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Translating Physical Activity Recommendations for Overweight Adolescents to Steps Per Day

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Abstract

Background—Steps/day guidelines for children aged 12 years and under are 12,000 to 16,000. There are limited reports in the literature on how many steps/day adolescents need to meet the 60-minutes/day moderate-to-vigorous physical activity (MVPA) recommendation. This study aimed to determine the steps/day that correctly classifies adolescents as meeting the 60-minute recommendation using objective measures.

Methods—This analysis used data from 40 overweight (BMI M=31.5, SD=5.3) adolescents enrolled between 2005 and 2006 in a study to lose weight. Participants were aged 11 to 16 years (M=13.2, SD=1.2), 70.0% girls, and 52.6% non-Hispanic white, 23.7% Hispanic, and 23.7% other race/ethnicity. Participants wore an Actigraph accelerometer for up to 7 days that measured accelerations and step counts simultaneously. The age-adjusted Freedson equation was used to estimate physical activity–intensity minutes. Two criteria were used to define MVPA (3/6 and 4/7 METs). Analyses were conducted between 2008 and 2009.

Results—Based on accelerometer data, approximately 48% and 10% of adolescents met the MVPA recommendation depending on the MVPA criteria. Adolescents who met physical activity recommendation had higher MVPA min/day ($p<0.001$) and higher step counts ($p<0.001$), after adjusting for gender, age, and ethnicity. Receiver operating characteristic (ROC) curve analyses found that 9930 steps produced 0.84 sensitivity and 0.81 specificity (area under the curve [AUC] =0.89) and 11,714 steps produced 0.75 and 0.81 specificity (AUC=0.94) for meeting the recommendation using the 3/6 and 4/7 criteria, respectively.

Conclusion—Depending on the MVPA criteria used, these data suggest that overweight adolescents are likely to meet national MVPA recommendations if they accumulate between 10,000 and 11,700 steps per day.

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Introduction

The well-known criterion of 10,000 steps per day is indicative of an active adult lifestyle,^{1–4} but is likely too low for children.^{1,5} Steps per day recommendations for children have been determined by both normative- and criterion-referenced approaches.^{5–12} The normative-referenced approach derives its estimate from the average number of steps taken by a representative group. The criterion-referenced approach compares step counts for two or more groups known to have differential status on a clinical outcome (e.g., overweight status). For children aged 6 to 12 years, Vincent et al.¹⁰ recommended 11,000 steps/day for girls and 13,000 steps/day for boys. Tudor-Locke and colleagues,⁵ using a criterion-referenced approach, suggested 12,000 steps/day for girls and 15,000 steps/day for boys for healthy body mass. Laurson et al.¹³ combined a receiver operating characteristic (ROC) curve analysis with the criterion-referenced approach and found that for boys 13,666 steps/day and for girls 9983 steps/day produced the optimal sensitivity and specificity for discriminating overweight and obese versus normal weight status.

To our knowledge, there are no published studies estimating how many steps/day adolescents need to meet the currently recommended 60 minutes per day of moderate-to-vigorous physical activity (MVPA).¹⁴ Determining the steps/day needed to meet the MVPA recommendation may be more accurate than estimating steps/day needed to discriminate weight status. The purpose of this study was: (1) to identify the amount of time a sample of overweight adolescents spent within various physical activity–intensity levels, and (2) to determine the optimal steps/day that correctly classifies adolescents as meeting the 60-minute recommendation using objectively-measured MVPA minutes and ROC curve analysis.

Methods

Data were from the baseline phase of a web- and phone-based intervention to promote weight loss or maintenance through healthful eating and physical activity in overweight adolescents. Fifty-two adolescents were recruited through their primary care providers between 2005 and 2007. Criteria for participation included being aged 11–16 years and having a BMI $\geq 85^{\text{th}}$ percentile for age and gender.¹⁵ Adolescents were excluded if they were pregnant or reported a cardiovascular or a musculoskeletal problem limiting their ability to meet physical activity recommendations. Written parental consent and the adolescents' assent were obtained following guidelines approved by the IRB at the University of California, San Diego.

Participants were instructed to wear an Actigraph model 7164 accelerometer for at least 10 hours per day for 7 days.¹⁶ MeterPlus 4.0 was used to determine valid days, using the option of classifying an hour as invalid when activity counts equaled zero for ≥ 30 consecutive minutes. The Actigraph measured activity counts and step counts simultaneously. An age-adjusted Freedson equation was used to estimate intensity minutes of inactivity (counts ≤ 100); light (≤ 2.9 METs); moderate (3–5.9 METs); and vigorous (6–11 METs) activities from raw activity counts. Additionally, because recent evidence suggests that these MET thresholds may overestimate MVPA, higher thresholds for light (≤ 3.9 METs); moderate (4–6.9 METs); and vigorous (7–11 METs) activity counts were also examined.^{17,18} Step counts were derived from the Actigraph's signal "cycle counts" per minute.

Accumulated physical activity minutes by intensity level were calculated by summing the number of minutes of activity that exceeded each intensity threshold and dividing by the number of days monitored. The Actigraph accelerometer and Freedson intensity estimates have acceptable reliability and validity for estimating youth physical activity.^{19,20} Steps/day estimates were computed by summing steps per minute for each day across days and dividing by the number of days worn. The Actigraph requires less force than traditional pedometers

(e.g., Yamax SW-200) to record movement and may detect more steps per day and be less likely to underestimate steps taken at slower walking speeds.^{21–23}

Statistical Analyses

Adolescents who accumulated ≥ 60 minutes/day of MVPA on average were classified as meeting guidelines. ANCOVA models tested for differences in accumulated minutes per day of inactivity, light, and MVPA and number of steps taken per day between participants who met guidelines and those who did not, after adjusting for gender, age, and race/ethnicity. Analyses were conducted using both the 3/6 MET thresholds and 4/7 MET thresholds used to define moderate and vigorous activity. ROC curve analysis determined the optimal steps/day that discriminated adolescents who met the guideline from those who did not (based on accumulated MVPA minutes).²⁴ All analyses were conducted with SPSS version 12 software in 2008 and 2009.

Results

Accelerometer counts and steps/day were available for 40 of the 52 adolescents (70.0% girls, aged 11–16 years [$M=13.2$, $SD=1.2$]); all overweight ($BMI\ M=31.5$, $SD=5.3$); and 52.6% white non-Hispanic, 23.7% Hispanic, and 23.7% other race/ethnicity. About 77% of all participants had 4 and 7 days of valid accelerometer data. Twelve adolescents were excluded because of an insufficient number of days with ≥ 10 hours of valid data.

3/6 MET Criteria

Participants averaged 7.9 (± 1.8) hrs/day of inactivity, 4.5 (± 0.97) hrs/day of light activity, 66.2 (± 27.3) min/day of MVPA, and 9826 (± 2769) steps/day. Approximately 48% of participants met MVPA recommendations based on 3/6 MET criteria. Table 1 (top) summarizes the ANCOVA results for inactive, light, and MVPA minutes, and steps/day. Participants averaged 41 more MVPA minutes/day, after adjusting for gender, age, and ethnicity ($p<0.001$). Adolescents who met the recommendation also averaged 4099 more steps/day after adjusting for the same covariates ($p<0.001$). A ROC curve analysis found that 9930 steps/day produced 0.84 sensitivity and 0.81 specificity for meeting the MVPA recommendation (area under the curve [AUC] = 0.89; Figure 1; left panel).

4/7 MET Criteria

Participants averaged 7.9 (± 1.8) hrs/day of inactivity, 5.1 (± 1.1) hrs/day of light activity, 29.4 (± 17.1) min/day of MVPA, and 9,866 (± 2823) steps/day. Ten percent of participants met MVPA recommendations based on 4/6 MET MVPA criteria. The bottom portion of Table 1 shows that after adjusting for gender, age, and ethnicity, participants meeting the guideline averaged 37 more MVPA minutes/day ($p<0.001$) and 3898 more steps/day ($p=0.007$). Figure 1 (right panel) shows that 11,714 steps/day produced 0.75 sensitivity and 0.81 specificity for meeting the MVPA recommendation (AUC=0.94).

Discussion

The current study examined steps per day and accumulated time in each intensity category simultaneously for adolescents aged between 11 and 16 years. Findings indicated that adolescents who met the 60-minute recommendation took considerably more steps per day and more MVPA minutes than adolescents who did not meet the guideline. Depending on the MET criteria used, the results suggest that overweight adolescents who reach between 10,000 to 11,700 steps are likely meeting youth MVPA guidelines.

These finding of 10,000 steps/day for adolescents may be lower than previous studies with children for a number of reasons. Groups were discriminated based on MVPA rather than body mass. Other factors, such as genetics and diet, influence BMI, and therefore the number of steps/day derived from BMI-referenced approaches may be higher compared to a direct assessment of physical activity. Also, as adolescents approach adulthood, they begin to approximate adults in stature and physical activity patterns. Moreover, the majority of the sample were girls, and evidence suggests that girls take fewer steps/day than boys at all ages.^{5,8,14} A recent study found that adolescents' daily steps/day range from 8400 to 11,300 steps for girls and 10,000 to 13,700 steps for boys.⁸ It may be that 10,000 steps/day is too low for children aged 6 to 12 years, but approximates meeting the physical activity guidelines for adolescents, especially girls. The 3- and 6-MET thresholds for moderate and vigorous activities appear to misclassify a considerable proportion of light activity as moderate activity. To examine this possibility, steps/day were examined using the 4- and 7-MET thresholds; only 10% of adolescents met the 60-minute guideline. This finding is similar to Troiano et al.²⁵ who found that only 6%–8% of National Health and Nutrition Examination Survey (NHANES) adolescents met the guideline using the 4/7 MET criteria. With this higher MVPA criteria, the use of 11,700 steps /day produced good discrimination for meeting guidelines. Therefore, depending on the MET classifications used to define MVPA, 10,000 to 11,700 steps/day are needed to identify adolescents meeting the 60-minute/day guideline. Further studies using objective physical activity measures with larger and more representative samples should be conducted.

This study is innovative in two ways: first by its use of an accelerometer to assess activity counts and pedometer steps simultaneously, and second by the use of ROC curve analysis to establish the number of steps needed for adolescents to achieve recommended MVPA guidelines. Nevertheless, there are important limitations that should be noted. Limited data exist on the reliability and validity of Actigraph step estimates; the accelerometer may be more sensitive than traditional pedometers.^{21,23} However, the use of one motion sensor to estimate both accumulated MVPA and steps/day may reduce measurement error that can occur when using two independent motion sensors. There are also important sample limitations. The sample size was small and restricted to overweight adolescents, primarily girls, which may limit the generalizability of the findings. However, because accelerometers measure movement directly, these findings may also generalize to normal-weight individuals. If this approach—the combination of a dual mode accelerometer and ROC curve—can be replicated in other studies, it may provide important information and a complementary approach to the criterion-referenced methods for determining public health guidelines and messages for step counts for adolescents.

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Figure 1. Receiver operating characteristic (ROC) curves showing the optimal steps/day cut-point for meeting 60-minute moderate-to-vigorous physical activity recommendations

Table 1

Average time per intensity category and steps/day for participants meeting and not meeting activity guideline using two MET thresholds for light and MVPA

	Did not meet 60-min guideline				Met 60-min guideline			
	<i>n</i>	M	SE		M	SE	<i>p</i> value	η^2
3/6 MET threshold^a								
Inactive time (hrs/day)	40	8.38	0.37		7.45	0.39	0.07	0.07
Light activity (min/day)	40	255.39	13.69		287.13	14.48	0.14	0.06
MVPA (min/day)	40	46.8	4.08		87.67	4.3	<0.001	0.55
Steps (day)	40	7,879	466		11,978	493	<0.001	0.48
	Did not meet 60-min guideline				Met 60-min guideline			
	<i>n</i>	M	SE		M	SE	<i>p</i> value	η^2
4/7 MET threshold^b								
Inactive time (hrs/day)	40	8.04	0.27		7.12	0.83	0.31	0.03
Light activity (min/day)	40	308.62	11.51		295.56	35.36	0.73	0.00
MVPA (min/day)	40	25.65	2.04		62.82	6.26	<0.001	0.47
Steps (day)	40	9,436	417		13,334	1,283	0.007	0.19

^a light = 1.0–2.9 METS; moderate = 3.0–5.9 METS; and vigorous $\geq$ 6 METS

^b light = 1.0–3.9 METS; moderate = 4.0–6.9 METS; and vigorous $\geq$ 7 METS

MVPA, moderate-to-vigorous physical activity