



## PAPER

# The relationship between pedometer-determined ambulatory activity and body composition variables

C Tudor-Locke<sup>1\*</sup>, BE Ainsworth<sup>1–3</sup>, MC Whitt<sup>4</sup>, RW Thompson<sup>3</sup>, CL Addy<sup>2</sup> and DA Jones<sup>5</sup>

<sup>1</sup>Prevention Research Center, School of Public Health, University of South Carolina, Columbia, South Carolina, USA; <sup>2</sup>Department of Epidemiology and Biostatistics, University of South Carolina, Columbia, South Carolina, USA; <sup>3</sup>Department of Exercise Science, University of South Carolina, Columbia, South Carolina, USA; <sup>4</sup>Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, USA; and <sup>5</sup>Division of Physical Activity and Nutrition, Center for Chronic Disease Prevention and Health Promotion, US Centers for Disease Control and Prevention, Atlanta, Georgia, USA

**OBJECTIVE:** To examine the relationship between pedometer-determined ambulatory activity (steps/day) and body composition variables body mass index (BMI) and percentage body fat).

**DESIGN:** Secondary analysis of a cross-sectional objective activity monitoring study for up to 21 consecutive days.

**SUBJECTS:** A total of 109 apparently healthy adults (eight African American males, 23 African-American females, 33 Caucasian males, 45 Caucasian females), age  $44.9 \pm 15.8$  y, BMI =  $26.9 \pm 5.1$  kg/m<sup>2</sup>.

**MEASUREMENTS:** Pedometer-assessed ambulatory activity (steps/day), height and weight, and percentage body fat by bioelectrical impedance.

**RESULTS:** Analyzed as both a continuous and a categorical variable (determined using 25th and 75th percentiles for distribution for steps/day), ambulatory activity was consistently related to body composition variables. Steps/day was inversely correlated with BMI and percentage body fat ( $r = -0.30$ , and  $r = -0.27$ , respectively, both  $P < 0.01$ ). The consistency of the relationship was also evident when examined using accepted BMI cut-off points for normal-weight, overweight, and obese categories.

**CONCLUSIONS:** Individuals in this small sample with values greater than approximately 9000 steps/day are more frequently classified as normal weight for height. Individuals with values less than approximately 5000 steps/day are more frequently classified as obese. These findings require further corroborative investigation but provide preliminary cutoff points for identifying individuals at risk who may benefit from appropriate physical activity intervention.

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**Keywords:** pedometer; walking

## Introduction

The dramatic increase in overweight and obesity over the last few decades is considered to be of epidemic proportions in many countries around the world.<sup>1</sup> The most recent statistics reported from NHANES III indicate that close to 55% of US adults are either overweight or obese.<sup>2</sup> Paradoxically, participation in leisure-time physical activity has remained relatively stable.<sup>3</sup> This finding suggests that traditional measurement approaches focused on leisure-time physical activ-

ity may be inadequately sensitive to changes in incidental, ubiquitous daily activity. As testament to the considered role of physical inactivity in obesity trends, the American College of Sports Medicine convened a February 1999 Roundtable of experts to examine the scientific evidence and deliberate pressing issues.<sup>4</sup> One of the issues identified for physical activity assessment was an inability to quantify trends in physical activity using currently available data.<sup>5</sup>

There is increasing interest in objective monitoring of daily physical activity using electronic motion sensors, including accelerometers<sup>6,7</sup> and pedometers.<sup>8–10</sup> This shift was apparent in the June 2000 *Research Quarterly for Exercise and Sport* Measurement of Physical Activity Special Issue<sup>11</sup> and again in the September 2000 *Medicine and Science in Sports and Exercise* Measurement of Moderate Physical Activity: Advances in Assessment Techniques Issue.<sup>12</sup> In

\*Correspondence: C Tudor-Locke, Prevention Research Center, Norman J Arnold School of Public Health, University of South Carolina, Columbia, SC 29208, USA.

E-mail: ctudor@sph.sc.edu

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both these special journal supplements most articles discussed objective monitoring to some extent. The science and practice of objective monitoring of physical activity is still in its infancy. Researchers are slowly beginning to acknowledge that, in terms of practicality, however, pedometers currently offer the best solution for a low-cost, objective monitoring tool.<sup>13–16</sup> Unfortunately, the cost of accelerometers (\$50–400 per unit) is prohibitive for most practical and larger-scale applications including surveillance, screening, program evaluation and intervention.<sup>9</sup>

The new generation of electronic pedometers are battery-operated devices containing a spring-suspended, horizontal lever arm that moves up and down in response to vertical accelerations of the trunk that occur during ambulatory movement (eg walking, running) when worn at the waist. This movement opens and closes an electrical circuit; each cycle is registered as a step and the accumulated total is displayed digitally. Pedometers are particularly sensitive to walking behavior, or ambulatory activity.<sup>15–20</sup> Walking is the most common manifestation of daily activity; engagement in other types of physical activities (ie structured and/or vigorous) is infrequent and intermittent.<sup>21,22</sup> Worn over the course of the day, pedometers can potentially capture intentional as well as incidental walking behaviors.<sup>23</sup> Pedometers are not designed to discriminate pattern or intensity of activity; their output is simply steps taken over the specified monitoring period. In a series of studies Bassett and colleagues<sup>23–25</sup> have shown that pedometers are most accurate at measuring steps taken (within 1% of actual steps taken), less accurate when the output is manipulated to estimate distance traveled, and even less accurate when used to extrapolate to energy expenditure. The findings of Hendelman *et al*<sup>26</sup> concur that the most accurate pedometer output is steps taken.

To be useful for assessment purposes (and for examining obesity-related trends), however, evidence of convergent validity of this objective monitoring tool must be presented. Specifically, pedometer output must be acceptably associated with indicators of body composition as well as other health consequences of physical activity. The purpose of this study is to describe the relationship between an objective measure of walking, assessed as steps/day using a pedometer, and two body composition variables, body mass index (BMI) and percentage body fat, among a group of African-American

and Caucasian adults living in South Carolina. Additional purposes include: (1) to describe preliminary evidence of specific steps/day ‘cut-off points’ useful for identifying sedentary individuals who might benefit from an appropriate physical activity intervention; and (2) to provide preliminary evidence toward a minimum recommended level of steps/day associated with body composition benefits.

## Methods

### Subjects

Subjects were recruited by word of mouth and from posted announcements in the University of South Carolina and Columbia communities. Inclusion criteria were: (1) apparently healthy; (2) able to walk on a treadmill for a submaximal exercise test; and (3) willingness to comply with the research protocol. One hundred and thirty-nine subjects enrolled in the study. Subsequently, 10 dropped out due to self-reported time constraints and three were not compliant with the study protocol. Among the remaining 126 subjects, 49 were male (11 African-American and 38 Caucasian) and 77 were female (27 African-American and 50 Caucasian). Volunteers ranged in age from 17 to 79 y. All subjects read and signed a written informed consent form approved by the University of South Carolina Institutional Review Board.

Of the total sample, one subject had missing BMI data, nine had missing percentage body fat data, and seven had missing pedometer data. Analyses were therefore conducted on data obtained from 109 subjects (eight African-American males, 23 African-American females, 33 Caucasian males, 45 Caucasian females) with complete body composition (BMI and fat percentage) and pedometer-assessed ambulatory activity (steps/day) data. Nineteen or more days of pedometer data were collected from 96 of the subjects. The average number of days of pedometer data collected on the remaining subjects was 14 (range 4–18).

Descriptive data for age, BMI, percentage body fat and steps/day (calculated for the days collected) for each race–gender group and for the total sample are presented in Table 1. African-American subjects were significantly younger than Caucasian subjects regardless of gender ( $F=7.01$ ,  $P<0.0002$ ). Caucasian females had a significantly lower BMI than African-American males or females; Caucasian males did not differ significantly from either Caucasian

**Table 1** Descriptive characteristics for each race gender group and the total sample

	African American (n = 31)		Caucasian (n = 78)		Total sample (n = 109)
	Males (n = 8)	Females (n = 23)	Males (n = 33)	Females (n = 45)	
Age	30.3 ± 15.9 <sup>A</sup>	36.6 ± 9.8 <sup>A</sup>	49.6 ± 15.1 <sup>B</sup>	48.2 ± 16.1 <sup>B</sup>	44.9 ± 15.8
BMI	28.7 ± 7.1 <sup>A</sup>	29.6 ± 6.3 <sup>A</sup>	26.8 ± 3.2 <sup>A,B</sup>	25.2 ± 4.5 <sup>B</sup>	26.9 ± 5.1
Percentage body fat	23.0 ± 8.3 <sup>A</sup>	34.0 ± 8.8 <sup>B</sup>	23.3 ± 4.3 <sup>A</sup>	32.0 ± 7.3 <sup>B</sup>	29.1 ± 8.3
Steps/day	7654 ± 3079 <sup>A</sup>	6198 ± 2735 <sup>A</sup>	7948 ± 3106 <sup>A</sup>	7494 ± 3167 <sup>A</sup>	7370 ± 3080

Note: Values are means ± s.d.

Means with different letter superscripts are significantly different,  $P < 0.05$ .

females or African-American subjects ( $F=4.5$ ,  $P=0.005$ ). Females of both races had significantly higher body fat percentage compared with males of both races ( $F=15.9$ ,  $P<0.0001$ ). Steps/day did not differ significantly between any race-gender groups ( $F=1.57$ ,  $P=0.20$ ).

### Study protocol

Subjects were enrolled in the study for 21 consecutive days during which time they wore a pedometer (Yamax Digi-walker, Model DW-500, Accusplit, CA) and completed a daily physical activity log as direct measures of physical activity. Subjects also completed physical activity questionnaires, physical fitness and anthropometric assessments (height, weight, and percent body fat) as indirect measures of physical activity. To determine participation in vigorous activities, subjects were asked, 'Last week, did you do vigorous activities continuously for at least 10 minutes that caused large increases in breathing or heart rate, such as running, swimming, aerobics, fast bicycling, competitive sports or heavy yard work?' If subjects answered positively, they were queried about the total minutes spent doing vigorous activities per day. This report focuses primarily on the body composition and pedometer data, using the vigorous activities question only to classify individuals with regard to participation in vigorous activities (minutes of vigorous activities  $>10$ ,  $n=61$ ) or not (minutes of vigorous activities  $<10$ ,  $n=48$ ). The purpose of this procedure was to allow for testing of differences in steps/day between individuals so classified.

Height was measured without shoes using a wall-mounted tape measure and body mass was assessed using a digital scale (Seca, Shorr Products, Model 770, Onley, MD). Body mass index (BMI) was computed as weight in kg/height in meters squared. Percentage body fat was determined using an RJL bioelectrical impedance analyzer (Model 101, Clinton Twp., MI). Bioelectrical impedance is an acceptable adjunct to anthropometry for assessing body composition in field studies.<sup>27</sup> Subjects were assessed over three consecutive trials conducted in the morning after a 12 h fast and within 30 min of voiding. Sex- and race-specific equations were used to predict percentage body fat from the average resistance and reactance in ohms.<sup>28,29</sup>

Subjects were instructed to wear the pedometer and to record the total number of steps taken each day in a physical activity log each night prior to retiring. If the pedometer was not worn on a day for any reason (eg forgot, chose not to) subjects were asked to leave the activity log blank on that day, indicating non-compliance. The pedometer was worn attached to the waistband of their clothing during waking hours, except when bathing or swimming. Subjects were encouraged not to alter their usual physical activity habits during the 3 week study. Subjects were contacted by telephone or face-to-face once a week during the 3 week study to check for compliance (ie 'Have you been wearing the pedometer and recording in the log?') with the protocol. At the

end of the study, subjects returned the pedometers and the physical activity logs to the study center where the logs were checked by study staff for completeness and comprehension.

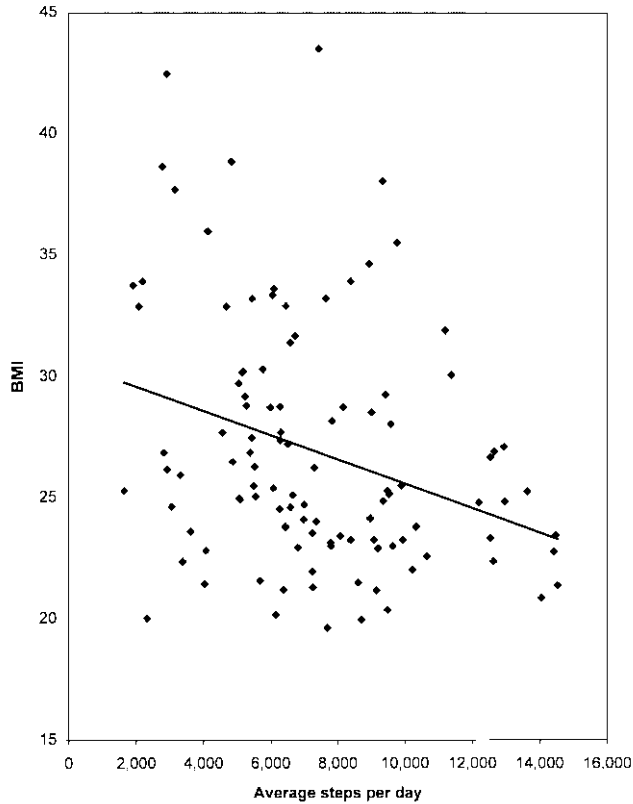
### Data treatment and statistical analysis

Physical activity (steps/day) was examined as a continuous variable (range 1647–14 529) using correlation analysis (Pearson product-moment correlation coefficients) to quantify the relationship between steps/day and BMI or percentage body fat, after exploring for evidence of confounding. In both cases, regression analysis was used to predict the line of best fit against the data distribution. Physical activity also was examined as a categorical variable defined as low, moderate and high according to tertiles of steps/day using the 25th and 75th percentiles for distribution. Set categories for BMI were applied to represent obesity ( $\text{BMI} \geq 30$ ), overweight ( $25 \leq \text{BMI} < 30$ ) and normal weight ( $\text{BMI} < 25$ ) status;<sup>30</sup> there was no one in this study classified as underweight ( $\text{BMI} < 18.5$ ). Effect size of steps/day was calculated as the difference between means of the obese and normal weight groups, divided by the standard deviation for the total sample. Calculating effect size is a recommended technique for presenting the 'meaningfulness' of differences between groups.<sup>31</sup> An effect size of 0.2 is considered small, 0.5 is moderate, and 0.8 is large.<sup>32</sup>

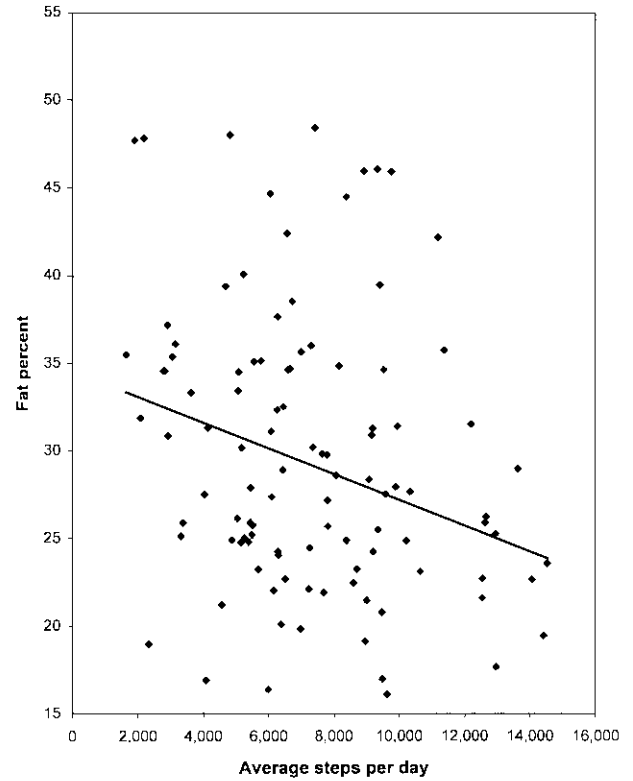
Comparison of mean steps/day between reported participation in vigorous activities (yes or no) was determined using independent *t*-tests, having satisfied relevant statistical assumptions. Chi-square analyses were used to examine frequency distributions of gender and race between pedometer-determined activity categories, and the frequency of BMI category classification between reported participation in vigorous activities. The relationship between steps/day and estimates of body fatness was further examined using one-way analysis of variance, statistical assumptions having been satisfied. In the first analysis, tertile of steps/day was the grouping variable and the dependent variables were age, BMI and percentage body fat. In the second analysis, BMI category was the grouping variable and dependent variables were age, percent body fat, and steps/day. *Post-hoc* analyses (Student–Newman–Keuls test) were used to compare differences between categories. Statistical analyses were conducted using SAS Version 6.12. Significance was set at an alpha level of  $P < 0.05$ .

### Results

Mean steps/day did not differ statistically between individuals reporting participation in vigorous activities or not ( $7036 \pm 2893$  vs  $7794 \pm 3285$  steps/day, respectively). Analyzed as a continuous variable, steps/day was inversely correlated with both BMI ( $r = -0.30$ ) and percentage body fat ( $r = -0.27$ ),  $P < 0.01$ . Age was not a confounder for these associations in this sample. Figure 1 presents the predicted regression line against the spread of steps/day vs BMI. A



**Figure 1** Regression of BMI and pedometer-determined steps/day.



**Figure 2** Regression of percent body fat and pedometer-determined steps/day.

similar relationship is presented in Figure 2 for steps/day vs percentage body fat.

Tertiles for steps/day as a measure of physical activity were defined as low activity (below the 25th percentile of distribution, or  $\leq 5267$  steps/day), moderate activity (between the 25th and 75th percentiles of distribution, or 5268–9356 steps/day) and high activity (above the 75th percentile of distribution, or  $\geq 9357$  steps/day). Table 2 presents the distribution of BMI category by pedometer-determined activity tertile. Forty-one percent of individuals in the lowest activity tertile were also classified as obese, compared with 11% of those in the highest activity tertile. Similarly, 57% of subjects in the highest activity tertile were also classified as normal weight for height compared with 30% of those in the lowest activity tertile. There was no difference in BMI cate-

gory distribution by reported participation in vigorous activities (data not shown).

Table 3 presents a summary of the comparison of variables between pedometer-determined activity categories. There were no significant differences in frequency of race or gender across activity categories as determined by  $\chi^2$  analyses. There were no significant differences in mean age across activity categories ( $F = 1.49, P = 0.23$ ). Both BMI and percentage body fat were significantly different across activity categories ( $F = 5.04, P = 0.01$ , and  $F = 3.90, P = 0.02$ ). *Post-hoc* analyses revealed significant differences in BMI between the low activity category vs the moderate and high activity categories. There were no differences in BMI between the moderate and high activity categories. Percentage body fat was significantly higher in the low activity category

**Table 2** Subject classification by tertile of pedometer activity and BMI category

Tertiles pedometer-assessed ambulatory activity	Categories of BMI-defined body composition		
	Normal (BMI < 25) n (%)	Overweight (25 ≤ BMI < 30) n (%)	Obese (≥ 30) n (%)
Low (n = 27) ≤ 5267 steps/day	8 (30%)	8 (30%)	11 (41%)
Moderate (n = 54) 5268–9356 steps/day	25 (46%)	17 (31%)	12 (22%)
High (n = 28) ≥ 9357 steps/day	16 (57%)	9 (32%)	3 (11%)

**Table 3** Comparison of variables between categories of pedometer-assessed ambulatory activity

Variable	Categories of pedometer-assessed ambulatory activity		
	Low (n = 27) ≤ 5267 steps/day (74% women, 33% African-Americans)	Moderate (n = 54) 5268–9356 steps/day (63% women, 28% African-Americans)	High (n = 28) ≥ 9357 steps/day (50% women, 25% African-Americans)
Age	49.2 ± 17.2 <sup>A</sup>	42.8 ± 14.6 <sup>A</sup>	44.6 ± 16.5 <sup>A</sup>
BMI	29.2 ± 5.9 <sup>A</sup>	26.6 ± 4.9 <sup>B</sup>	25.1 ± 3.4 <sup>B</sup>
Percentage body fat	32.3 ± 8.1 <sup>A</sup>	29.0 ± 8.1 <sup>A,B</sup>	26.2 ± 8.0 <sup>B</sup>

Note: values are means ± s.d.

Categories of pedometer-assessed physical activity determined using percentiles of distribution: low ≤ 25th; > 25th moderate < 75th; high ≥ 75th. Means with different letter superscripts are significantly different,  $P < 0.05$ .

compared with the high activity category. There was no difference in percentage body fat between the moderate activity category and the low or high activity categories.

The comparisons of mean age, percentage body fat, and pedometer steps/day by BMI categories are presented in Table 4. Women and African-Americans (compared with men and Caucasians) were more frequently classified as obese according to this partitioning strategy. As expected, percentage body fat was significantly different across BMI categories ( $F = 38.10$ ,  $P < 0.001$ ) with percentage body fat increasing in higher BMI categories. There was a significant difference across BMI categories for steps/day with subjects classified as normal weight taking significantly more steps/day than those classified as obese. There was no significant difference in steps/day between overweight subjects and those classified as normal weight or obese by BMI categories. Calculated effect size between the normal weight and obese BMI categories for steps/day was 0.75.

## Discussion

This is the first study to examine the relationship between electronic pedometer-assessed ambulatory activity expressed as steps/day and two body composition variables in an adult population. Although Tryon *et al*<sup>33</sup> previously used pedometers for a similar purpose, those authors expressed the pedometer output as a rate of distance traveled per hour. The authors concluded that pedometer-determined activity was inversely related to percentage of overweight in 127 women

aged 19–55 y ranging from 14 to 99% overweight ( $r = -0.217$ ,  $P < 0.02$ ).

We resolved not to convert raw pedometer outputs to an estimate of distance traveled during the day. The process of manipulating the raw step data in this manner introduces possible errors due to individual differences in stride length.<sup>8</sup> The conversion of steps taken to distance walked is based on the assumption that all strides taken over the course of the day are similar in length. This makes little sense in a field study; steps taken while milling about the kitchen engaged in meal preparation probably differ in stride length from those taken while running an errand, walking the dog, dancing, or running for exercise. In a laboratory study of treadmill walking, Bassett *et al*<sup>24</sup> demonstrated that error in estimating distance from pedometer stepping at fast speed was due to stride lengthening rather than to step miscounting, and while the pedometer is designed to be most sensitive to the vertical movements of walking, other movements throughout the day like hopping, kneeling and bending, will also cause a ‘step’ to register; this error will only be compounded if multiplied by an estimated stride length.<sup>34</sup> Despite our different approaches to presenting pedometer output, however, our conclusions concur with those presented by Tryon *et al*,<sup>33</sup> there was a distinct relationship, in the expected direction, between pedometer data and body composition variables.

This relationship is consistently reported in other populations as well. McClung *et al*<sup>35</sup> reported that increased BMI was associated with reduced pedometer-assessed ambulatory activity (steps/day), adjusted for age and gender ( $P = 0.05$ ) in 209 subjects, including 151 subjects with hip or knee joint

**Table 4** Comparison of variables between categories of BMI-defined body composition

Variable	Categories of BMI-defined body composition		
	Normal (BMI < 25), n = 49 (71% women, 18% African-Americans)	Overweight (25 ≤ BMI < 30), n = 34 (41% women, 50% African-Americans)	Obese (≥ 30), n = 26 (73% women, 58% African-Americans)
Age	42.1 ± 16.7 <sup>A</sup>	49.9 ± 15.6 <sup>A</sup>	43.5 ± 13.3 <sup>A</sup>
Percentage body fat	24.8 ± 6.1 <sup>A</sup>	28.3 ± 5.6 <sup>B</sup>	38.3 ± 7.4 <sup>C</sup>
Steps/day	8325 ± 3060 <sup>A</sup>	7035 ± 2984 <sup>A,B</sup>	6006 ± 2717 <sup>B</sup>

Note: values are means ± s.d.

Means with different letter superscripts are significantly different,  $P < 0.05$ .

replacements. The mean pedometer values recorded for the present sample ( $7370 \pm 3080$  steps/day) are similar to those reported by McClung *et al*<sup>35</sup> for their subsample of 58 normal healthy adults aged 22–82 y ( $7781 \pm 2807$  steps/day), although the brand of pedometer was not reported in that study. Rowlands *et al*<sup>36</sup> reported that both the Yamax pedometer and the Tritrac accelerometer activity outputs were negatively correlated (both showing  $r = -0.42$ ,  $P < 0.05$ ) with body fat (determined using skinfold measurements) in 8 to 12-y-old children. The present study confirms a similar inverse relationship (on the order of  $r = -0.30$ ) between pedometer-assessed physical activity (expressed as steps/day) and BMI in an adult sample. Further, we document a similar relationship with percent body fat. The calculated effect size of the difference in steps/day taken by normal weight individuals compared with obese individuals (classified according to BMI) in this study can be considered moderate to large<sup>32</sup> representing a meaningful difference between groups.<sup>31</sup>

Examination of the results from self-reported physical activity questionnaire validation studies<sup>37</sup> shows that statistically significant negative correlations between self-reported physical activity and BMI range from  $-0.12$ <sup>38</sup> to  $-0.13$ .<sup>39</sup> Likewise, statistically significant negative correlations between self-reported physical activity and percent body fat range from  $-0.13$ <sup>40</sup> to  $-0.51$ .<sup>41</sup> The correlations we report agree favorably with these values.

Information about associations between accelerometers and body composition variables is more limited and variable depending on how the accelerometer data is presented (eg in the case of the Caltrac accelerometer, data has been presented as counts, kcal/day, and MET/min/day). Rutter<sup>42</sup> reported a significant negative association between Caltrac accelerometer counts (an indicator of raw movement) and BMI ( $r = -0.47$ ,  $P < 0.01$ ) in 39 young university students monitored for 4–6 days, but no correlation between Caltrac counts and any measures of body fat for the first 3-day period. The Survey of Activity, Fitness, and Exercise (SAFE) study reported a significantly positive association of  $r = 0.52$  between Caltrac accelerometer data (expressed as kcal/day) and percentage body fat determined by hydrostatic weighing,<sup>43</sup> suggesting that individuals with greater adiposity expended more energy, but not necessarily due to increased movement. Expressed as MET minutes/day (summed minutes/day multiplied by the MET intensity level), the correlation between Caltrac accelerometer data and percent body fat determined by hydrostatic weighing was non-significant for either men ( $r = -0.10$ ) or women ( $r = 0.06$ ).<sup>41</sup> The body composition variables we report are similar to the SAFE data,<sup>41</sup> a finding that increases our confidence in the validity of our data. There does not appear to be any other studies relating other brands of accelerometers to body composition variables in adults at this time.

Identification of risk groups, including obese and sedentary individuals, is a priority for appropriate targeting of public health approaches to increase physical activity. A

specific ‘sedentary lifestyle index’<sup>44</sup> would be helpful to identify those individuals who are not active in their daily lives and who would most likely benefit from an appropriate intervention.<sup>45</sup> Based on up to 21 days of monitoring 109 adults in the present study, individuals with pedometer values lower than approximately 5000 steps/day (representing the 25th percentile of distribution of this sample’s data) were more frequently classified as obese than either overweight or normal weight for height (see Table 2). These individuals could logically benefit from a physical activity intervention designed to increase steps/day.<sup>46</sup> It is important to emphasize here, however, that not all individuals with values of approximately 5000 steps/day are obese; the mean value for obese individuals is closer to 6000 steps/day (see Table 4). Accordingly, pedometer values greater than approximately 9000 steps/day (representing the 75th percentile of this sample’s data) were more frequently classified as normal weight by BMI category (see Table 2).

Japanese health promotion efforts recommend a goal of 10 000 steps/day.<sup>47,48</sup> A review of the published literature<sup>49</sup> indicates that this value seems a reasonable estimate for younger and/or otherwise healthy individuals, but there is currently little empirical evidence to support such a threshold. According to Hatano,<sup>47</sup> walking 10 000 steps is approximately equivalent to energy expenditures of between 300 and 400 kcal/day (depending on walking speed and body size). This is substantially greater than the 150 kcal/day that accumulated evidence suggests is associated with health benefits in the US Surgeon General’s Report on Physical Activity and Health<sup>50</sup> and the average steps/day accumulated by those classified as normal weight according to their BMI (see Table 4). To be useful, a health promotion slogan for increasing physical activity using pedometers must be evidence-based.

The limitations of this study include its cross-sectional design of a convenience sample of adult volunteers. Such a design limits conclusions about causal inference and generalizability. In addition, pedometers do not distinguish speed or velocity of movement. Some activities will be missed or underestimated (eg swimming, bicycling). It has been suggested that a combination of pedometers and self-report methods (to eliminate or at least account for participation in vigorous and/or non-ambulatory activities) may extend the utility of a simple pedometer for physical activity assessment purposes.<sup>51</sup> In the present study, however, pedometer-assessed steps/day did not differ between groups classified according to reported participation in vigorous activity or not. Further, there was no difference in BMI category distribution by reported participation in vigorous activities. Therefore, the differences observed in body composition variables related to steps/day could not be explained solely by reported participation in vigorous activities. Although the simple and inexpensive pedometer is admittedly not the best measure of overall physical activity, it appears to be useful for objectively describing daily incidental and intentional ambulatory activity.

A strength of this study is the extended length of monitoring frame; the ability to capture habitual activity is likely to be increased with more days of monitoring.<sup>52</sup> Gretebeck and Montoye<sup>53</sup> reported that 5–6 days (including weekend days) of pedometer data were needed to accurately (with less than 5% error) describe the physical activity patterns of young males purposefully recruited for exhibiting varied physical activity pursuits. The monitoring frame in the present study extends well beyond this minimal recommendation based on a sample likely to exhibit both extreme intra- and interindividual variability. Although it was not the purported objective of this study, it is important to determine the minimum monitoring frame necessary to achieve a reliable estimate of ambulatory activities; twenty-one days is not practical for clinical applications.

In summary, the findings of this study indicate that, regardless of analysis approach, there is a distinct inverse relationship between pedometer-assessed ambulatory activity and two body composition variables. The relationship is both statistically significant and meaningful. Further, similar relationships are consistently reported in other populations.<sup>33,35,36</sup> The findings provide preliminary support of approximately > 9000 steps/day associated with body composition benefits, and approximately < 5000 indicative of an index for sedentarism related to unhealthy body composition. Caution is recommended when applying these cut-off points at this time. Further evidence of a confirmatory nature is required before any threshold values can be accepted as established guidelines for either health-related pedometer goals or for a 'sedentary lifestyle index'. Given the practical appeal of the pedometer,<sup>9,46</sup> we concur with others<sup>54</sup> that the effectiveness of behavioral and environmental lifestyle physical activity interventions needs to be assessed using such simple and inexpensive approaches.

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