Abstract

Recently, many cross-sectional studies observed that body mass index (BMI) and percentage of body fat (%BF) were inversely associated with pedometer-determined physical activities, but studies on Asian populations, including the Japanese, are sparse. Height, weight, body fat percentage (%BF, bioelectrical impedance analyzer), and waist circumference were measured on 117 women (62.8±4.5 years, 22.2±2.2 kg/m²) and 62 men (64.0±4.6 years, 23.6±2.5 kg/m²). Pearson correlations and partial correlation coefficients after controlling for age were calculated between steps/day and variables. Furthermore, participants were classified into four groups as follows: <5,000, 5,000–7,499, 7,500–9,999, and ≥10,000 steps/day, and analyzed using ANOVA across activity groups. In women, a significant correlation was found between steps/day and BMI ($r=0.217$, $p=0.018$), %BF ($r=0.292$, $p=0.0014$), and the relationship was still significant after controlling for age. The relationship between steps/day and waist circumference was not significant. In men, a significant relationship was not observed between steps/day and obesity indices. The correlations between steps/day and both BMI and %BF were significant in Japanese women, but weak compared with Caucasian and African–American women as reported previously. A possible cause is racial difference in degree of obesity and body shape. The effects of physical activity on body shape and composition may differ according to race. *J Physiol Anthropol* 27(4): 179–184, 2008 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.27.179]

Keywords: pedometer, steps/day, physical activity, racial difference, Japanese

Introduction

The prevalence of obesity and related diseases has been a crucial health concern across the world (WHO, 2000). Diverging trends of decreasing energy and fat intake and increasing body weight suggest that a modern inactive lifestyle is the most important factor contributing to the rapid increase of obesity (Prentice and Jebb, 1995; Heini and Weinsier, 1997).

Recently, physical activity assessed using a pedometer has gained popularity because of its simplicity and low cost (Tudor-Locke and Bassett, 2004). Although a pedometer is unable to detect upper body movement, swimming, and cycling, but walking is the most common form of physical activity (Kriska, 2000). The sensitivity and reliability are well examined, and some brands are comparable to more expensive accelerometers (Tudor-Locke et al., 2002; Schneider et al., 2003). Recently, many cross-sectional studies observed that body mass index (BMI) and percentage of body fat (%BF) were inversely associated with pedometer-determined physical activities (Tudor-Locke et al., 2001; Chan et al., 2003; Thompson et al., 2004; Hornbuckle et al., 2005; Krumm et al., 2006). The correlation coefficients between steps/day and BMI or %BF reported in these studies were from $-0.30$ (Tudor-Locke et al., 2001) to $-0.479$ (Hornbuckle et al., 2005) and from $-0.27$ (Tudor-Locke et al., 2001) to $-0.713$ (Thompson et al., 2004), respectively, and those who accumulate more ambulatory activity have significantly lower BMI values, %BF, and waist circumferences.

On the other hand, studies on Asian populations, including the Japanese, are sparse. As far as we know, Nawata et al. (2006) only reported a weak relationship between steps/day on a working day and self-reported BMI in male workers ($r=-0.188$, $n=310$, $p<0.01$). Although obesity has been
increasing in Japan as well, the mean BMI is 22.3 kg/m² for women and 23.3 kg/m² for men, and the incidence of obese people with BMI≥25 kg/m² (Japan Society for the Study of Obesity, 2002) is 27.3% for men and 19.9% for women (Ministry of Health, Labour and Welfare, 2006), which is significantly lower than that of other nations, such as the United States, European countries, and Pacific island countries (WHO, 2000). In spite of their relatively lower BMI, Asians have a higher body fat content than BMI-matched Caucasians (Wang et al., 1994), and body weight gain is detrimental to life-related diseases, including diabetes, compared with other races (Shai et al., 2006). Therefore, a clear relationship between pedometer-determined physical activity, steps/day, and obesity indices observed in previous studies is questionable for the Japanese population, and examination of health indicators including blood constituents might be necessary. The purpose of this study is to examine the relationship between pedometer-determined physical activity and indicators of health such as BMI, %BF, blood pressure, blood glucose, and blood lipoproteins in the Japanese population.

Methods

Participants

All participants were local residents aged between 48 and 69 years who had a medical check-up at public health center. This medical check-up is for residents aged over 40 years. One hundred nineteen women and 63 men participated in this study after giving written informed consent. The response ratio was 6.4% by those who had consulted with this institute during the specified period. The criteria of the participants were as follows: ambulant, apparently healthy, and had no history of serious disease such as cancer, stroke, cardiovascular disease, and dialysis. However, the participants had medications as follows: 24 (13.4%) for hypertension; 15 (8.4%) for knee or hip pain; 7 (3.9%) for osteoporosis, 5 (2.8%) for gout, 4 (2.2%) for thyroid gland, and 4 (2.2%) for diabetes. The incidence of ex-smokers and current smokers were 13 (7.3%) and 18 (10.1%), respectively. This study was approved by the Research Ethics Committee of Yokkaichi City Office.

Measurements of anthropometrics, body fat, and blood constituents

All measurements were conducted after overnight fasting. A foot-to-foot bioelectrical impedance analyzer (BIA, TBF-210, Tanita Co., Tokyo, Japan) was used to measure height, body weight, and %BF. The correlation coefficients of this apparatus to dual-energy X-ray absorptiometry are 0.69 for men and 0.79 for women (Mitsui et al., 2006). BMI was calculated by dividing weight in kilograms by height in meters squared. Waist circumference was measured at the narrowest part of torso, with the participant standing erect and the abdomen relaxed. Blood pressure was measured using a mercury sphygmomanometer. Blood samples were drawn from a medial cubital vein. The concentrations of glucose, glycohemoglobin (HbA1c), total cholesterol (T-C), high-density lipoprotein cholesterol (HLD-C), and triacylglycerols were measured by a certified laboratory (Mitsubishi BCL, Yokkaichi, Japan).

Physical activity monitoring

After laboratory testing, each participant was given a pedometer [EM-180 (EM), YAMASA, Tokyo, Japan], and their steps/day for a week were measured. The subjects were asked to put a pedometer on their waists between waking and going to bed, except during water activities, and requested to record the number of steps taken every evening. We have previously examined the accuracy of the pedometer compared with a more reliable accelerometer [Kenz Lifecorder (KL), Suzuken, Nagoya, Japan] in 69 ambulatory adults. The mean difference, the number of steps per day taken (EM−KL)/KL, was −8.6% and the correlation coefficient was r=0.91 (p<0.001) (unpublished data), which was almost the same as in previous studies (Schneider et al., 2003).

Data analysis

Pearson correlations were used to examine the relationship between average steps per day and all the variables described above. Partial correlation coefficients were calculated between steps/day and variables while controlling for age. Furthermore, walking volume was classified into four groups by each gender as follows: <5,000 steps/day is sedentary, 5,000–7,499 is low active, 7,500–9,999 is somewhat active, and ≥10,000 is active (Tudor-Locke and Bassett, 2004). A one-way ANOVA was run to compare variables among the physical activity categories. If a significant difference was obtained, a Dunnett multiple comparison test was used to compare the least active group. Pearson correlations and partial correlations were calculated using EXCEL 2003 with add-in software, EXCEL Tahenyoukaiseki (Multivariate analysis) Version 5.0 (Esumi Co., Tokyo, Japan), and a one-way ANOVA test was conducted using KaleidaGraph Version 3.6 (HULINKS Inc., Tokyo, Japan). Significance was set at p<0.05 for all tests.

Results

Two women and one man were excluded from the data because they had a history of cancer; thus, 117 women and 62 men were targeted for statistical analysis. General characteristics of the participants are shown in Table 1. The mean BMI were in the normal range, 22.2±2.2 kg/m² for women and 23.6±2.5 kg/m² for men. The incidence of obesity with BMI≥25.0 kg/m² was 28 (15.6%), including 2 (0.56%) who had BMI≥30 kg/m². Table 2 shows the correlation and partial correlation after controlling for age. In women, significant inverse relationships were seen between average steps per day and BMI (r={-0.217}, p=0.018); %BF (r={-0.292}, p=0.0014); and triacylglycerol (r={-0.187}, p=0.047). The relationships were still significant after controlling for age. The relationship between steps/day and
other variables, including waist circumference, were not significant. In men, there was no significant relationship between steps/day and all the variables. When examined by activity group, there were significant differences in BMI and %BF in women but not in men (Table 3). Compared with the least active group, significant differences were seen in the somewhat active group, 7,500–9,999 steps/day, but not in the active group, >10,000 steps/day. Apart from triacylglycerol in male participants, there was no significant difference in blood pressure and constituents among groups.

**Discussion**

Although causality cannot be determined by cross-sectional design, it is reasonable to suppose that pedometer-determined physical activity is inversely associated with obesity or fewer steps is seen in obese population. To our knowledge, this observation is consistent with all recent investigations (Tudor-Locke et al., 2001; Chan et al., 2003; Thompson et al., 2004; Hornbuckle et al., 2005; Wyatt et al., 2005; Krumm et al., 2006; Dwyer et al., 2007; Clemes et al., 2007). On the other hand, this relationship is complicated in cross-sectional data using a self-reported questionnaire because of methodological problems (Erlichman et al., 2002). A questionnaire is basically dependent on a subject’s ability to recall, and usually underestimates low intense activities, including walking (Kriska, 2002). A pedometer is an objective tool and is able to quantify the activity in concrete numbers, which may result in statistical significance and make it possible to compare data across nations and/or races.

In women, the relationship between BMI and steps/day is significant but weak compared with Caucasian ($r = -0.417$, $p < 0.05$).
Table 3 Comparison of variables across activity group (Mean±SD).

<table>
<thead>
<tr>
<th>Female n</th>
<th>&lt;5,000</th>
<th>5,001–7,499</th>
<th>7,500–9,999</th>
<th>&gt;10,000</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>63.7±4.7</td>
<td>62.8±4.0</td>
<td>62.7±3.8</td>
<td>61.1±5.7</td>
<td>0.34</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>22.9±2.3</td>
<td>22.4±1.9</td>
<td>21.2±1.9**</td>
<td>22.2±2.8</td>
<td>0.021</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>30.1±5.2</td>
<td>29.3±4.4</td>
<td>27.0±4.3*</td>
<td>26.9±4.3</td>
<td>0.027</td>
</tr>
<tr>
<td>Waist, cm</td>
<td>85.2±7.5</td>
<td>84.0±7.9</td>
<td>81.4±8.0</td>
<td>84.3±8.1</td>
<td>0.27</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>130±20</td>
<td>131±16</td>
<td>129±16</td>
<td>127±23</td>
<td>0.91</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>76±11</td>
<td>76±10</td>
<td>75±9</td>
<td>74±11</td>
<td>0.84</td>
</tr>
<tr>
<td>Blood glucose, mg/dL</td>
<td>95±13</td>
<td>93±8</td>
<td>91±9</td>
<td>93±12</td>
<td>0.90</td>
</tr>
<tr>
<td>T-C, mg/dL</td>
<td>5.0±0.7</td>
<td>5.0±0.3</td>
<td>5.0±0.3</td>
<td>5.1±0.5</td>
<td>0.88</td>
</tr>
<tr>
<td>HDL-C</td>
<td>231±26</td>
<td>229±20</td>
<td>247±33</td>
<td>226±25</td>
<td>0.67</td>
</tr>
<tr>
<td>Triacylglycerol, mg/dL</td>
<td>61±11</td>
<td>61±14</td>
<td>64±14</td>
<td>71±12</td>
<td>0.62</td>
</tr>
<tr>
<td>Female n</td>
<td>19</td>
<td>41</td>
<td>29</td>
<td>14</td>
<td>—</td>
</tr>
<tr>
<td>Age, years</td>
<td>64±4.0</td>
<td>63±4.7</td>
<td>63.5±4.2</td>
<td>64.4±5.2</td>
<td>0.78</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.7±2.7</td>
<td>23.4±2.2</td>
<td>24.1±2.4</td>
<td>23.4±1.8</td>
<td>0.36</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>24.9±3.6</td>
<td>22.8±3.9</td>
<td>22.8±5.0</td>
<td>22.8±3.3</td>
<td>0.14</td>
</tr>
<tr>
<td>Waist, cm</td>
<td>89.9±7.6</td>
<td>85.2±6.4</td>
<td>88.2±7.8</td>
<td>85.6±5.4</td>
<td>0.10</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>137±19</td>
<td>141±21</td>
<td>135±15</td>
<td>135±17</td>
<td>0.79</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>84±11</td>
<td>83±12</td>
<td>87±13</td>
<td>81±9</td>
<td>0.58</td>
</tr>
<tr>
<td>Blood glucose, mg/dL</td>
<td>98±16</td>
<td>103±16</td>
<td>89±4</td>
<td>103±14</td>
<td>0.71</td>
</tr>
<tr>
<td>HbA1c, %</td>
<td>4.9±0.6</td>
<td>5.1±0.5</td>
<td>4.8±0.1</td>
<td>5.2±0.6</td>
<td>0.53</td>
</tr>
<tr>
<td>T-C, mg/dL</td>
<td>211±23</td>
<td>226±28</td>
<td>218±14</td>
<td>202±21</td>
<td>0.52</td>
</tr>
<tr>
<td>HDL-C</td>
<td>53±11</td>
<td>52±8</td>
<td>48±7</td>
<td>49±13</td>
<td>0.32</td>
</tr>
<tr>
<td>Triacylglycerol, mg/dL</td>
<td>128±47</td>
<td>114±30</td>
<td>136±60</td>
<td>104±46*</td>
<td>0.008</td>
</tr>
</tbody>
</table>

* p<0.05, ** p<0.01 compared with the least active group.

n=80) (Thompson et al., 2004) and African–American women (r=−0.479, n=69) (Hornbuckle et al., 2005). A possible cause is that the degree of obesity is mild in most Japanese. They also observed a strong relationship between waist circumference and walking volume in female participants (r=−0.506). We assessed %BF and obtained a significant relationship as well, but if we had used a more reliable method, such as the underwater weighing method, air-displacement plethysmography, or dual-energy X-ray absorptiometry, a stronger relationship might have been obtained. Because BIA tended to overestimate in higher %BF group (Sun et al., 2005; Mitsui et al., 2006). We did not obtain a significant relationship between waist circumference and walking volume in female participants (r=−0.110, p=0.240), while a strong relationship is observed in the study of Caucasian (r=−0.616) and African–American women (r=−0.438) cited above. The mean waist size of our participants was 83.8±8.0 cm, which was not smaller than that of the Caucasians, 82.7±12.4 cm, observed in their group. A possible reason is racial difference in body shape, i.e., Japanese women tend to exhibit pear-shaped obesity, having more subcutaneous fat on the hip and thigh rather than the waist.

The cause is unclear, to obtain a significant relationship between walking volume and obesity may be difficult in men. As mentioned above, Nawata et al. (2006) reported that the relationship between steps/day and BMI of Japanese men was significant but weak. We do not know of available data on Caucasian and/or black men separately. Tudor-Locke et al. (2001) examined 109 apparently healthy adults consisting of 33 Caucasian males, 45 Caucasian females, 8 African–American males, and 23 African–American females and found a significant association between steps/day and BMI for r=−0.30 and %BF (by BIA) for r=−0.27. This value is relatively lower than those of the data on Caucasian and African–American women cited above. If we combined male and female participants, the correlation between steps/day and %BF was still significant (r=−0.204, p=0.006), while BMI was not significant (r=−0.105, p=0.163). Non-ambulatory physical activity may take a substantial portion of the total energy expenditure in men compared with women.

In general, a physically active lifestyle has a beneficial effect on blood pressure, blood glucose, and lipoproteins (American College of Sports Medicine Position Stand, 1998). We obtained a significant relationship or difference among groups only in triacylglycerol. Probably, the normal range of blood constituents made it difficult to obtain a significant relationship. This medical check-up is basically for healthy middle-aged and older people, not for chronic patients.

In pedometer-determined physical activity it is easy to set a goal. Today, 10,000 steps/day has been widely accepted not only for public use but also for a goal in intervention studies.
(Yamanouchi et al., 1995; Tully et al., 2005). Our result that the 7,500–9,999 steps female group had significantly lower BMI and %BF than those of the least active group is interesting. Probably because of the insufficient number of participants, there was no significant difference in %BF between the <5,000 steps group and the >10,000 steps group. A value of 10,000 steps/day seems to be reasonable and practical for somewhat inactive adults, who generally walk about 6,000–7,000 steps/day. However, this may be a high goal for a sedentary group that walks <5,000 steps/day, including extremely obese, older people and patients with chronic diseases. The American College of Sports Medicine and the Centers for Disease Control and Prevention have recommended that individuals accumulate 30 minutes of moderate-intensity physical activity, such as brisk walking, on most days of the week, preferably every day (Pate et al., 1995). There is evidence that only 38%–50% of women reached 10,000 steps/day on any single day, even with a prescribed 30-minute walk (Wilde et al., 2001). We assume that a goal of 10,000 steps/day is tentative, and a 30-minute period of daily walking, which is equal to about 3,000 steps increment, combined with diet, is practical to reduce obesity and other lifestyle-related diseases for a sedentary population.

We are not sure whether the participants of this study were representative of the local residents. Considering the low response ratio of 6.4% in voluntary medical check-ups, normal range of blood data, and low incidence of smokers (7.3%), the participants may be fitter than the general population. The mean age of the participants of this study is over 60 years, so setting a criterion of “apparent healthy” seems to be quite subjective, as people around this age are often taking one or two medications.

Physical inactivity is closely associated with obesity and lifestyle-related diseases in the Japanese population, while exercise, such as walking, is surely effective in the treatment of these diseases (Yamanouchi et al., 1995; Ito et al., 2001). The significance of this study is that a clear relationship between pedometer-determined activity and obesity as observed in Caucasian and African–American women was not seen in the Japanese population. In other words, the effects of physical activity on body shape and composition may differ according to race.

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References

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