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Brief Report

Year-Long Physical Activity and Metabolic Syndrome in Older Japanese Adults: Cross-Sectional Data From the Nakanojo Study

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Background. We determined associations between habitual physical activity and metabolic syndrome in elderly persons.

Methods. Pedometer/accelerometers measured step count and activity intensity on a 24-hour basis in 220 free-living Japanese persons 65–84 years old throughout an entire year. At year end, participants were screened for metabolic syndrome (modified criteria of National Cholesterol Education Program Adult Treatment Panel III [NCEP-ATP III]).

Results. Most individuals 65–74 years old who took >10,000 steps/d and/or spent >30 min/d of activity >3 metabolic equivalents (METs) had ≤2 metabolic syndrome diagnostic markers, as did those 75–84 years old with >8000 steps/d and/or >20 min/d at >3 METs. Multivariate-adjusted logistic regression analyses showed that the risk of metabolic syndrome was 4.3 (1.6–11.7) and 3.3 (1.3–8.8) times greater in the least active quartiles of participants (taking <4700 steps/d and spending <9 min/d at >3 METs, respectively) relative to the most active quartiles (taking >8500 steps/d and spending >24 min/d at >3 METs, respectively).

Conclusions. The metabolic syndrome is less likely in elderly people taking >8000–10,000 steps/d, and reaching an intensity >3 METs for >20–30 min/d, relative to their sedentary peers.

***Key Words*:** Accelerometer—Aging—Blood glucose—Blood pressure—Body mass index—Cholesterol—Moderate-exercise duration—Step count.

INDIVIDUALS showing a specific group of diagnostic markers (the metabolic syndrome) have a several-fold increase in the risk of certain cardiovascular diseases and all-cause mortality (1). The metabolic syndrome is now a serious health problem for the elderly population in Japan, as in many developed societies. The underlying mechanisms have not been entirely elucidated, but obesity (2) and inadequate physical activity (3) are crucial factors. The proportion of elderly Japanese persons with a body mass index (BMI) ≥25 kg/m^2 [the insulin resistance threshold proposed by the World Health Organization (WHO) Western Pacific Region (2)] has risen progressively to a current level of 31% in men and 30% in women (4).

Regular moderate-intensity physical activity seems sufficient to reduce the risk of both obesity and metabolic syndrome in older people (5,6); it increases insulin sensitivity and cardiovascular capacity, while decreasing body mass and preventing an excessive accumulation of fat. However, the required pattern of physical activity remains unclear, because most investigators have either used questionnaires, or limited accelerometer or pedometer measurements to a single week, despite clear evidence of seasonal changes in activity patterns, particularly among elderly persons (7,8).

The present study thus examined relationships between metabolic risk factors and yearlong pedometer/accelerometer assessments of the quantity and quality of habitual physical activity in elderly adults.

Methods

Participants

The participants were a convenience sample of 91 male and 129 female volunteers, 65–84 years old, drawn from the Nakanojo Study (7–11). Recruitment criteria were willingness to participate, attendance at an annual medical examination, and the absence of chronic conditions that could limit physical activity. Participants gave their written informed consent to this institutionally approved study after the protocol, stresses, and possible risks had been explained to them. None dropped out during the course of our observations.

Physical Activity Measurements

Details of the procedure and its validation have been described previously (7–11). An electronic pedometer/accelerometer with a 36-day storage capacity (modified Kenz Lifecorder; Suzuken Co., Ltd., Nagoya, Aichi, Japan) was attached to a waist belt. The number of steps taken and the intensity of physical activity were recorded on a 24-hour basis for an entire year. Monthly visits to the Nakanojo Public Health Center allowed data retrieval and battery replacement. After inspection for inappropriate recording, 1-year averages were computed for daily step count and daily duration of exercise >3 metabolic equivalents (METs).

Metabolic Risk Factor Criteria

Diagnoses of metabolic risk were based on a modification of criteria proposed by the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) (12). The NCEP-ATP III waistline criterion of abdominal obesity appears to be inappropriate for Asians. There is a close association between BMI and waist circumference ($r > 0.9$), regardless of sex or age; BMI thus replaced waist circumference in our assessments [WHO Asia-Pacific guidelines (2)]. The metabolic syndrome was diagnosed in participants who showed three or more of the following criteria: (i) a BMI $\geq$25 kg/m^2, (ii) a fasting serum triglyceride (TG) concentration $\geq$1.7 mmol/L ($\geq$150 mg/dL), (iii) a fasting serum high-density lipoprotein cholesterol (HDL-C) concentration <1.0 mmol/L (<40 mg/dL) for men or <1.3 mmol/L (<50 mg/dL) for women, (iv) a systolic blood pressure (SBP) $\geq$130 mmHg and/or a diastolic blood pressure (DBP) $\geq$85 mmHg, and (v) a fasting plasma glucose $\geq$6.1 mmol/L ($\geq$110 mg/dL) and/or a hemoglobin A1c (HbA1c) $\geq$5.5%. Criteria for categories (ii)–(v) included values observed in individuals who were receiving medication.

Statistical Analyses

Analyses of covariance (ANCOVA) assessed independent associations between our two indices of habitual physical activity (daily step count and daily duration of activity at an intensity >3 METs) and the presence or absence of each of the metabolic syndrome and the five individual diagnostic criteria (BMI, TG, HDL-C, SBP and/or DBP, and glucose and/or HbA1c), after controlling for age and sex. We divided participants arbitrarily into quartiles of habitual physical activity, Q1 being the lowest and Q4 the highest. Logistic regression analyses determined odds ratios and 95% confidence intervals adjusted for age, sex, smoking status (smoker/nonsmoker), and alcohol consumption (drinker/nondrinker), assessing independent associations between physical activity category and the risk of the metabolic syndrome. Chi-square tests for linear trends were used to analyze independent associations between habitual physical activity and the metabolic syndrome in adjusted models. Data are presented as means ± standard deviation or standard error of the mean, with all statistical contrasts made at the .05 level of significance.

Results

The respective numbers of male and female participants 65–74 years old were 63 and 89, and the corresponding figures for participants 75–84 years old were 28 and 40. Of our participants, 13.6% were regular smokers, and 42.3% drank alcohol regularly. The mean BMI was 23 kg/m^2 in both men and women.

ANCOVA controlling for age and sex showed a trend toward lower levels of habitual physical activity in participants showing any of the metabolic criteria than in those who did not (Figure 1); contrasts versus both step count and duration of activity at an intensity >3 METs were statistically significant for blood pressure, blood glucose, and presence of the metabolic syndrome. With a few exceptions, all participants 65–74 and 75–84 years old taking, respectively, >10,000 and >8000 steps/d and/or spending >30 and >20 min/d at an intensity >3 METs showed two or fewer risk factors for the metabolic syndrome.

Chi-square tests showed a significant trend for a lower risk of the metabolic syndrome in participants with a higher level of habitual physical activity (Table 1). Logistic regression analyses showed that the risk of metabolic syndrome was significantly related to both step count and the duration of physical activity >3 METs. After adjustment for physical characteristics (age and sex) and lifestyle-related factors (current smoking and alcohol intake), participants in the lowest quartile (Q1) of step count and moderate exercise duration were, respectively, at 4.3 (1.6–11.7) and 3.3 (1.3–8.8) times greater risk of metabolic syndrome than were participants in the highest quartile (Q4).

Discussion

The definition and pathogenesis of metabolic syndrome remain to be clarified, but it is widely accepted that an individual's risk increases exponentially with the number of risk factors that he or she shows (3,13). The dominant risk factors seem to be insulin resistance and abdominal fat accumulation, but other contributing influences include genotype, an excessive energy intake, and/or a sedentary lifestyle. The development of obesity predominates in the early stages of the metabolic syndrome, and the accumulation of abdominal fat contributes greatly to an increased insulin resistance. Therefore, the control of body fat content is important for prevention and early treatment.

Our observations in elderly adults demonstrate significant associations between pedometer/accelerometer assessments of the volume and intensity of habitual physical activity and criteria of the metabolic syndrome, especially excessive blood pressure and blood glucose readings. Over the previous year, participants who had SBP $\geq$130 mmHg and/or DBP $\geq$85 mmHg, and a glucose $\geq$6.1 mmol/L ($\geq$110 mg/dL) and/or HbA1c $\geq$5.5% had taken significantly fewer steps per day and spent a shorter daily duration of physical activity >3 METs than their peers who did not show these diagnostic criteria. In contrast, physical activity did not differ significantly between participants with a BMI $\geq$25 kg/m^2 and those with values <25 kg/m^2. Abdominal fat accumulation was not estimated specifically by our test

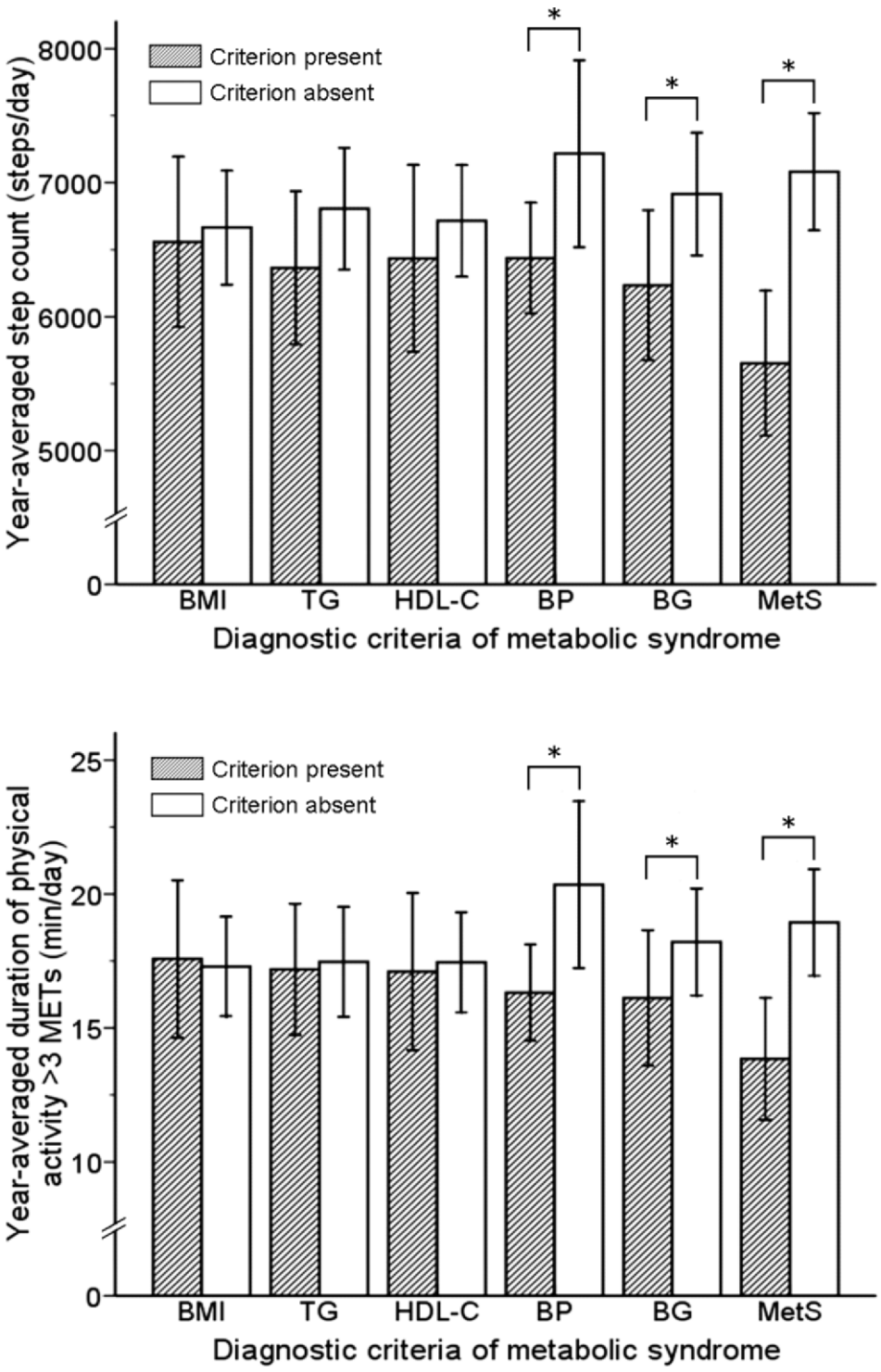

Figure 1. Relationships between habitual physical activity and the presence or absence of each metabolic syndrome diagnostic criteria. METs = metabolic equivalents; BMI = body mass index; TG = triglyceride; HDL-C = high-density lipoprotein cholesterol; BP = blood pressure; BG = blood glucose; MetS = metabolic syndrome. Number (%) with diagnostic criterion = 52 (24) for BMI, 83 (38) for TG, 59 (27) for HDL-C, 163 (74) for BP, 89 (40) for BG, and 68 (31) for MetS. Values are means ± standard error of the mean. *Significant ($p < .05$) difference between participants with and those without the criterion.

battery, but BMI may not be the best tool for diagnosis of this aspect of the metabolic syndrome in elderly Japanese persons.

Other recent studies from our laboratory have shown that poor mental health (9) and a poor quality of life (10) are less likely in elderly men and women who exceed very modest minimum standards of habitual physical activity: approximately 4000 steps/d and/or 5 min/d at an intensity >3 METs. In contrast, better bone health is seen in individuals who undertake >7000 steps/d and/or spend >15 min/d at >3 METs (11). The threshold dose of physical activity associated with absence of the metabolic syndrome is even greater for persons 65–74 and ≥75 years old, approximately 10,000 and 8000 steps/d and/or 30 and 20 min/d at an intensity >3 METs, respectively. Very few participants who exceeded these proposed standards showed three or more of our five selected metabolic risk factors (BMI, TG, HDL-C, SBP and/or DBP, and glucose and/or HbA1c).

When physical activity data were categorized into quartiles, the multifactor-adjusted odds ratio showed significant relationships between vulnerability to the metabolic syndrome and both of our measures of habitual physical activity, associations being larger for the year-averaged daily step count than for the volume of activity >3 METs. Participants in the top physical activity quartiles took an average of 10,100 steps/d, spending 34 min/d at an intensity >3 METs. The lower three quartiles, with respective mean counts of 3400, 5600, and 7400 steps/d and durations of 4, 12, and 19 min/d at an intensity >3 METs, all had a 1.8–4.3 times greater risk of the metabolic syndrome. In general, these results are in keeping with current health guidelines from the American College of Sports Medicine and the American Heart Association for older adults (14), which have recommended performing moderate-intensity aerobic activity for a minimum of 30 minutes on 5 days each week or vigorous-intensity aerobic activity for a minimum of 20 minutes on 3 days each week to prevent disease and promote health. They also underline recent WHO comments that minimum physical activity recommendations that have focused on other aspects of physical and mental health need to be increased substantially if the obesity epidemic is to be controlled and the spread of the metabolic syndrome countered (15). Such activity may reduce the risk of functional impairment and disability commonly found in older individuals with metabolic syndrome (16).

Table 1. Relationships Between the Quartiles (Q1–Q4) of Habitual Physical Activity and the Risk of Metabolic Syndrome

	No. (%) of Diagnoses	Odds Ratio (95% Confidence Interval)
Year-averaged step count (steps/d)		
Q1: 3427 ± 1056 (650–4693)	24 (44)	4.32 (1.59–11.70)
Q2: 5581 ± 505 (4694–6405)	19 (35)	2.58 (1.00–6.74)
Q3: 7420 ± 594 (6406–8519)	17 (31)	2.44 (0.91–6.50)
Q4: 10,129 ± 1402 (8520–13,806)	8 (15)	1
Test for trend	$p < .05$	
Year-averaged duration of physical activity >3 METs (min/d)		
Q1: 4.4 ± 2.6 (0.1–8.5)	23 (42)	3.33 (1.25–8.83)
Q2: 12.1 ± 2.3 (8.6–15.8)	18 (33)	2.09 (0.81–5.36)
Q3: 19.4 ± 2.5 (15.9–24.3)	16 (29)	1.78 (0.69–4.62)
Q4: 33.5 ± 8.1 (24.4–57.3)	11 (20)	1
Test for trend	$p < .05$	

Notes: $n = 55$ for each quartile. Activity data are means ± standard deviation, with ranges in parentheses. Odds ratios and 95% confidence intervals were adjusted for age, sex, current smoking, and alcohol intake.

METs = metabolic equivalents.

Conclusions

Our cross-sectional data indicate that, after adjustment for anthropometric and/or lifestyle-related variables, the prevalence of metabolic syndrome in older people is associated with both the daily step count and the daily duration of physical activity >3 METs. Furthermore, our data point toward a conclusion that, depending on age, elderly people should undertake >8000–10,000 steps/d and reach an exercise intensity >3 METs for >20–30 min/d to limit their risk of developing the metabolic syndrome. Nevertheless, randomized controlled studies are recommended to test the cause-and-effect nature of the relationships that we have demonstrated. It is also desirable that such studies include people of working age and those living in other parts of the world.

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References

1. Otiniano ME, Du XL, Maldonado MR, Ray L, Markides K. Effect of metabolic syndrome on heart attack and mortality in Mexican-American elderly persons: findings of 7-year follow-up from the Hispanic Established Populations for the Epidemiological Study of the Elderly. *J Gerontol A Biol Sci Med Sci.* 2005;60:466–470.
2. World Health Organization Western Pacific Region, International Association for the Study of Obesity, International Obesity Task Force. The Asia-Pacific perspective: redefining obesity and its treatment. Sydney: Health Communications Australia Pty Limited, 2000.
3. Franks PW, Ekelund U, Brage S, Wong MY, Wareham NJ. Does the association of habitual physical activity with the metabolic syndrome differ by level of cardiorespiratory fitness? *Diabetes Care.* 2004; 27:1187–1193.
4. Japan Ministry of Health, Labour and Welfare. *The National Nutrition Survey in Japan 2001.* Tokyo, Daiichi-shuppan; 2003.
5. Laaksonen DE, Lakka HM, Salonen JT, Niskanen LK, Rauramaa R, Lakka TA. Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. *Diabetes Care.* 2002;25:1612–1618.
6. Ryan AS, Pratley RE, Goldberg AP, Elahi D. Resistive training increases insulin action in postmenopausal women. *J Gerontol Med Sci.* 1996;51A:M199–M205.
7. Togo F, Watanabe E, Park H, Shephard RJ, Aoyagi Y. Meteorology and the physical activity of the elderly: the Nakanojo Study. *Int J Biometeorol.* 2005;50:83–89.
8. Yasunaga A, Togo F, Watanabe E, et al. Sex, age, season, and habitual physical activity of older Japanese: the Nakanojo Study. *J Aging Phys Act.* 2008;16:3–13.
9. Yoshiuchi K, Nakahara R, Kumano H, et al. Yearlong physical activity and depressive symptoms in older Japanese adults: cross-sectional data from the Nakanojo Study. *Am J Geriatr Psychiatry.* 2006;14: 621–624.

10. Yasunaga A, Togo F, Watanabe E, Park H, Shephard RJ, Aoyagi Y. Yearlong physical activity and health-related quality of life in older Japanese adults: the Nakanojo Study. *J Aging Phys Act*. 2006;14: 288–301.
11. Park H, Togo F, Watanabe E, et al. Relationship of bone health to yearlong physical activity in older Japanese adults: cross-sectional data from the Nakanojo Study. *Osteoporos Int*. 2007;18: 285–293.
12. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA*. 2001;285: 2486–2497.
13. Maison P, Byrne CD, Hales CN, Day NE, Wareham NJ. Do different dimensions of the metabolic syndrome change together over time? Evidence supporting obesity as the central feature. *Diabetes Care*. 2001;24:1758–1763.
14. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39:1435–1445.
15. Erlichman J, Kerbey AL, James WP. Physical activity and its impact on health outcomes. Paper 2: Prevention of unhealthy weight gain and obesity by physical activity: an analysis of the evidence. *Obes Rev*. 2002;3:273–287.
16. Blaum CS, West NA, Haan MN. Is the metabolic syndrome, with or without diabetes, associated with progressive disability in older Mexican Americans? *J Gerontol A Biol Sci Med Sci*. 2007;62:766–773.

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