Target Step Count for the Secondary Prevention of Cardiovascular Disease

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Background Obtaining an accurate measure of physical activity energy expenditure (PAEE) can be difficult, so the simple measurement of steps per day has become widely promoted and accepted in the general population. However, the relationship between PAEE and steps per day has not been evaluated in patients with cardiovascular disease.

Methods and Results A total of 77 (53 men, 24 women) cardiac rehabilitation program participants aged between 46 and 88 years were enrolled. By means of an accelerometer the step count per day, amount of PAEE, as well as time per day spent in physical activity at light (<3 metabolic equivalents (METs)), moderate (3–6 METs) and vigorous (>6 METs) intensity were evaluated for each subject. The number of daily step counts strongly correlated with total PAEE (r=0.92, p<0.001) and time spent in moderate to vigorous intensity physical activity (r=0.85, p<0.001). The mean (95% confidence intervals) step counts associated with 214 and 314 kcal/day (ie, 1,500 and 2,200 kcal/week) were 6,470 and 8,496 steps/day, respectively.

Conclusion To achieve the total amount of PAEE generally recommended for the secondary prevention of cardiovascular disease, patients should be encouraged to accumulate 6,500–8,500 steps/day. (Circ J 2008; 72: 299–303)

Key Words: Accelerometer; Cardiac rehabilitation; Pedometer
Table 1 Characteristics of the Study Subjects

<table>
<thead>
<tr>
<th></th>
<th>All (n=77)</th>
<th>Men (n=53)</th>
<th>Women (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Mean±SD</td>
<td>68.1±9.2</td>
<td>66.8±9.6</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(60.0–70.2)</td>
<td>(64.2–69.5)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>Mean±SD</td>
<td>170.7±8.5</td>
<td>174.2±7.0</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(160.8–172.6)</td>
<td>(172.4–176.2)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>Mean±SD</td>
<td>79.3±13.5</td>
<td>83.9±12.2</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(75.9–82.0)</td>
<td>(80.6–87.3)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>Mean±SD</td>
<td>27.0±3.4</td>
<td>27.6±3.4</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(26.2–27.8)</td>
<td>(26.6–28.5)</td>
</tr>
</tbody>
</table>

Values are mean±SD (95% CI).
CI, confidence interval; BMI, body mass index.
*Significant difference between men and women at p<0.05.

Table 2 Step Count Pattern in CRP Participants

<table>
<thead>
<tr>
<th></th>
<th>All (n=77)</th>
<th>Men (n=53)</th>
<th>Women (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (steps/day)</td>
<td>Mean±SD</td>
<td>6,752±2,659</td>
<td>7,046±2,785</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(6,148–7,355)</td>
<td>(6,279–7,814)</td>
</tr>
<tr>
<td>CRP days (steps/day)</td>
<td>Mean±SD</td>
<td>8,499±3,173</td>
<td>8,850±3,298</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(2,662–18,777)</td>
<td>(3,827–18,777)</td>
</tr>
<tr>
<td>Non-CRP days (steps/day)</td>
<td>Mean±SD</td>
<td>5,491±2,305</td>
<td>5,731±2,998</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>(1,460–18,759)</td>
<td>(1,568–18,759)</td>
</tr>
</tbody>
</table>

Values are mean±SD (95% CI).
All, data were averaged over all experimental days.
CRP days, data were averaged over the 3 days comprising the CRP.
Non-CRP days, data were averaged over the 4 days not attending the CRP.
CRP, cardiac rehabilitation program. Other abbreviation see in Table 1.
*Significant difference between CRP days and non-CRP days at p<0.01.

All participants were clinically stable during this study, and all were New York Heart Association class II or I. Furthermore, based on the classification of the severity of heart failure according to maximal oxygen uptake, established by Weber et al.67 (87%) subjects were categorized as class A (>20 ml·kg⁻¹·min⁻¹) and 10 (13%) were categorized as class B (16–20 ml·kg⁻¹·min⁻¹). They had been participating in the CRP at Wake Forest University for more than 3 months, and the average period was 5.4±5.3 years. In this program, participants undergo annual measurement of maximal aerobic capacity, as well as blood pressure, blood cholesterol and blood glucose. In the latest results, the mean maximal aerobic capacity, estimated by the incremental treadmill test, was 9.1±2.8 metabolic equivalents (METs). The mean values for systolic blood pressure, diastolic blood pressure, total cholesterol, high-density lipoprotein-cholesterol, low-density lipoprotein-cholesterol, and blood glucose were 137±17 mmHg, 78±10 mmHg, 175±35 mg/dl, 47±13 mg/dl, 97±30 mg/dl and 108±22 mg/dl, respectively. The reported error in step counts for this device is less than 3%. 20,21 Details of the device have been described previously17-21.

Days of continuous wear, the device was retrieved and the data were downloaded into a computer with Microsoft Excel software. In order to assess the usual daily physical activity level, this investigation used the final 7 days of continuous data from the 10-day collection period.

The Lifecorder is a small (6x4.6x2.6cm), lightweight (40g) activity monitor that samples vertical acceleration ranges between 0.06 and 1.94G (1G is equal to earth’s gravity acceleration) at 32 Hz. From the magnitude and frequency of acceleration, the Lifecorder determines a level of movement intensity every 4s on a scale of 1 (minimal intensity of movement) to 9 (maximal intensity of movement). As shown in previous studies,17,18 the intensity levels as described above are closely related and approximate the METs between 2 and 9. Consequently, based on body weight and the acceleration pattern, the device determines the PAEE (PAEE in kcal/day), time spent in light (<3 METs) and vigorous (>6 METs) intensity physical activity (min/day), as well as the step count (steps/day).

Statistical Analysis

Data are presented as mean and standard deviation (mean±SD) and 95% confidence intervals (CI). Independent T-test was used to determine if gender differences exist across any variable. The correlation between 2 variables was assessed by the Pearson correlation coefficient (r). The variables related to physical activity were classified according to the 25th, 50th and 75th percentiles for the distribution of step counts. ANOVA was used to determine the differences in the variables related to physical activity across the quartiles of step counts. The effect size was calculated as the differences between the highest and lowest quartiles means, divided by the group standard deviation. A p-value <0.05 was considered statistically significant for all analy-
appears to be 6,500–8,500 steps/day. Based on these results, the target step count needed for this cohort to obtain the minimal and optimal levels of PAEE, respectively, were 5,046 (4,256–5,836), 6,485 (5,555–7,205), and 8,345 (7,385–9,965) steps/day, respectively.

Target Step Goals

The daily amount of energy expenditure through physical activity (effect size <0.80).

For the combined sample, as well as for men and women independently, the step counts were significantly higher (for the combined sample, as well as for men and women independently) on the days that subjects attended the CRP (Mon, Wed and Fri) vs “non-program” days (Tue, Thurs, and weekends).

Results

Subject Characteristics

The characteristics of the subjects are presented in Table 1 and are reflective of typical CRP participants.

Table 3 Comparison of Energy Expenditure and Time Spent on Light, Moderate and Vigorous Physical Activity Across Quartiles of Daily Step Counts

<table>
<thead>
<tr>
<th>Quartiles of daily step count</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>F (p value)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy expenditure (kcal/day)</td>
<td>120.4±38.8</td>
<td>179.4±42</td>
<td>250.2±49</td>
<td>368.8±138.5</td>
<td>35.94</td>
<td>2.05</td>
</tr>
<tr>
<td>Light-intensity physical activity (min/day)</td>
<td>35.4±8.2 (31.6–39.3)</td>
<td>50.2±8.9 (45.9–54.5)</td>
<td>61.9±12.6 (55.8–68.0)</td>
<td>68.0±18.8 (59.0–77.1)</td>
<td>&lt;0.0001</td>
<td>1.83</td>
</tr>
<tr>
<td>Moderate-intensity physical activity (min/day)</td>
<td>5.2±5.6 (2.6–7.8)</td>
<td>12.6±7.0 (9.3–16.0)</td>
<td>16.6±8.1 (12.8–20.5)</td>
<td>34.5±16.0 (26.8–42.2)</td>
<td>&lt;0.0001</td>
<td>2.01</td>
</tr>
<tr>
<td>Vigorous-intensity physical activity (min/day)</td>
<td>0.2±0.5 (0.0–0.4)</td>
<td>0.2±0.4 (0.0–0.4)</td>
<td>1.3±2.8 (0.0–2.7)</td>
<td>1.6±2.1 (0.6–2.6)</td>
<td>6.0±2.6 (0.0165)</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Values are mean±SD (95%CI).
F (p value) are the result of ANOVA.
I, 2,541–5,087 steps/day (n=20; 13 men, 7 women); II, 5,174–6,567 steps/day (n=19; 11 men, 8 women); III, 6,571–8,362 steps/day (n=19; 15 men, 4 women); IV, 8,369–16,450 steps/day (n=19; 14 men, 5 women).
Abbreviation see in Table 1.

Relationship Between Step Count, PAEE and Time Spent in Moderate to Vigorous Intensity Physical Activity (MVPA)

The daily amount of energy expenditure through physical activity, and the MVPA were categorized according to the step counts, as shown in Table 3. The mean (range) step rate in the 4 quartiles (I–IV) was 3,769 (2,542–5,087), 5,872 (5,174–6,567), 7,863 (6,571–8,362) and 10,160 (8,369–16,450) steps/day. There were significant differences in energy expenditure related to physical activity (F=35.942, p<0.001), in time spent in light (F=24.633, p<0.001), moderate (F=30.266, p<0.0001) and vigorous intensity physical activity (F=3.647, p<0.001) across the quartiles of daily step counts. The differences of these values across the quartiles exhibited a clear distinction (effect size >0.80), except for the time spent in vigorous intensity physical activity (effect size <0.80).

Target Step Counts

The step count significantly correlated with the MVPA (r=0.85) and total PAEE (r=0.92) (Fig 1). The correlation between time spent in light intensity physical activity was modest (r=0.69), although still significant. The mean (95% CI) step rate corresponding to 144, 214 and 314kcal/day (reflective of weekly values of 1,000, 1,500 and 2,200kcal, respectively), were 5,046 (4,256–5,836), 6,485 (5,555–7,414) and 8,510 (7,385–9,636) steps/day, respectively. Based on these results, the target step count needed for this cohort to obtain the minimal and optimal levels of PAEE appears to be 6,500–8,500 steps/day.

Discussion

The data from this investigation indicate that in order to achieve the PAEE goals generally accepted for secondary prevention of cardiovascular disease, patients should seek to accumulate 6,500–8,500 steps/day. Achieving 5,000 or fewer steps/day would be associated with a PAEE of less than 1,000 kcal/week, a level thought to promote coronary disease progression. Given the difficulties associated with accurately quantifying PAEE (via accelerometry or estimated based on work rate), a target step count would be useful for patients to self-monitor physical activity that accumulates from a structured exercise program, as well as from non-structured physical activity. Although most CRP participants perform 30–40m of moderate-intensity physical activity 3–4 times per week in a rehabilitation facility, this “dose” of physical activity alone may be insufficient to obtain the 1,500–2,200kcal of PAEE thought necessary to limit cardiovascular disease progression and for potential disease regression. Several investigations have demonstrated that most CRP participants fail to expend 300kcal/day through standard CRP exercise sessions and that the total weekly energy expenditure and/or the amount of moderate intensity physical activity are substantially lower than the desirable levels.

Several studies have evaluated step counts in a variety of
chronic disease populations and in general have found these levels to be significantly lower to those observed in apparently healthy populations. The reported average daily step count for a group of peripheral arterial disease patients was nearly 4,500 steps/day and it ranged from 3,500–4,300 steps/day in heart disease patients:23 Hoodless et al demonstrated that chronic heart failure patients had a 60% reduction in step count compared with age-matched healthy controls. In the present investigation, the mean observed step count was 5,49±2,805 steps/day for non-CRP days, and 8,499±3,173 steps/day on CRP days. Consequently, the average step count (6,752±2,659 steps/day) in this investigation was slightly higher than that reported from earlier evaluations of a chronic disease population. These findings are not surprising given that our participants regularly attended the CRP and they were also likely to have a greater functional capacity than the subjects observed in the aforementioned studies. Although the average step count for the subjects in the present study corresponded to the minimal goal for PAEE in secondary prevention (1,500 kcal/week) (Table 2), 48% of patients failed achieve this minimal goal. Therefore, as previously reported, nearly half of our CRP participants failed to reach the current exercise recommendation of 6,500 steps/day or 215 kcal/day (1,500 kcal/week) for secondary prevention.

As shown in Table 3, there was a clear distinction in the time spent in light and moderate intensity physical activity across the quartiles of daily step counts. In the most active quartile (IV), the step counts and MVPA were 10,160±2,339 steps/day and 36±17 min/day, respectively. Linear regression equation demonstrated that this step count equates to 35 min/day of MVPA. Walking 10,000 steps expends approximately 333 kcal in the average-size Japanese man, based on the assumption that 1 step of walking expends 0.55 calories/kg of body weight.11 However, for the larger subjects observed in this study, walking 10,000 steps should, based on the aforementioned equation, result in approximately 385 kcal of PAEE. Interestingly, in the present study, the actual calorie expenditure and step counts determined from the accelerometer were 368.8±138.5 kcal/day and 10,160±2,339 steps/day, respectively, in the most active quartile (IV). Consistent with our findings, Sieminski et al found that in patients with peripheral arterial occlusive disease, 9,229±5,678 steps equated to 352±248 kcal over a 48-h period.12 Thus, data from these 2 investigations suggest that recommending 10,000 steps/day to the typical chronic disease population (ie, cardiac rehabilitation patient) would be likely to yield a PAEE output >350 kcal/day. If performed 7 days/week, this would result in a PAEE >2,450 kcal/week. Although this level of PAEE would provide maximal protection against cardiovascular disease progression, it may be unnecessary and potentially excessive.

One important consideration in the application of these findings is related to the reliability of the pedometer. There are a variety of pedometers available and there are measurable differences in the reported accuracy of these devices. In general, most are reliable and can detect ambulatory activity with acceptable error. However, previous studies have shown that many pedometers are unable to detect ambulation during slow walking common to an older, lower-functioning population as well as those with central obesity. In obese individuals, the abdominal adiposity appears to interfere with pedometer accuracy because of inappropriate positioning. So, while more expensive than accelerometers, pedometers are more accurate and reliable. In 1 study, the pedometer detected just 75.0% of the actual step count taken while walking at 54 m/min on a treadmill, whereas the accelerometer detected 98.9% of the step count taken during the same walk. Consequently, there is a difference of 2,000 steps/day between the 2 devices (accelerometer>pedometer) over 24 h in the free-living condition. Thus, even the most accurate pedometers may be inappropriate for frail older adults, particularly those with slow gait.

In this context, as with obese subjects, the accelerometer may be more appropriate given its enhanced accuracy. Although we used the Lifecorder Ex (Suzuken) in the present study, there are several other accelerometers available. The Lifecorder Ex appears to an excellent device with a measurement error of less than 5% during usual walking. Most accelerometers, including the Lifecorder Ex, cost $300 or more and require a computer for data analysis, which, while acceptable for research purposes, may limit the feasibility of its use for large field studies and/or individual use. Until the cost of accelerometers decreases, there are several less expensive pedometers, particularly the Digiwalker and NL-2000, that have been shown to have excellent accuracy.

There are several limitations in the present investigation. First, PAEE (calories) were estimated via the Lifecorder Ex according to the magnitude and frequency of the acceleration pattern and were not directly measured. Although PAEE assessed by the Lifecorder Ex is well correlated to indirect calorimetry, the validity of this approach is not as well described during physical activity in obese individuals and/or those with a slow gait pattern. Furthermore, the present investigation did not measure specific outcomes related to coronary artery disease progression and/or regression. Consequently, the target step counts related to specific levels of PAEE associated with changes in coronary artery pathology is purely theoretical and based on previous investigations. Finally, most of the subjects in the present investigation were classified as overweight or obese, and the calorie cost of 1 step depends on body weight. Thus, the results of the present investigation should be confirmed in normal weight patients; however, we found that 6,500–8,500 steps/day indicated a meaningful level of moderate intensity physical activity.

In summary, the purpose of this investigation was to determine the step count that corresponded to the minimal and optimal levels of PAEE recommended for the secondary prevention of cardiovascular disease. We observed a clear distinction in the PAEE and the time spent in light and moderate intensity physical activity across the daily step counts. Furthermore, the daily step count strongly correlated with PAEE and time spent in MVPA, with the mean (95% CI) step count corresponding to PAEE levels of 214 and 314 kcal/day (1,500 and 2,200 kcal/week), which corresponded to 6,470 (5,542–7,398) and 8,496 (7,372–9,620) steps/day, respectively. Thus, this finding indicates that 6,500–8,500 steps/day should be considered the minimal goal and optimal level, respectively, of physical activity for secondary prevention of cardiovascular disease. Of concern is that 48% of subjects evaluated in this investigation failed to accumulate 6,500 steps/day, which suggests that they are more likely to experience cardiovascular disease progression rather than regression. Because the average step count on CRP days was nearly 8,500 steps/day, increasing physical activity on non-CRP days should be emphasized as the primary strategy to increase the PAEE of CRP participants.
Acknowledgments
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References