Age-Related Decline in Physical Activity Level in the Healthy Older Japanese Population

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(Received April 12, 2021)

Summary

The Dietary Reference Intakes 2020 divided the older population into those aged 65–74 y and those over 75 y old. However, physical activity level in each age group was not specified. This study examined age-related differences in physical activity level among healthy Japanese older people, and the effect of lifestyles on these differences. In total, 70 people (22 men, 48 women) aged 65–85 y old participated in this study. Total energy expenditure was measured using the doubly labeled water method, and basal metabolic rate using expired gas concentration and volume. The Physical Activity Scale for the Elderly and a triaxial accelerometer were used to assess physical activities. Physical activity level was significantly higher among 65–74 y old (median 1.86) than those over 75 y old (1.76). However, the Physical Activity Scale for the Elderly did not show any significant differences between the age groups. The duration of physical activity with 3.0–5.9 metabolic equivalents was longer for both locomotive and household activities among 65–74 y old than those over 75 y old. Younger participants walked a median of 6,364 steps a day, compared with 4,419 steps for older people. The 65–74 y old participants involved in paid work or who habitually exercised, and those over 75 y old taking more than 40 min a day of moderate to vigorous physical activity, and walking more than the median level for their sex and age group had significantly higher physical activity levels.

Key Words
doubly labeled water method, total energy expenditure, walking step, triaxial accelerometer, questionnaire

According to the 2020 dietary reference intakes (DRIs) for Japanese people, physical activity level (PAL: total energy expenditure (TEE) divided by basal metabolic rate (BMR)) for each age group is stable between 18 and 64 y old. After that age, the level of PAL declines from 1.75 to 1.70 for those aged 65–74 y old and to 1.65 for those over 75 y old (https://www.mhlw.go.jp/content/10904750/000586553.pdf). These values were established from 23 studies assessing PAL among older people using the doubly labeled water (DLW) method. However, only three of these studies were in the Japanese population (1–3), and only one involved a group of healthy Japanese people (1). The others assessed residents in care homes (2) and long-term care facilities (3). In the study among healthy Japanese people, the participants were recruited from those in an annual physical function checkup study. Average PAL among 64–87 y olds was 1.97 (1). This value is very high compared with studies among non-Japanese people used in the DRIs (https://www.mhlw.go.jp/content/10904750/000586553.pdf). A second study divided these participants into those who were habitually involved in sport and those who were not (2). Even those not involved in sport had a higher PAL (mean: 1.90) than that used in the DRIs (https://www.mhlw.go.jp/content/10904750/000586553.pdf) and average steps per day (mean: 8,334) than the results of the Japan National Health and Nutrition Survey (JNHNS) (https://www.mhlw.go.jp/bunya/kenkou/eiyou/h22-houkoku.html). Additionally, the age-related differences in PAL were unclear because the participants were not divided by age.

One review suggested that physical activity energy expenditure (PAEE) accounted for 46% of the age-related decrease in TEE (4). The DLW method is considered the most accurate method for measuring TEE in daily life (5). However, it only provides daily average TEE during 1–2 wk of measurement. To examine which changes in physical activity cause the age-related decline in PAEE requires other methods of assessment.
physical activity, such as an accelerometer. The use of a triaxial accelerometer is considered to be more accurate than a uniaxial accelerometer (1, 6). Another method to assess physical activity is through a questionnaire. These are often used in epidemiological studies, and their accuracy depends on the differences between the target population and the group used to develop or validate the questionnaire. A review comparing the existing physical activity questionnaires for older adults suggested that only 3 of 13 questionnaires were sufficiently reliable (7). The Physical Activity Scale for the Elderly (PASE) was one of the three considered reliable, but previous results are still inconsistent. Hagiwara et al. translated the PASE into Japanese, and showed an acceptable validity and reliability (8).

In this study, we examined whether age-related differences in PAL were present among Japanese older adults with a typical lifestyle. We also wanted to clarify whether any age-related differences were associated with different types of physical activity.

**MATERIALS AND METHODS**

**Participants.** Participants were recruited from among people who joined the Habashi Cohort Study in 2006 (n=154) and 2011 (n=504). This district is located in northwest Tokyo. It is an old residential area, offering convenient transport links and good shopping and public facilities. We excluded individuals who were not independent in their daily life, or who had a stroke, angina pectoris, myocardial infarction, diabetes mellitus, cancer, or depression. Of the remaining 255 participants, 136 registered for this study. We assessed their daily steps using a pedometer (AS-200, YAMASA, Tokyo, Japan), the same model used for the JNHS. We selected 81 participants whose mean daily steps was similar to the mean from the 2010 JNHS (https://www.mhlw.go.jp/bunya/kenkou/eiyou/h22-houkoku. html). Of these, nine could not start the measurement process because of their health or for personal reasons. Two other people were also excluded because of unnatural changes in urinary isotope concentration. This left data from 70 people (22 men and 48 women) for analysis.

This study was approved by the ethics committee of the National Institute of Health and Nutrition (20090327, approved on 2009.3.27). This study was conducted according to the guidelines laid down in the Declaration of Helsinki. The purpose and methodology of the study were explained in detail to all the participants and they gave their written informed consent.

**Study protocol.** We took measurements between February 2013 and May 2014. The participants were asked to visit the study location for anthropometric and BMR measurements, collection of baseline urine sample, and dose of DLW. For the next 2 wk, they were asked to maintain their normal diet and activity patterns, to collect urine samples for TEE measurements, and to wear an accelerometer. They were also asked to complete a questionnaire about physical activity and dietary intake. Two weeks later, they were asked to visit the study site again, when their urine samples and accelerometers were collected, body mass was measured, and the questionnaires were checked for accuracy.

**Measurement of total energy expenditure.** TEE was measured using the doubly labeled water method (9). On the first day, the participants were asked to collect a baseline urine sample and drank a single dose of water, some of which was labeled with $^{18}$O and $^2$H. The isotopic ratios of the urine samples were analyzed using an isotope ratio mass spectrometry (DELTA Plus; Thermo Fisher Scientific, Waltham, MA, USA). TEE was calculated using the A6 equation of Schoeller et al. (10) and Weir's equation (11). The mean food quotient was calculated using Black's equation (12) with the results from a dietary questionnaire instead of the respiratory quotient. PAL was calculated as TEE/BMR. PAEE was calculated as 0.9TEE−BMR.

**Measurement of basal metabolic rate.** The participants were asked to attend the study location in the morning, and at least 12 h after their last meal. They were asked to rest in a supine position for at least 30 min before the measurements. Two samples of expired air taken over 10 min were collected in Douglas bags. The $O_2$ and $CO_2$ concentrations were measured using a gas analyzer (AR-1, Arco System, Chiba, Japan). The volume of the gas was measured using a dry gas volume meter (DC-5, Shinagawa corporation, Tokyo, Japan). BMR was calculated using Weir's equation (11).

**Anthropometric measurements.** Body mass was measured on the first day and the final day (2 wk later) at the study site to the nearest 0.1 kg. Body height was measured at the first day to the nearest 0.1 cm. Fat-free mass was calculated as the dilution space assessed with TEE, and divided by 0.732. Fat mass was calculated as the mean body mass from the first and second measurements minus fat-free mass (FFM). Body mass index (BMI) was calculated by dividing the mean body mass by height squared.

**Accelerometer.** Participants wore a triaxial accelerometer (HJA-350IT, Omron Healthcare, Kyoto, Japan); they did so on the waist at the midline of the left thigh for 2 wk during the study. They were asked to wear the accelerometer all day except when bathing, swimming, or sleeping. Recorded data of ≥60 min of consecutive zero counts were defined as non-wear periods. Only days with wear time ≥600 min were included in the analysis. Physical activity was divided into locomotive activity and household activity using an algorithm described elsewhere (13, 14). Intensity of physical activity was divided into sedentary (≤1.5 metabolic equivalents [METs]), 1.6–2.9 METs, 3.0–5.9 METs, and ≥6.0 METs. Moderate and vigorous physical activity (MVPA) was defined as physical activity with an intensity of at least 3.0 METs.

**Questionnaires.** We used the brief-type self-administered diet history questionnaire (BDHQ) to calculate food quotient for TEE (15, 16).

We used the PASE to assess physical activity. This was originally developed by the New England Research Insti-
Table 1. Physical characteristics of study participants.

|               | 65–74 y olds       | 75 y old and over | p<sup>1</sup> |
|---------------|---------------------|-------------------|---------------|
|               | Men | Women | Total | Men | Women | Total |               |
| n             | 13  | 28    | 41    | 9   | 20    | 29    |               |
| Age           | 72.0 (70.0, 73.0)   | 71.0 (68.0, 72.8) | 71 (69, 73) | 78.0 (75.5, 83.0) | 80.0 (76.3, 83.0) | 79.0 (76.0, 83.0) | <0.001 |
| Height        | 164.2 (161.3, 166.6) | 151.6 (149.1, 154.6) | 154.4 (150.3, 161.3) | 158.3 (155.6, 162.2) | 147.7 (143.1, 151.4) | 151.1 (145.6, 157.3) | 0.031 |
| Body mass Pre | 61.2 (58.9, 69.1)   | 53.4 (49.5, 58.3) | 57.8 (51.0, 61.0) | 55.4 (52.2, 64.9) | 49.9 (43.5, 58.6) | 52.0 (46.4, 62.0) | 0.117 |
| Post          | 60.6 (58.9, 69.7)   | 53.6 (49.5, 58.5) | 57.4 (51.3, 60.4) | 54.8 (51.2, 64.7) | 50.1 (43.3, 58.8) | 51.8 (47.0, 62.2) | 0.116 |
| Difference    | 0.0 (–0.5, 0.4)     | 0.2 (–0.4, 0.4)   | 0 (–0.4, 0.4)   | –0.4 (–0.6, –0.1) | 0.2 (–0.2, 0.4)   | 0 (–0.4, 0.4)   | 0.649 |
| BMI           | 23.1 (21.5, 27.4)   | 23.3 (21.1, 25.7) | 23.1 (21.4, 25.9) | 22.8 (20.9, 25.2) | 23.0 (22.3, 26.5) | 22.8 (20.6, 25.9) | 0.524 |
| Fat free mass | 43.4 (41.6, 46.5)   | 32.9 (35.2, 41.2) | 37.1 (32.1, 41.7) | 43.0 (38.7, 46.6) | 31.8 (28.1, 35.2) | 34.3 (30.9, 41.7) | 0.401 |
| Fat mass (%)  | 30.5 (29.2, 34.4)   | 37.8 (35.2, 41.2) | 35.6 (29.9, 38.5) | 27.9 (23.1, 31.6) | 36.0 (31.3, 41.3) | 31.9 (26.7, 37.7) | 0.260 |
| Paid work     | 5 (38.5)            | 10 (35.7)         | 15 (36.6)        | 4 (44.4)          | 4 (20.0)          | 8 (27.6)         | 0.453 |
| Habitually exercise | 7 (53.8) | 17 (60.7) | 24 (58.5) | 4 (44.4) | 8 (40.0) | 12 (41.4) | 0.225 |
| Paid work or habitually exercise | 10 (76.9) | 21 (75.0) | 31 (75.6) | 6 (66.7) | 11 (55.0) | 17 (58.6) | 0.191 |

Median (interquartiles) for age, height, body mass, BMI, fat free mass and fat mass, number and percentage for paid work, habitually exercise, and paid work or habitually exercise. BMI: body mass index.  
<sup>1</sup>p differences between 65–74 y olds and those aged 75 y and over assessed using Mann-Whitney U test for continuous variables and Fisher’s exact test for categorical variables. 
<sup>2</sup>Participating in paid full-time or part-time work.
<sup>3</sup>Participating in exercise resulting in sweating for more than 30 min a time, more than twice a week, and for a year or more.

Table 2. Energy expenditure and physical activity level.

|               | 65–74 y olds       | 75 y old and over | p<sup>1</sup> |
|---------------|---------------------|-------------------|---------------|
|               | Men | Women | Total | Men | Women | Total | Gender | Age |
| n             | 13  | 28    | 41    | 9   | 20    | 29    |        |     |
| BMR (kcal/d)  | 1,176 (1,134, 1,333) | 1,029 (940, 1,101) | 1,078 (994, 1,181) | 1,138 (1,089, 1,343) | 1,024 (926, 1,111) | 1,058 (971, 1,138) | <0.001 | 0.508 |
| (kcal/kg/d)   | 18.9 (17.7, 19.7)   | 19.2 (17.9, 20.2) | 19.0 (17.8, 20.1) | 20.3 (19.8, 21.2) | 19.8 (18.3, 23.1) | 20.1 (18.9, 21.7) | 0.830 | 0.030 |
| (kcal/kgFFM/d)| 27.1 (26.3, 28.9)   | 30.5 (28.8, 32.2) | 29.7 (27.4, 32.0) | 28.7 (27.0, 29.2) | 30.9 (29.2, 34.3) | 29.5 (28.5, 32.3) | <0.001 | 0.407 |
| TEE (kcal/d)  | 2,284 (2,098, 2,478) | 1,951 (1,739, 2,094) | 2,063 (1,782, 2,232) | 2,204 (1,773, 2,489) | 1,751 (1,477, 1,945) | 1,880 (1,619, 2,154) | <0.001 | 0.036 |
| (kcal/kg/d)   | 34.1 (32.4, 38.3)   | 35.5 (32.8, 39.1) | 35.2 (32.7, 39.0) | 34.8 (31.8, 41.2) | 35.5 (30.9, 40.2) | 35.5 (31.4, 40.2) | 0.595 | 0.825 |
| PAEE (kcal/d) | 764 (739, 947)      | 681 (572, 805)    | 737 (606, 865)    | 680 (441, 938)    | 565 (431,699)    | 634 (433, 779)    | 0.020 | 0.022 |
| (kcal/kg/d)   | 12.8 (11.2, 13.5)   | 12.5 (10.9, 15.9) | 12.5 (11.1, 14.3) | 11.5 (8.4, 16.1)  | 12.4 (8.7, 13.7) | 12.1 (8.7, 14.1) | 0.899 | 0.291 |
| PAL           | 1.86 (1.72, 1.97)   | 1.86 (1.71, 1.94) | 1.86 (1.71, 1.94) | 1.76 (1.58, 1.96) | 1.77 (1.61, 1.87) | 1.76 (1.60, 1.89) | 0.929 | 0.035 |

Median (interquartiles). BMR: basal metabolic rate, TEE: total energy expenditure, PAEE: physical activity energy expenditure, PAL: physical activity level, FFM: fat-free mass.  
<sup>1</sup>p differences between 65–74 y olds and those aged 75 y and over were compared using Mann-Whitney U test for continuous variables.
tute, and translated into Japanese by Hagiwara et al. (8). It was used with the permission of the New England Research Institute and Hagiwara et al.

Participation in paid work was assessed by asking whether participants had a full-time or part-time job. Being in the habit of exercising was defined as participating in exercise that resulted in sweating for more than 30 min at a time, more than twice a week, and having done so for at least 1 y; the definition used in the JNHNS.

**Statistical analysis.** Continuous variables were expressed as median and interquartile ranges because most of the data were not normally distributed. Age was divided into 65–74 y old (65–74 y) and 75 y old and over (75 y) to match the age categories used in the dietary reference intakes. The differences between age groups were compared using the Mann–Whitney U-test (17). Proportional variables were expressed as percentages and compared using Fisher’s exact test (17). The significance level was set at p<0.05. Statistical analysis used SPSS ver.23 (IBM, Inc., Armonk, NY, USA).

**RESULTS**

Physical characteristics are shown in Table 1. When we used data from both men and women, only height was significantly higher among 65–74 y olds. Steps per day assessed using a pedometer (AS-200) at recruitment were 6,584±2,777 for 65–74 y old men, 3,984±965 for men over 75. 6,023±2,435 for women aged 65–74 y, and 4,948±2,774 for women over 75.

Men had significantly higher values of BMR, TEE and PAEE (Table 2). Women had significantly higher daily BMR expressed per kg of FFM than men. When these values were expressed as per body mass per day, there were no significant differences between men and women. There were significant differences between age groups for BMR per body mass, TEE, PAEE and PAL. Only BMR per body mass was higher among those over 75 y old, but this was not significant when BMR was expressed per FFM. PAL was significantly lower among those over 75 y old compared with those aged 65–74 y (median: 1.76 vs. 1.86).

The total PASE score did not vary between age groups (Table 3). The duration of most leisure time activity was also not significantly different. Only a small number of participants were involved in light, moderate, and strenuous sports and recreational activities in each sex and age group. Around half of the women aged over 75 y participated in light sport and recreational activity, and muscle strength/endurance exercise, but both frequency and duration were low. The rate of participation in household activities did not vary between age groups.

The duration of both locomotive and household activities of 3.0–5.9 METs was greater among 65–74 y olds (Table 4). This was also true for combined locomotive and household activities. The median values for the duration of physical activity over 6.0 METs were zero for both locomotive and household activities because only a few participants carried out this intensity of physical activity. Using the accelerometer (HJA-360IT), those aged 65–74 y old took around 2,000 steps per day more than those over 75 y old.

To examine the effect of aging and lifestyle on PAL, we compared PAL by participation in paid work, habitual exercise, duration of MVPA, and daily steps (Table 5). Duration of MVPA was split at 40 min per day, to fit both the median duration of MVPA for all participants (44 min per day) and the recommended level of any intensity of physical activity for older people (40 min per day) (18). Daily steps were divided by the median values for each sex and age group. There were no significant differences in PAL by exercise habit, duration of MVPA, and daily steps in those aged 65–74. Participants involved in paid work or who also habitually exercised had significantly higher PAL. However, among those over 75 y, participants with MVPA more than 40 min per day and who walked more than the median values for their age and sex group had significantly higher PAL.

**DISCUSSION**

We found that study participants aged 75 and over had lower PAL than those aged 65–74 y. Those aged 65–74 y who participated in paid work or habitually exercised and those over 75 y who took more than 40 min of MVPA each day or more steps than the median also had higher PAL.

We thought the characteristics of the participants were fairly representative of the wider Japanese population. The daily steps were similar but higher than the results from the 2010 JNHNS (e.g., 6,684 steps per day in our study vs. 6,703 steps per day in the JNHNS among men aged 65–74 y) (https://www.mhlw.go.jp/bunya/kenkou/eiyou/h22-houkoku.html). Participants’ height was similar to the height of the JNHNS participants, but body mass was lower among over 75 y old men in our study (JNHNS: 58.2 kg on average). The proportion of women who exercised habitually was also high in our study than in the JNHNS (JNHNS: 42.0% of 65–74 y olds and 31.4% of over 75 y olds).

The median PAL in our study was 1.86 for 65–74 y olds and 1.76 for over 75 y olds. These PALS were higher than those for both the same age group and younger age groups in the present DRIs (https://www.mhlw.go.jp/content/10904750/000586553.pdf). To be representative of older Japanese adults, we selected subjects with respect to their habitual walking steps in accordance with the results of the National Health and Nutrition Survey. However, it is possible that healthier or more socially active subjects participated in the present study. It is necessary to obtain more data and have greater discussion about PALS for Japanese. According to the present and previous studies, it appears that healthy community-dwelling older adults in Japan are very active. The present PAL was lower than studies by Yamada et al. (1, 2) for community-dwelling older people (1.97), and community-dwelling older people with (2.12) and without an exercise habit (1.90). In those studies, the participants were recruited from an ongo-
Table 3. The results of the Physical Activity Scale for the Elderly (PASE).

|                            | 65–74 y olds | 75 y old and over | p<sup>1</sup> |
|---------------------------|-------------|------------------|---------------|
|                           | Men         | Women            | Total         | Men        | Women      | Total |
| n                         | 13          | 28               | 41            | 9          | 20         | 29    |
| Leisure time activity (h/d) |             |                  |               |            |            |       |
| Sedentary                 | 4.3 (2.6, 4.3) | 2.6 (1.8, 4.3) | 2.6 (2.5, 4.3) | 2.6 (1.3, 4.3) | 3.4 (2.6, 4.3) | 2.6 (1.5, 4.3) | 0.975 |
| Walking outside the home   | 1.3 (1.0, 1.9) | 1.3 (0.4, 1.3) | 1.3 (0.4, 1.3) | 0.8 (0.4, 1.3) | 1.0 (0.4, 1.5) | 0.8 (0.4, 1.4) | 0.826 |
| Light sports and recreational activities | 0 (0, 0.3) [5] | 0 (0, 0.3) [2] | 0 (0, 0.3) [7] | 0 (0, 0.4) [3] | 0.1 (0, 0.4) [14] | 0.1 (0, 0.4) [17] | 0.292 |
| Moderate sports and recreational activities | 0 (0, 0) [1] | 0 (0, 0) [2] | 0 (0, 0) [3] | 0 (0, 0) [1] | 0 (0, 0) [2] | 0 (0, 0) [3] | 0.654 |
| Strenuous sports and recreational activities | 0 (0, 0) [1] | 0 (0, 0) [2] | 0 (0, 0) [3] | 0 (0, 0) [0] | 0 (0, 0) [1] | 0 (0, 0) [1] | 0.477 |
| Muscle strength/endurance exercise | 0 (0, 0.1) [3] | 0 (0, 0) [2] | 0 (0, 0) [5] | 0 (0, 0.1) [3] | 0.1 (0, 0.3) [10] | 0 (0, 0.1) [13] | 0.003 |
| Household activity (%)     |             |                  |               |            |            |       |
| Light housework            | 100.0       | 96.4             | 97.6          | 100.0      | 100.0      | 100.0 | 1.000 |
| Heavy housework or chores  | 61.5        | 89.3             | 80.5          | 55.6       | 70.0       | 65.5  | 0.177 |
| Home repairs               | 0.0         | 3.6              | 2.4           | 11.1       | 5.0        | 6.9   | 0.566 |
| Lawn work or yard care     | 38.5        | 25.0             | 29.3          | 33.3       | 20.0       | 24.1  | 0.786 |
| Outdoor gardening          | 0.0         | 42.9             | 29.3          | 11.1       | 20.0       | 17.2  | 0.275 |
| Caring for another person   | 0.0         | 0.0              | 0.0           | 0.0        | 15.0       | 10.3  | 0.067 |
| Work-related activity (h/d) |             |                  |               |            |            |       |
| Work for pay or as volunteer | 0 (0, 0) | 0 (0, 0.6) | 0 (0, 0.4) | 0.2 (0, 2.3) | 0 (0, 1.1) | 0 (0, 1.3) | 0.297 |
| Total PASE score           | 85 (76, 143) | 93 (71, 146) | 91 (75, 146) | 96 (73, 160) | 95 (68, 157) | 96 (70, 153) | 0.775 |

Median (interquartiles), household activities were shown in percentage of the participants.

The number in square brackets shows the number of study participants involved in these activities.

<sup>1</sup>p: differences between age groups assessed using Mann-Whitney U test for continuous variables and Fisher’s exact test for categorical variables.
Table 4. Physical activity assessed using an accelerometer.

|                         | 65–74 y olds |               | 75 y old and over |               | p¹ |
|-------------------------|--------------|---------------|-------------------|---------------|----|
|                         | n            | Men           | Women             | Total         | Men | Women | Total |     |
| Sedentary activity (min/d) | 13           | 28            | 41                | 9             | 20  | 29    | 29    | 1.000 |
| Locomotive activity (min/d) | 460 (398, 598) | 451 (379, 537) | 452 (388, 553) | 505 (407, 583) | 511 (432, 641) | 505 (433, 589) |
| 1.6 to 2.9 METs         | 34 (22, 56)  | 43 (30, 59)   | 42 (27, 58)       | 37 (32, 62)   | 38 (27, 54)   | 38 (30, 57)   | 0.394 |
| 3.0 to 5.9 METs         | 37 (16, 47)  | 29 (17, 41)   | 33 (18, 43)       | 17 (6, 20)    | 14 (9, 32)    | 14 (7, 28)    | <0.001 |
| ≥ 6.0 METs              | 0 (0, 0) [3] | 0 (0, 0) [10] | 0 (0, 0) [13]    | 0 (0, 0) [1]  | 0 (0, 0) [4]  | 0 (0, 0) [5]  | 0.468 |
| Household activity (min/d) | 260 (210, 296) | 334 (287, 421) | 302 (276, 363) | 259 (174, 330) | 318 (241, 376) | 302 (218, 363) | 0.962 |
| 1.6 to 2.9 METs         | 13 (7, 21)   | 22 (13, 38)   | 18 (10, 36)       | 5 (3, 8)      | 12 (4, 14)    | 8.2 (3.7, 13.2) | 0.003 |
| 3.0 to 5.9 METs         | 0 (0, 0) [2] | 0 (0, 0) [5]  | 0 (0, 0) [7]      | 0 (0, 0) [0]  | 0 (0, 0) [3]  | 0 (0, 0) [3]  | 0.200 |
| ≥ 6.0 METs              | 294 (248, 361) | 371 (326, 475) | 351 (306, 406) | 285 (226, 393) | 369 (279, 429) | 323 (267, 415) | 0.384 |
| Total (min/d)           | 1.6 to 2.9 METs | 51 (24, 81)   | 54 (36, 88)       | 51 (34, 81)   | 21 (14, 24)   | 27 (15, 48)   | <0.001 |
| 3.0 to 5.9 METs         | 0 (0, 0) [4] | 0 (0, 0) [13] | 0 (0, 0) [17]    | 0 (0, 0) [1]  | 0 (0, 0) [6]  | 0 (0, 0) [7]  | 0.185 |
| ≥ 6.0 METs              | 6,588 (4,790, 8,009) | 6,052 (4,300, 7,792) | 6,364 (4,434, 7,860) | 4,042 (3,379, 4,470) | 5,157 (2,516, 6,688) | 4,419 (3,023, 5,788) | 0.007 |

Median (interquartiles).
The number in square brackets is the number of participants involved in physical activity of 6.0 or more METs.

¹ p: Differences between age groups were assessed using the Mann-Whitney U test.
ing annual physical function checkup study. They may therefore have been more physically active or health-conscious than older people in the general population. In the study by Yamada et al., even the participants who did not habitually exercise had a higher daily average step count (8,334) than in the JNHNS. One study suggested a similar PAL (1.81) for non-diabetic subjects with an average age of 67.1 y (19). However, PAL among our study participants was higher than among Japanese residents of care homes (mean: 1.54) (6). Our study may therefore have underestimated the effect of prolonged sedentary time, and found that participants in the highest quartile of sedentary time participated in MVP A for more than 40 min/d had higher PAL. This is consistent with the review suggesting that aging results in a decline in PAL and less participation in higher-intensity activities (24). Bonn et al. examined the effect of prolonged sedentary time, and found that participants in the highest quartile of sedentary time were older and had lower PAEE (25).

In our study, we assessed TEE using a triaxial accelerometer and physical activity questionnaire. The duration of MVPA was similar to results among older Japanese people assessed with a different accelerometer (30 min/d for people aged 71.1 y old) (26). We suggest that taking the recommended level of 40 min/d of MVPA might prevent any age-related decline in PAL (18). We used the same algorithm for the accelerometer, though previous studies have observed that the accelerometer estimated a lower physical activity intensity than measured intensity even among healthy older people (6, 27). Our study may therefore have underesti-

### Table 5. Comparison of physical activity level by lifestyles.

|                      | 65–74 y olds |               | 75 y old and over |               |
|----------------------|--------------|---------------|-------------------|---------------|
|                      | n            | PAL           | p†                | n             | PAL           | p†                |
| **Paid work**        |              |               |                   |               |               |                   |
| No                   | 26           | 1.81 (1.69, 1.88) | 0.030            | 21           | 1.72 (1.58, 1.85) | 0.075            |
| Yes                  | 15           | 1.90 (1.82, 2.02) |                   | 8             | 1.90 (1.65, 2.02) |                   |
| **Habitual exercise**|              |               |                   |               |               |                   |
| No                   | 17           | 1.81 (1.65, 1.88) | 0.085            | 17           | 1.76 (1.56, 1.87) | 0.471            |
| Yes                  | 24           | 1.87 (1.78, 2.01) |                   | 12           | 1.77 (1.65, 1.92) |                   |
| **Paid work or habitual exercise** | |               |                   |               |               |                   |
| No                   | 10           | 1.74 (1.61, 1.82) | 0.008            | 12           | 1.63 (1.53, 1.84) | 0.073            |
| Yes                  | 31           | 1.87 (1.79, 2.00) |                   | 17           | 1.80 (1.66, 1.94) |                   |
| **Duration of MVPA** |              |               |                   |               |               |                   |
| <40 min/d            | 13           | 1.81 (1.70, 1.92) | 0.497            | 20           | 1.67 (1.56, 1.83) | 0.018            |
| 40 min/d or more     | 28           | 1.86 (1.78, 2.01) |                   | 9             | 1.87 (1.74, 1.97) |                   |
| **Daily steps**      |              |               |                   |               |               |                   |
| <median              | 20           | 1.86 (1.71, 1.94) | 0.744            | 15           | 1.66 (1.54, 1.85) | 0.026            |
| median or more       | 21           | 1.86 (1.73, 1.96) |                   | 14           | 1.83 (1.70, 1.96) |                   |

Physical activity level (PAL) was shown as median (interquartiles).

†p: differences in physical activity between groups assessed using Mann-Whitney U test.

MVPA: moderate and vigorous physical activity assessed by accelerometer (at least 6.0 METs).

Daily steps were divided using the median values for each gender and age group.
mated the intensity of activities, especially as the accelerometer measurements suggested that very few participants took any vigorous activity.

The accuracy of physical activity questionnaires is greatly affected by the lifestyles of the target population (7). Older people are generally thought to engage more in lighter activity, and may perform activities on an irregular basis (7). We used a questionnaire developed for an older population. However, we could not find any differences in total score and duration of each activity by age groups although there was a significant difference in PAL assessed using the DLW method. PASE was previously validated for Japanese older people and a community including Japanese-American people (8, 28). These studies suggested correlations with daily steps, muscle strength, and the SF-36, and showed similar results to other well-validated questionnaires. In our population, total PASE score (median 91 for 65–74 y olds, 96 for over 75 y olds) was quite low compared with previous studies (114.9 for people with an average age of 72.6 y) (8). Participation in light to strenuous sports and recreational activities were especially low. We speculate that the examples of sports and recreational activities given might have resulted in participants assessing their involvement as low participation (the examples were gateball, radio calisthenics, and ground golf for light activity, tennis, social dancing, and folk dancing for moderate activity, and hiking, mountain climbing, and jogging for strenuous activity).

The most notable limitation of our study was the small sample size. It may also not have been sufficiently representative. We aimed to represent the Japanese older population, and used daily steps as one of inclusion criteria to match our participants with those in the JNHSN. However, only comparing height, body mass, and daily steps might not have been enough to guarantee the representativeness. Our study participants were also recruited from only one area in Tokyo. The study results should therefore be generalized with care.

In conclusion, participants aged over 75 had significantly lower PAL than those aged 65–74 y. This was mainly owing to decreases in MVPA and number of daily steps. Participating in more than 40 min/d of MVPA, walking more than the median level, or participating in paid work or exercise might prevent age-related decline in PAL.

Authorship

KIT measured the total energy expenditure, analyzed the data, and drafted the manuscript. SN measured the total energy expenditure and resting metabolic rate, and analyzed the data. SS contributed to the study design and interpretation of the data. FK contributed to the interpretation of the data. ST measured resting metabolic rate and contributed to the interpretation of the data. All authors reviewed the manuscript.

Disclosure of COI

ST received consigned research funds from Omron Healthcare Co., Ltd. All other authors declare no conflicts of interest.

Acknowledgments

We thank all participants in this study. We also thank the late Dr. Hideyo Yoshida, Tokyo Metropolitan Institute of Gerontology, who was a member of this study group. We also wish to thank the members of the National Institute of Health and Nutrition and Tokyo Metropolitan Institute of Gerontology. We thank Melissa Leffler, MBA, from Edanz Group ((https://en-author-services.edanz.com/ac) for editing a draft of this manuscript. This study was partly supported by Health and Labor Sciences Research Grants (H24-Jyunkanki-Ipan-004) and the Japan Agency for Medical Research and Development (JP20ek0210112).

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