Table 5. Step-down multiple regression analysis in Japanese children and adolescents of 6–17 y.

	REE of boys and girls				REE of boys				REE of girls			
	Un std coefficients		Change in % R^2	SE (kcal/d)	Un std coefficients		Change in % R^2	SE (kcal/d)	Un std coefficients		Change in % R^2	SE (kcal/d)
Predictors	B	Standard error			B	Standard error			B	Standard error		
Constant	314.0**	127.1	—		403.8**	181.4	—		852.0**	44.7	—	
Body weight	12.7**	1.3	55.0		14.4**	1.6	70.7		9.3**	1.4	32.1	
Height	5.4**	1.3	2.1		5.1**	1.9	1.7		—	—	—	
Age	−35.4**	5.4	3.0		−34.0**	8.9	1.8		—	—	—	
Gender	147.3**	17.4	15.1		—	—	—		—	—	—	
Puberty	—	—	—		—	—	—		−87.0**	31.7	4.6	
Total			75.2	118.0			74.2	125.4			36.7	102.8
Constant	796.6**	35.4	—		871.6**	52.7	—		837.2**	46.4	—	
Fat-free mass-1	21.6**	1.6	60.8		20.7**	2.1	68.7		19.0**	3.0	33.2	
Fat mass-1	5.5**	2.2	0.7		9.9**	3.2	2.3		—	—	—	
Age	−28.1**	4.5	3.8		−24.6**	7.2	2.9		−20.8**	6.4	6.0	
Gender	125.3**	18.2	10.6		—	—	—		—	—	—	
Puberty	—	—	—		—	—	—		—	—	—	
Total			75.9	116.0			73.9	126.2			39.2	100.6
Constant	821.9**	34.6	—		895.3**	52.8	—		740.2**	56.6	—	
Fat-free mass-2	20.9**	1.4	63.6		22.0**	2.3	65.2		15.0**	2.1	34.6	
Fat mass-2	7.9**	1.8	2.1		10.4**	2.7	3.5		—	—	—	
Age	−30.5**	4.6	8.9		−33.2**	8.5	5.6		—	—	—	
Gender	98.9**	20.4	1.6		—	—	—		—	—	—	
Puberty	—	—	—		—	—	—		−86.2**	30.1	4.7	
Total			76.2	115.5			74.3	125.0			39.3	100.5

REE, resting energy expenditure; Un std coefficients, unstandarized coefficients; B, intercept and partial regression coefficient; SE, standard error of estimate.
** $p<0.05$.

adults, and the increase in SM mass during each growth stage seemed to be fairly constant in the extremities and trunk in both boys and girls (*27*). The increase in SM mass with age would tend to reduce REE expressed in terms of FFM during growth. The greater REE/FFM ratio in children and adolescents may be explained by the attribution of a high proportion of FFM to residual mass, including metabolically active organs such as the liver and brain, and a low proportion to tissues such as fat-free adipose tissue, SM, and bone relative to adult subjects (*28*). Thus, the decline in REE/FFM during growth is likely due to both a decrease in the proportion of the more metabolically active organs and tissues and to changes in the metabolic rates of individual organs and tissues (*29*). It appears that differences in the rates of maturation among genders, and factors other than body composition are responsible for the gender differences in REE adjusted for FFM in our subjects aged 12–17 y.

Predicted REE was calculated using a formula based on the Japan-DRI (1969) (*3*), Japan-DRI (1975) (*4*), Japan-DRI (2009) (*1*), and previously published equations (*2, 5–7*). As the Maffeis equation and Molnár equation were developed for children and adolescents aged 6–10 y and 10–16 y, respectively, prediction of REE was performed using these two equations for their intended age groups. Mean REE predicted by all formulas except the WHO (1985) and the Maffeis equation in girls, and the Maffeis equation in boys were not significantly different than measured REE. The mean percent differences between predicted REE using the seven formulas and measured REE (the bias) were within 8% of measured REE. Five of the seven formulas overestimated, and the other two formulas underestimated, the REE of our subjects. A higher percentage of accurate prediction was obtained with the Japan-DRI (1969) formula and Molnár equation. The Japan-DRI (1969) formula and the Japan-DRI (1975) formula had the smallest biases in boys and girls, respectively. RMSPE indicates how well the equation predicted actual REE in our data set. Smaller values for RMSPE were obtained using the Japan-DRI (1969) formula and Molnár equation than other formulas in boys and girls.

The Japan-DRI equations were developed based on data collected from Japanese subjects 50 y ago. Although body size and body composition may have changed since then, these earlier values are still being used (*1*). Recently, Ganpule et al. (*30*) developed an REE predictive equation using data from 137 healthy Japanese adults, and Miyake et al. (*31*) reported that Ganpule equation was the most accurate for predicting REE in Japanese adult subjects. They examined the validity of the Ganpule equation for Japanese adults, the Japan-DRI (2009), and several previously proposed equations derived mainly from data in Caucasian subjects, and found that the mean difference and total error values for the Japan-DRI (2009) formula and Ganpule equation were smaller than those for the other equations. However, for individuals with larger body weights, the difference between predicted REE using the Japan-DRI equation and measured REE was larger; in contrast, the difference was smaller for normal-weight subjects. In lean subjects over 18 y of age, Yamamura et al. (*32*) reported that the difference between REE predicted by the Japan-DRI (1999) equation and measured REE was larger than the difference when using the WHO or Schofield equation. The Japan-DRI equation is only a multiple of body weight and does not involve an intercept term, and therefore, systematic error was observed in Japanese adult subjects (*31, 32*). In our child and adolescent subjects, the Japan-DRI (1975) and Japan-DRI (2009) equations did not have a larger bias, but had larger RMSPEs than the internationally-used equations.

The Molnár and Maffeis equations were developed for use in children and adolescents, including both normal-weight and obese subjects. They found that the REE of obese children and adolescents was not significantly different from that of nonobese children and adolescents when REE was adjusted for body composition (FFM+FM) (*9, 10*), and that fat mass (FM) was a significant independent predictor of REE in children and adolescents. Although our population included a smaller proportion of overweight subjects (12.7%) and a larger proportion of underweight subjects (33.5%), Molnár equation predicted REE with fairly good accuracy. Other investigators also reported that Molnár equation had greater accuracy for obese and nonobese children and adolescents (*13, 14*). Kim et al. (*14*) reported that Molnár equation had a high level of accuracy (bias of 0.6%, RMSPE of 90.4 kcal/d, and accuracy rate of 72%) for non-obese and obese Korean children and adolescents. Our data demonstrate that Molnár equation may also be suitable for Japanese children and adolescents 10–16 y old.

We carried out step-down multiple regression analysis using age, gender, BW, height, body composition, and pubertal status (only for girls) in Japanese children and adolescents. There was an independent and highly significant association between REE and FFM, FM, age, and gender, and between REE and BW, height, age, and gender. FFM and BW were the best predictors of REE, followed by gender, age, and height, or fat mass. Seventy-five to 76% and 74% of variation in REE could be explained by a regression equation comprising these three or four parameters in all subjects and male subjects, respectively. However, in the female subgroup, less than 40% of the variation in REE could be explained by the same parameters. When separate regression equations were applied to only pre-menarche or post-menarche girls, these parameters accounted for a slightly greater proportion of variation in REE.

We assessed the influence of puberty on REE in girls, with pubertal status retrospectively classified as before menarche or after menarche. Multiple regression analysis revealed a contribution of pubertal status to REE as indicated by a slight increase in calculated variation (Table 5). Investigation of the contribution of pubertal status to REE has previously yielded conflicting results (*10, 33–36*). Sun et al. (*33*) found an inverse relationship between Tanner stage and REE adjusted for ethnicity, gender, FM, and lean mass. Spadano et al. observed significantly higher mean absolute REE at menarche (±6 mo) than at 4 y after menarche in a longitudinal study (*34*), and also observed in a longitudinal study of girls 10 to 15 y that the increase in REE most likely begins in mid-puberty and persists through menarche (*35*). In contrast, Molnár and Schutz (*10*) reported that there was no significant contribution of pubertal stage determined according to Tanner towards regression of REE either in girls or in boys. Henry et al. (*36*) reported that the inclusion of pubertal stage afforded only minor improvements in the derivation of regression equations for REE in children aged 10–15 y. The lack of significance of pubertal status as a variable in our study may reflect a limited contribution of pubertal status to REE in our subjects.

In our subjects, FM had slightly decreased predictive power as a determinant of REE than in previous studies (*9, 10*). The result may be explained by the small number of obese subjects in our study population compared with other studies. The involvement of FM in REE makes sense because adipose tissue is metabolically active, and fat tissue secretes endocrine factors, such as leptin, in proportion to FM, which in turn increase energy expenditure (*37*). FFM had the highest correlation with REE; however, the multiple correlation coefficient adjusted for degrees of freedom (R^2) for REE was similar (0.75 and 0.76) when the predictive equation utilized BW and height or FFM and FM with age and gender. This result may be partially explained by the limited accuracy of FFM and FM determined using bioelectrical impedance (FFM-1) or skinfold thickness measurement (FFM-2) compared with the typically high accuracy of anthropometric variables such as weight and height. As mentioned above, more advanced measurement of body composition using DXA or other methods may allow more accurate prediction of FFM and FM, and consequently REE. Further studies are needed to explain the residual variability in REE (excluding measurement error) not accounted for in our study, after adjusting REE for age, gender, changes in FFM activity, and FM, and the hormonal effects of age and maturation should be investigated in detail. In the interim, BW and height can be used to accurately assess REE in practice.

Ethnicity and familial effects have been noted as a factor in REE prediction in adults (*15, 16*), and among black and white American children and adolescents (*11, 33, 37–39*) but few data exist on other ethnic differences in REE prediction. These studies suggest that it is necessary to use an ethnicity-specific REE equation for certain ethnic populations. Dietary intake and physical activity patterns may explain some of the residual REE variability not accounted for.

We have proposed a new equation for estimation of REE based on age, gender, BW, and height. However, this new equation may be limited by the fact that the standard errors estimated were not reduced as much as RMSPE calculated using previously published formulas (Table 4). The validity of this formula should be further tested in an independent group of Japanese children and adolescents of the same ages.

In conclusion, absolute REE increased and REE adjusted for BW or FFM decreased with age 6–17 y. The major determinant of REE was FFM. There was no significant gender difference in REE adjusted for FFM in subjects 6–11 y of age, but there was a significant difference between genders in the 12–17 y age group. The differences in absolute REE and adjusted REE between genders may be explained by changes in FFM, specifically, an increase in SM mass, a decrease in the proportion of the more metabolically active organs and tissues, and changes in the metabolic rate of individual organs and tissues, as well as the influence of puberty and other unknown factors. We derived our simple REE predictive equation based on BW, height, age, and gender in Japanese children and adolescents. The predictive validity of the equation should be further investigated in future research.

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ORIGINAL ARTICLE

Locomotive and non-locomotive activities evaluated with a triaxial accelerometer in adults and elderly individuals

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Abstract

Background and Aims Comparative data on locomotive and non-locomotive physical activity (PA) by age and gender are lacking for Japanese adults. The purpose of this study was to investigate objectively the levels of PA in each intensity in adults and older people by both genders living in Japan with triaxial accelerometry with discrimination between locomotive and non-locomotive PA.

Methods In 571 women and 315 men aged 18–92 years from the Kanto region, PA was assessed for 6 consecutive days with a triaxial accelerometer (Active style Pro: HJA-350IT), and minutes of light and moderate-to-vigorous physical activity (MVPA) classified by metabolic equivalents were evaluated.

Results Japanese elderly women over 70 years, spent less time in not only locomotive PA (light and MVPA), but also in non-locomotive MVPA. For non-locomotive light activity, however, there was no significant difference between women over 70 years and younger women. In contrast, for men, non-locomotive light activity and MVPA remained constant with age, while elderly men over 70 years spent less time in locomotive activities (light and MVPA). Women spent more time in non-locomotive activity than men, except for MVPA in elderly individuals, and time in non-locomotive MVPA occupied more than half of the total MVPA in all age groups for women.

Conclusions These findings suggest that the intensity and the type of PA for Japanese were obviously affected by age, while locomotive PA for men and non-locomotive light PA for Japanese women were obviously unaffected by age. The finding also indicates gender differences. Thus, evaluation of both locomotive and non-locomotive activity is important in the overall assessment of PA.

Keywords Physical activity · Aging · Gender · Japanese

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Introduction

Accurate evaluation of physical activity (PA) is essential in the survey and promotion of PA. Step counts have been used to evaluate daily PA in various surveys, including the Japan Heath and Nutrition Survey, which is conducted annually by the Ministry of Health, Labour and Welfare of Japan in a nationally representative sample of Japanese adults. The results indicate that total number of steps per day decreases with age, and is much lower in the over 70-year-old age groups relative to younger age groups [1]. On the other hand, Speakman and Westerterp [2] reported that in 529 Dutch adults aged 18–96 years, the physical activity level (PAL) evaluated by the doubly labeled water (DLW) method and the basal metabolic rate (BMR) gradually decreased with age in subjects aged 52 years or more. PA consists of locomotive activity such as walking and running and non-locomotive activity such as performing yard work, undertaking agricultural tasks, and household activities (e.g., typing, vacuuming, dishwashing, and fidgeting). We speculate that the greater time for daily PA in elderly individuals may consist of PA non-locomotive activity, and that an evaluation of PA by step counts for Japanese elderly individuals is largely underestimated. However, there is a lack of large-scale comparative data on PA intensity and type, including non-locomotive PA, for Japanese elderly individuals and adults. Objective measurement with an accelerometer has been used to estimate energy expenditure and to classify levels of PA relatively accurately. The relationship between PA intensity and acceleration counts is different for locomotion than for other types of PA [3]. As a result, most predictive equations tend to underestimate non-locomotive PA and total energy expenditure (TEE) [4]. Studies by our group [5, 6] showed that in adults, discrimination between locomotive and non-locomotive activities, such as certain types of physical activity (e.g., household activities), with a triaxial accelerometer (Active style Pro, HJA-350IT, Omron Healthcare, Kyoto) enables more accurate evaluation of PA intensity. Our previous study showed that the relative contributions of non-locomotive MVPA time and locomotive MVPA time as measured by triaxial accelerometry are dependent on sex, age and occupation in free-living Japanese adults [7, 8]. In independent adults, non-locomotive activities, such as household activities, significantly contribute to TEE in daily living [4, 9]. However, a pedometer, which has been used to measure PA in many surveys, does not evaluate non-locomotive activity [1]. In addition, the contribution of non-locomotive activity to total PA may vary with age and gender, considering the PA in Japanese adults and elderly individuals.

We are aware of four studies that objectively measured PA in large samples of adults and older people in Western populations and one study in a Chinese population [10–13]. To our knowledge, however, no study has assessed the relationship between locomotive and non-locomotive PA in different age groups and both genders. Therefore, the purpose of the present study was to examine the differences in habitual PA in Japanese adults and older people in each gender, by objectively measuring PA with triaxial accelerometry with discrimination between non-locomotive and locomotive PA.

Methods

Subjects

Subjects were Japanese adults and elderly individuals, living in the Tokyo Metropolitan area. We collected data from several sources, mainly from a study on the comparison of PA by occupation [8] and intervention studies [14]. As for intervention study [14], pre-intervention data were used. Subjects were invited to participate by word-of-mouth advertising or leaflets, such as a community newsletter. A total of 989 adults and elderly individuals participated in the present study. All reported being in good health, without a history of conditions affecting PA, such as abnormal thyroid gland function or orthopedic disease. Elderly individuals had independent lifestyles. Informed consent was obtained from all subjects, and the Ethical Committee of J. F. Oberlin University and Tokyo Metropolitan Institute of Gerontology approved the study protocol in 2009.

Measurement materials and methods

Anthropometry

Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated as body weight (kg) divided by height squared (m^2).

Physical activity measurements

Habitual PA was measured with a triaxial accelerometer (Active style Pro HJA-350IT, OMRON HEALTHCARE, Kyoto), 74 × 46 × 34 mm and 60 g including batteries. Subjects wore the accelerometer on the left side of the waist. Anteroposterior (x axis), mediolateral (y axis) and vertical (z axis) acceleration measurements were obtained during each activity at a rate of 32 Hz to 12-bit accuracy. The range of the acceleration data of each axis is ±6G, resulting in a resolution of 3 mG. The acceleration data were uploaded to a personal computer. The signals obtained from the triaxial accelerometer were processed in the following way: Each of the three signals from the triaxial accelerometer was passed through a high-pass filter with a cut-off frequency of 0.7 Hz to remove the gravitational acceleration component from the signal. We calculated the synthetic acceleration of all three axes using signals before and after high-pass filtering. Then, the ratio of unfiltered to filtered acceleration was calculated. The acceleration signals, calculated as the average of the absolute value of the accelerometer output of each axis from 10 s epochs at the middle of each activity, were processed to various acceleration output variables. In our previous study, we reported the algorithm for the classification of household and locomotive activities by the unfiltered/filtered acceleration ratio, which resulted in almost 100 % correct demarcation for our eleven selected activities [7]. The Active style Pro was set to record in 10-s epochs, and the value of 1-min epoch was calculated as the mean value of physical intensity in 10 s epochs. PA was monitored continuously for 7–10 days. Subjects were requested to wear these devices at all times, except under special circumstances, such as dressing and bathing. We adopted days in which more than 600 min (10 h) of wearing time had accrued, not counting time allowed for the above-mentioned unavoidable reasons. In addition, periods with over 20 min of consecutive "non-wearing time" were considered to be non-wearing time. The criteria used in the present study were similar to those in other papers [15]. Subjects with data from at least 3 days were included in the analysis [15].

Analyses

The average number of minutes spent in light intensity activity: 2 ≥ metabolic equivalents (METs) < 3, moderate intensity activity: 3 ≥ METs < 6, vigorous intensity activity: 6 ≥ METs, and moderate-to-vigorous physical activity (MVPA): 3 ≥ METs was calculated for each individual. PA assessed by the accelerometer is presented as: (1) PA states for locomotive activity or non-locomotive activity in intensity-specific categories (light intensity activity, MVPA); (2) PAL, TEE (kcal/day) divided by BMR (kcal/day), calculated using the mean value of METs; (3) number of steps registered per day and; (4) percentage of subjects accumulating MVPA ≥ 60 or 30 min per day.

Subjects were distinguished between three age groups according to the age category of Dietary Reference Intakes in Japan. Student's *t* test was carried out to assess the influence of gender. The association between PA variables and age groups and gender was analyzed by analysis of variance. All results are shown as means and standard deviations (SDs). Statistical analyses were performed with SPSS version 17.0J for Windows (SPSS Inc, Japan, Tokyo). All statistical tests were regarded as significant when *P* values were less than 0.05.

Results

Results of only subjects with data from at least 3 days were used in the analysis. As a result, PA was measured successfully in 886 subjects (89.6 %) (571 females and 315 males; mean age 44.0 ± 15.3 years; range 18–92 years). There were no equipment failures.

The physical characteristics of the subjects are shown in Table 1. Overweight and lean were defined as a BMI of ≧25 and <18.5, respectively [16]. The numbers of overweight and lean subjects based on BMI were 166 and 95, respectively. Other 625 subjects were classified as normal.

Table 1 Physical characteristics of subjects

Age Group	18–49		Mean difference (Men–Women)	95 % CI	*P* value	50–69		Mean difference (Men–Women)	95 % CI	*P* value	70–		Mean difference (Men–Women)	95 % CI	*P* value
	Women	Men				Women	Men				Women	Men			
N	405	234				125	56				41	25			
Age (years)	35.3 ± 7.4	36.6 ± 8.1	1.3	0.1 to 2.6	0.629	61.6 ± 5.6	61.9 ± 5.9	0.3	−1.5 to 2.1	0.741	74.6 ± 3.5	75.1 ± 6.2	0.4	−1.9 to 2.8	0.745
Height (cm)	158.3 ± 5.2	172.4 ± 5.0	14.1	13.3 to 15.0	<0.001	152.8 ± 5.5	166.0 ± 6.1	13.2	11.4 to 15.0	<0.001	147.5 ± 5.2	161.2 ± 6.2	13.7	10.9 to 16.6	<0.001
Body weight (kg)	51.9 ± 7.8	68.9 ± 10.9	17.0	15.4 to 18.6	<0.001	54.8 ± 9.2	65.3 ± 8.2	10.5	7.6 to 13.3	<0.001	51.8 ± 7.1	60.3 ± 9.1	8.5	4.5 to 12.5	<0.001
Body mass index (kg/m^2)	20.7 ± 2.8	23.2 ± 3.4	2.5	1.9 to 3.0	<0.001	23.4 ± 3.6	23.7 ± 2.5	0.2	−0.7 to 1.1	0.645	23.8 ± 3.0	23.1 ± 2.7	−0.7	−2.2 to 0.8	0.351

CI confidence interval

PAL, step counts, time spent at different activity intensity levels for locomotive and non-locomotive activity and total time are shown in Tables 2–4. Most of the variables in the present study showed an interaction with age group and sex. Therefore, the results are shown for women and men. The median time over 6 METs for women and men was less than 1.0 min/day in all gender and age groups.Therefore, PA over 6 METs was shown as a part of MVPA in the following analysis.

Each PA was compared between age groups in each gender. For women, the participants over 70 years spent significantly less time in non-locomotive and total MVPA and total light activity than those in the other age groups, and less time in locomotive MVPA and light activity than those 18–49 years. Time in locomotive and total MVPA and locomotive light activity for women ages 50–69 years was also significantly lower compared with those ages 18–49 years. On the other hand, time in non-locomotive light activity for women ages 50–69 years was significantly higher than for those of the other age groups. For men, time in locomotive and total MVPA and locomotive light activity for those over 70 years was significantly lower than for those of the other age groups. There was no significant group difference for non-locomotive time in MVPA and light activity and total light activity. There was no significant difference between men aged 50–69 years and men aged 18–49 years. Percentages of female subjects accumulating MVPA ≥60 or 30 min per day are shown in Table 3.

Discussion

This study evaluated PA, ranging from light to vigorous PA, and locomotive and non-locomotive activity with triaxial accelerometry in Japanese adults, including elderly individuals. To our knowledge, no previous study has addressed the differences in a physically active lifestyle with discrimination between locomotive and non-locomotive PA, and in a relatively large sample size of Japanese adults, except that we indicated that non-locomotive time as measured by triaxial accelerometry contributed more to PA than locomotive time in free-living Japanese preschool children [17]. Therefore, the present study focused on the difference between age groups for each gender, PA, and activity type in Japanese adults and elderly individuals. As a result, age difference for non-locomotive PA was observed just in females.

PAL for Level II (Normal) in Japanese individuals is categorized as 1.75 (1.60–1.90) for those 18–69 years and 1.70 for those over 70 years by Dietary Reference Intakes for Japanese -2010-, which is based on the DLW method [18]. The mean with all age groups was categorized "Normal", although women 18–49 years of age and men over 70 years of age had a slightly higher and lower PAL, respectively. In the Japan Health and Nutrition Survey, 2010, step counts for women are 7,458 ± 3,829 steps/day for those 15–19 years, 7,104 ± 4,075 steps/day for those 20–29 years, 6,669 ± 3,361 steps/day for those 30–39 years, 6,986 ± 3,414 steps/day for those 40–49 years, 7,184 ± 3,624 steps/day for those 50–59 years, 6,234 ± 3,612 steps/day for those 60–69 years, and 3,872 ± 3,183 steps/day for those over 70 years. For men, they were 7,872 ± 4,545 steps/day for those 15–19 years, 8,322 ± 4,833 steps/day for those 20–29 years, 8,278 ± 4,901 steps/day for those 30–39 years, 7,873 ± 4,576 steps/day for those 40–49 years, 7,684 ± 4,368 steps/day for those 50–59 years, 7,092 ± 4,379 steps/day for those 60–69 years, and 4,890 ± 3,362 steps/day for those over 70 years [19]. In the present study, those in women and men over 70 years and men 50–69 years were slightly

Table 2 Physical activity level, category and step counts

Age group	Women Mean ± SD	Category	Men Mean ± SD	Category	Mean difference (Men–Women)	95 % CI	*P* value
Physical activity level							
18–49	1.83 ± 0.14[a]	Normal	1.74 ± 0.15[a]	Normal	−0.09	−0.11 to −0.07	<0.001
50–69	1.79 ± 0.15[a,b]	Normal	1.74 ± 0.16[a]	Normal	−0.05	−0.10 to 0.01	0.074
70–	1.69 ± 0.11	Normal	1.60 ± 0.13	Normal	−0.09	−0.15 to −0.03	0.004
Step counts (steps/day)							
18–49	7,957 ± 2,960[a]		8,864 ± 3,286[a]		907	410 to 1,404	<0.001
50–69	6,557 ± 3,038[a,b]		9,229 ± 5,297[a]		2,672	1,161 to 4,184	0.001
70–	5,219 ± 3,209		4,722 ± 2,733		−496	−2,037 to 1,044	0.522

Category of physical activity level, *CI* confidence interval and *SD* standard deviation. Low (I): 1.50 (1.40–1.60), Normal (II): 1.75 (1.60–1.90), High (III): 2.00 (1.90–2.20) for 18–69 years. Low (I): 1.45 (1.35–1.55), Normal (II): 1.70 (1.55–1.85), High (III):1.95 (1.85–2.15) for over 70 years. Significant differences: [a]over 70 versus 18–49 years or 50–69 years, [b]50–69 versus 18–49 years

Table 3 Time in moderate-to-vigorous physical activity for locomotive, non-locomotive and total physical activity and percentage of accumulating total moderate-to-vigorous physical activity

Age group	Women Mean ± SD		Men Mean ± SD		Mean difference (Men–Women)	95 % CI	*P* value
Time in locomotive MVPA (min/day)							
18–49	40 ± 26[a]		56 ± 28[a]		16	12 to 21	<0.001
50–69	29 ± 19[b]		54 ± 43[a]		25	13 to 37	<0.001
70–	22 ± 20		20 ± 19		−2	−12 to 8	0.655
Time in non-locomotive MVPA (min/day)							
18–49	46 ± 27[a]		24 ± 23		−22	−26 to −18	<0.001
50–69	46 ± 37[a]		26 ± 21		−20	−29 to −12	<0.001
70–	27 ± 16		18 ± 27		−9	−19 to 2	0.103
Time in MVPA (min/day)							
18–49	87 ± 36[a]		81 ± 38[a]		−6	−12 to 0	0.051
50–69	75 ± 47[a,b]		80 ± 48[a]		4	−11 to 19	0.571
70–	49 ± 28		38 ± 43		−11	−28 to 6	0.211
Accumulating MVPA (%)	≥60 min/day	≥30 min/day	≥60 min/day	≥30 min/day			
18–49	76	97	68	96			
50–69	55	89	59	89			
70–	34	73	8	52			

Significant differences; [a]over 70 versus 18–49 or 50–69 years, [b]50–69 versus 18–49 years

MVPA moderate-to -vigorous physical activity, *CI* confidence interval, *SD* standard deviation

Table 4 Time in low intensity physical activity for locomotive and non-locomotive and total physical activity

Age group	Women Mean ± SD	Men Mean ± SD	Mean difference (Men–Women)	95 % CI	*P* value
Time in locomotive 2METs ≥ 3METs<activity (min/day)					
18–49	57 ± 25[a]	61 ± 31[a]	4	−1 to 8	0.134
50–69	44 ± 20[b]	65 ± 29[a]	21	12 to 29	<0.001
70–	39 ± 25	44 ± 14	5	−6 to 16	0.406
Time in non-locomotive 2METs ≥ 3METs <activity (min/day)					
18–49	211 ± 58	123 ± 50	−88	−96 to −79	<0.001
50–69	225 ± 63	133 ± 44	−92	−108 to −75	<0.001
70–	203 ± 60	127 ± 44	−76	−104 to −49	<0.001
Time in 2METs ≥ 3METs<activity (min/day)					
18–49	268 ± 60[a]	184 ± 68	−84	−95 to −74	<0.001
50–69	269 ± 69	198 ± 59	−71	−92 to −50	<0.001
70–	242 ± 61	171 ± 50	−71	−100 to −43	<0.001

Significant differences; [a]over 70 versus 18–49 or 50–69 years, [b]50–69 versus 18–49 years

METs metabolic equivalents, *CI* confidence interval, *SD* standard deviation

higher compared with a nationally representative sample of Japanese adults. Other groups were comparable.

The variations in objective PA by accelerometer with age and gender are different between countries, although PA for all countries in the present and previous studies declines with age [10–13]. In the present study after 50 years of age, women spent less time in locomotive and total MVPA, and locomotive light activity and had lower PAL and step counts than younger participants. This beginning age of decrease of PA was in consistency with the Swedish study. On the other hand, PAL, time in locomotive and total MVPA, time in non-locomotive light activity and step counts for men remained steady with age, until 69 years, after which activity levels declined. This beginning age of decrease of PA was in consistency with Norway and Portuguese studies.

For women, time in non-locomotive MVPA occupied more than half of the total MVPA in all age groups, while that in men was much lower in all age groups. As a result, the large amount of decrease of non-locomotive MVPA with age was observed only in women. On the other hand, there were no age differences for non-locomotive MVPA, non-locomotive light activity and total light activity. However, the percentages of non-locomotive activity for elderly men were higher than those of other age groups. Thus, non-locomotive activity may not largely influence PA in men, but is relatively important in elderly individuals. Surprisingly, for women in the present study, non-locomotive light activity increased slightly with increasing age. Evidence from our study supports the assertion that not only locomotive activity but also non-locomotive activity is an important factor in evaluating a PA lifestyle in women, including elderly women. These data may be particularly important for providing insight into improving age and gender as determinants of PA in adults and elderly individuals.

Several previous studies have investigated the gender difference of PA, but inconsistent results have been obtained. When PA was assessed by the method used in the present study, much more time was spent in non-locomotive light activity for women in all age groups than for men. It is useful to use such an algorithm with triaxial accelerometry to discriminate between different types of activities including locomotive and non-locomotive activity to evaluate PA intensity [7, 8]. The previous studies did not discriminate between locomotive and non-locomotive PA. Thus, the differences in methods used to assess PA may also account, in part, for differences in the outcomes of the previous studies. In the present study, compared with men, women spent more time in non-locomotive activity except for MVPA in elderly women. Many household activities are applicable to activity under 3METs, as reported by Ainsworth et al. [20], washing dishes, cooking or food preparation, serving food, setting the table, ironing, laundry, making beds, watering plants, child care, sitting or standing—playing with children, etc. On the other hand, those of MVPA are carpet sweeping, sweeping floors, mopping, vacuuming, elder care, carpentry, bagging grass, etc. The inconsistency between Western studies and the present study might be attributable in part to the fact that Japanese females may spend more time than Western women doing activities that are classified as household and child care activities. Over 90 % of Japanese women carry out housework on weekdays and weekends, while for men, only 41 % do so on weekdays, 51 % do so on Saturdays and 56 % do so on Sundays, according to the NHK National Time Use Survey [21]. As a result, women spend about 4 h and 30 min on housework each day. In contrast, men spend about 50 min on weekdays, 1 h and 23 min on Saturdays and 1 h and 33 min on Sundays. Thus, national lifestyle characteristics might affect the results of gender differences in PA. In particular, an evaluation of non-locomotive activity is important for Japanese women.

Overall, the strengths of our study include an objective and quantitative measure of PA classifying locomotive and non-locomotive activity, the inclusion of both gender and a wide age range, and the use of a sample population of Japanese adults and elderly individuals. There are, however, several methodological points to be considered in interpreting these results. Because of the cross-sectional nature of this research, the change in PA with age may be slightly different from the results of the present study. Our sample was not a representative sample of Japanese adults and elderly individuals. These are the limitations of the present study. The accelerometer is a widely used tool to measure PA, especially in Japan, but it cannot assess all PA, such as swimming and cycling. In addition, validity of the accelerometry used in the present study has been well established in elderly individuals, although our unpublished data indicate that PA intensities of locomotive activities can be predicted with small underestimation.

Conclusions

Japanese elderly women spent less time not only in locomotive MVPA and light activity, but also in non-locomotive MVPA. For non-locomotive light activity, however, there was no significant difference between women over 70 years and younger women. On the other hand, for men, non-locomotive MVPA and light activity remained steady with age. Women spent more time in non-locomotive activity than men, except for MVPA in elderly individuals, and time in non-locomotive MVPA occupied more than half of the total MVPA in all age groups for women. Thus, intensity and type of PA for Japanese was obviously affected by age and gender. These findings indicate that evaluation of non-locomotive activity is important in the overall assessment of PA.

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Conflict of interest None.

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