Endocrine (2019) 64:552–563
https://doi.org/10.1007/s12020-019-01926-9

ORIGINAL ARTICLE

Check for updates

Independent relationships of daily life activity and leisure-time exercise with metabolic syndrome and its traits in the general Japanese population

Hirokazu Uemura[1] · Sakurako Katsuura-Kamano[1] · Yuki Iwasaki[1] · Kokichi Arisawa[1] · Asahi Hishida[2] · Rieko Okada[2] · Takashi Tamura[2] · Yoko Kubo[2] · Hidemi Ito[3] · Isao Oze[4] · Chisato Shimanoe[5] · Yuichiro Nishida[6] · Yasuyuki Nakamura[7] · Naoyuki Takashima[8] · Sadao Suzuki[9] · Hiroko Nakagawa-Senda[9] · Daisaku Nishimoto[10] · Toshiro Takezaki[11] · Haruo Mikami[12] · Yohko Nakamura[12] · Norihiro Furusyo[13,14] · Hiroaki Ikezaki[13,14] · Etsuko Ozaki[15] · Teruhide Koyama[15] · Kiyonori Kuriki[16] · Kaori Endoh[16] · Mariko Naito[2,17] · Kenji Wakai[2] · for the Japan Multi-institutional Collaborative Cohort (J-MICC) Study Group

Received: 19 December 2018 / Accepted: 8 April 2019 / Published online: 22 April 2019

Abstract

Purpose This study aimed to investigate independent relationships of daily non-exercise life activity and leisure-time exercise volume and intensity with the prevalence of metabolic syndrome and its traits in Japanese adults.

Methods Data of 24,625 eligible subjects (12,709 men, 11,916 women) who participated in the baseline survey of the Japan Multi-Institutional Collaborative Cohort (J-MICC) Study were analyzed. Information about lifestyle characteristics was obtained from a questionnaire. Logistic regression analyses were performed to evaluate the independent associations of daily life activity as well as leisure-time exercise volume and intensity with the prevalence of metabolic syndrome and its traits by sex.

Results Male subjects with higher daily life activity as well as with higher leisure-time exercise volume had a lower prevalence of metabolic syndrome, independently with each other. Female subjects with higher daily life activity also had a lower prevalence of metabolic syndrome. Particularly, male and female subjects with the highest daily life activity quartile showed considerably low odds ratios of 0.66 (95% CI, 0.53–0.81) and 0.64 (0.52–0.79), respectively, for low HDL-cholesterol even after the adjustment for BMI compared with the first quartile. Meanwhile, male subjects with the higher leisure-time exercise showed a quite lower prevalence of elevated triglycerides. Higher moderate-intensity exercise was more intensely associated with a lower prevalence of metabolic syndrome and some of its traits in both sexes.

Conclusions Our results suggest that higher daily life activity and higher moderate-intensity exercise may be independently associated with a lower risk of metabolic syndrome in Japanese adults.

Keywords Daily life activity · Leisure-time exercise · Metabolic syndrome · Cross-sectional study

Introduction

The prevalence of metabolic syndrome, characterized by a cluster of several metabolic disorders such as central obesity, dyslipidemia, elevated blood pressure, and glucose intolerance [1, 2], has been globally increasing [3]. Individuals with metabolic syndrome are at a high risk of developing type 2 diabetes and cardiovascular diseases [4–7]. Because cardiovascular disease is a leading cause of death, preventing cardiovascular damage is an important public health issue worldwide. Early preventive countermeasures against metabolic disorders can contribute to preventing the occurrence or progression of cardiovascular damage.

Sufficient physical exercise can contribute to the prevention of various chronic diseases, including obesity, type 2 diabetes, and cardiovascular disease [8–11]. In contrast, excessive sedentary behavior, distinct from a lack of volitional exercise, may be linked to various health problems

✉ Hirokazu Uemura
uemura.hirokazu@tokushima-u.ac.jp

Extended author information available on the last page of the article

[12–14]. A proportional relationship between sitting time and mortality from all causes and from cardiovascular disease independent of leisure-time exercise has been reported [15]. That is, usual activities of daily living, including fidgeting, cleaning, spontaneous muscle contractions, and maintaining posture when upright, may effectively prevent health disorders independent of leisure-time exercise. Leisure-time exercise is also effective for at preventing various health problems; however, its impact on health may differ among exercise intensities when exercise volumes are similar.

Here we evaluated the independent relationships of daily life activity as well as leisure-time exercise with the prevalence of metabolic syndrome and its traits in a large Japanese population. We also compared the prevalence of metabolic syndrome and its traits by leisure-time exercise intensity and exercise volume.

Materials/subjects and methods

Study subjects

Participants aged 35–69 years were enrolled in the baseline survey of a prospective cohort study between February 2004 and March 2014 by 13 research sites throughout Japan. The details of the J-MICC Study have been described elsewhere [16]. Briefly, this cohort study aimed to examine the interactions of lifestyle and genetic factors, as well as their associations with lifestyle-related diseases.

Of the 13 research sites, 2 did not collect biochemical data from their subjects, while another did not measure fasting plasma glucose. Another 2 research sites used different questions about physical activities, while 1 had a considerably higher prevalence of metabolic syndrome than the residual research sites. Excluding the participants in these research sites, 35,833 subjects (17,360 men, 18,473 women) in the remaining 7 research sites were initially included in the current study. Among the 35,833 subjects, we excluded total of 11,208 (4651 men, 6557 women) with overlapping characteristics as follows: (1) 1351 with a history of ischemic heart disease or stroke; (2) 1836 lacking complete data on daily life activities and leisure-time exercise; (3) 658 whose estimated daily total energy intake was extremely high (>4000 kcal/day) or low (<1000 kcal/day); (4) 7710 subjects for whom data were missing for body mass index (BMI), blood pressure, and biochemical measurements including serum triglyceride, high-density lipoprotein (HDL) cholesterol, fasting plasma glucose, and medical histories that are essential to the diagnosis of metabolic syndrome; and (5) 466 subjects for whom complete data were lacking for smoking status, alcohol drinking status, or sleep duration required in the multivariate models. Data for a total of 24,625 subjects (12,709 men, 11,916 women) were finally analyzed (the dataset is ver. 20180602).

All participants in the J-MICC Study provided written informed consent prior to participating. The study was approved by the ethics committees of Nagoya University Graduate School of Medicine, Japan, Tokushima University Graduate School, Japan and other participating institutions, conducted in accordance with the principles of the Declaration of Helsinki, and performed in accordance with the relevant guidelines and regulations.

Questionnaire

Information on individual medical histories and lifestyle characteristics, including smoking habits, alcohol drinking status, sleep duration and dietary behavior over the past year, was obtained through a structured self-administered questionnaire. All responses were reviewed by trained staff at the time of the survey. The dietary assessment was performed using the validated short food frequency questionnaire (FFQ) included in this questionnaire in the baseline survey of the J-MICC Study [17–20]. This FFQ included questions about the intake of 47 varieties of foods and beverages over the past year. Daily total energy intake was estimated using a program developed by the Department of Public Health, Nagoya City University School of Medicine [17, 18].

Assessment of leisure-time exercise and daily life activities

We used the questionnaire to obtain information regarding leisure-time exercise and daily life activities. Leisure-time exercise was estimated on the basis of the International Physical Activity Questionnaire [21]. Leisure-time exercise was divided into three levels: light intensity (e.g., walking and hiking), moderate intensity (e.g., light jogging and swimming), and vigorous intensity (e.g., marathon running and competitive sports). The volumes of leisure-time exercise for the three levels were estimated as metabolic equivalent (MET)-h/week (MET level × hours of activity × events per week), and the total leisure-time exercise volume was estimated by summing these volume for the three levels. In these estimations, light, moderate, and vigorous-intensity exercises were assigned 3.4, 7.0, and 10.0 METs, respectively.

Information on daily life activities was obtained for four ranks according to activity level sequentially from the strongest: (1) behaviors that require muscle power (4.5 METs); (2) walking (3.0 METs); (3) standing (2.0 METs); and (4) sitting (1.5 METs). The duration of each activity was assigned one of the following eight categories: none,

<1, 1 to <3, 3 to <5, 5 to <7, 7 to <9, 9 to <11, and ≥11 h/day. In the analyses, these eight categories were replaced with 0, 0.5, 2, 4, 6, 8, 10, and 11 h/day, respectively. Similar to the estimation of leisure-time exercise volume, daily life activity volume was estimated as MET-h/week for the three higher ranks [(1) behaviors that require muscle power, (2) walking, and (3) standing] excluding sitting and summed, because sedentary behavior such as sitting or reclining position, a low-energy expenditure (≤1.5 METs), may be associated with various health problems [22].

Anthropometric and biochemical measurements

Data on anthropometric measurements (height and weight), blood pressure, fasting plasma glucose, and serum levels of triglycerides and HDL-cholesterol were obtained at health screening. BMI was calculated as weight (in kg) divided by height (in meters squared).

Assessment of metabolic syndrome

We assessed the prevalence of metabolic syndrome using a modification of the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) revised definition (NCEP-R 2005) [1]. Metabolic syndrome was diagnosed in participants with at least three of the following five criteria: (a) Obesity: BMI ≥ 25 kg/m^2 instead of abdominal waist circumference; (b) High blood pressure: systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg or receiving treatment for hypertension; (c) Elevated triglycerides: serum triglyceride level ≥ 150 mg/dL or receiving hypertriglyceridemia medication; (d) Low HDL-cholesterol: serum HDL-cholesterol level < 40 mg/dL in men or <50 mg/dL in women; and (e) Elevated blood glucose: fasting plasma glucose level ≥ 100 mg/dL or receiving treatment for diabetes.

Statistical analyses

Continuous variables are expressed as mean ± standard deviation; those with a skewed distribution are expressed as median (25th, 75th percentiles). Categorical variables are expressed as number and proportion (%). The *t*-test, Wilcoxon-rank sum test, or chi-square test was used to compare the characteristics between the prevalence of metabolic syndrome where appropriate. The associations of daily life activities as well as leisure-time exercise with the prevalence of metabolic syndrome and its traits were evaluated separately by sex using logistic regression analyses. Adjusted covariates were as follows: (Model 1): age (year, continuous); (Model 2): age, research sites (Shizuoka-Sakuragaoka, Okazaki, Shizuoka, Iga, Takashima, Kyoto, and Tokushima), education level (≤9, 10–15, ≥16 years, and unknown), smoking habit (current, past, and never), alcohol drinking status (current or other), energy intake (kcal/day, quartiles), sleep duration (<6, 6.0 to <7.0, 7 to <8, and ≥8 h/day), and menopausal status (postmenopause or others) if women; (Model 3): covariates in Model 3 plus BMI (kg/m^2, quartiles). Daily life activity (MET-h/week, quartiles) and leisure-time exercise (MET-h/week, quartiles) were simultaneously inserted into all models, and categorical variables were converted into dummy variables. The proportional relationships of daily physical activities as well as leisure-time exercise with the prevalence of metabolic syndrome and its traits were assessed by assigning ordinal categorical variables of 1, 2, 3, and 4 per quartile in the logistic regression analyses. We additionally evaluated the relationships of leisure-time exercise with the prevalence of metabolic syndrome and its traits according to leisure-time exercise intensity by replacing total leisure-time exercise volume with light, moderate, and vigorous-intensity exercise (three categories of 0, >0 to 10.0, and ≥10.0 MET-h/week were made at each intensity) in the similar logistic models (Models 2 and 3). In these analyses, the proportional relationships of each leisure-time exercise intensity with the prevalence of metabolic syndrome and its traits were assessed by assigning ordinal categorical variables of 1, 2, or 3 for the three categories (0, >0 to 10.0, and >10.0 MET-h/week) at each intensity.

All calculations and statistical tests were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). Statistical tests were based on two-sided probabilities, and values of $P < 0.05$ were considered significant.

Results

Baseline characteristics

The mean (SD) age was 54.1 (9.8) years in men and 52.9 (9.7) years in women, showing a significant difference ($P < 0.001$). The prevalence of metabolic syndrome was significantly higher in men (21.0%) than in women (9.0%) ($P < 0.001$).

The baseline characteristics of the subjects according to the prevalence of metabolic syndrome by sex are shown in Table 1. Male subjects with metabolic syndrome were older, had lower education level, and showed lower ratio of never smoking than those without metabolic syndrome. Male subjects with metabolic syndrome had higher prevalence of all traits of metabolic syndrome and showed lower amounts of both daily physical activity and leisure-time exercise than those without metabolic syndrome. Female subjects with metabolic syndrome were also older and had higher ratio of

Table 1 Characteristics of the study subjects according to the prevalence of metabolic syndrome by sex

	Men			Women		
	Metabolic syndrome			Metabolic syndrome		
	No ($n = 10,041$)	Yes ($n = 2668$)	*P*	No ($n = 10,843$)	Yes ($n = 1073$)	*P*
Age (years)[a]	53.8 (9.9)	55.2 (9.1)	<0.001	52.4 (9.7)	57.7 (8.2)	<0.001
Body mass index (kg/m^2)[b]	22.7 (21.1, 24.3)	26.2 (25.0, 28.0)	<0.001	21.3 (19.6, 23.2)	26.4 (24.5, 28.6)	<0.001
Systolic blood pressure (mmHg)[a]	124.2 (16.3)	137.5 (15.8)	<0.001	121.2 (18.1)	139.4 (17.0)	<0.001
Diastolic blood pressure (mmHg)[a]	77.6 (10.3)	85.3 (10.0)	<0.001	73.6 (10.8)	82.7 (10.2)	<0.001
Triglycerides (mg/dL)[b]	97 (72, 131)	176.5 (132, 236)	<0.001	76 (57, 104)	163 (112, 214)	<0.001
HDL-cholesterol (mg/dL)[a]	61.6 (15.5)	51.2 (13.9)	<0.001	74.0 (16.6)	55.5 (14.0)	<0.001
Fasting plasma glucose (mg/dL)[b]	95 (89, 101)	106 (100, 118)	<0.001	90 (85, 96)	103 (96, 113)	<0.001
Energy intake (kcal/day)[b]	1885 (1711, 2081)	1879 (1691, 2072)	0.071	1551 (1427, 1678)	1532 (1400, 1678)	0.015
Sleep duration (h/day)	6.67 (1.00)	6.66 (1.06)	0.600	6.44 (0.97)	6.50 (1.01)	0.052
Daily life activity (MET-h/week)[b]	98.0 (49.0, 189.0)	85.8 (38.5, 169.80)	0.001	140.0 (85.8, 203.0)	133.0 (80.5, 197.8)	0.140
Leisure-time exercise (MET-h/week)[b]	7.50 (1.28, 20.40)	6.45 (0.43, 17.89)	<0.001	5.10 (0, 17.83)	5.10 (0.43, 17.85)	0.098
Education level (years) (no., %)						
≤9	904 (9.0)	262 (9.8)	0.01	760 (7.0)	154 (14.4)	<0.001
10–15	4826 (48.1)	1307 (49.0)		7880 (70.6)	758 (70.6)	
≥16	3937 (39.2)	973 (36.5)		1718 (15.8)	91 (8.5)	
Unknown	374 (3.7)	126 (4.7)		485 (4.5)	70 (6.5)	
Smoking habit (no., %)						
Current	2765 (27.5)	718 (26.9)	<0.001	673 (6.2)	68 (6.3)	0.980
Past	4128 (41.1)	1249 (46.8)		920 (8.5)	92 (8.6)	
Never	3148 (31.4)	701 (26.3)		9250 (85.3)	913 (85.1)	
Current alcohol drinking (no., %)						
Yes	7549 (75.2)	2034 (76.2)	0.261	4482 (41.3)	359 (33.5)	<0.001
No	2492 (24.8)	634 (23.8)		6361 (58.7)	714 (66.5)	
Menopausal status (no., %)						
Premenopause				4910 (45.3)	244 (22.7)	<0.001
Postmenopause				5933 (54.7)	829 (77.3)	
Prevalence (no., %)						
Obesity	1512 (15.1)	2017 (75.6)	<0.001	1110 (10.2)	770 (71.8)	<0.001
High blood pressure	4154 (41.4)	2331 (87.4)	<0.001	3601 (33.2)	943 (87.9)	<0.001
Elevated triglycerides	1572 (15.7)	1863 (69.8)	<0.001	752 (6.9)	650 (60.6)	<0.001
Low HDL-cholesterol	301 (3.0)	599 (22.5)	<0.001	427 (3.9)	474 (44.2)	<0.001
Elevated blood glucose	3019 (30.1)	2078 (77.9)	<0.001	1542 (14.2)	751 (70.0)	<0.001

Obesity: body mass index ≥ 25 kg/m^2; High blood pressure: SBP ≥ 130 mmHg or DBP ≥ 85 mmHg or hypertension medication

Low HDL-cholesterol: serum HDL-cholesterol < 40 mg/dL in men and < 50 mg/dL in women

Elevated triglycerides: serum triglyceride ≥ 150 mg/dL or hypertriglyceridemia medication

Elevated blood glucose: fasting plasma glucose ≥ 100 mg/dL or diabetes medication

MET metabolic equivalent, *HDL* high-density lipoprotein

[a]Mean (SD)

[b]Median (25%, 75%)

postmenopause, and showed lower energy intake, lower education level and lower ratio of current alcohol drinking than those without metabolic syndrome. Female subjects with metabolic syndrome also had higher prevalence of all traits of metabolic syndrome than those without metabolic syndrome. The amounts of daily physical activity and leisure-time exercise were not different between female subjects with and without metabolic syndrome.

Relationships of daily life activity and leisure-time exercise volume with the prevalence of metabolic syndrome and its traits in men and women

Table 2 presents that higher daily life activity volume was associated with a lower prevalence of metabolic syndrome and its traits excluding high blood pressure in a multivariate-adjusted model (Model 2) in men. Although further adjustment for BMI (Model 3) did not change most of these findings, the inverse association between daily life activity volume and the prevalence of elevated blood glucose fell into non-significant. The highest daily life activity quartile showed a considerably low odds ratio of 0.66 (95% confidence interval (CI), 0.53–0.81; Model 3) for low HDL-cholesterol compared with the first quartile (reference). Higher leisure-time exercise volume was also associated with a lower prevalence of metabolic syndrome and its traits excluding low HDL-cholesterol in a multivariate-adjusted model (Model 2) in men. Although further adjustment for BMI (Model 3) did not change most of these findings, the inverse association between leisure-time exercise volume and the prevalence of elevated blood glucose fell into non-significant. The highest leisure-time exercise quartile showed a quite low odds ratio of 0.69 (95% CI, 0.62–0.78; Model 3) for elevated triglycerides compared with the first quartile (reference).

As shown in Table 3, daily life activity volume was inversely and proportionally associated with the prevalence of metabolic syndrome, elevated triglycerides, and low HDL-cholesterol but not with that of obesity in multivariate-adjusted models (Models 2 and 3) in women. Leisure-time exercise volume was inversely associated with the prevalence of obesity (*P*-values for trend were 0.004, in Model 2). The highest daily life activity quartile showed a considerably low odds ratio of 0.64 (95% CI, 0.52–0.79;

Table 2 Associations of the volume of daily life activity and leisure-time exercise with the prevalence of metabolic syndrome and its traits in men

	Daily life activity (MET-h/week)				Leisure-time exercise (MET-h/week)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Metabolic syndrome								
OR (95% CI) in Model 1	1	0.92 (0.82–1.04)	0.92 (0.81–1.03)	0.77 (0.68–0.87)	1	0.90 (0.80–1.02)	0.84 (0.74–0.94)	0.73 (0.65–0.83)
P for trend			<0.001				<0.001	
OR (95% CI) in Model 2	1	0.91 (0.81–1.03)	0.89 (0.79–1.01)	0.75 (0.65–0.85)	1	0.90 (0.79–1.02)	0.83 (0.73–0.94)	0.72 (0.63–0.82)
P for trend			<0.001				<0.001	
Obesity								
OR (95% CI) in Model 2	1	0.96 (0.86–1.08)	0.96 (0.86–1.07)	0.78 (0.69–0.88)	1	0.91 (0.81–1.02)	0.90 (0.80–1.00)	0.82 (0.73–0.92)
P for trend			<0.001				0.001	
High blood pressure								
OR (95% CI) in Model 2	1	1.06 (0.95–1.17)	1.11 (0.99–1.23)	1.01 (0.90–1.13)	1	0.95 (0.85–1.06)	0.91 (0.82–1.01)	0.81 (0.73–0.91)
P for trend			0.681				<0.001	
OR (95% CI) in Model 3	1	1.08 (0.97–1.20)	1.13 (1.01–1.27)	1.09 (0.97–1.23)	1	0.97 (0.86–1.08)	0.92 (0.83–1.02)	0.83 (0.75–0.93)
P for trend			0.081				0.001	
Elevated triglycerides								
OR (95% CI) in Model 2	1	0.91 (0.82–1.02)	0.85 (0.75–0.95)	0.69 (0.61–0.78)	1	0.89 (0.79–1.00)	0.76 (0.68–0.85)	0.69 (0.61–0.77)
P for trend			<0.001				<0.001	
OR (95% CI) in Model 3	1	0.92 (0.82–1.03)	0.85 (0.76–0.96)	0.73 (0.65–0.83)	1	0.90 (0.79–1.01)	0.76 (0.68–0.86)	0.69 (0.62–0.78)
P for trend			<0.001				<0.001	
Low HDL-cholesterol								
OR (95% CI) in Model 2	1	0.92 (0.76–1.10)	0.74 (0.60–0.90)	0.60 (0.48–0.75)	1	0.98 (0.80–1.19)	0.95 (0.78–1.15)	0.82 (0.66–1.00)
P for trend			<0.001				0.070	
OR (95% CI) in Model 3	1	0.94 (0.78–1.13)	0.76 (0.62–0.93)	0.66 (0.53–0.81)	1	1.00 (0.81–1.22)	0.96 (0.79–1.17)	0.84 (0.68–1.04)
P for trend			<0.001				0.131	
Elevated blood glucose								
OR (95% CI) in Model 2	1	0.93 (0.83–1.03)	0.92 (0.83–1.03)	0.89 (0.79–0.99)	1	0.99 (0.88–1.10)	0.87 (0.79–0.97)	0.91 (0.81–1.01)
P for trend			0.040				0.017	
OR (95% CI) in Model 3	1	0.93 (0.84–1.03)	0.93 (0.84–1.04)	0.94 (0.84–1.05)	1	1.00 (0.89–1.11)	0.88 (0.79–0.98)	0.93 (0.83–1.04)
P for trend			0.279				0.056	

Daily life activity (quartiles) and leisure-time exercise (quartiles) were simultaneously inserted in all models

Model 1: adjusted for age

Model 2: adjusted for age, research sites, education level, smoking habit, current alcohol drinking, energy intake, and sleep duration

Model 3: adjusted for the covariates in Model 2 + body mass index

MET metabolic equivalent, *OR* odds ratio, *CI* confidence interval, *Q1* first quartile, *Q2* second quartile, *Q3* third quartile, *Q4* fourth quartile, *HDL* high-density lipoprotein

Table 3 Associations of the volume of daily life activity and leisure-time exercise with the prevalence of metabolic syndrome and its traits in women

	Daily life activity (MET-h/week)				Leisure-time exercise (MET-h/week)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Metabolic syndrome								
OR (95% CI) in Model 1	1	0.87 (0.73–1.03)	0.81 (0.67–0.97)	0.78 (0.65–0.94)	1	1.08 (0.90–1.30)	1.04 (0.87–1.25)	0.84 (0.70–1.01)
P for trend			0.007				0.073	
OR (95% CI) in Model 2	1	0.85 (0.71–1.01)	0.77 (0.64–0.92)	0.71 (0.58–0.86)	1	1.01 (0.83–1.23)	1.01 (0.83–1.22)	0.82 (0.67–1.01)
P for trend			<0.001				0.058	
Obesity								
OR (95% CI) in Model 2	1	0.94 (0.81–1.08)	0.88 (0.76–1.02)	0.93 (0.80–1.08)	1	1.06 (0.92–1.22)	0.92 (0.80–1.07)	0.83 (0.71–0.96)
P for trend			0.260				0.004	
High blood pressure								
OR (95% CI) in Model 2	1	1.15 (1.02–1.29)	1.12 (0.99–1.26)	1.11 (0.98–1.25)	1	1.01 (0.89–1.14)	1.06 (0.94–1.20)	0.94 (0.83–1.06)
P for trend			0.164				0.431	
OR (95% CI) in Model 3	1	1.16 (1.03–1.30)	1.14 (1.01–1.28)	1.11 (0.98–1.25)	1	1.00 (0.89–1.14)	1.07 (0.95–1.22)	0.97 (0.85–1.10)
P for trend			0.184				0.831	
Elevated triglycerides								
OR (95% CI) in Model 2	1	0.93 (0.79–1.08)	0.80 (0.68–0.94)	0.73 (0.61–0.87)	1	0.94 (0.79–1.12)	1.01 (0.85–1.20)	0.79 (0.66–0.95)
P for trend			<0.001				0.028	
OR (95% CI) in Model 3	1	0.93 (0.79–1.09)	0.80 (0.68–0.95)	0.72 (0.60–0.86)	1	0.93 (0.78–1.11)	1.02 (0.86–1.22)	0.82 (0.68–0.98)
P for trend			<0.001				0.087	
Low HDL-cholesterol								
OR (95% CI) in Model 2	1	0.85 (0.70–1.02)	0.76 (0.62–0.93)	0.65 (0.53–0.80)	1	1.01 (0.82–1.24)	1.01 (0.82–1.25)	0.90 (0.73–1.12)
P for trend			<0.001				0.362	
OR (95% CI) in Model 3	1	0.85 (0.70–1.02)	0.77 (0.63–0.94)	0.64 (0.52–0.79)	1	1.00 (0.81–1.23)	1.03 (0.83–1.26)	0.93 (0.75–1.16)
P for trend			<0.001				0.600	
Elevated blood glucose								
OR (95% CI) in Model 2	1	0.95 (0.83–1.08)	0.88 (0.77–1.02)	0.95 (0.83–1.10)	1	1.01 (0.87–1.16)	1.02 (0.89–1.18)	0.95 (0.82–1.10)
P for trend			0.377				0.499	
OR (95% CI) in Model 3	1	0.95 (0.83–1.08)	0.89 (0.77–1.03)	0.95 (0.82–1.10)	1	1.00 (0.87–1.16)	1.04 (0.90–1.20)	0.98 (0.84–1.13)
P for trend			0.360				0.832	

Daily life activity (quartiles) and leisure-time exercise (quartiles) were simultaneously inserted in all Models

Model 1: adjusted for age

Model 2: adjusted for age, research sites, education level, smoking habit, current alcohol drinking, energy intake, sleep duration, and menopausal status

Model 3: adjusted for the covariates in Model 2 + body mass index

MET metabolic equivalent, *OR* odds ratio, *CI* confidence interval, *Q1* first quartile, *Q2* second quartile, *Q3* third quartile, *Q4* fourth quartile, *HDL* high-density lipoprotein

Model 3) for low HDL-cholesterol compared with the first quartile (reference), similar to the finding in men. Although leisure-time exercise volume was inversely associated with the prevalence of elevated triglycerides in Model 2 (*P*-value for trend was 0.028), this inverse association was non-significant after further adjustment for BMI (*P*-value for trend was 0.087 in Model 3).

Relationships of leisure-time exercise intensity with the prevalence of metabolic syndrome and its traits in men and women

As shown in Table 4, moderate- and vigorous-intensity exercise was inversely associated with the prevalence of metabolic syndrome in men (*P*-values for trend were <0.001 and 0.029, respectively, in Model 2); however, light-intensity exercise was not. Moderate-intensity exercise was inversely associated with the prevalence of obesity and other metabolic traits (Model 2), although its inverse association with elevated blood glucose was non-significant after further adjustment for BMI (Model 3). Light-intensity exercise was inversely associated with the prevalence of high blood pressure and elevated triglycerides after adjustment for BMI (*P*-values for trend were 0.002 and 0.033 in Model 3, respectively) but not with other traits. Vigorous-intensity exercise was inversely associated with the prevalence of elevated triglycerides and elevated blood glucose (*P*-values for trend were 0.049 and 0.045 in Model 3, respectively).

As shown in Table 5, moderate-intensity exercise was inversely associated with the prevalence of metabolic

Table 4 Associations of the volume of each intensity of leisure-time exercise with the prevalence of metabolic syndrome and its traits in men

	Leisure-time exercise								
	Light intensity (MET-h/week)			Moderate intensity (MET-h/week)			Vigorous intensity (MET-h/week)		
	0	>0 to 10.0	>10.0	0	>0 to 10.0	>10.0	0	>0 to 10.0	>10.0
Number (%)	3446 (27.1)	6068 (47.7)	3195 (25.1)	8501 (66.9)	2288 (18.0)	1920 (15.1)	11,692 (92.0)	476 (3.7)	541 (4.3)
Metabolic syndrome									
OR (95% CI) in Model 1	1	1.03 (0.92–1.14)	0.93 (0.82–1.05)	1	0.81 (0.71–0.91)	0.73 (0.64–0.83)	1	0.83 (0.63–1.06)	0.84 (0.66–1.07)
P for trend		0.284			<0.001			0.069	
OR (95% CI) in Model 2	1	1.02 (0.92–1.15)	0.92 (0.81–1.05)	1	0.81 (0.72–0.92)	0.73 (0.63–0.83)	1	0.81 (0.62–1.05)	0.81 (0.63–1.02)
P for trend		0.237			<0.001			0.029	
Obesity									
OR (95% CI) in Model 2	1	1.03 (0.93–1.14)	1.01 (0.90–1.14)	1	0.91 (0.82–1.02)	0.84 (0.75–0.95)	1	0.94 (0.76–1.17)	0.84 (0.68–1.03)
P for trend		0.819			0.003			0.090	
High blood pressure									
OR (95% CI) in Model 2	1	0.95 (0.86–1.04)	0.85 (0.76–0.95)	1	0.90 (0.81–0.99)	0.82 (0.73–0.91)	1	0.93 (0.76–1.14)	0.84 (0.70–1.02)
P for trend		0.005			<0.001			0.065	
OR (95% CI) in Model 3	1	0.92 (0.84–1.02)	0.83 (0.74–0.93)	1	0.91 (0.82–1.01)	0.84 (0.75–0.95)	1	0.93 (0.76–1.15)	0.86 (0.70–1.04)
P for trend		0.002			0.002			0.098	
Elevated triglycerides									
OR (95% CI) in Model 2	1	0.98 (0.89–1.09)	0.88 (0.78–1.00)	1	0.83 (0.74–0.92)	0.68 (0.60–0.77)	1	0.92 (0.73–1.15)	0.80 (0.64–0.99)
P for trend		0.051			<0.001			0.033	
OR (95% CI) in Model 3	1	0.96 (0.86–1.07)	0.87 (0.77–0.99)	1	0.83 (0.74–0.93)	0.69 (0.60–0.78)	1	0.92 (0.73–1.16)	0.81 (0.65–1.01)
P for trend		0.033			<0.001			0.049	
Low HDL-cholesterol									
OR (95% CI) in Model 2	1	1.03 (0.86–1.23)	0.99 (0.80–1.23)	1	0.91 (0.74–1.10)	0.72 (0.57–0.90)	1	0.82 (0.52–1.24)	0.99 (0.67–1.42)
P for trend		0.940			0.004			0.708	
OR (95% CI) in Model 3	1	1.02 (0.86–1.22)	0.99 (0.80–1.23)	1	0.93 (0.76–1.12)	0.74 (0.58–0.93)	1	0.82 (0.52–1.24)	1.02 (0.68–1.46)
P for trend		0.963			0.011			0.788	
Elevated blood glucose									
OR (95% CI) in Model 2	1	1.02 (0.93–1.12)	1.06 (0.95–1.18)	1	0.82 (0.74–0.91)	0.94 (0.84–1.05)	1	0.85 (0.69–1.04)	0.84 (0.69–1.02)
P for trend		0.311			0.036			0.032	
OR (95% CI) in Model 3	1	1.01 (0.91–1.11)	1.06 (0.94–1.18)	1	0.83 (0.75–0.92)	0.97 (0.87–1.09)	1	0.84 (0.68–1.04)	0.86 (0.70–1.04)
P for trend		0.341			0.133			0.045	

Daily life activity (quartiles) and each intensity of leisure-time exercise (0, >0 to 10.0, >10 MET-h/week) were simultaneously inserted in all Models

Model 1: adjusted for age

Model 2: adjusted for age, research sites, education level, smoking habit, current alcohol drinking, energy intake, and sleep duration

Model 3: adjusted for the covariates in Model 2 + body mass index

MET metabolic equivalent, *OR* odds ratio, *CI* confidence interval, *Q1* first quartile, *Q2* second quartile, *Q3* third quartile, *Q4* fourth quartile, *HDL* high-density lipoprotein

Table 5 Associations of the volume of each intensity of leisure-time exercise with the prevalence of metabolic syndrome and its components in women

	Leisure-time exercise								
	Light intensity (MET-h/week)			Moderate intensity (MET-h/week)			Vigorous intensity (MET-h/week)		
	0	>0 to 10.0	>10.0	0	>0 to 10.0	>10.0	0	>0 to 10.0	>10.0
Number (%)	3745 (31.4)	5472 (45.9)	2699 (22.7)	8603 (72.2)	1594 (13.4)	1719 (14.4)	11,507 (96.6)	161 (1.4)	248 (2.1)
Metabolic syndrome									
OR (95% CI) in Model 1	1	1.07 (0.91–1.25)	1.06 (0.88–1.26)	1	0.97 (0.80–1.18)	0.63 (0.51–0.77)	1	1.00 (0.50–1.80)	1.01 (0.58–1.65)
P for trend		0.541			< 0.001			0.979	
OR (95% CI) in Model 2	1	1.01 (0.85–1.19)	1.02 (0.84–1.23)	1	0.99 (0.81–1.19)	0.64 (0.52–0.79)	1	1.03 (0.52–1.87)	1.05 (0.60–1.73)
P for trend		0.871			< 0.001			0.840	
Obesity									
OR (95% CI) in Model 2	1	1.04 (0.91–1.18)	1.06 (0.91–1.23)	1	0.94 (0.80–1.09)	0.71 (0.60–0.83)	1	1.17 (0.73–1.80)	0.53 (0.32–0.84)
P for trend		0.453			< 0.001			0.022	
High blood pressure									
OR (95% CI) in Model 2	1	1.07 (0.96–1.18)	1.06 (0.94–1.20)	1	0.88 (0.78–1.00)	0.90 (0.80–1.01)	1	0.76 (0.52–1.11)	0.97 (0.72–1.30)
P for trend		0.317			0.033			0.508	
OR (95% CI) in Model 3	1	1.06 (0.96–1.18)	1.08 (0.96–1.22)	1	0.88 (0.77–1.00)	0.94 (0.83–1.06)	1	0.71 (0.48–1.04)	1.01 (0.74–1.36)
P for trend		0.216			0.154			0.589	
Elevated triglycerides									
OR (95% CI) in Model 2	1	1.00 (0.87–1.16)	0.88 (0.74–1.04)	1	1.03 (0.86–1.22)	0.81 (0.68–0.97)	1	0.86 (0.48–1.45)	0.85 (0.53–1.32)
P for trend		0.131			0.041			0.409	
OR (95% CI) in Model 3	1	0.99 (0.86–1.15)	0.89 (0.75–1.06)	1	1.03 (0.86–1.23)	0.85 (0.71–1.01)	1	0.81 (0.45–1.38)	0.90 (0.55–1.40)
P for trend		0.201			0.121			0.496	
Low HDL-cholesterol									
OR (95% CI) in Model 2	1	1.03 (0.86–1.23)	1.04 (0.84–1.27)	1	1.15 (0.93–1.42)	0.79 (0.63–0.99)	1	0.59 (0.23–1.24)	0.89 (0.49–1.50)
P for trend		0.733			0.148			0.401	
OR (95% CI) in Model 3	1	1.02 (0.85–1.22)	1.06 (0.86–1.30)	1	1.17 (0.94–1.44)	0.83 (0.66–1.04)	1	0.56 (0.22–1.19)	0.93 (0.51–1.58)
P for trend		0.612			0.300			0.458	
Elevated blood glucose									
OR (95% CI) in Model 2	1	1.09 (0.97–1.24)	1.06 (0.92–1.22)	1	0.89 (0.76–1.03)	0.83 (0.72–0.96)	1	1.15 (0.74–1.73)	0.81 (0.53–1.18)
P for trend		0.443			0.005			0.438	
OR (95% CI) in Model 3	1	1.09 (0.96–1.24)	1.08 (0.93–1.24)	1	0.88 (0.76–1.02)	0.86 (0.75–0.99)	1	1.10 (0.70–1.67)	0.83 (0.55–1.22)
P for trend		0.330			0.019			0.485	

Daily life activity (quartiles) and each intensity of leisure-time exercise (0, >0 to 10.0, >10 MET-h/week) were simultaneously inserted in all Models

Model 1: adjusted for age

Model 2: adjusted for age, research sites, education level, smoking habit, current alcohol drinking, energy intake, sleep duration, and menopausal status

Model 3: adjusted for the covariates in Model 2 + body mass index

MET metabolic equivalent, *OR* odds ratio, *CI* confidence interval, *Q1* first quartile, *Q2* second quartile, *Q3* third quartile, *Q4* fourth quartile, *HDL* high-density lipoprotein

syndrome in women (P-value for trend was <0.001 in Model 2); however, light- or vigorous-intensity exercise was not. Moderate- and vigorous-intensity exercise was inversely associated with the prevalence of obesity. Moderate-intensity exercise was also inversely associated with the prevalence of high blood pressure, elevated triglycerides, and elevated blood glucose (Model 2), although its inverse associations with high blood pressure and elevated triglycerides fell into non-significant after further adjustment for BMI (Model 3).

Discussion

The present study revealed that daily life activity volume was inversely associated with the prevalence of metabolic syndrome, independent of leisure-time exercise, in men and women. Especially, higher daily life activity was associated with considerably lower prevalence of low HDL-cholesterol even after the adjustment for BMI in both sexes. Leisure-time exercise volume was inversely associated with the prevalence of metabolic syndrome and some of its traits in men and with the prevalence of obesity in women, independent of daily life activity. Moderate-intensity exercise might be more intensely associated with lower prevalence of metabolic syndrome and its traits among the three intensity levels in both sexes.

Physical exercise is one of the key preventive factors for numerous chronic diseases [8–11]. In turn, a lack of physical exercise is a risk factor for many health disorders. Excessive sedentary behavior, distinct from a lack of volitional exercise, may be linked to various health problems [12–15]. Physical activity can be roughly classified into two categories: volitional exercise (namely, leisure-time exercise) and non-exercise physical activity (namely, daily life activity). Among the range of daily non-exercise life activities, even low-intensity behaviors such as standing are suggested to contribute to daily calorie expenditure [23]. In contrast, sedentary behaviors such as assuming a sitting or reclining position, which features a low-energy expenditure (≤1.5 METs), is suggested to be associated with various health problems [22]. Therefore, we calculated daily life activity volume by including low-intensity behaviors such as standing (2.0 METs) but not sitting. Moreover, total duration of daily life activity may be affected by sleep duration, because staying awake duration might be tended to be longer in a person with shorter sleep duration. Therefore, sleep duration was included as a covariate in multivariate-adjusted models (Models 2 and 3).

We determined here that a higher daily life activity volume was associated with a lower prevalence of metabolic syndrome independent of leisure-time exercise in Japanese men and women. This finding is fundamentally concordant with those of previous reports focusing on the associations between sedentary behaviors and the risk of metabolic syndrome [23–25].

Interestingly, among the five traits of metabolic syndrome defined by the modified NCEP ATP III criteria, as daily life activity volume increased, the prevalence of a low HDL-cholesterol markedly decreased in a proportional fashion independent of leisure-time exercise in both men and women (Model 2). Further adjustment for BMI (Model 3) did not substantially alter these inverse associations. Moreover, daily life activity volume was inversely associated with the prevalence of obesity in men but not in women. Therefore, a higher daily life activity volume may be associated with a lower prevalence of HDL-cholesterol mainly thorough mechanisms besides decreases in BMI or improvements in obesity. In contrast, as leisure-time exercise volume increased, the prevalence of low HDL-cholesterol tended to decrease independent of daily life activity in both sexes, however, the proportional relationships were not significant (Models 2 and 3). A circulating low HDL-cholesterol level is a well-recognized risk factor for cardiovascular diseases. Although few established factors raise circulating HDL-cholesterol levels, aerobic exercise is one. It has been reported that circulating HDL-cholesterol levels are higher in active women than inactive women [26]. Although the mechanisms by which aerobic exercise increases circulating HDL-cholesterol levels are not elucidated in detail, the enhancement of lipoprotein lipase (LPL) activity by aerobic exercise is considered a primary mechanism as LPL is a key enzyme in triglyceride uptake and HDL-cholesterol production [27]. Meanwhile, sedentary behavior may be associated with low circulating HDL-cholesterol levels [24]. LPL has been extensively studied at the cellular level during physical inactivity, and muscle LPL activity is reduced during physical inactivity [28–30]. Low LPL activity is demonstrated to lead to attenuated plasma triglyceride uptake and reduced plasma HDL-cholesterol levels [28, 31]. In our study, lower prevalence of low HDL-cholesterol was closely associated with higher daily life activity volume. Daily non-exercise life activity that is more abundant and frequent than leisure-time exercise may be more important for increasing circulating HDL-cholesterol levels.

Among the three leisure-time exercise intensity levels, moderate-intensity exercise was most closely associated with a lower prevalence of metabolic syndrome and some of its traits in men and women. Although there may be insufficient statistical power and estimated odds ratios might be unstable in cases of vigorous-intensity exercise because few subjects performed vigorous-intensity exercise; this finding is plausible because aerobic exercise at appropriate intensities is recognized to be beneficial for preventing obesity and metabolic disorders. Because the viewpoint of easy practice and easy continuation is very important, moderate-intensity exercise is more suitable for preventing metabolic disorders than vigorous-intensity exercise. Lower prevalence of low HDL-cholesterol was also observed in higher volume of moderate-intensity exercise but not in vigorous-intensity exercise in men. This observation is concordant with that of a previous study reporting that vigorous exercise training is not associated with increase in LPL activity in fast-twitch muscle fibers [24].

The strength of the present study is that the sample size is considerably large. In addition, we obtained detailed information on daily life activity and leisure-time exercise including volume according to intensity. We also obtained information about various potential confounding factors and adjusted them in the analyses, although unadjusted or residual confounding factors may remain.

This study has several limitations. First, due to its cross-sectional design, the causal relationships of daily life activity and leisure-time exercise with metabolic syndrome and its traits should be interpreted with caution. Second, as information on daily life activity, leisure-time exercise, and other lifestyle factors was obtained using a self-reported questionnaire, misclassifications may be inevitable. However, such a misclassification might be non-differential and attenuate the true associations. Third, we defined metabolic syndrome and obesity using BMI instead of waist circumference; however, BMI may not rigorously reflect central obesity. Finally, as most of our subjects were Japanese, our results may not be applicable to other ethnic populations.

In conclusion, our study demonstrated that daily life activity volume is inversely associated with the prevalence of metabolic syndrome independent of leisure-time exercise in Japanese men and women. A higher daily life activity volume was especially associated with a considerably low prevalence of low HDL-cholesterol in both sexes. Encouraging abundant usual physical activity in daily life and appropriate leisure-time moderate-intensity exercise might be advisable for preventing metabolic disorders. Further prospective studies are needed to clarify the causal and conclusive preventative effects of daily life activity and leisure-time exercise against metabolic syndrome and its traits.

Acknowledgements This study was funded by Grants-in-Aid for Scientific Research on Priority Areas of Cancer (No. 17015018), on Innovative Areas (No. 221S0001), and Platform of Supporting Cohort Study and Biospecimen Analysis (JSPS KAKENHI Grant Number JP16H06277) from the Japanese Ministry of Education, Culture, Sports, Science and Technology, and by Grants-in-Aid for Scientific Research (C) (JSPS KAKENHI Grant Numbers JP15K08778 and JP18K10086) from the Japan Society for the Promotion of Science.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the ethics committees of Nagoya University Graduate School of Medicine, Japan, Tokushima University Graduate School, Japan and other participating institutions, conducted in accordance with the principles of the Declaration of Helsinki, and performed in accordance with the relevant guidelines and regulations.

Informed consent Informed consent was obtained from all individual participants included in the study.

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

1. S.M. Grundy, J.I. Cleeman, S.R. Daniels, K.A. Donato, R.H. Eckel, B.A. Franklin, D.J. Gordon, R.M. Krauss, P.J. Savage, S.C. Smith Jr., J.A. Spertus, F. Costa, American Heart Association; National Heart, Lung, and Blood Institute: Diagnosis and management of the metabolic syndrome - An American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation **112**, 2735–2752 (2005)
2. K.G. Alberti, P. Zimmet, J. Shaw, Metabolic syndrome—a new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabet. Med. **23**, 469–480 (2006)
3. M.G. Saklayen, The Global Epidemic of the Metabolic Syndrome. Curr. Hypertens. Rep. **20**, 12 (2018). https://doi.org/10.1007/s11906-018-0812-z
4. C. Lorenzo, M. Okoloise, K. Williams, M.P. Stern, S.M. Haffner, The metabolic syndrome as predictor of type 2 diabetes: the San Antonio Heart Study. Diabetes Care **26**, 3153–3159 (2003)
5. S. Malik, N.D. Wong, S.S. Franklin, T.V. Kamath, G.J. L'Italien, J.R. Pio, G.R. Williams, Impact of the metabolic syndrome on mortality from coronary heart disease, cardiovascular disease, and all causes in United States adults. Circulation **110**, 1245–1250 (2004)
6. A.M. McNeill, W.D. Rosamond, C.J. Girman, S.H. Golden, M.I. Schmidt, H.E. East, C.M. Ballantyne, G. Heiss, The metabolic syndrome and 11-year risk of incident cardiovascular disease in the atherosclerosis risk in communities study. Diabetes Care **28**, 385–390 (2005)
7. P.W. Wilson, R.B. D'Agostino, H. Parise, L. Sullivan, J.B. Meigs, Metabolic syndrome as a precursor of cardiovascular disease and type 2 diabetes mellitus. Circulation **112**, 3066–3072 (2005)
8. A. Ghosh, Effects of daily exercise on blood pressure, plasma glucose, and obesity measures in 55-64-year-old obese Asian Indian men: the Calcutta longitudinal study. Am. J. Hum. Biol. **18**, 718–721 (2006)
9. J.M. Gill, A.R. Cooper, Physical activity and prevention of type 2 diabetes mellitus. Sports Med. **38**, 807–824 (2008)
10. M. Nocon, T. Hiemann, F. Müller-Riemenschneider, F. Thalau, S. Roll, S.N. Willich, Association of physical activity with all-cause and cardiovascular mortality: a systematic review and meta-analysis. Eur. J. Cardiovasc. Prev. Rehabil. **15**, 239–246 (2008)
11. G.P. Nassis, P. Klentrou, A. Palmeira, D.J. Stensel, The influence of physical activity on obesity and health. J. Obes. **2012**, 298953 (2012). https://doi.org/10.1155/2012/298953

12. D.W. Dunstan, E.L. Barr, G.N. Healy, J. Salmon, J.E. Shaw, B. Balkau, D.J. Magliano, A.J. Cameron, P.Z. Zimmet, N. Owen, Television viewing time and mortality: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). Circulation **121**, 384–391 (2010)
13. A. Grøntved, F.B. Hu, Television viewing and risk of type 2 diabetes, cardiovascular disease, and all-cause mortality: a meta-analysis. JAMA **305**, 2448–2455 (2011). https://doi.org/10.1001/jama.2011.812
14. K. Wijndaele, G. Orrow, U. Ekelund, S.J. Sharp, S. Brage, S.J. Griffin, R.K. Simmons, Increasing objectively measured sedentary time increases clustered cardiometabolic risk: a 6 year analysis of the ProActive study. Diabetologia **57**, 305–312 (2014). https://doi.org/10.1007/s00125-013-3102-y
15. P.T. Katzmarzyk, T.S. Church, C.L. Craig, C. Bouchard, Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med. Sci. Sports Exerc. **41**, 998–1005 (2009)
16. N. Hamajima, The Japan Multi-Institutional Collaborative Cohort Study (J-MICC Study) to detect gene-environment interactions for cancer. Asian Pac. J. Cancer Prev. **8**(2), 317–323 (2007)
17. S. Tokudome, C. Goto, N. Imaeda, Y. Tokudome, M. Ikeda, S. Maki, Development of a data-based short food frequency questionnaire for assessing nutrient intake by middle-aged Japanese. Asian Pac. J. Cancer Prev. **5**(1), 40–43 (2004)
18. Y. Tokudome, C. Goto, N. Imaeda, T. Hasegawa, R. Kato, K. Hirose, K. Tajima, S. Tokudome, Relative validity of a short food frequency questionnaire for assessing nutrient intake versus three-day weighed diet records in middle-aged Japanese. J. Epidemiol. **15**(4), 135–145 (2005)
19. C. Goto, Y. Tokudome, N. Imaeda, K. Takekuma, K. Kuriki, F. Igarashi, M. Ikeda, S. Tokudome, Validation study of fatty acid consumption assessed with a short food frequency questionnaire against plasma concentration in middle-aged Japanese people. Scand. J. Nutr. **50**, 77–82 (2006)
20. N. Imaeda, C. Goto, Y. Tokudome, K. Hirose, K. Tajima, S. Tokudome, Reproducibility of a short food frequency questionnaire for Japanese general population. J. Epidemiol. **17**(3), 100–107 (2007)
21. C.L. Craig, A.L. Marshall, M. Sjöström, A.E. Bauman, M.L. Booth, B.E. Ainsworth, M. Pratt, U. Ekelund, A. Yngve, J.F. Sallis, P. Oja, International physical activity questionnaire: 12-country reliability and validity. Med. Sci. Sports Exerc. **35**, 1381–1395 (2003)
22. A.A. Thorp, N. Owen, M. Neuhaus, D.W. Dunstan, Sedentary behaviors and subsequent health outcomes in adults a systematic review of longitudinal studies, 1996–2011. Am. J. Prev. Med. **41**, 207–215 (2011)
23. H. Uemura, S. Katsuura-Kamano, M. Yamaguchi, M. Nakamoto, M. Hiyoshi, K. Arisawa, Abundant daily non-sedentary activity is associated with reduced prevalence of metabolic syndrome and insulin resistance. J. Endocrinol. Invest. **36**, 1069–1075 (2013).
24. M.T. Hamilton, D.G. Hamilton, T.W. Zderic, Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. Diabetes **56**, 2655–2667 (2007)
25. G.N. Healy, D.W. Dunstan, J. Salmon, E. Cerin, J.E. Shaw, P.Z. Zimmet, N. Owen, Breaks in sedentary time: beneficial associations with metabolic risk. Diabetes Care **31**, 661–666 (2008)
26. P.A. Taylor, A. Ward, Women, high-density lipoprotein cholesterol, and exercise. Arch. Intern. Med. **153**, 1178–1184 (1993)
27. M.A. Kantor, E.M. Cullinane, S.P. Sady, P.N. Herbert, P.D. Thompson, Exercise acutely increases high density lipoprotein-cholesterol and lipoprotein lipase activity in trained and untrained men. Metabolism **36**, 188–192 (1987)
28. L. Bey, M.T. Hamilton, Suppression of skeletal muscle lipoprotein lipase activity during physical inactivity: a molecular reason to maintain daily low-intensity activity. J. Physiol. **551**, 673–682 (2003)
29. M.T. Hamilton, D.G. Hamilton, T.W. Zderic, Exercise physiology versus inactivity physiology: an essential concept for understanding lipoprotein lipase regulation. Exerc. Sport Sci. Rev. **32**, 161–166 (2004)
30. T.W. Zderic, M.T. Hamilton, Physical inactivity amplifies the sensitivity of skeletal muscle to the lipid-induced downregulation of lipoprotein lipase activity. J. Appl. Physiol. **100**, 249–257 (2006)
31. I.J. Goldberg, N.A. Le, H.N. Ginsberg, R.M. Krauss, F.T. Lindgren, Lipoprotein metabolism during acute inhibition of lipoprotein lipase in the cynomolgus monkey. J. Clin. Invest. **81**, 561–568 (1988)

Affiliations

Hirokazu Uemura[1] · Sakurako Katsuura-Kamano[1] · Yuki Iwasaki[1] · Kokichi Arisawa[1] · Asahi Hishida[2] · Rieko Okada[2] · Takashi Tamura[2] · Yoko Kubo[2] · Hidemi Ito[3] · Isao Oze[4] · Chisato Shimanoe[5] · Yuichiro Nishida[6] · Yasuyuki Nakamura[7] · Naoyuki Takashima[8] · Sadao Suzuki[9] · Hiroko Nakagawa-Senda[9] · Daisaku Nishimoto[10] · Toshiro Takezaki[11] · Haruo Mikami[12] · Yohko Nakamura[12] · Norihiro Furusyo[13,14] · Hiroaki Ikezaki[13,14] · Etsuko Ozaki[15] · Teruhide Koyama[15] · Kiyonori Kuriki[16] · Kaori Endoh[16] · Mariko Naito[2,17] · Kenji Wakai[2] for the Japan Multi-institutional Collaborative Cohort (J-MICC) Study Group

[1] Department of Preventive Medicine, Institute of Biomedical Sciences, Tokushima University Graduate School, Tokushima, Japan

[2] Department of Preventive Medicine, Nagoya University Graduate School of Medicine, Nagoya, Japan

[3] Division of Cancer Information and Control, Aichi Cancer Center Research Institute, Nagoya, Japan

[4] Division of Cancer Epidemiology and Prevention, Aichi Cancer Center Research Institute, Nagoya, Japan

[5] Clinical Research Center, Saga University Hospital, Saga, Japan

[6] Department of Preventive Medicine, Faculty of Medicine, Saga University, Saga, Japan

[7] Department of Food Science and Human Nutrition, Faculty of Agriculture, Ryukoku University, Otsu, Japan

[8] Department of Public Health, Shiga University of Medical Science, Otsu, Japan

[9] Department of Public Health, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan

[10] Kagoshima University School of Health Sciences, Kagoshima, Japan

[11] Department of International Island and Community Medicine, Kagoshima University Graduate School of Medical and Dental Sciences, Kagoshima, Japan

[12] Cancer Prevention Center, Chiba Cancer Center Research Institute, Chiba, Japan

[13] Department of General Internal Medicine, Kyushu University Hospital, Fukuoka, Japan

[14] Department of Environmental Medicine and Infectious Disease, Kyushu University, Fukuoka, Japan

[15] Department of Epidemiology for Community Health and Medicine, Kyoto Prefectural University of Medicine, Kyoto, Japan

[16] Laboratory of Public Health, School of Food and Nutritional Sciences, University of Shizuoka, Shizuoka, Japan

[17] Department of Oral Epidemiology, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima, Japan