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Step based physical activity guidelines for preschool-aged children

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Abstract

Objective: Public health organizations recommend that preschool-aged children accumulate at least 3h of physical activity (PA) daily. Objective monitoring using pedometers offers an opportunity to measure preschooler's PA and assess compliance with this recommendation. The purpose of this study was to derive step-based recommendations consistent with the 3h PA recommendation for preschool-aged children.

Method: The study sample comprised 916 preschool-aged children, aged 3 to 6 years (mean age = 5.0 ± 0.8 y). Children were recruited from kindergartens located in Portugal, between 2009 and 2013. Children wore an ActiGraph GT1M accelerometer that measured PA intensity and steps per day simultaneously over a 7-day monitoring period. Receiver operating characteristic (ROC) curve analysis was used to identify the daily step count threshold associated with meeting the daily 3 hour PA recommendation.

Results: A significant correlation was observed between minutes of total PA and steps per day ($r=0.76$, $p<0.001$). The optimal step count for ≥ 3 hours of total PA was 9177 steps per day (sensitivity (90%) and specificity (66%)) with area under the ROC curve = 0.86 (95% CI: 0.84 to 0.88).

Conclusion: Preschool-aged children who accumulate less than 9000 steps per day may be considered insufficiently active

Keys words: Physical Activity Guidelines; Steps; Preschool Children

Introduction

Physical activity (PA) is recognized as a fundamental component of a healthy lifestyle in young children (Pate et al., 2006b). Recent PA guidelines from the United Kingdom, Australia and Canada recommend that preschool-aged children accumulate at least 3 hours of PA across an entire day (Ageing, 2010; Department of Health, 2011; Okely et al., 2008; Tremblay et al., 2012). These recommendations state that children can accumulate PA intermittently throughout the day, and can include light-intensity activities such as standing, moving around and active play as well as moderate-to-vigorous intensity activities such as brisk walking, running and climbing, (Ageing, 2010).

Accelerometer-based motion sensors have become a commonly used and accepted measure of PA in children and youth and are the preferred assessment methods in studies involving young children (Trost and O'Neil, 2014). However, because accelerometry is relatively expensive and requires software for initialization, download, and data analysis, it is more labour intensive and less economical for use in general clinical practice or educational settings like schools and early childhood education centers. In contrast to accelerometers, pedometers are simple and low cost PA assessment tools that record steps taken over time, usually expressed as steps per day (Freedson and Miller, 2000). Furthermore, since pedometers enable a wide range of end users to monitor PA levels using a common metric related to ambulatory activity, they provide a unique opportunity for bridging the gap between research and practice, and ultimately to real-world applications for health promotion (Tudor-Locke et al., 2013). As such, daily step counts are an important behavioral target for PA interventions (Simpson et al., 2003).

Although pedometers provide useful information about the PA levels of young children, the number of steps per day that corresponds to PA guidelines for preschool-aged children is not well understood. To our knowledge only one published study has operationalized the current 3-hour guideline on the basis of daily step counts (Gabel et al., 2013). Gabel et al. (2012) employed accelerometry to simultaneously measure daily step counts and total PA (sum of light-, moderate- and vigorous-intensity PA) in a sample of Canadian preschool-aged children (N=133). Using regression-based prediction models and ROC curve analyses, a step target of 6,000 steps per day was identified as equivalent to 3 hours of daily total PA. They produced separate models (with associated cut-points), one for 3 hours PA at any intensity and another for 3 hours at any intensity and including 1 hour at MVPA, in their analysis. Both models

produced slightly different values but both approximated to just over 6,000 steps per day. As a consequence Gabel et al. (2012) proposed a single cut off point of 6,000 steps per day as representative of 3 hours daily PA. Although this study provided a clear and empirically-based daily step target for preschool-aged children, the accelerometer-based estimates of minutes spent in total PA or daily minutes spent in PA that were at least of light-intensity were based on an accelerometer count threshold or “cut-point” of just 8 counts per 3 second epoch (160 counts per min (cpm)). The use of the 160 cpm cut-point to distinguish light-intensity PA from sedentary activity is questionable. This threshold may misclassify sedentary activities such as seated play and doing arts and crafts as light-intensity PA, resulting in an overestimation of total PA minutes, and an underestimation of the steps per day required to achieve the daily 3 hour PA recommendation. Presently, there is no consensus on the optimal cut-point for delineating sedentary from light-intensity PA in preschool-aged children. However, recent work suggests that a ≥ 200 counts per 15 second epoch should be used to differentiate between sedentary and light PA because that cut-point corresponded to the lowest count rate recorded during slow walking among preschool-aged children (Byun et al., 2013; Espana-Romero et al., 2013).

Given the need to further explore the impact of different accelerometer count cut-points on daily step count equivalencies for preschool-aged children, and the need to apply count cut-points that more accurately differentiate light intensity PA from sedentary behavior, the purpose of this study was to derive step-based recommendations consistent with current PA recommendations for preschool-aged children.

Methods and Procedures

Participants and data collection

Participants in this study were preschool-aged children enrolled in the Preschool Physical Activity, Body Composition and Lifestyle Study (PRESTYLE). A random sample of children, aged 2–6 years, was recruited from kindergartens located in the metropolitan area of Porto, Portugal. For this analysis, we included only children aged three to six years with seven days of accelerometer data. The final sample included 916 preschool-aged children (50% girls). Data were collected between April 2009 and November 2013. Informed written consent was obtained from parents and school supervisors. Study procedures were approved by the Portuguese Foundation for Science and Technology and by the Scientific Board of the Physical Activity and Health doctoral program.

Anthropometric Assessment

Body mass and height were measured using standard anthropometric methods. Body mass was measured to the nearest 0.1 kg, with participants lightly dressed (underwear and tee-shirt) using a portable digital beam scale (Tanita Inner Scan BC 532). Height was measured to the nearest millimetre in bare or stocking feet with children standing upright against a Holtain portable stadiometer (Tanita). The measurements were repeated twice and the average was recorded. BMI was calculated as body mass (kg) divided by height (m) squared.

Physical Activity Assessment

Daily total PA was measured using an ActiGraph GT1M accelerometer (Pensacola, FL USA). This device produces output in the form of activity counts, which provides information about the intensity of PA, the higher the counts the greater the intensity (Janz, 1994). Participants wore the accelerometer on seven consecutive days (Monday to Sunday) and a minimum wear time of 10 hours per day was considered valid data for the analysis (Rich et al., 2013). Non-wear time was defined as a period of at least 60 consecutive minutes of zero counts (Byun et al., 2011; Choi et al., 2011; Pfeiffer et al., 2009). In this study, the epoch duration was set to 5 seconds, which has been shown to be more accurate for the assessment of the spontaneous and intermittent activities of the young children (Vale et al., 2009). The accelerometer output can also be interpreted using intensity-based thresholds or count cut-points, which categorize activity counts as sedentary, light, moderate, or vigorous intensity PA. Total PA or daily minutes spent in activity of at least light-intensity was calculated using a cut-point of ≥ 200 counts per 15 sec, which corresponds to the lowest count rate recorded for slow walking in a previously conducted accelerometer calibration study involving preschool-aged children (España-Romero et al., 2013; Pate et al., 2006a). To process the data we used *Actilife*® software which automatically scaled the 15 sec cut-point value to the 5-sec epoch. Parents were instructed to attach the accelerometer when the child awoke and to remove it when they went to bed. The accelerometer was firmly adjusted at the child's hip by an elastic waist belt under their clothing. Activities were not prescribed or directed by the teachers or researchers. All children participated in normal activities with their classmates.

For total PA, we followed the guidelines of UK recommendations, Australian National Physical Activity Recommendations for Children 0-5 years of age and Canadian recommendations (Ageing, 2010; Department of Health, 2011; Tremblay et al., 2012)

calculating the proportion of children with 3 hours or more of total PA. Children were classified as meeting (Sufficiently Active) or not meeting (Insufficiently Active) guidelines if they accumulated at least 3h of total PA, as measured by the accelerometer, on at least 5 of the 7 monitoring days (Addy et al., 2014).

Statistical analyses

Descriptive data are presented as means and standard deviation. All variables were checked for normality using Kolmogorov–Smirnov tests. Comparisons between genders for all variables were conducted with independent t-tests. Pearson’s correlation and linear regression were used to model steps per day as a function of accelerometer-measured minutes of total PA per day. To identify the steps per day value that maximized the sensitivity (true-positives) and specificity (true-negatives) for classifying children as “Sufficiently Active” or “Insufficiently Active”, a receiver operating characteristic (ROC) curve was created and analyzed. The area under the ROC curve (ROC-AUC) provides a measure of classification accuracy that jointly considers sensitivity and specificity. The curve plots the false-positive rate (1 - specificity) on the x axis and the true positive rate (sensitivity) on the y axis. An area of 1 represents perfect classification, whereas an area of 0.50 represents a complete absence of classification accuracy. ROC-AUC values of ≥ 0.90 are considered excellent, 0.80–0.89 good, 0.70–0.79 fair, and <0.70 poor. (Metz, 1978). Data were analyzed using MedCalc v13.0.

Results

Children’s descriptive characteristics, including average daily total PA and steps per day, are summarized in Table 1. On average, boys engaged in significantly more total daily PA and accumulated significantly greater steps per day than girls ($p \leq 0.001$ and $p \leq 0.05$, respectively). About 71% of the children did not accomplish the recommended 3 or more hours of total PA daily.

INSERT TABLE 1

Steps = (46 X minutes per day total)+ 1862.

Minutes per day of total PA was a significant predictor of steps per day (steps = 46 + 1862 × Minutes per day of total PA; $R^2 = 0.581$; $p < 0.001$) (Figure 1). In addition, using ROC curve analysis, sensitivity and specificity were optimized at 9177 steps per day (sensitivity (90%) and specificity (66%)) (95% CI: 9041 to 9408) with an associated AUC of 0.86 (95% CI: 0.84 to 0.88) (see Figure 2). This finding indicated that preschool-aged children should be

accumulate at least 9000 steps per day to meet the recommendation of at least 3 hours of total PA per day.

INSERT FIGURE 1 and 2

Although, boys exhibited significantly greater steps per day than girls, the gender-specific ROC curve values are similar (boys: 9225 steps per day vs girls: 9177 steps per day) (Figure 3 and 4)

INSERT FIGURE 3 and 4

Discussion

The beneficial impact of regular PA on children's health and well-being is well-established. However, the number of steps per day associated with meeting the recommended dose of total PA in preschool-aged children is poorly understood. The present study extends understanding in this area by identifying daily step-based recommendations consistent with current PA recommendations in preschool-aged children. A key finding of our study is that preschool-aged children who accumulate less than 9000 steps per day may be considered insufficiently active.

On average, participants accumulated 162 ± 35 min per day of total PA and 9297 ± 2167 steps per day. This step count value is somewhat higher than that reported by Gabel et al. (2012) (8968 steps per day) and Pagels et al. (2011) (7313 steps per day), but lower than those reported by Tanaka et al. (2009) (13037 steps per day) and Cardon et al. (2007) (9980 steps per day). The discrepancy between prior studies in this area may be related, at least in part, to the different instruments and methodology used as well as cultural and environmental differences in the daily lifestyle of preschool-aged children from different countries. Furthermore, consistent with the majority of prior studies conducted in preschool-aged children (Hinkley et al., 2008; Pagels et al., 2011; Tanaka and Tanaka, 2009), boys in our sample exhibited higher levels of daily total PA and accrued more steps per day than girls. Similar to other studies (Gabel et al., 2012; Pagels et al., 2011) our data showed a strong and positive correlation between steps per day and minutes of accelerometer-measured total PA, irrespective of gender.

Based on accelerometer determined minutes of total PA, just under 30% of the preschool-aged children in our sample achieved the recommended level of at least 3h per day of total

PA, with boys (36.9%) more likely to meet the recommendation than girls (20.8%). Our data are consistent with other studies with regards to gender differences in PA (Beets et al., 2011; Vale et al., 2010; Vale et al., 2013) but the proportion of children meeting the daily 3h recommendation is lower than that reported in these studies. This discrepancy may be related to, in part, the count cut-point used to estimate total PA. In the studies by Vale et al. (2013) and Gabel et al. (2012) the accelerometer cut-point (≥ 38 counts per 15 sec and ≥ 40 counts per 15 sec, respectively) was lower than that used in the current study (≥ 200 counts per 15 sec), which considered light-intensity to be equivalent to the intensity of slow walking (España-Romero et al., 2013). Thus, as a consequence of using a higher count threshold, the percentage of children who met the 3-hour Total PA recommendation was lower (Gabel et al. (2012) – 73% and Vale et al. (2013) - 90%). The issue of different cut-points and their associated impact on prevalence estimates for PA in preschool-aged children is worthy of further discussion. Moreover, different criterion measures have been used in previous studies establishing PA related cut-points which may help explain the different cut-points that have been proposed. Reilly et al. (2003), Sirard et al. (2005) and Van Cauwenberghe et al. (2011) calibrated the ActiGraph accelerometer with the use of direct observation, whereas Pate et al. (2006a) calibrated the ActiGraph accelerometer with the use of VO₂ measured via indirect calorimetry. In this study, cut-points for moderate- and vigorous-intensity PA were published however cut-points for sedentary behavior and light-intensity PA were identified and have been published in recent studies (Byun et al., 2013; España-Romero et al., 2013; Pfeiffer et al., 2009; Williams et al., 2008).

Previous research involving school-aged children and adolescents has developed various step-based recommendations for achieving PA guidelines (Adams et al., 2013; Tudor-Locke et al., 2004; Vincent and Pangrazi, 2002). Nevertheless, there is inconsistency in the exact values that are being suggested. Based on accelerometer steps per day and accelerometer determined daily minutes of moderate-to-vigorous intensity PA, one recent study identified 12,000 steps per day as a threshold to determine compliance with the 60 minutes of MVPA daily recommendation in children and youth age 6-19 years, for both genders groups (Colley et al., 2012). To the best of our knowledge, only one study in preschool-aged children has been carried out with this purpose and employing ROC curve analysis (Gabel et al., 2012).

However, in their study, Gabel et al. (2013) used 160 cpm as the threshold for light-intensity physical activity. In our opinion, this threshold may be inappropriate as 160 cpm could misclassify predominantly sedentary activities such as children being seated while playing, as light-intensity activity. To further explore this point, we replicated the work of Gabel et al

(2012) and identified a daily step threshold of 6736 steps per day, which is comparable to the 6000 steps per day threshold they proposed. That we were able to replicate Gabels' findings in our sample indicates that the task of deriving daily step thresholds from accelerometer determined minutes of total PA is dependent on: 1) the operational definition of light or non-sedentary activity; and 2) the choice of accelerometer cut-point to match this definition. If physical activity guidelines are operationalized as 3 or more hours per day of *any* movement, including standing, then a lower accelerometer cut-point may be appropriate, resulting in a lower, more conservative daily step recommendation. Alternatively, if physical activity guidelines are operationalized as 3 or more hours per day of light-intensity physical activity, and slow walking is used as a behavioral indicator of light-intensity, then a higher accelerometer cut-point may be appropriate, resulting in a higher, less conservative daily step recommendation. To reconcile the differences between these two approaches, it may be useful to view daily step counts between 6000 and 9000 steps as an intermediate "needs improvement" zone for preschool children. Future studies should explore the utility of this approach.

In our study we observed a gender-related difference in steps per day, minutes of engagement in total PA and achievement of the 3h total PA recommendations. However, steps per day thresholds identified in the gender-specific ROC curve analyses were quite similar (boys: 9225 steps per day vs girls: 9177 steps per day) for the same cut-point value. Additional analysis was carried out accounting for age and no differences were found. Therefore, the suggested steps per day threshold in the present analysis is not gender specific and a single cut point for all preschool age children may be more practical for research, clinical use and in promoting community public health.

The strengths of this study include our focus on PA levels in preschool-aged children and an assessment of compliance with PA recommendations and steps per day using an objective PA measure. It should, however, be recognized that intensity of some activities maybe underestimated by an accelerometer. Nevertheless, some limitations of the study should be recognized. Although recognized criteria for judging the optimal classification accuracy were employed in this study, it should also be acknowledged that the resultant steps per day threshold had high sensitivity but lower specificity. Thus, while a small percentage (~ 5%) of sufficiently active children would not meet the 9,000 step per day criterion and be

misclassified as insufficiently active, about 30% of insufficiently active children would meet the 9,000 steps per day criterion and be misclassified as sufficiently active. Future research might therefore explore how steps per day thresholds might be influenced in situations where sensitivity and specificity are matched. The present study included preschool-aged children from only one metropolitan area, making it difficult to generalize the findings to other environments or locations. In addition, we were not able to collect data in relation to the context of PA in the preschool setting (e.g., to understand any PA intensity differences between activities initiated by the teacher or the child) due to the labor intensive nature of this form of data collection. However, multiple method approaches that integrate accelerometer and direct observation might be useful in future research.

Conclusion

The results of the present study suggest that preschool-aged children who accumulate less than 9000 steps per day may be considered insufficiently active. Public health professionals, clinicians and community groups engaged in PA programs for preschool-aged children may therefore benefit from promoting this daily step target.

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Table 1 – Children’s descriptive characteristics

	Total Sample (n=916)	Girls (n=454)	Boys (n=462)	<i>p</i>	
Age (years)	5,0 ± 0,8	5,0 ± 0,8	5,1±0,8	0,121	
Weight (kg)	20,8 ± 4,0	20,6 ± 4,0	21,0±3,9	0,106	
Height (cm)	110,6 ± 7,5	109,6 ± 7,3	111,5±7,5	≤0,001	
Body Mass Index (kg/m ²)	16,9 ± 2,0	17,0 ± 2,0	16,8±2,0	0,088	
Total PA (minutes)	161 ± 36	152 ± 35	171±35	≤0,001	
Steps (steps per day)	9281 ± 2183	9079 ± 2058	9484±2287	0,007	
PA Guideline at least 3hours per day total PA (%)	Sufficiently Active	28,9	20,8	36,9	≤0,001
	Insufficiently Active	71,1	79,2	63,1	

PA – physical activity

Sufficiently Active - meeting guideline at least 3hours per day total PA

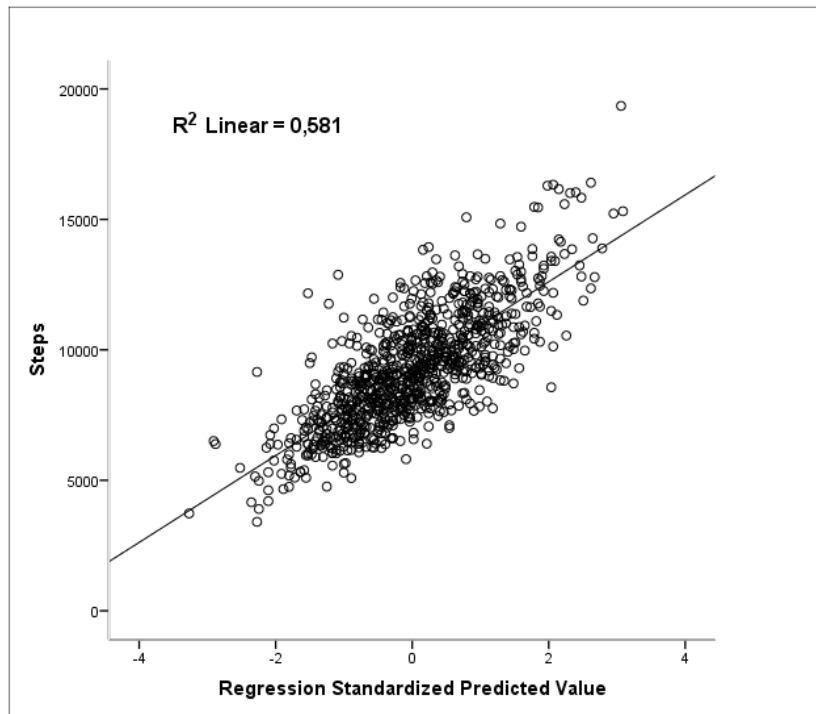


Figure 1 - Relationship between minutes engaged in physical activity and daily step counts.

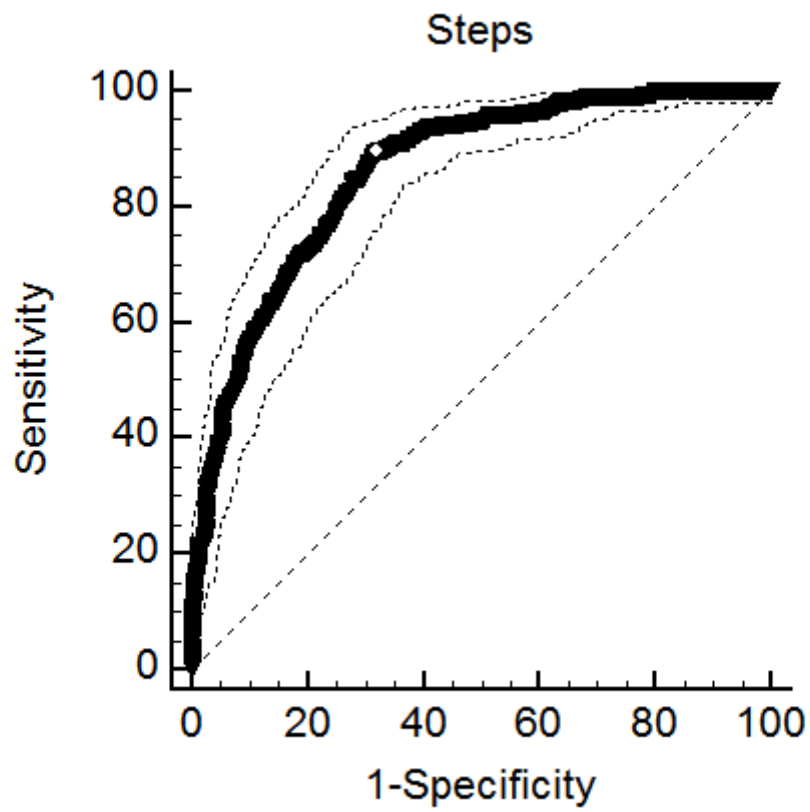


Figure 2 - Receiver operating characteristic curve for steps per day predicting whether the 3 hours of total PA recommendation was met in this population.

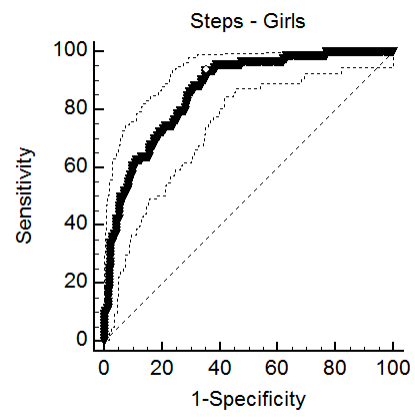
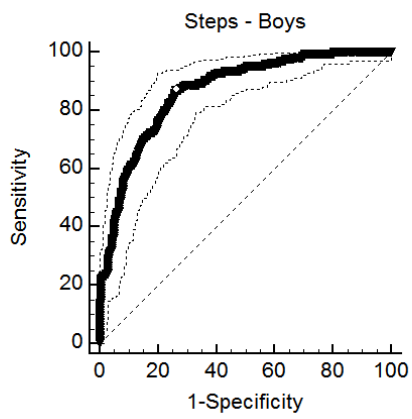


Figure 3 and 4 - Receiver operating characteristic curve for steps per day predicting whether the 3 hours of total PA recommendation was met in this population.

