring days meeting the recommendation of 180 min of physical activity of any intensity recorded 9338 ± 2544 steps (range: 4333 – 23347; Figure 1), while those days not meeting recorded 5088 ± 1220 steps (range: 3255 – 8251; Figure 1). Monitoring days meeting the recommendation of 180 min of physical activity of any intensity including at least 60 min of MVPA recorded 9557 ± 2475 steps (range: 4894 – 23347), while those days not meeting recorded 5601 ± 1248 steps (range: 3255 – 8377).

Prediction equations derived from the regression analyses are presented in Table 2. Corresponding step count thresholds from the prediction equations were lower in the 3- to 4-year old grouping compared to the 5-year old grouping; this difference averaged around 400-600 steps/day (Table 2). The R^2 of the prediction equations ranged from 0.56 – 0.59 for analyses of 180 min physical activity of any intensity and 0.59 – 0.61 for analyses of the 180 min of physical activity of any intensity including at least 60 min of MVPA.

Comparison of three different step count thresholds (6000, 6500, and 7000) indicated that the 6000 step count threshold provided the smallest discrepancy between days meeting both physical activity recommendations and days meeting the step count target, except for the oldest

age grouping for the 180 min of physical activity of any intensity including at least 60 min MVPA threshold (Table 3).

Resulting ROC analyses demonstrated good efficacy for assessing physical activity recommendations based on step counts. The area under the curve (AUC) was 0.952 and 0.945 for 180 min of physical activity of any intensity and 180 min of physical activity of any intensity including at least 60 min of MVPA daily, respectively. ROC analyses revealed that a slightly higher step count target for the 180 min of physical activity including at least 60 min of MVPA recommendation was necessary to provide more balanced sensitivity and specificity compared to the 180 min of physical activity recommendations (Figure 2 and 3). Nevertheless, a single cut point for both recommendations would be more practical for clinical and research use. Therefore, due to its sample-specific predictive value (Table 3) and decent sensitivity (0.74, 0.62) and specificity (0.94, 0.96) for both recommendations (Figure 2 and 3), the 6000-step count threshold was chosen as the most appropriate step count target.

In calculating the proportion of participants meeting physical activity guidelines and step count targets, participants were required to meet the recommendations on each day the accelerometer was worn (e.g. participants were only classified as having met the recommendations if prescribed physical activity levels were achieved on all days he/she was monitored). Note that these values are distinct from those presented in Table 3, which evaluated all monitoring days independent of the participants. Seventy-three and 57% of participants achieved the recommended 180 min of physical activity of any intensity and 180 min of physical activity of any intensity, including at least 60 min of MVPA every day, respectively. Sixty-five, 51, and 40% of participants met daily step count targets of 6000, 6500, and 7000 steps, respectively.

DISCUSSION

The main objective of this study was to determine step count thresholds corresponding to new physical activity guidelines for the early years. We propose a new step count target of 6000 steps per day for children ages 3 to 5 years. To our knowledge, this is the first step count target derived from evidence-based recommendations specific to preschoolers.

The new Canadian physical activity guidelines for the early years recommend 180 min of physical activity at any intensity spread throughout the day, including progression toward at least 60 min of energetic play by 5 years of age (16). One limitation to broad surveillance of these guidelines is the lack of a corresponding step count target that can be used to evaluate adherence to physical activity recommendations. Therefore, step count targets derived to align with physical activity recommendations will be useful for monitoring the health of young children.

To test the suitability of our proposed step count target, we compared the proportion of *days* meeting the step count target and physical activity recommendations. Disparities between the two were small when using the 6000 steps per day target, ranging from a difference of 0.4 to 6.3% across age groupings (Table 3). Furthermore, we also compared the proportion of *participants* classified as meeting the step count and physical activity recommendations. To meet recommendations, participants had to achieve these targets every day they wore the accelerometer. Using the 6000 steps per day target, 65% of our participants met the recommendation every day, a value in between the proportion of preschoolers meeting 180 minutes of physical activity of any intensity (73%) and 180 minutes of physical activity of any intensity including at least 60 min of MVPA (57%), every day.

A common finding during the early years is an increase in physical activity and/or step counts with age (7,9,11)(6,8,10). To determine if the same step count thresholds are appropriate for the entire 3- to 5-year old age range, we performed analyses for two age groupings: 3- to 4-year olds and 5-year olds. Male and female data were analyzed together, as in agreement with others (3,9), we did not observed a sex-related difference in step count. Although our predicted equations indicated slightly higher step count targets for the older children (6486 and 6577 vs. 5868 and 6146), the 6000 step target indicated a similar proportion of days meeting both the step count and the physical activity recommendation. Thus, we propose that 6000 steps per day is an appropriate target to determine if 3-to 5-year old children are meeting the recommendations of 180 min of any physical activity of intensity and 180 min of physical activity of any intensity including at least 60 min of MVPA.

The average daily step count of 8968 (± 1855) observed in our study was similar to the 9,980 (± 2,605) observed by Cardon and colleagues (3) in a smaller sample of 4- to 5-year old children living in Belgium. Our study and others (3,10,14)[4,8–10] observed a similar strength of relationship between daily step count and min of physical activity, indicating the appropriateness of accelerometry to derive step count targets. Despite these similarities, children in our study were significantly more physically active compared with the study by Cardon et al. (3): 93 vs. 34 min of MVPA, respectively. This disparity can most likely be explained by the use of different accelerometer cut-points. Although choosing appropriate cut-points from the many options available remains a contentious issue, we are confident that the physical activity levels observed in our study are representative of the preschool population, as other studies from around the world using the same cut-points have observed similar min per day of MVPA and total physical activity (2,10,18)(1,7,12). As step count targets were derived using regression equations, the use

of different cut-points also created disparities between our step count targets and those created previously. Much higher targets of 9,934 (14) and 13,874 (3) steps per day have previously been proposed for attaining 60 min of MVPA in preschoolers.

Our target is also significantly lower than the 12,000 steps recently proposed by Colley and colleagues for 6- to 19-year-olds (4). In that study, however, the authors did note that in some age and sex groups, a 12,000 step cut-point may be underestimating (by up to 12%) the proportion of children and youth who are achieving the physical activity guideline of 60 min of MVPA. This disparity is not entirely surprising given the obvious size differences (i.e. leg length) between young children and older adolescents. It is therefore reasonable to expect that step count targets will be different for the preschool age group. Furthermore, we derived a step count target for a different physical activity recommendation. Our step count target for preschoolers would have been higher (6700 steps) had we derived it for only 60 min of MVPA instead of for the new recommendation. Another important consideration to possibly explain the difference between our step count target and that of Colley et al. (4) is how physical activity was measured. In addition to different types of accelerometers and cut-points between our studies, Colley et al. used accelerometer data with 60 sec epochs from the Canadian Health Measures Survey. We (10) and others (17) have previously demonstrated that longer epochs such as 60 sec significantly underestimate the amount of MVPA obtained – by approximately 30%. Thus, children in the Colley et al. (4) study who met the 60 min MVPA threshold were likely much more active (~30% more) by virtue of misclassification of MVPA using the 60 sec epoch. It could then be expected, given the very strong positive correlation between steps and MVPA, that the reported step count by Colley et al. actually corresponded to a much higher MVPA level. If we reduce the 12,000 step count by 30%, we find a value (8,400) closer to the one that we report

for preschoolers. Together these factors may explain the disparity between our step count targets.

We propose a step count target of 6000 steps per day should be used to determine if children 3 to 5 years of age are meeting new physical activity recommendations of 180 min of physical activity at any intensity and 180 min of physical activity of any intensity including at least 60 min of MVPA. This target will aid practitioners and researchers in monitoring physical activity in the early years.

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The authors declare no conflict of interest.

The results of the present study do not constitute endorsement by ACSM

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FIGURE CAPTIONS:

Figure 1. Kernel density plot illustrating the distribution of step counts for days meeting and not meeting 180 min of physical activity of any intensity.

Figure 2. Receiver operating curve illustrating step count thresholds for attaining 180 min of daily physical activity of any intensity.

Figure 3. Receiver operating curve illustrating step count thresholds for attaining 180 min of total physical activity including at least 60 min of MVPA daily.

FIGURE 1

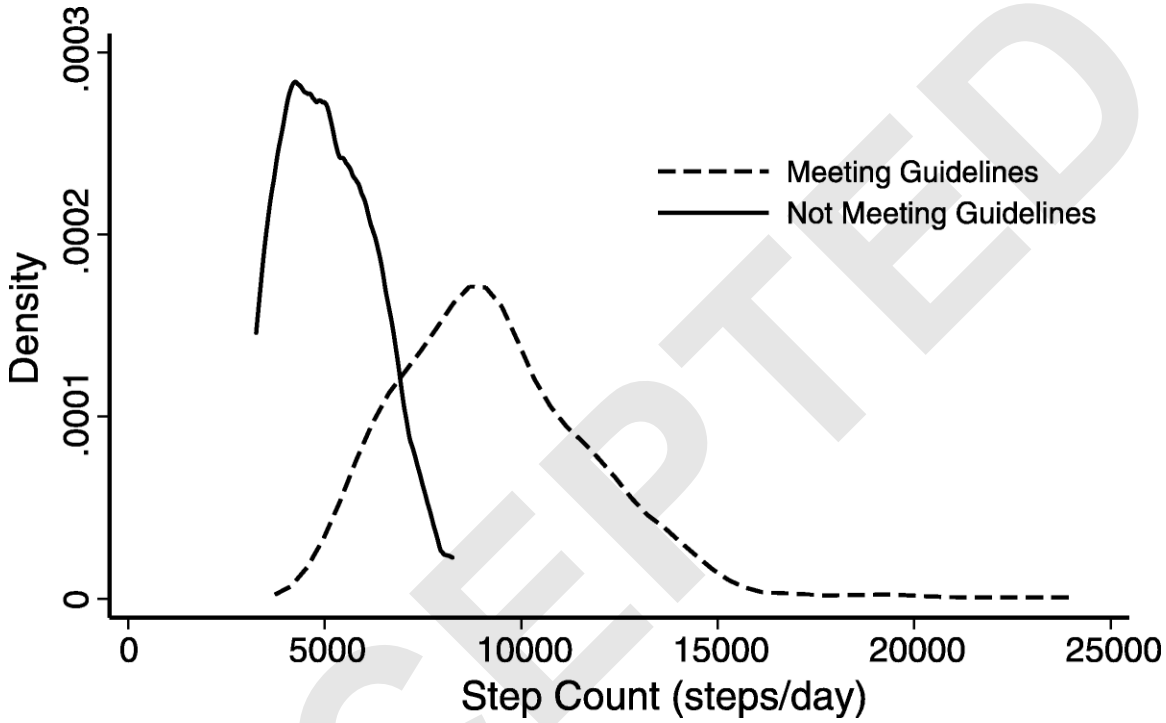

FIGURE 2

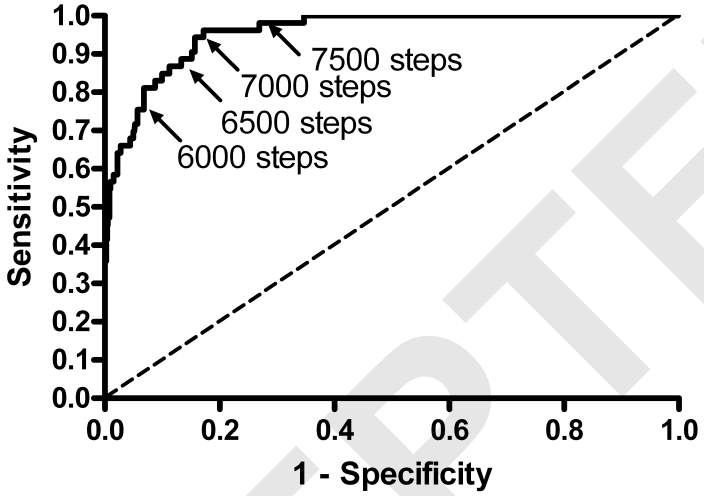

FIGURE 3

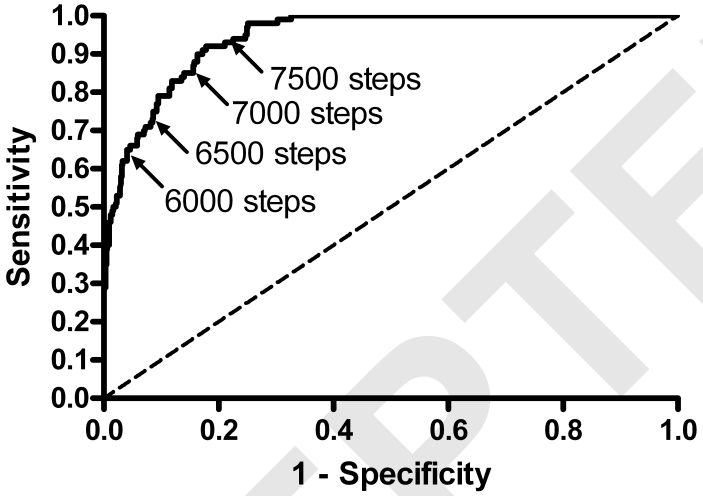

Table 1: Participant and physical activity characteristics

Variable	Total	3- to 4-year-olds	5-year-olds
n (*girls/boys*)	133 (*63/70*)	89 (*47/42*)	44 (*16/28*)
Height (cm)	106.5 ± 7.7	103.1 ± 6.6	113.2 ± 4.9
Weight (kg)	18.2 ± 3.1	17.0 ± 2.6	20.6 ± 2.9
BMI (kg/m^2)	16.0 ± 1.1	16.0 ± 1.1	16.0 ± 1.3
% Overweight[a]	20	20	18
MVPA (min/day)	92 ± 21	89 ± 21	99 ± 20
TPA (min/day)[b]	256 ± 36	251 ± 37	266 ± 33
Step Count (steps/day)	8968 ± 1855	8513 ± 1864	9886 ± 1472

[a]% overweight (overweight + obese) is based on the CDC data(7).

[b]TPA, Total minutes of physical activity of any intensity.

Table 2: Step count thresholds for new physical activity guidelines based on regression analyses

Age	Prediction Equations	R^2	Step Count Thresholds: steps ± S.E. [95% CI]
	180 min physical activity of any intensity		
All	Steps = 39.19*TPA - 1041.51	0.58	6013 ± 88 [5840-6186]
3 – 4	Steps = 37.55*TPA - 890.47	0.56	5868 ± 105 [5662-6074]
5	Steps = 36.26*TPA - 581.30	0.59	6486 ± 153 [6186-6786]
	180 min physical activity of any intensity, including at least 60 min MVPA		
All	Steps = 34.47*MVPA + 22.09*TPA + 146.84	0.61	6191 ± 103 [5989-6393]
3 – 4	Steps = 45.00*MVPA + 15.36*TPA + 680.92	0.61	6146 ± 120 [5911-6381]
5	Steps = 17.11*MVPA + 30.45*TPA + 69.30	0.59	6577 ± 184 [6216-6938]

Notes: 725, 477, and 248 valid days for All, 3- to 4-year olds, and 5-year olds, respectively.

Table 3: Comparison of 6000, 6500, and 7000 step count thresholds to new physical activity guideline recommendations: 180 min of physical activity of any intensity and 180 min of physical activity of any intensity including at least 60 min of MVPA.

		6000 Steps		6500 Steps		7000 Steps	
Age	% valid days meeting PA Guidelines	% meeting step target	Difference: PA guidelines – step target	% meeting step target	Difference: PA guidelines – step target	% meeting step target	Difference: PA guidelines – step target
			180 min physical activity of any intensity				
All	92.7	88.6	4.1	82.8	9.9	76.0	16.7
3 – 4	91.8	85.5	6.3	78.0	13.8	70.2	21.6
5	94.8	94.4	0.4	91.9	2.9	87.1	7.7
			180 min physical activity of any intensity, including at least 60 min MVPA				
All	86.8	88.6	-1.8	82.8	4.0	76.0	10.8
3 – 4	84.3	85.5	-1.2	78.0	6.3	70.2	14.1
5	91.5	94.4	-2.9	91.9	-0.4	87.1	4.4