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ORIGINAL RESEARCH

Evaluation of Physical Activity Assessment Using a Triaxial Activity Monitor in Community-Dwelling Older Japanese Adults With and Without Lifestyle-Related Diseases

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Background: Several previous studies investigated physical activity of older adults using wearable devices, but more studies need to develop normative values for chronic disease conditions. This study aimed to investigate physical activity using a triaxial activity monitor in community-dwelling older Japanese adults with and without lifestyle-related diseases. ***Methods:*** Data from a total of 732 community-dwelling older Japanese men and women were collected and analyzed in a cross-sectional study. The participants' physical activity was assessed for seven consecutive days by a triaxial accelerometer. Physical activity was assessed by number of lifestyle-related diseases and six lifestyle-related diseases categories by gender. Physical activity was assessed separately for total, locomotive, and nonlocomotive physical activity. ***Results:*** Participants with multiple (two or more) diseases had significantly lower total light-intensity physical activity (LPA; 278.5 ± 8.4 min/day) and nonlocomotive LPA (226.4 ± 7.0 min/day) versus without diseases in men. Compared in each disease category, total LPA and nonlocomotive LPA was significantly lower in men with hypertension and diabetes. Total sedentary time was significantly higher in men with hypertension, diabetes, and heart disease. Locomotive LPA was significantly lower in men with diabetes. In women, locomotive moderate- to vigorous-intensity physical activity was significantly higher in women with diabetes, and nonlocomotive moderate- to vigorous-intensity physical activity was significantly lower in women with heart disease. ***Conclusion:*** This study demonstrated that older Japanese men with multiple lifestyle-related diseases had lower physical activity. In each disease category, hypertension, diabetes, and heart disease affected lower physical activity, especially in men.

Keywords: accelerometers, device measured, locomotive, nonlocomotive

Physical activity has been assessed for various objectives, including health promotion, prevention of lifestyle-related diseases and frailty, and improvement of physical functions. In addition to such objectives, there is a need for physical activity assessment in older people in Japan, a country with one of the highest longevity with an average lifespan of 81.6 years in men and 87.7 years in women as indicated in recent statistics in 2020 (*Statistical Handbook of Japan 2022*, 2022).

Physical activity can be assessed by self-reported methods such as a questionnaire, or device-measured methods such as an activity monitor with a built-in acceleration sensor. Especially in older people, subjective methods such as self-reports using questionnaires were reported to be affected by factors including health condition and cognitive function (Rikli, 2000), device-measured objective methods are considered recommendable.

The activity monitor is a device that continuously measures the exercise intensity using an algorithm derived from the relationship between data obtained by an acceleration sensor and energy consumption obtained by expired gas analysis. The device used to be uniaxial but was recently developed to triaxial which became the mainstay. Recently, triaxial activity monitors are used widely in research as a method for objective assessment of physical activity during free movements. Moreover, some recent devices are designed to capture a wider variety of activities by distinguishing various activity patterns using features such as the amounts of acceleration and applying an algorithm to each activity pattern (Bonomi et al., 2009; Crouter et al., 2006, 2010; Ohkawara, Oshima, et al., 2011; Oshima et al., 2010). The target population of activity monitors are also widening, and several studies have reported on the validity of measurements in the older adults (Corbett et al., 2016; Hall et al., 2013; Nagayoshi et al., 2019; Park et al., 2018).

Assessing physical activity in older adults is essential for maintaining healthy longevity in Japan and other countries. The validity of activity monitors as an objective tool for physical activity assessment has also been evaluated. Thus far, several studies in which the activity of older people was assessed objectively using activity monitors are available (Amagasa et al., 2017, 2021; Chen et al., 2018; Yatsugi et al., 2021). In addition, there have also been several studies on the relationship between physical activity both device-measured and self-reported and various lifestyle-related diseases, such as hypertension, diabetes, and heart failure (Aune et al., 2015; Autenrieth et al., 2013; Gerage et al., 2015; Hains-Monfette et al., 2019; Ho et al., 2022; Miyamoto et al., 2017; Shibata et al., 2019). In Japan, where the aging rate is

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expected to increase, it will be necessary to consider the amount of physical activity of older adults with lifestyle-related diseases, and further research is needed to develop normative values for such subjects.

Therefore, this study aimed to evaluate physical activity assessment using activity monitor in community-dwelling older Japanese adults with and without lifestyle-related diseases.

Methods

Participants

A cross-sectional study was carried out as a baseline survey of the Itoshima Felix Study from September to December 2017. The detail of the I. Frail Study design was described elsewhere (Chen et al., 2020). Questionnaires were mailed to the participants, inviting them to community centers for further assessments. This study was approved by the Institutional Review Board of Kyushu University (approval no. 201708). All participants provided written informed consent.

Lifestyle-Related Disease

A self-administered questionnaire mailed to the participants was used to survey them about the lifestyle-related diseases they were currently being treated for and the medications they were taking. Participants completed the aforementioned items prior to participating and submitting the measurement survey. During the measurement survey meeting, the trained staff checked the answers directly with the participant if there were any incomplete or missing answers. The lifestyle-related diseases included in the survey were osteoporosis, hypertension, hyperlipidemia, diabetes, stroke, and heart disease (including arrhythmia). Each disease was considered existence if they had been diagnosed by a doctor or were taking medication. If the participants had more than one disease, they answered all of them. Participants were then split into mutually exclusive categories of without disease, single disease, and multiple diseases based upon their responses.

Physical Activity Assessment

Physical activities were measured objectively using a waist-mounted, triaxial, accelerometer (Active style Pro HJA-350IT, Omron Healthcare), 74 × 46 × 34 mm and 60 g including batteries. Participants wore the activity monitor for seven consecutive days after the health assessment. 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 ±6 G, resulting in a resolution of 3 mG. Each of the three signals from the triaxial accelerometer was passed through a high-pass filter with a cutoff frequency of 0.7 Hz to remove the gravitational acceleration component from the signal. The integral of the absolute value of each three axes acceleration signals was calculated over 10-s intervals. This activity monitor can classify locomotive activities such as walking and running and nonlocomotive activities such as PC work, laundry, and dish washing by the unfiltered/filtered acceleration ratio and assess metabolic equivalents (METs; Oshima et al., 2010). The validity of the sensor and measurement algorithm in adults and older people were evaluated in previous studies (Nagayoshi et al., 2019; Ohkawara, Oshima, et al., 2011). In brief, a significant correlation between actual and device-measured METs was observed in both adults ($r = .88$, $p < .001$) and older people ($r = .85$, $p < .001$). Device-measured METs significantly underestimated compared with actual METs in both groups ($p < .001$). The mean of the errors was −0.1 ± 0.5 METs in adults and −0.6 ± 0.6 METs in older adults (Nagayoshi et al., 2019). The participants were instructed by trained personnel to wear the accelerometer on either side of their waist during their waking hours, and to remove the device only before going to bed or when engaging in water activities. Simple instruction and a log diary were also provided to encourage compliance with the accelerometer protocols. Data were recorded in 60-s periods for the data analysis. Nonwear time was defined as consecutive minutes of no activity (i.e., estimated activity intensity < 1.0 MET) for at least 60 min, with an allowable 2 min to reach up to 1.0 MET (Migueles et al., 2017). Data for the participants with at least four valid wear days including at least one weekend day (at least 10 hr of device wearing time per day) were included in the analysis (Troiano et al., 2008; Trost et al., 2005). Sedentary time (ST) was defined as a minute in which the activity intensity was ≤1.5 METs, light-intensity physical activity (LPA) was defined as activities of 1.6–2.9 METs, moderate- to vigorous-intensity physical activity (MVPA) was defined as activities of ≥3.0 METs.

Other Variables

Participant's weight (in kilograms) and height (in meters) were measured using standard protocols with the participant in light clothing and without shoes. Body mass index was calculated as weight in kilograms divided by height in meters squared. Age and gender were collected via a questionnaire as sociodemographic characteristics.

Statistical Analysis

Values are presented as mean and *SD* and estimated marginal mean ± *SE*. Analysis of covariance was used for the comparison of the activity level among the group by numbers of lifestyle-related diseases and between those with and without each disease category. In the analysis among the group by numbers of lifestyle-related diseases, analysis of covariance was performed adjusted for age, gender, body mass index, and device wearing time. In the analysis between those with and without each disease category, analysis of covariance was performed adjusted for age, gender, body mass index, device wearing time, presence or absence of other diseases, other than it being compared and presence of diseases interaction. All statistical analyses were performed using IBM SPSS Statistics (version 24.0 for Windows, IBM). Differences were considered to be significant if the p value was less than .05.

Results

In this study, of 5,000 individuals who were randomly selected and contacted, 1,589 submitted questionnaires. Of these respondents, 732 who had no defect in the entries of disease history and fulfilled the adoption criteria for activity monitors were enrolled as participants.

Table 1 shows the basic characteristics of the participants. The mean age was 70.5 ± 2.8 years and more than half were female (53.4%). Of all participants, without diseases, single disease, and multiple diseases were 35.5%, 31.7%, and 32.8%, respectively. In each disease category, hypertension was the most common lifestyle-related disease (40.7%).

Table 2 shows the results of the comparison of physical activity by number of lifestyle-related diseases in men and women. In men, participants with multiple diseases had significantly lower total LPA and nonlocomotive LPA versus without diseases. However, no significant difference was observed among the group of numbers of lifestyle-related diseases in women.

Table 3 shows the comparison of physical activity in each disease category in men. Total LPA and nonlocomotive LPA was significantly lower in men with hypertension and diabetes versus without diseases. Total ST was significantly higher in men with hypertension, diabetes, and heart disease versus without disease. Locomotive LPA was significantly lower in men with diabetes versus without diseases.

Table 4 shows the comparison of physical activity in each disease category in women. Locomotive MVPA was significantly higher in women with diabetes versus without diseases. Nonlocomotive MVPA was significantly lower in women with heart disease versus without diseases. The number of steps showed no significant difference in all analyses.

Discussion

This study found that men with multiple diseases had significantly lower total LPA and nonlocomotive LPA versus without diseases. However, no significant difference was observed among the group

Table 1 Characteristics of Study Participants

	All (*n* = 732)	Men (*n* = 341)	Women (*n* = 391)
Age (years)	70.5 ± 2.8	70.4 ± 2.8	70.5 ± 2.7
Height (cm)	158.2 ± 8.6	165.2 ± 5.8	152.1 ± 5.3
Weight (kg)	57.4 ± 10.2	63.6 ± 8.8	52.0 ± 7.9
BMI (kg/m^2)	22.9 ± 3.2	23.3 ± 2.9	22.5 ± 3.3
Without diseases, *n* (%)	260 (35.5)	134 (39.3)	126 (32.2)
Single disease, *n* (%)	232 (31.7)	114 (33.4)	118 (30.2)
Multiple diseases, *n* (%)	240 (32.8)	93 (27.3)	147 (37.6)
Osteoporosis, *n* (%)	59 (8.1)	4 (1.2)	55 (14.1)
Hypertension, *n* (%)	298 (40.7)	138 (40.5)	160 (40.9)
Hyperlipidemia, *n* (%)	239 (32.7)	73 (21.4)	166 (42.5)
Diabetes, *n* (%)	106 (14.5)	64 (18.8)	42 (10.7)
Stroke, *n* (%)	29 (4.0)	15 (4.4)	14 (3.6)
Heart disease, *n* (%)	75 (10.2)	44 (12.9)	31 (7.9)

Note. Data show mean ± *SD* and *n* (%). Multiple diseases: participants with two or more diseases. BMI = body mass index.

Table 2 Comparison of Physical Activity by Number of Lifestyle-Related Diseases in Men and Women

Men (min/day)	Without diseases (*n* = 134)	Single disease (*n* = 114)	Multiple diseases (*n* = 93)
Total MVPA	50.0 ± 2.7	52.0 ± 2.9	50.2 ± 3.3
Total LPA	307.5 ± 7.0	302.9 ± 7.5	278.5 ± 8.4*
Total ST	462.5 ± 8.1	465.1 ± 8.7	491.3 ± 9.8
Locomotive MVPA	27.2 ± 1.9	30.3 ± 2.1	31.4 ± 2.3
Locomotive LPA	58.4 ± 2.4	58.9 ± 2.6	52.1 ± 2.9
Nonlocomotive MVPA	22.9 ± 1.5	21.7 ± 1.6	18.8 ± 1.8
Nonlocomotive LPA	249.1 ± 5.8	244.0 ± 6.2	226.4 ± 7.0*
Women (min/day)	**Without diseases (*n* = 126)**	**Single disease (*n* = 118)**	**Multiple diseases (*n* = 147)**
Total MVPA	58.2 ± 2.9	56.0 ± 3.0	54.1 ± 2.7
Total LPA	385.8 ± 6.3	389.5 ± 6.5	384.0 ± 5.8
Total ST	419.8 ± 7.4	418.4 ± 7.6	425.8 ± 6.8
Locomotive MVPA	21.6 ± 1.6	21.9 ± 1.6	21.8 ± 1.4
Locomotive LPA	41.7 ± 1.6	45.3 ± 1.6	40.9 ± 1.4
Nonlocomotive MVPA	36.7 ± 2.1	34.1 ± 2.2	32.3 ± 2.0
Nonlocomotive LPA	344.2 ± 5.9	344.2 ± 6.0	343.0 ± 5.4

Note. Data show estimated marginal mean ± *SE*. Data adjusted for age, body mass index, and device wearing time. MVPA = moderate- to vigorous-intensity physical activity; LPA = low-intensity physical activity; ST = sedentary time.
*$p < .05$ without disease versus multiple diseases.

Table 3 Comparison of Physical Activity in Each Disease Category in Men

	Without diseases (*n* = 134)	Osteoporosis (*n* = 4)	Without diseases (*n* = 134)	Hypertension (*n* = 138)
Total MVPA (min/day)	50.7 ± 2.7	54.1 ± 16.7	49.9 ± 2.7	49.6 ± 5.3
Total LPA (min/day)	310.5 ± 6.6	265.1 ± 40.7	307.8 ± 6.7	272.2 ± 13.3*
Total ST (min/day)	465.3 ± 8.1	507.3 ± 49.8	463.9 ± 7.8	499.8 ± 15.6*
Locomotive MVPA (min/day)	27.6 ± 1.7	32.9 ± 10.5	26.9 ± 1.9	31.4 ± 3.7
Locomotive LPA (min/day)	58.9 ± 2.4	62.6 ± 14.4	58.3 ± 2.4	57.6 ± 4.7
Nonlocomotive MVPA (min/day)	23.1 ± 1.6	21.2 ± 10.1	23.0 ± 1.5	18.2 ± 3.0
Nonlocomotive LPA (min/day)	251.6 ± 5.4	202.6 ± 33.2	249.5 ± 5.6	214.6 ± 11.2**
	Without diseases (*n* = 134)	**Hyperlipidemia (*n* = 73)**	**Without diseases (*n* = 134)**	**Diabetes (*n* = 64)**
Total MVPA (min/day)	50.4 ± 2.6	50.1 ± 5.4	50.3 ± 2.7	44.6 ± 6.0
Total LPA (min/day)	308.1 ± 6.8	287.1 ± 14.2	307.2 ± 7.0	258.2 ± 15.3**
Total ST (min/day)	464.4 ± 8.2	485.6 ± 17.1	461.2 ± 8.2	515.7 ± 17.9**
Locomotive MVPA (min/day)	27.4 ± 1.7	27.5 ± 3.5	27.5 ± 1.9	26.6 ± 4.2
Locomotive LPA (min/day)	58.3 ± 2.2	53.0 ± 4.6	58.6 ± 2.4	45.3 ± 5.2*
Nonlocomotive MVPA (min/day)	23.0 ± 1.6	22.6 ± 3.2	22.7 ± 1.5	18.1 ± 3.2
Nonlocomotive LPA (min/day)	249.7 ± 5.7	234.2 ± 11.8	248.6 ± 5.8	212.9 ± 12.8*
	Without diseases (*n* = 134)	**Stroke (*n* = 15)**	**Without diseases (*n* = 134)**	**Heart disease (*n* = 44)**
Total MVPA (min/day)	50.7 ± 2.8	53.4 ± 9.9	50.3 ± 2.7	39.1 ± 6.1
Total LPA (min/day)	310.6 ± 6.5	275.1 ± 23.4	308.9 ± 6.9	276.1 ± 15.7
Total ST (min/day)	466.3 ± 8.0	499.2 ± 28.6	464.4 ± 8.3	508.4 ± 19.1*
Locomotive MVPA (min/day)	27.5 ± 1.7	28.8 ± 6.2	27.3 ± 1.8	22.8 ± 4.0
Locomotive LPA (min/day)	58.7 ± 2.3	59.9 ± 8.4	58.6 ± 2.4	49.0 ± 5.4
Nonlocomotive MVPA (min/day)	23.2 ± 1.6	24.6 ± 5.8	23.0 ± 1.5	16.3 ± 3.5
Nonlocomotive LPA (min/day)	252.0 ± 5.4	215.2 ± 19.3	250.4 ± 5.6	227.1 ± 12.9

Note. Data show estimated marginal means ± *SE*. In every disease category, compared to participants without diseases. Data adjusted for age, body mass index, device wearing time, presence or absence of other diseases other than it being compared, and presence of diseases interaction. LPA = light-intensity physical activity; MVPA = moderate- to vigorous-intensity physical activity; ST = sedentary time.
*$p < .05$. **$p < .01$ versus without diseases.

by numbers of lifestyle-related diseases in women. Compared in each disease category, total LPA and nonlocomotive LPA was significantly lower in men with hypertension and diabetes versus without diseases. Total ST was significantly higher in men with hypertension, diabetes, and heart disease versus without disease. Locomotive LPA was significantly lower in men with diabetes versus without diseases. In women, locomotive MVPA was significantly higher in women with diabetes versus without diseases, and nonlocomotive MVPA was significantly lower in women with heart disease versus without diseases.

Amagasa et al. (2017) assessed the physical activity level (PAL) using an activity monitor in randomly selected 450 community-dwelling older Japanese men and women. They reported that the MVPA time of men/women was 43.6 min/46.3 min, LPA time was 263.1 min/365.3 min, and ST was 548.3 min/487.0 min, respectively. A paper by Shibata et al. (2019) who investigated sedentary behavior using an activity monitor in 287 Japanese older adults with and without chronic conditions reported that the mean ST of each group with zero, one, and over two chronic conditions was 515.5, 517.3, and 539.1 min, respectively. In our study, since MVPA and LPA were longer, and ST was shorter compared with the aforementioned studies, the participants in our study are considered to be a relatively active population.

However, the activity level of the participants in our study did not differ from the standard activity levels in multiple cohorts of community-dwelling older Japanese, including this cohort study that showed MVPA mean range 47.2–65.5 min, LPA mean range 285.8–391.4 min, and ST mean range 408.0–476.5 min (Yatsugi et al., 2021).

The present study demonstrated that men with multiple diseases had significantly lower total LPA and nonlocomotive LPA versus without diseases, but women with multiple diseases had no significant results in this study. Several studies reported the association of multiple chronic diseases with physical activity. Hains-Monfette et al. (2019) investigated that the physical activity and sedentary behaviors in 6,270 Canadians with chronic diseases. They reported that two and more chronic diseases had significantly lower daily duration of MVPA and LPA, daily step counts, and higher daily duration of sedenatry behavior compared with adults without chronic diseases. Autenrieth et al. (2013) reported that physical activity is inversely associated with multimorbidity only in older men. From the results of previous studies and our study, having multiple diseases may affect the amount of physical activity in community-dwelling older Japanese men.

In order to investigate whether having a specific disease affects physical activity, we compared the amount of physical activity for

Table 4 Comparison of Physical Activity in Each Disease Category in Women

	Without diseases ($n = 126$)	Osteoporosis ($n = 55$)	Without diseases ($n = 126$)	Hypertension ($n = 160$)
Total MVPA (min/day)	59.7 ± 3.1	44.7 ± 7.0	58.0 ± 2.9	51.2 ± 5.1
Total LPA (min/day)	389.9 ± 6.3	401.4 ± 14.4	383.7 ± 6.6	383.3 ± 11.5
Total ST (min/day)	414.9 ± 7.6	418.4 ± 17.2	420.0 ± 7.8	427.1 ± 13.7
Locomotive MVPA (min/day)	22.3 ± 1.6	16.0 ± 3.7	21.5 ± 1.5	19.4 ± 2.6
Locomotive LPA (min/day)	42.4 ± 1.6	41.7 ± 3.6	41.3 ± 1.6	42.4 ± 2.8
Nonlocomotive MVPA (min/day)	37.5 ± 2.3	28.7 ± 5.2	36.4 ± 2.2	31.8 ± 3.9
Nonlocomotive LPA (min/day)	347.5 ± 5.9	359.7 ± 13.4	342.4 ± 6.1	340.9 ± 10.7
	Without diseases ($n = 126$)	**Hyperlipidemia ($n = 166$)**	**Without diseases ($n = 126$)**	**Diabetes ($n = 42$)**
Total MVPA (min/day)	59.1 ± 2.9	54.3 ± 5.3	59.7 ± 2.9	65.2 ± 7.1
Total LPA (min/day)	388.9 ± 6.4	393.1 ± 11.7	390.7 ± 6.3	403.8 ± 15.5
Total ST (min/day)	420.5 ± 7.5	421.1 ± 13.6	422.7 ± 7.5	404.1 ± 18.4
Locomotive MVPA (min/day)	21.9 ± 1.5	23.3 ± 2.8	22.2 ± 1.5	30.0 ± 3.6*
Locomotive LPA (min/day)	42.0 ± 1.6	41.8 ± 2.8	42.3 ± 1.6	47.8 ± 3.8
Nonlocomotive MVPA (min/day)	37.2 ± 2.2	31.0 ± 3.9	37.5 ± 2.3	35.2 ± 5.7
Nonlocomotive LPA (min/day)	346.9 ± 6.0	351.3 ± 11.0	348.4 ± 5.9	356.0 ± 14.5
	Without disease ($n = 126$)	**Stroke ($n = 14$)**	**Without diseases ($n = 126$)**	**Heart disease ($n = 31$)**
Total MVPA (min/day)	60.0 ± 2.8	47.6 ± 9.6	59.8 ± 2.7	51.6 ± 6.7
Total LPA (min/day)	391.2 ± 6.2	385.1 ± 20.9	391.3 ± 6.1	391.5 ± 15.0
Total ST (min/day)	422.2 ± 7.4	440.8 ± 24.9	423.4 ± 7.3	431.4 ± 17.8
Locomotive MVPA (min/day)	22.4 ± 1.4	16.5 ± 4.8	22.2 ± 1.4	26.2 ± 3.5
Locomotive LPA (min/day)	42.5 ± 1.5	46.2 ± 5.0	42.4 ± 1.5	44.7 ± 3.6
Nonlocomotive MVPA (min/day)	37.6 ± 2.3	31.1 ± 7.8	37.6 ± 2.2	25.4 ± 5.4*
Nonlocomotive LPA (min/day)	348.7 ± 5.8	338.9 ± 19.5	348.9 ± 5.7	346.8 ± 13.9

Note. Data show estimated marginal mean ± *SE*. In every disease category, compared with participants without diseases. Data adjusted for age, body mass index, device wearing time, presence or absence of other diseases other than it being compared, and presence of diseases interaction. LPA = light-intensity physical activity; MVPA = moderate- to vigorous-intensity physical activity; ST = sedentary time.
*$p < .05$ versus without diseases.

each disease category. As a result, significant differences were observed in men with hypertension, diabetes, and heart disease, and women with diabetes and heart disease compared with those without diseases. Gerage et al. (2015) investigate the association between the time spent in physical activities of different intensities and blood pressure levels in 87 hypertension patients. They demonstrated that lower time spent in sedentary activities and higher time spent in light physical activities are associated with lower blood pressure. Aune et al. (2015) reported in their systematic review that total physical activity, MVPA, and LPA were associated risk of type 2 diabetes and increasing physical activity reduce the risk of type 2 diabetes. The study by Ho et al. (2022) investigating the dose–response relationship between device-measured physical activity and heart failure by intensity of physical activity. They reported that total PA, MVPA, and LPA were all associated with a lower risk of incident heart failure. The results of our study are supported by those of previous studies suggesting an association between having and occurring diseases and lower physical activity especially in men. However, in our study, there was a limited significant association between physical activity and disease status in women. We also found that women with diabetes had higher locomotive MVPA versus without diseases. Amagasa et al. (2021) reported that Japanese women are more physically active, with 19% less time in sedenatry behavior and 19.8% more time in LPA than men. In our study, we obtained similar results for each disease category. Moreover, in the study by Yatsugi et al. (2021) showed that Japanese older women more adhered to the Japanese physical activity guideline compared to men. Since the female subjects in our study were a particularly active population and Japanese older women had high adherence to physical activity, it was possible that no significant association was found between physical activity and disease.

Our study showed interesting findings that significant differences were observed especially in nonlocomotive physical activity. Tanaka et al. (2013) assessed locomotive and nonlocomotive activities using a triaxial activity monitor in healthy Japanese adults and older people. They observed differences in the activity type, such as locomotive and nonlocomotive activities, and the amount of activity of different intensity levels depending on the sex and age, and suggested the necessity to measure both locomotive and nonlocomotive activities to assess total physical activities. Ohkawara, Ishikawa-Takata, et al. (2011) demonstrated that in the human calorimeter study, an increase in the number of steps to ≥25,000 or more was needed to improve PAL from low (1.45) to active (1.75), but, in doubly labeled water study, PAL and step counts were 1.73 ± 0.15 and 10,022 ± 2,605 steps/day in healthy Japanese adults. There was no significant relationship between PAL and daily steps. Therefore, they suggested that nonlocomotive activity may also play a significant role in increasing PAL for free-living individuals. In a previous study with intervention in nonlocomotive activity using a triaxial activity monitor in patients with type 2 diabetes, a significant decrease in the duration of sedentary behaviors by nonlocomotive activity intervention was reported (Miyamoto et al., 2017). The results of the previous studies and our study suggest that assessment in consideration of the activity type, such as locomotive and nonlocomotive activities, is important for a comprehensive evaluation of physical activity in community-dwelling older Japanese with lifestyle-related diseases.

We found that the actual state of physical activity was assessed using a triaxial activity monitor in community-dwelling older Japanese people with lifestyle-related diseases. However, this study has some limitations. The first is the medical history was taken through a questionnaire survey, so details of diagnosis, disease information, and duration of illness are not available. The second is the difficulty of generalization of the results because of the small number of participants, limitation of the study area, and voluntary participation of the participants. Third is the cause–effect relation between the presence or absence of lifestyle-related diseases and physical activity is unclear because of the cross-sectional design of the study. The fourth is participants in our study were very active and might not be a representative sample. In addition, a previous study (Nagayoshi et al., 2019) confirmed a tendency that this activity monitor underestimates moderate- to vigorous-intensity activity, particularly in older Japanese people. Thus, it was possible that we underestimated total amount of physical activity in our study participants. However, it is an interesting finding that even among active older adults, those with lifestyle-related diseases were found to be less active versus those without diseases. Further studies on the relationship between physical activity and lifestyle-related diseases are warranted. Last, although the validity of the accuracy of METs measurement was evaluated, the validity of distinction of activity types by the triaxial activity monitor used in this study (HJA-350IT) has not been evaluated in old Japanese people. Thus, to develop normative values for chronic disease conditions, further studies concerning the physical activity assessment using triaxial activity monitor in older Japanese people with lifestyle-related diseases are needed.

Conclusion

In this study, we evaluate physical activity assessment using activity monitoring in community-dwelling older Japanese adults with and without lifestyle-related diseases. Analysis by the number of lifestyle-related diseases, men with multiple diseases had significantly lower total LPA and nonlocomotive LPA versus without diseases. Compared in each disease category, total LPA and nonlocomotive LPA was significantly lower in men with hypertension and diabetes versus without diseases. Total ST was significantly higher in men with hypertension, diabetes, and heart disease versus without disease. Locomotive LPA was significantly lower in men with diabetes versus without diseases. In women, locomotive MVPA was significantly higher in women with diabetes versus without diseases, and nonlocomotive MVPA was significantly lower in women with heart disease versus without diseases. This study suggested that lifestyle-related disease status affects physical activity in community-dwelling older Japanese adults, especially in men. Thus, it may be beneficial to consider the participant's lifestyle-related disease status, how many and which, when examining increases in physical activity among older adults living in the community, especially in older men.

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