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Sex, Age, Season, and Habitual Physical Activity of Older Japanese: The Nakanojo Study

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The interactions of sex, age, season, and habitual physical activity were examined in 41 male and 54 female Japanese age 65–83 yr, using a pedometer/accelerometer that determined step counts and amounts of physical activity (<3 and >3 metabolic equivalents [METs]) throughout each 24-hr period for an entire year. All 3 measures were greater in men than in women. In women, age was negatively correlated with step count and activity <3 METs, but in men, it was correlated with step count and activity >3 METs. Irrespective of sex or age, all 3 activity variables were low in the winter, peaking in spring or autumn. In the summer, step counts matched the annual average, but durations of activity <3 and >3 METs were, respectively, longer and shorter than in other seasons. These findings have practical implications for those promoting physical activity for older adults.

***Keywords**:* pedometer/accelerometer, aging, seasonal variation

Adequate habitual physical activity is important for health promotion, disease prevention, and especially as a means of delaying functional loss in older adults (American College of Sports Medicine, 1998; Rejeski & Mihalko, 2001; Shephard, 1996, 1997). As in many developed countries (Katzmarzyk & Tremblay, in press), however, approximately two thirds of older Japanese adults currently engage in no regular leisure-time physical activity; average pedometer counts over an arbitrary 1-day period are 6,884 and 4,569 steps/day in those 60–69 and over 70 years of age, respectively, falling far short of health objectives set for this age group (Japan Ministry of Health, Labor, and Welfare, 2006). Furthermore, the average count is similar to or exceeds that reported for U.S. populations in this age range (Tudor-Locke et al., 2004; Wyatt, Peters, Reed, Barry, & Hill, 2005).

Previous studies have demonstrated that physical activity is greater in men than in women, in younger people, and in those with better health (Caspersen, Pereira, & Curran, 2000; Harada, Chiu, King, & Stewart, 2001; Japan Ministry of Health, Labor, and Welfare, 2006; Martinez-Gonzalez et al., 2001; Washburn, McAuley,

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Katula, Mihalko, & Boileau, 1999; Washburn, Smith, Jette, & Janney, 1993). Seasonal differences in physical activity and aerobic fitness are also well documented (Centers for Disease Control and Prevention, 1997; Pivarnik, Reeves, & Pafferty, 2003; Plasqui & Westerterp, 2004; Shephard, 1994). Thus, it is important to understand how such factors as sex, age, and season influence current sedentary behavior before designing tactics to bring daily physical activity closer to optimal levels. In the past, physical activity has commonly been assessed by a simple questionnaire asking about the frequency and duration of light, moderate, and vigorous activity during a typical recent week (e.g., Harada et al.; Pivarnik et al.; Washburn et al., 1999). Such subjective estimates have limited accuracy. Problems are particularly great in older adults, many of whom have difficulties with recall or cognitive function. Recently, pedometers and accelerometers have been used in an attempt to assess physical activity more accurately (Hoos, Kuipers, Gerver, & Westerterp, 2004; Westerterp, 2001). Such objective measurements of physical activity have usually covered no more than a single week, although it remains unclear whether the volume and intensity of physical activity remain stable, particularly in older adults who are no longer employed.

The purpose of the current study was to examine associations of sex, age, and season with objective pedometer/accelerometer assessments of the quantity and quality of habitual physical activity undertaken by healthy, community-living older adults. Daily records of the total number of steps completed and the amounts of low- and moderate-intensity physical activity performed were compiled over 12 consecutive months.

Methods

Participants

The participants were a convenience sample of 41 male and 54 female volunteers age 65–83 years. All were drawn from a larger longitudinal study (Yasunaga et al., 2007). None of the participants dropped out during the course of this investigation. Very few of them were still employed, and few played sports or deliberately exercised on a regular basis. Criteria of recruitment were willingness to participate, a recent medical examination, and absence of chronic disease or pain that could influence physical activity behavior. All participants lived in Nakanojo, Gunma Prefecture, central Japan, a residential town (population of 18,112 in 2003) situated about 150 km northwest of Tokyo. Participants gave their written informed consent to participate after the protocol and potential risks had been fully explained. Research ethical approval was acquired through the review committee of the Tokyo Metropolitan Institute of Gerontology.

Physical Activity Measurements

An electronic pedometer/accelerometer with a storage capacity of 36 days (modified Kenz Lifecorder, Suzuken Co., Ltd., Nagoya, Aichi, Japan; for details, see Togo, Watanabe, Park, Shephard, & Aoyagi, 2005) measured the number of steps taken and the intensity of physical activity every 4 s throughout each day. This instrument yields reliable and accurate step counts and metabolic-equivalent values (multiples of resting metabolic rate, METs), particularly during walking (the main form of physical activity in these older adults; Kumahara et al., 2004). The monitor was attached to the waist belt on the left side of the body for consistency. Our preliminary unpublished data have shown that this device records similar scores on both sides of the body. Participants wore the instrument throughout each 24-hr period for 1 year, from July 2002 to June 2003. Monthly visits to the Nakanojo Public Health Center allowed data retrieval and battery replacement in a time of less than 10 min.

Before we calculated scores, we inspected data obtained during waking hours using a custom computer program (Kenz Lifecorder02 Basic, Suzuken Co., Ltd., Nagoya, Aichi, Japan). This detected any consecutive intervals with no recorded body movement that the participant had not marked with an event stamp to indicate such things as removal of the pedometer/accelerometer for bathing, showering, napping, or dressing. Intervals of this type lasting for longer than 3 hr were typically seen on less than 5% of measurement days. To avoid a possible systematic underestimation of daily physical activity, when such intervals were detected the corresponding 24-hr data segment was excluded rather than replaced by arbitrary interpolated values. Step counts were totaled and intensity categories were determined over each 24-hr period from midnight to the following midnight. Parameters calculated were the daily step count and the daily periods of exercise at a low intensity (<3 METs) and at an intensity higher than moderate for an older adult (>3 METs); these values were each averaged by month and for the entire year. The counts recorded during walking reflected both low and moderate intensities, depending on the individual's speed of movement, habitual physical activity patterns, and physical fitness. Periods of rest (1 MET) and activity >6 METs were not considered in our analysis, given that the former were simply the residual of our data and the latter was seen on average <1 min/day.

Statistical Analyses

Nonpaired *t* tests analyzed sex differences in physical characteristics. Analyses of covariance (ANCOVAs) assessed independent associations between year-averaged physical activity variables and sex (after controlling for age) and age group (65–74 vs. 75–83 years) after controlling for sex. Within each sex, simple Pearson's correlation analyses tested relationships between age and year-averaged scores for physical activity variables. A one-factor (sex or age) repeated-measures analysis of variance (ANOVA) assessed seasonal changes in month-averaged physical activity variables over the year. All statistical contrasts were made at the .05 level of significance (Statistical Package for Social Science 11.5, SPSS Inc., Chicago, IL). Data are presented as means and standard errors of the mean (*SEM*s).

Results

Sex and Age Differences in Physical Characteristics and Physical Activity

The respective physical characteristics of the men and women were age 71.2 ± 0.7 and 71.6 ± 0.6 years, height 1.61 ± 0.01 and 1.48 ± 0.01 m, body mass 59.4 ± 1.3

and 51.8 ± 0.8 kg, and body-mass index (BMI) 23.0 ± 0.5 and 23.6 ± 0.3 kg/m^2. Appropriate *t* tests showed the anticipated differences in height and body mass between men and women ($p < .05$), but age and BMI did not differ significantly between sexes.

An ANCOVA controlling for age showed that the year-averaged daily step count and daily durations of physical activity <3 and >3 METs were all significantly greater in men than in women (Table 1); the respective mean differences were approximately 1,700 steps/day, 14 min/day, and 6 min/day. After controlling for sex, the three measures of physical activity were all significantly greater in 65- to 74- than in 75- to 83-year-old participants (Table 1), with mean differences amounting to approximately 2,000 steps/day, 11 min/day, and 8 min/day.

Age and Physical Activity

Simple Pearson's correlation analyses showed significant negative relationships between age and the year-averaged daily step count in both men and women (r = –.33 and –.35, respectively; Figure 1). Similarly, the average daily durations of physical activity <3 and >3 METs tended to have negative associations with age (Figure 1), significantly so for the lower intensity in women (r = –.34) and the higher intensity in men (r = –.33).

Sex and Age Differences of Seasonal Variations in Physical Activity

A one-factor repeated-measures ANOVA showed that after month-averaged physical activity data over the entire year were pooled, step counts and the durations of activity <3 and >3 METs were all significantly greater in men than in women and in 65- to 74- than in 75- to 83-year-old participants (Figure 2).

Table 1 Influence of Sex and Age Group on Three Measures of Habitual Physical Activity, *M* (*SEM*)

Measure	All	Men	Women	Age 65–74 years	Age 75–83 years
Number of participants	95	41	54	74	21
Year-averaged step count (steps/day)	6,896 (280)	7,884 (437)	6,145 (334)*	7,332 (298)	5,360 (615)†
Year-averaged duration of physical activity					
<3 METs (min/day)	52.5 (1.8)	60.2 (2.9)	46.6 (2.0)*	55.0 (2.0)	43.6 (3.9)†
>3 METs (min/day)	19.7 (1.4)	23.2 (2.3)	17.0 (1.6)*	21.5 (1.5)	13.4 (2.9)†

Note. METs = metabolic equivalents. The total for each 24-hr interval is substantially less than 1,440 min because we excluded activities at 1 MET.

*Versus men ($p < .05$). †Versus age 65–74 years ($p < .05$).

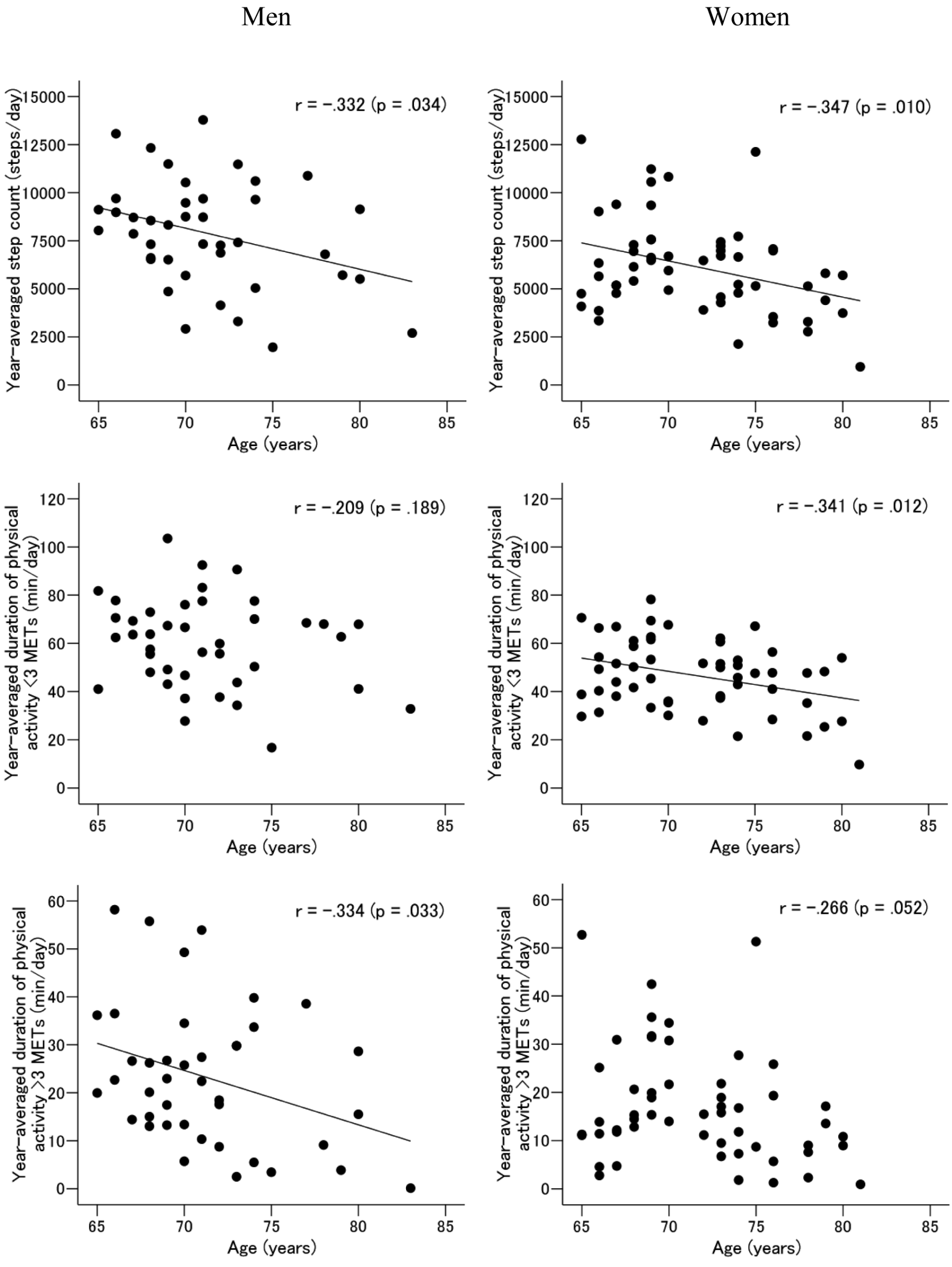

Figure 1 — Relationships between age and the year-averaged daily step count, and daily durations of physical activity <3 and >3 metabolic equivalents (METs). *Note*. n = 41 men and n = 54 women.

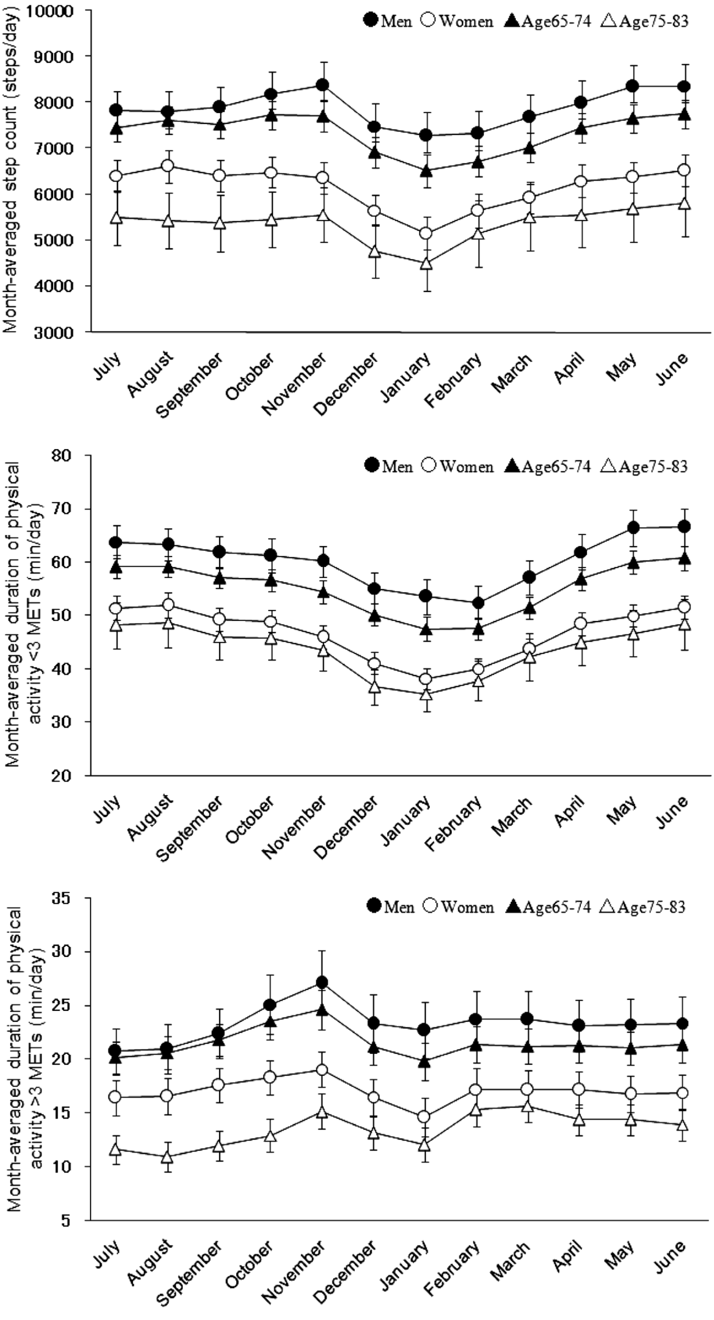

Figure 2 — Changes in the month-averaged daily step count, and daily durations of physical activity <3 and >3 metabolic equivalents (METs) over 1 year. *Note*. $n = 41$ men, $n = 54$ women, $n = 74$ age 65–74, and $n = 21$ age 75–83. Values are $M \pm SEM$.

Nakanojo has four distinct seasons that we have arbitrarily designated as spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). During the 1-year period of this experiment, the highest month-averaged mean ambient temperature was 25.1 °C (77.2 °F) in July 2002, and the lowest mean ambient temperature was –0.3 °C (31.5 °F) in January 2003, with typical spring and autumn values of 11.1 °C (52.0 °F; April 2003) and 13.8 °C (56.8 °F; October 2002; Table 2). The corresponding peak (daytime) temperatures were 30.4 °C (86.7 °F), 6.0 °C (42.8 °F), 17.1 °C (62.8 °F), and 20.0 °C (68.0 °F). Values for precipitation ranged from 10.7 mm in July 2002 to 0.4 mm in February 2003, with minima in the early spring and late autumn and the heaviest and most frequent rainfalls in the summer months (Table 2).

Irrespective of the sex and age of our participants, there was a clear seasonal variation in the month-averaged data for the three indices of physical activity. All values generally peaked in spring or autumn and reached their nadir in the winter months (Figure 2). The respective differences in mean physical activity values between the highest and the lowest months for men, women, 65- to 74-, and 75- to 83-year-old participants were as follows: step counts 1,087 (8,368 ± 510 vs. 7,281 ± 500), 1,460 (6,609 ± 363 vs. 5,149 ± 357), 1,235 (7,749 ± 311 vs. 6,514 ± 351), and 1,299 (5,802 ± 710 vs. 4,503 ± 598) steps/day; duration of low-intensity effort 14.2 (66.5 ± 3.5 vs. 52.3 ± 3.1), 13.7 (51.8 ± 2.3 vs. 38.1 ± 2.0), 13.2 (60.6 ± 2.2 vs. 47.4 ± 2.2), and 13.3 (48.5 ± 4.5 vs. 35.2 ± 3.2) min/day; and duration of moderate-intensity activity 6.4 (27.1 ± 3.0 vs. 20.7 ± 2.2), 4.4 (19.0 ± 1.8 vs.14.6 ± 1.7), 4.8 (24.6 ± 1.9 vs. 19.8 ± 1.7), and 4.7 (15.6 ± 1.5 vs. 10.9 ± 1.4) min/day. In summer, when the daily step count approximated the average for the year, the durations of physical activity <3 and >3 METs tended to be longer and shorter than in other seasons, respectively (Figure 2).

Discussion

The main purpose of this study was to examine relationships among sex, age, season, and accurate pedometer/accelerometer measurements of the volume and intensity of habitual physical activity in older individuals. Our participants were healthy older Japanese, but there seems no a priori reason to anticipate that the findings would not be applicable to other ethnic groups of similar age living in similar circumstances. The influence of demographic factors such as income, education, and BMI was not explored, because our participants showed only minor interindividual differences in these variables. Nonetheless, the substantial associations of physical activity with sex, age, and season suggest that these factors should be taken into account when designing interventions to increase the physical activity of older adult populations.

Sex and Physical Activity

Questionnaire studies from both Europe and North America have suggested previously that habitual physical activity is likely to be greater in men than in women (Caspersen et al., 2000; Martinez-Gonzalez et al., 2001; Washburn et al., 1999). Our results support this view; objective and accurate yearlong estimates of step counts and durations of physical activity <3 and >3 METs were on average 28%, 29%,

Table 2 Month-Averaged Data for Selected Meteorological Variables in Nakanojo

	2002						2003					
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean ambient temperature	25.1 (77.2)	25.0 (77.0)	19.4 (66.9)	13.8 (56.8)	5.6 (42.1)	2.0 (35.6)	–0.3 (31.5)	1.2 (34.2)	3.4 (38.1)	11.1 (52.0)	16.1 (61.0)	20.3 (68.5)
Maximum ambient temperature	30.4 (86.8)	30.5 (86.8)	24.3 (75.8)	20.0 (68.0)	12.6 (54.6)	7.3 (45.1)	6.0 (42.8)	7.7 (45.9)	9.3 (48.8)	17.1 (62.8)	21.7 (71.1)	25.2 (77.4)
Minimum ambient temperature	20.8 (69.4)	20.7 (69.3)	15.7 (60.3)	9.1 (48.4)	0.4 (32.8)	–1.9 (28.5)	–5.1 (22.8)	–3.8 (25.1)	–1.8 (28.7)	5.1 (41.2)	10.9 (51.7)	15.8 (60.4)
Precipitation (mm)	10.7	5.9	5.7	5.4	0.6	1.3	1.4	0.4	2.7	3.4	2.3	4.5
Mean relative humidity (%)	71	69	72	65	58	63	54	53	50	59	63	67
Mean wind speed (m/s)	0.7	0.9	0.7	0.9	1.1	1.1	1.2	1.4	1.5	1.3	1.1	0.9
Day length (min)	862	811	745	676	616	584	599	650	716	786	845	876
Duration of bright sunshine (min)	221	288	175	280	287	232	310	346	307	257	242	164

Note. Temperatures are given in °C, with Fahrenheit equivalents (°F) in parentheses. Daily means for ambient temperature and wind speed, together with daily totals for precipitation and duration of bright sunshine, were provided by the meteorological station in Nakanojo (36° 35.1´ N, 138° 51.3´ E, elevation 354 m). The mean daily relative humidity was obtained from a second nearby meteorological station (Maebashi; 36° 24.3´ N, 139° 3.6´ E, elevation 112 m). Significant accumulations of snow were rare. The day length was calculated from the official times of sunrise and sunset for the region.

and 36% greater in men than in women, respectively. There was no sex difference in the distribution of time between low and moderate intensities of effort, however; approximately 72% and 28% of step counts reflected low- and moderate-intensity physical activity in men, with corresponding figures of 73% and 27% in women. The implication seems to be that, at least in older adults, although the total volume of stepping activity is greater in men than in women, the relative proportions of low- and moderate-intensity activity do not differ between the sexes.

Age and Physical Activity

Habitual physical activity is known to decrease with age (Caspersen et al., 2000; Japan Ministry of Health, Labor, and Welfare, 2006). In confirmation of this view, our data showed an inverse association between age and the year-averaged daily step count in both men and women. This reflected mainly an age-related reduction in activity >3 METs in men but <3 METs in women. The weak and statistically insignificant trends relating age and activity <3 METs in men and >3 METs in women might be explained by the following possibilities: Regardless of age, many older women spend long periods performing low-intensity household tasks (Kriska & Caspersen, 1997; Wareham et al., 2002), and community-living older men progressively assume the burden of such household tasks because of the infirmity or death of their spouses. Although we need more precise data on relationships between household tasks and the quantity and quality of habitual physical activity, our findings suggest that the extent to which physical activity patterns change with age depends in part on the life circumstances of older adults.

Season and Physical Activity

Earlier studies have shown seasonal variations in physical activity and aerobic fitness, often with a peak in the summer and a nadir in the winter months (Centers for Disease Control and Prevention, 1997; Pivarnik et al., 2003; Plasqui & Westerterp, 2004; Shephard, 1994). Looking at a large U.S. population, the Centers for Disease Control and Prevention reported that leisure-time physical activity was reduced during the winter and increased during the summer months, this being true for both sexes and most age and racial or ethnic groups. Similarly, Pivarnik et al. demonstrated that average weekly leisure-time energy expenditure was 15–20% higher during the spring and summer than in other seasons. These two studies based their conclusions on infrequent, subjective questionnaire estimates of physical activity in a North American climate. In the somewhat different climate of central Japan, our continuous, yearlong pedometer/accelerometer assessments showed that irrespective of sex or age, there were clear seasonal variations in the month-averaged step count and the durations of low- and moderate-intensity physical activity; these three selected measures of habitual activity peaked in spring and/or autumn and reached their lowest values in the winter months.

The findings are consistent with a recent 450-day analysis of 41 healthy older Japanese adults (Togo et al., 2005) that showed a peaking of daily step count at a mean outdoor temperature of around 17 °C (63 °F) when precipitation was <1 mm, with quadratic decreases above and especially below this temperature. In the study of Togo et al., other meteorological variables (mean relative humidity, mean wind speed, length of day, and duration of bright sunshine) had little influence on habitual physical activity. The 30–40% differences in activity between the most and the least active months are twice as large as those noted by Pivarnik et al.; this could reflect not only differences in climate but also the small number (four per year) of self-reports obtained in the latter study. In summer, when our daily step count approximated the average for the year, activity <3 METs was increased at the expense of that >3 METs. Such a seasonal change could be a manifestation of behavioral thermoregulation (Aoyagi, McLellan, & Shephard, 1997). It is possible that exercise >3 METs was reduced selectively to reduce body-heat production and maintain thermal equilibrium. This type of behavioral thermoregulation might also explain the finding that the month-averaged physical activity <3 METs peaked in May or June, when mean ambient temperature was on the increase, whereas that >3 METs peaked in November, when the temperature was decreasing.

In conclusion, our data suggest that sex, age, and seasonal changes in microclimate should all be considered when designing interventions to increase the quantity and quality of habitual physical activity in older adults. In particular, there is a need to encourage indoor (air-conditioned or climate-controlled) physical activity during extremes of summer and winter weather to ensure consistent participation in at least the moderate levels of physical activity necessary to optimize health. Further research using more participants, covering a wider range of environments and including frailer individuals, is recommended to provide a more detailed understanding of the influence of these variables on physically active behavior.

Acknowledgments

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