
Translating Physical Activity Recommendations into a Pedometer-Based Step Goal

3000 Steps in 30 Minutes

Simon J. Marshall, PhD, Susan S. Levy, PhD, Catrine E. Tudor-Locke, PhD, Fred W. Kolkhorst, PhD, Karen M. Wooten, MA, Ming Ji, PhD, Caroline A. Macera, PhD, Barbara E. Ainsworth, PhD

Background: It is a public health recommendation to accumulate at least 150 minutes per week of moderate intensity physical activity. Although pedometers are widely used as a physical activity-monitoring tool, they are unable to measure activity intensity. Translating current physical activity recommendations into a pedometer-based guideline could increase the public health impact of physical activity interventions.

Methods: A community sample of 97 adults (60% women, with a mean age of 32.1 [± 10.6] years and a mean BMI of 28.8 [± 5.5]) completed four 6-minute incremental walking bouts on a level treadmill at 65, 80, 95, and 110 $\text{m}\cdot\text{min}^{-1}$. A calibrated metabolic cart was used to measure energy expenditure at each speed. Steps were measured using a Yamax SW-200 pedometer. Step-rate cut points associated with minimally moderate-intensity activity (defined as 3 METs) were determined using multiple regression, mixed modeling, and receiver operating characteristic (ROC) curves. All data were collected and analyzed in 2006.

Results: For men, step counts per minute associated with walking at 3 METs were 92 $\text{step}\cdot\text{min}^{-1}$ (multiple regression); 101 $\text{step}\cdot\text{min}^{-1}$ (mixed modeling); and 102 $\text{step}\cdot\text{min}^{-1}$ (ROC curve). For women, step counts per minute associated with walking at 3 METs were 91 $\text{step}\cdot\text{min}^{-1}$ (multiple regression); 111 $\text{step}\cdot\text{min}^{-1}$ (mixed modeling); and 115 $\text{step}\cdot\text{min}^{-1}$ (ROC curve). However, for each analysis there was substantial error in model fit.

Conclusions: Moderate-intensity walking appears approximately equal to at least 100 $\text{step}\cdot\text{min}^{-1}$. However, step counts per minute is a poor proxy for METs, and so 100 $\text{step}\cdot\text{min}^{-1}$ should be used only as a general physical activity promotion heuristic. To meet current guidelines, individuals are encouraged to walk a minimum of 3000 steps in 30 minutes on 5 days each week. Three bouts of 1000 steps in 10 minutes each day can also be used to meet the recommended goal.

(Am J Prev Med 2009;36(5):410–415) © 2009 American Journal of Preventive Medicine

Introduction

It is recommended that U.S. adults engage in moderate-intensity physical activity for a minimum of 150 minutes each week,¹ equivalent to 30 minutes daily, 5 days per week. Health benefits can also be achieved when this 30-minute goal is accomplished as a series of shorter bouts (typically three bouts of 10 minutes) accumulated throughout the day. Although it

is easy to measure the frequency and duration of physical activity, evidence suggests that many individuals are unable to gauge their activity intensity when reading or hearing a description about what it should feel like.² This presents a challenge, because health benefits are dependent on the intensity of activity, yet there are few valid and reliable monitoring tools available to the public that are affordable and simple to use.

One objective activity-monitoring tool that is feasible for use in public health settings is the pedometer.³ A pedometer can be used to accurately track the volume of daily activity using the simple output of steps per day,⁴ and it may serve a motivational function because it instantly displays to the user the number of steps taken. A recent meta-analysis⁵ of 26 RCTs and observational studies reported that pedometer users increased their levels of physical activity by 27% over baseline levels. Significant decreases in BMI and blood pressure were also reported. Although the vast majority of

From the School of Exercise and Nutritional Sciences (Marshall, Levy, Kolkhorst), the Graduate School of Public Health (Ji, Macera), San Diego State University; the San Diego Prevention Research Center (Marshall); the School of Medicine, University of California San Diego (Wooten), San Diego, California; Pennington Biomedical Research Center (Tudor-Locke), Baton Rouge, Louisiana; and the Department of Exercise and Wellness, Arizona State University (Ainsworth), Mesa, Arizona

Address correspondence and reprint requests to: Simon J. Marshall, PhD, School of Exercise and Nutritional Sciences, San Diego State University, 5500 Campanile Drive, San Diego CA 92182-7251. E-mail: smarshal@mail.sdsu.edu.

commercially available pedometers do not measure activity intensity, pedometers are relatively inexpensive (\$10–\$25), which may explain why they have rapidly become a centerpiece of many local and national physical activity campaigns.^{6,7} Moreover, individuals appear able to remember pedometer-based recommendations when targeted by public health campaigns⁸ and counseling.⁹ The most widely recognized step recommendation is to accumulate 10,000 steps per day.¹⁰ Although step goals do increase the effectiveness of pedometer use,⁵ the goal of 10,000 steps per day is based on limited evidence, may be unrealistic for many people,¹¹ and does not incorporate activity intensity.

Researchers and practitioners have called for a directly measured index for the number of steps taken in 30 minutes of moderate-intensity walking.¹¹ This would enable national recommendations to be translated easily for pedometer-based interventions and public health campaigns. Although accumulated evidence^{12–15} suggests that 30 minutes of moderate-intensity walking translates to approximately 3000–4000 steps in healthy adults, the results are based on small samples, and activity intensity is often unmeasured, determined by self-report, or implied by walking speed. Only one study¹³ has used an objective measure of activity intensity to develop a step-based recommendation, but the findings lack generalizability because they are based on a sample of young healthy adults, and there was no control for data dependence in the analysis.¹⁶ The purposes of this study were (1) to evaluate the utility of using a commercially available pedometer to measure moderate-intensity walking in a community sample, (2) to determine the range of step counts per minute that define moderate-intensity walking for people of different weight status, and (3) to translate current recommendations for moderate-intensity physical activity into a pedometer-based step goal.

Methods

Participants

A community sample of 97 Latino adults (39 men, 58 women) with a mean age of 32.1 (± 10.6) years, volunteered to participate in the study. The mean BMI for men was 27.5 (± 3.7) kg·m² and for women was 29.7 (± 6.3) kg·m². All participants were initially screened for age (18–55 years) and for cardiovascular abnormalities or symptoms using the Physical Activity Readiness Questionnaire.¹⁷ The study was approved by the IRB at San Diego State University, and all subjects provided informed consent before participating.

Height and Weight Measurement

Height was measured without shoes to the nearest 0.5 centimeter using a calibrated stadiometer. Weight was measured in light clothing and without shoes to the nearest 0.1 kg using a standard physician's balance scale.

Step Counts

The Yamax SW-200 pedometer was used to count steps. A number of well-designed multi-brand comparison studies undertaken in controlled^{18–20} and free-living conditions^{19,20} have consistently identified Yamax-brand pedometers as valid and reliable. The pedometer contains a horizontal, spring suspended lever arm that deflects with the up-and-down motion of the hips during walking. An electrical circuit opens and closes with each detected deflection, and an accumulated step count is displayed digitally on a feedback screen. Two pedometers were attached to each participant's waistband, one over the midline of the right thigh and one over the midline of the left thigh. Vertical positioning was checked in accordance with the manufacturer's recommendations. Prior to use in this study, all pedometers were checked for accuracy using a standard 20-step test.²¹ As an additional measure of criterion validity, step counts from the pedometer during the protocol were compared to a gold standard hand tally taken from a video recording of each participant.

Treadmill Testing

Prior to all testing, participants completed a brief habituation session to familiarize themselves with walking on a treadmill and wearing the face mask that was attached to the metabolic measurement cart. Participants performed up to four 6-minute incremental walking bouts on a level treadmill at 65, 80, 95, and 110 m·min⁻¹ (2.4 mph, 3.0 mph, 3.5 mph, and 4.1 mph, respectively). Participants were given the option of seated rest between bouts. The order of the treadmill bouts was not randomized (the bouts went from slowest speed to highest speed) because of concerns that some participants would be unable to walk at the higher speeds due to limitations in fitness.

Expired air was collected continuously using a system with VacuMed O₂ and CO₂ gas analyzers and a heated pneumotachometer. Heart rate was monitored using a telemetry transmitter attached to the chest. Participants were also asked to rate their perceived exertion (RPE), using Borg's 6–20 scale.²² The test was terminated if the RPE became 18 or greater. RPE scores at each treadmill speed are presented in the results for descriptive purposes only. Oxygen uptake (VO₂=milliliters [mL]·kg⁻¹·minute [min]⁻¹) and heart rate from the last 2 minutes of exercise were averaged and reported. Pedometer steps were collected over the final 2 minutes to ensure exact congruence with the VO₂ measurements.

Data Analysis

Step-rate cut points were developed separately for men and women and for different categories of BMI status, as each has previously been associated with pedometer counts.¹¹ Using guidelines proposed for the calibration of accelerometer data,¹⁶ step-rate cut points were determined using three analytic approaches: multiple regression, mixed modeling, and receiver operating characteristic (ROC) curves. In the multiple regression approach, step counts from each treadmill speed were used to develop a prediction equation for a step-rate cut point associated with moderate-intensity activity, defined as 3.00–5.99 METs. Although this approach is commonly used in studies involving the calibration of pedometers

Table 1. M±SD of measured variables at each treadmill speed by weight status

Speed 1 (65 m·min ⁻¹)	n	Step rate (steps·min ⁻¹)–		Step rate (steps·min ⁻¹)– pedometer right hip	Stride length (m·step ⁻¹)	VO ₂ (mL·kg ⁻¹ ·min ⁻¹)	METs ^a	Heart rate (bpm)	RPE (6–20)
		hand tally	pedometer left hip						
Normal weight	25	109.96±9.46	106.62±17.74	105.12±18.05	0.63±0.15	11.49±3.51	3.28±1.00	100.44±10.48	7.48±2.10
Overweight	34	106.18±7.19	101.28±14.76	99.68±17.40	0.66±0.11	10.38±1.79	2.96±0.51	98.03±14.14	7.82±2.62
Obese	37	112.19±8.50	111.79±11.46	106.18±25.90	0.59±0.06	10.79±1.54	3.08±0.44	112.08±15.42	8.86±2.18
Speed 2 (80 m·min⁻¹)									
Normal weight	25	115.44±7.29	117.46±12.28	116.26±8.22	0.69±0.06	13.55±3.20	3.87±0.92	107.08±11.90	10.12±1.99
Overweight	34	113.06±6.45	114.56±7.06	110.03±18.88	0.70±0.05	12.58±1.99	3.59±0.57	105.35±13.98	8.94±2.82
Obese	35	117.47±7.47	119.87±10.28	115.43±16.19	0.67±0.06	13.19±1.57	3.77±0.45	119.91±17.41	9.91±1.95
Speed 3 (95 m·min⁻¹)									
Normal weight	22	123.66±7.01	128.21±20.78	124.33±6.53	0.75±0.08	17.30±4.87	4.94±1.39	118.88±14.75	11.88±1.70
Overweight	30	121.10±7.05	121.91±7.01	115.47±24.70	0.78±0.04	16.27±2.64	4.65±0.75	117.43±18.39	10.77±2.96
Obese	29	125.66±6.56	127.14±6.24	125.77±8.08	0.80±0.04	18.30±2.75	5.23±0.79	134.22±20.89	12.48±2.59
Speed 4 (110 m·min⁻¹)									
Normal weight	22	135.02±8.87	141.50±30.77	135.02±8.87	0.80±0.10	24.67±6.92	7.05±1.98	145.86±22.68	14.27±2.39
Overweight	26	131.75±7.89	133.15±9.20	131.75±7.89	0.83±0.06	22.50±4.16	6.43±1.19	136.77±22.70	13.12±3.13
Obese	16	136.41±8.11	134.97±14.00	136.41±8.11	0.82±0.10	25.41±5.45	7.26±1.56	149.75±22.21	14.69±3.05

Note: Stride length multiplied by step rate (left pedometer) will not exactly equal distance walked at each speed due to rounding error at the individual level.

^aMETs (1 MET=3.5mL·O₂·kg⁻¹·min⁻¹)

bpm, beats per minute; kg, kilogram; m, meters; min, minute; mL, milliliters; RPE, rate of perceived exertion

and accelerometers, it violates the assumption of data independence because multiple data points (i.e., speeds) from each individual are used in the analysis. To overcome this limitation, mixed modeling was also used, in which a random-coefficients model was developed to take account of the data-dependence structure.¹⁶ Finally, ROC curves were developed to examine optimal step-rate cut points in terms of sensitivity (correctly identifying those who were at moderate intensity) and specificity (correctly identifying those who were not at moderate intensity).

Results

Means and SDs of measured variables at each treadmill speed by participant weight status are presented in Table 1. Although data analysis was conducted separately by gender, combined data are presented in the table because few gender differences emerged.

Preliminary Analysis

Separate 2 (pedometer/hand tally) × 4 (speed) repeated-measures ANOVAs were conducted for each hip placement site to examine the differences in step counts obtained from pedometers and from hand tallies. For the left and right hip, no significant main effects or interactions were found. A 2 (left hip/right hip) × 4 (speed) repeated-measures ANOVA conducted to examine differences in step rate based on hip placement and speed revealed a significant main effect for speed ($p<0.001$, $\eta^2=0.59$) and a significant main effect for hip ($p<0.04$, $\eta^2=0.07$). Because the hip-placement site accounted for a small percentage of the variance in step rate, the difference was deemed not practically meaningful. For simplicity, left-hip step rates were used for the remainder of the analyses.

Multiple Regression

Multiple regression analyses resulted in equations that explained 35% of the variability ($R^2=0.35$, standard error of estimate [SEE]=1.30, $p<0.001$) and 23% of the variability ($R^2=0.23$, SEE=1.52, $p<0.001$) in METs for men and women, respectively. For men, the equation $\hat{Y}=0.061x-2.597$ (where x =steps per minute) solved for 3 METs resulted in a step-rate cut point of 92 step·min⁻¹. For women, the equation $\hat{Y}=0.042x-0.82$ solved for 3 METs resulted in a step-rate cut point of 91 step·min⁻¹. For BMI, step-rate cut points for 3 METs were 127 step·min⁻¹ for normal-weight (BMI <25) individuals; 94 step·min⁻¹ for overweight (BMI 25–29.9) individuals; and 103 step·min⁻¹ for obese (BMI >30) individuals. The prediction equations explained 15%, 34%, and 41% of the variability in METs for normal weight, overweight, and obese individuals, respectively.

Mixed Modeling

A mixed-model approach with slopes and intercepts for individuals modeled as random effects and average intercept and slope as fixed effects yielded slightly higher step-rate cut points for men (101 $\text{step}\cdot\text{min}^{-1}$; $\hat{Y}=0.101x-7.14$) and women (111 $\text{step}\cdot\text{min}^{-1}$; $\hat{Y}=0.125x-10.77$). The step-rate cut points by weight status are presented Table 2.

Receiver Operating Characteristic Curves

Receiver operating characteristic curves were developed to establish step-rate cut points based on optimal levels of sensitivity and specificity. Initially, data were examined for all speeds. From these data, Speed 1 was used to examine the sensitivity and specificity of step-rate cut points based on MET values of 3.00–5.99, equating to moderate-intensity activity. Speed 1 was chosen because all participants completed the protocol at this speed, and the number of participants classified at moderate intensity was similar to those classified as not at moderate intensity.

The optimal (best specificity and sensitivity) step-rate cut point was 107 $\text{step}\cdot\text{min}^{-1}$. Using this cutoff value, 52% of those in moderate intensity would be correctly classified, with 48% being incorrectly classified. The area under the curve (AUC) was 0.56 (SE=0.06, $p>0.31$, 95% CI=0.44, 0.68).

Gender. For men, ROC-curve coordinates suggested that the optimal step-rate cut point was 102 $\text{step}\cdot\text{min}^{-1}$, with 67% true positives and 27% false positives. For men, the AUC was 0.65 (SE=0.097, $p>0.11$, 95% CI=0.46, 0.84), suggesting that using a step-rate cut point to identify moderate-intensity walking was not significantly better than chance. For women, the optimal step-rate cut point was 115 $\text{step}\cdot\text{min}^{-1}$. However, only 43% would be true positives, while 22% would be false positives. For women, the AUC was 0.58 (SE=0.077, $p>0.30$, 95% CI=0.43, 0.73).

BMI. For normal-weight individuals, the ROC curve suggested an optimal step-rate cut point of 106 $\text{step}\cdot\text{min}^{-1}$, indicating 63% as true positives and 22% as false positives. The AUC was 0.76 (SE=0.095, $p<0.04$, 95% CI=0.58, 0.95). For overweight individuals, the optimal step-rate cut point was 103 $\text{step}\cdot\text{min}^{-1}$, with 58% being true positives and 53% being false positives. The AUC was 0.42 (SE=0.104, $p>0.41$, 95% CI=0.21, 0.62). For obese individuals, the optimal step-rate cut

Table 2. Minimum pedometer-based step rates for moderate-intensity walking using three different analytic approaches

	<i>n</i>	Minimum step rates ($\text{step}\cdot\text{min}^{-1}$) for moderate-intensity (3 METs) walking		
		Multiple regression analysis	Mixed-model analysis	ROC-curve analysis
All	97	89	106	107
Men	39	92	101	102
Women	58	91	111	115
Normal weight	25	127	105	106
Overweight	34	94	106	103
Obese	37	103	105	110

ROC, receiver operating characteristic

point was 110 $\text{step}\cdot\text{min}^{-1}$, with 63% being true positives and 50% being false positives. The AUC was 0.62 (SE=0.094, $p>0.22$, 95% CI=0.43, 0.80). A summary of the step-rate cut-points derived from the different analyses is presented in Table 2.

Discussion

The main finding of this study is that considerable error exists when using pedometer step counts to measure METs during treadmill walking in a community sample. Based on three different analytic models, the findings suggest that steps per minute explain 15%–41% of the variance in METs, and that only 50%–60% of individuals could be correctly classified as walking at moderate intensity using step rate alone.

Of the 18 different step rates computed across subsamples and analytic methods, 11 (61%) were between 100 and 110 $\text{step}\cdot\text{min}^{-1}$ as a minimum threshold for moderate-intensity walking. To date, only one other study¹³ has used indirect calorimetry to empirically validate a step-rate cut point associated with moderate-intensity walking. Tudor-Locke and colleagues¹³ determined that 96 and 107 $\text{step}\cdot\text{min}^{-1}$ represented the minimum threshold for moderate-intensity walking in a sample of young, healthy men and women, respectively. Although the current study's estimates are consistent with those findings, step rate in this study explained substantially less variance in METs than in the Tudor-Locke study (30% vs 80%). In contrast to the Tudor-Locke sample, this study's participants were predominantly sedentary, either overweight or obese, and older; they therefore reached moderate intensity (3 METs) at a slower treadmill speed. This may have introduced additional measurement error because the relationship between step rate and METs at slower walking speeds may be different than at higher speeds.

We believe that these data support a general recommendation of walking at $>100 \text{step}\cdot\text{min}^{-1}$ on level terrain to meet the minimum of the moderate-intensity guideline. However, it is important to emphasize that this cut point should not be used as a precise criterion

for determining moderate-intensity walking because step rate is not an accurate proxy for METs. However, there does appear to be sufficient evidence for step rate to be used as a heuristic with which to promote physical activity, much the same way that recommendations are made for 150 minutes of moderate-intensity physical activity each week¹ or for walking 10,000 steps per day.¹⁰ At a rate of 100 steps per minute, current recommendations for moderate-intensity physical activity¹ would equate to walking at least 3000 steps in 30 minutes on 5 days each week, or three daily bouts of 1000 steps in 10 minutes on 5 days each week. It should be noted that this recommendation is also consistent with the estimate of 3000–4000 steps in 30 minutes that comes largely from observational studies of healthy adults.^{14,20,23,24}

Although different step rates did emerge by gender and weight status, the differences were relatively small and not consistent across analytic methods. Because there is considerable error in all these estimates, it is believed that having a different recommendation for men and women and for people of different weight status is not supported by the data. Although the data do provide support for a step rate that is slightly higher than 100 steps per minute (14 of 18 step-rate cut points were >100 steps per minute), it is believed that the lack of precision in these estimates and the need for a simple public health message justifies the “3000-in-30” recommendation (i.e., 3000 steps in 30 minutes on 5 days each week). Indeed, the use of a single and simple pedometer-based guideline that is easy both to remember and measure may be more effective in a health-communication strategy than the promotion of multiple guidelines and, therefore, messages.²⁴ It is important to emphasize again that this 3000-in-30 recommendation is intended as a physical activity promotion heuristic rather than a precise criterion. Further study should attempt to examine the dose–response relationship of walking at different step rates as well as the effectiveness of a health-communication strategy promoting the 3000-in-30 recommendation.

There are a number of limitations to this study. First, pedometers are limited as physical activity measurement devices because they capture movement only of the lower body in the vertical plane and cannot distinguish between walking on different gradients. These recommendations may not apply to other movements, load carriage, or changes in surface or gradient. In addition, the current data were collected under controlled conditions (treadmill walking), which reduces their ecologic validity. However, evidence does suggest that walking on a treadmill and walking overground are kinetically and kinematically equivalent in healthy subjects.²⁵ Unfortunately, little is known about gait equivalence under other free-living walking conditions (e.g., along sidewalks with curbs, across multiple surfaces). One final limitation is the use of a constant (3.5

mL·kg⁻¹·min⁻¹) as an estimate of resting energy expenditure instead of a direct measurement. Although the use of this constant is widely accepted in the scientific literature,²⁶ it is likely to overestimate or underestimate resting-energy demands at the individual level.

The results of this study suggest that researchers and practitioners should use caution when using pedometer-assessed step rates as a proxy for METs because there is substantial error in predicting METs from step rate alone. However, the authors believe that their evidence does support a public health recommendation of walking at least 3000 steps in 30 minutes on 5 days each week (or three daily bouts of 1000 steps in 10 minutes on 5 days each week) to help meet current physical activity recommendations. This recommendation should not be used as precise criterion but as a health promotion heuristic to help people lead more active lifestyles.

The authors thank Dr. Patricia Quintana, Dr. Monica Yépez-Ríos, and Dr. Greg Talavera of the San Ysidro Health Center (San Ysidro CA) for providing laboratory space and staff support during participant testing. This work was supported by a cooperative agreement (special interest project 9_04; U48 DP000036-01S1; principal investigator Dr. Simon Marshall) between the CDC and the San Diego Prevention Research Center. The San Diego Prevention Research Center is a member of the Prevention Research Centers Program, supported by the CDC Cooperative Agreement number 5-U48-DP-000036.

No financial disclosures were reported by the authors of this paper.

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