Association Between Moderate Physical Activity Level and Subsequent Frailty Incidence Among Community-Dwelling Older Adults: A Population-Based Cohort Study

Wenjing Zhao
Department of Public Health, Faculty of Medicine Hokkaido University

Shigekazu Ukawa
Research Unit of Advanced Interdisciplinary Care Science, Graduate School of Human Life Science, Osaka City University

Sachiko Sasaki
Department of Physical Therapy, Faculty of Human Science, Hokkaido Bunkyo University

Emiko Okada
Department of Nutritional Epidemiology, National Institute of Health and Nutrition

Tomoko Kishi
Department of Public Health, Graduate School of Medicine Hokkaido University

Kastunori Kondo
Center for Preventive Medical Science, Chiba University

Akiko Tamakoshi (tamaa@med.hokudai.ac.jp)
Faculty of Medicine Hokkaido University

Research

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Abstract

Background

The evidence concerning longitudinal association between physical activity (PA) and frailty is scarce, and variation in the scales, tools, or modules of PA made it challenging to obtain consistent results. This association among the individules who reached an older age where age-related cumulative chronic diseases and physical function declines were common, was unclear. Our study aimed to demonstrate the association between PA and frailty incidence among Japanese community-dwelling older adults with narrow age range of 70–74 years.

Mothods:

About 485 participants aged 70–74 years from the Japan Gerontological Evaluation Study were included in this study. Frailty was assessed at baseline and 3 years later by using the Kaigo-Yobo Checklist. PA was assessed using the short-term International Physical Activity Questionnaire. Logistic regression was performed to calculate relative risk (RR) with 95% confidence intervals (CIs) after adjusting for potential confounders.

Results

After a 3-year follow-up, 46 new frailty cases were recorded. The association of frailty incidence with both PA volume and daily walking time presented a U-shaped curve, albeit statistically insignificant. After adjusting for potential confounders, walking for 0.5–1 h/d displayed a greater association with decreased frailty risk (OR, 0.35; 95% CI, 0.12–0.98) than higher levels of daily walking time. No association between PA volume and subsequent frailty was observed.

Conclusions

Incorporating moderate regular walking levels of 0.5–1 h/d in older adults may delay the onset of frailty and improve the aging process. Further studies are needed to investigate the effect of higher PA levels on frailty risk.

Background

Frailty, as a complex geriatric syndrome, is a consequence of impairment and loss of physiological reserve in multiple systems, including the brain, endocrine system, immune system, respiratory system, cardiovascular system, and skeletal muscle [1]. Frailty is considered a state of transition from successful aging to low quality of life and increased vulnerability to falling [2], fractures [3], disability [4], institutionalization [5], hospitalization [6], and even mortality [7] among community-dwelling older adults. Reportedly, frailty affected 4.9–27.3% of adults aged ≥65 years globally [8]. A progressive global increase in the aging population is expected to aggravate the prevalence of frailty, which inevitably increases the burden of health care costs for individuals and the countries.

Physical inactivity, along with age, is one of the dominant risk factors for frailty incidence and a modifiable factor for the prevention of frailty [9, 10]. Physical activity (PA) is well known for promoting functional capacity in older adults. Practicing regular PA preserves the normal functioning of several body systems including musculoskeletal, cardiorespiratory, endocrine, and nervous systems; the dysfunctioning of which increases the risk of frailty development [1]. Although several previous studies have investigated the longitudinal association between frailty and leisure-time PA [10–12]; PA frequency [13–15], intensity [16, 17], volume [16], type [16], and length [18, 19]; and the daily number of walking steps [18], longitudinal studies remain scarce, and variation in the scales, tools, or modules of PA made it challenging to obtain consistent results. Meanwhile, most previous studies covered an extensive age range, where age is one of the essential risk factors for cumulative chronic diseases and physical function declines, including frailty development. Reportedly, older adults should practice PA according to their physical capacity, and the PA level (intensity or volume) beyond the individuals' physical capacity confers no additional benefits regarding health-related outcomes [20]. Therefore, our study aimed to investigate the association between PA and sequential frailty incidence among Japanese community-dwelling older adults with narrow age range of 70–74 years.

Methods

Study population

The Japan Gerontological Evaluation Study 2013 (JAGES 2013) is one of the waves of JAGES, an ongoing population-based panel study aimed at investigating the association between social and behavioral factors and health-related outcomes in the elderly population.[21] JAGES 2013 was conducted from October to December 2013 recruiting 195,290 community-dwelling residents aged ≥65 years who were ineligible for the long-term care certification from 30 municipalities in 14 of 47 Japanese prefectures. In the Hokkaido prefecture, JAGES at Taisetsu community Hokkaido in 2014 (JAGES ATTACH 2014) was developed based on JAGES 2013. JAGES ATTACH 2014 further limited the number of participants compared with the JAGES 2013 by eliminating those living in Taisetsu community Hokkaido (Higashikawa, Higashikagura, and Biei town) aged 70–74 years who were ineligible for the long-term care certification at the beginning of the study, thereby finally enrolling 1,127 participants. Overall, 824 participants responded to the questionnaire by mail (response rate: 73.1%), and a home visit survey was conducted to measure weight, height, and other indicators after agreeing to participate in the study. The follow-up survey was conducted in August 2017. Follow-up data on frailty were obtained by mailing the Kaigo-Yobo Checklist, and data related to total mortality or the number of participants who moved out of their community were obtained from the local basic resident registry. Responding to the questionnaire was considered informed consent. This study was approved by the Ethics Review Committee of Hokkaido University Graduate School of Medicine (NO. 14-024).

Physical activity assessment

PA was evaluated using the short-term International Physical Activity Questionnaire (IPAQ), a useful tool for evaluating PA in young and older Japanese adults [22]. Participants were asked about the number of days they engaged in vigorous PA, moderate PA, or walking during the past 7 days; the options included "none" and frequencies of the given PA. If the answer was not "none," they were then asked to report the time spent on the given PA. Vigorous PA (heavy lifting, digging, and jogging) requires extensive physical effort, making the participants breathe heavier than normal. Moderate PA requires moderate physical effort and makes the participants breathe somewhat heavier than normal (carrying light loads, gardening, or table tennis, but not walking). Daily walking should last at least 10 minutes at a time, such as walking at work or at home, walking to move from one place to another, and any other walking that one does solely for recreation, sport, exercise, or leisure. The PA volume for each PA intensity (Metabolic Equivalent of Task [MET]-minutes/week) is as follows: vigorous PA volume = 8.0 × vigorous-intensity activity minutes × vigorous-intensity days; moderate PA volume = 4.0 × moderate-intensity activity minutes × moderate days; walking volume = 3.3 × walking minutes × walking days. The total PA volume was defined as the sum of the volumes of vigorous PA, moderate PA, and walking and was further categorized into low, moderate, and high levels according to the guidelines for data processing analysis of the IPAQ. Daily walking time was defined as the weekly average of walking time (walking minutes × walking days) and then classified into 4 categories: daily walking ≤0.5 h, daily walking 0.5–1 h, daily walking 1–2 h, and daily walking >2 h.

Frailty assessment

Frailty at baseline and follow-up was assessed using the Kaigo-Yobo Checklist, a brief questionnaire for screening frailty in older Japanese adults [23]. It consists of 15 items and includes 3 subscales as follows: home boundness, falling, and lower nutrition. Each item scored 1 for those with a risk of frailty (e.g., low ability, has difficulty, and has no friends); otherwise, a score of 0 was given. The total scores ranged from 0–15, and those who had scores of ≥4 were classified to have frailty. Considering the missing data on 15 items, frailty was further defined as follows: (i) participants whose total scores were ≥4 were defined as frail regardless of missing data; (ii) participants whose total scores were 3 without missing data were defined as non-frail; (iii) participants whose total scores were 2 with ≤1 missing data point on any of the items were defined as non-frail; (iv) participants whose total scores were 1 with ≤2 missing data points on any of the items were defined as non-frail; (v) participants whose total scores were 0 with ≤3 missing data points on any of the items were defined as non-frail, and (vi) participants who did not meet any of the previously described criteria were deemed “missing” and excluded from the analysis.

Covariate assessment

The covariates were self-reported through the questionnaires or measured during the home visiting survey. These included demographic factors (age and sex), lifestyle factors (smoking status, drinking status, work status, and living arrangement), and health status (body mass index [BMI], depressive symptoms, and comorbidity index). Smoking status included “never,” “former,” or “current smoker.” Drinking status included “never,” “occasional,” and “heavy drinker.” Occasional drinking was defined as the daily consumption of Japanese sake, beer, Japanese spirits, whisky, and wine (<23 g/d); for heavy drinkers, the daily consumption amounted to ≥23 g/d. The information related to alcohol consumption was obtained from the Brief-Type Self-Administered Diet History Questionnaire, through which alcohol consumption could be estimated by the amount of each alcoholic drink consumed at a time, with its frequency being recorded [24]. Working status included “currently employed,” “retired,” or “never employed.” Living status included “living alone” or “living with others.” BMI ($kg \cdot m^{-2}$) was calculated using height and weight measured during the home visiting survey and categorized into 3 groups: <18.5, 18.5–25, and ≥25. If data on BMI were missing, the data input was self-reported BMI calculated from self-reported height and weight in the questionnaires. The short-term Geriatric Depression Scale was used for screening depressive symptoms, and participants with scores of ≥6 were considered to have depressive tendencies. The comorbidity index was defined as the number of historical incidences of hypertension, stroke, heart disease, diabetes mellitus, hyperlipidemia, musculoskeletal disorders, injuries (e.g., fall or fracture), cancer, and depression.

Statistical analysis

Baseline descriptive statistics of the participants are shown as number (percentage) for categorical variables and as the mean (standard deviation) or median (range) for continuous variables according to PA volume and daily walking time; Chi-squared test and Kruskal–Wallis test were used to test between-group differences. Multiple logistic regression was applied to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for subsequent frailty based on PA volume or daily walking time. There were two multi-adjusted models: Model 1 adjusted for age and sex and Model 2 adjusted for age, sex, BMI, smoking status, drinking status, working status, living arrangement, depressive symptoms, and comorbidity index. The presence of a linear trend was tested by placing the continuous variable of PA volume or daily walking time into the unadjusted or adjusted model. A quadratic trend was tested by placing a second-order polynomial of PA volume or daily walking time into the corresponding models. Sensitivity analysis was conducted by excluding participants with a history of cancer (15 participants), stroke (8 participants), or heart diseases (37 participants) because these participants were susceptible to frailty and these diseases might impact their PA practices.

Statistical analysis was conducted using the SAS statistical software package version 9.4 for Microsoft Windows (SAS Institute Inc., Cary, NC, USA). Two-tailed tests were used for statistical analysis, and P-values <0.05 were considered statistically significant.

Results

During the 3-year follow-up, 9 participants died and 6 moved out of the communities. Accordingly, 601 participants were eligible for the follow-up survey; of which, 487 participants responded (response rate: 80.2%). After excluding those with missing data on frailty at the follow-up survey (3 participants), 485 participants remained; data from 475 participants were used for the analysis of PA volume because 10 participants could not be identified as having a moderate PA volume due to missing data on vigorous PA. Furthermore, data from 456 participants were used for the analysis of daily walking time because 29 participants did not report daily walking time (Fig. 1). Meanwhile, the baseline distribution of age and gender in the participants who did not respond to the follow-up survey were not different from those who did respond.

After the 3-year follow-up, 46 new frailty cases were recorded. Table 1 shows the baseline characteristics of the participants according to PA volume and daily walking time. Participants who remained employed were more likely to practice a high volume of PA. Male participants were likely to walk for a longer time each day. Furthermore, retirees were more likely to walk more than those who had never been employed or remained employed.

Table 1

Baseline characteristics of the participants according to physical activity volume and daily walking time

	Physical activity volume (N = 475)				Daily walking time (N = 456)				
	Low (n=134)	Moderate (n=152)	High (n=189)	P-value*	≤0.5 h/d (n=147)	0.5–1 h/d (n=115)	1–2 h/d (n=92)	>2 h/d (n=102)	P-value*
Age, years, mean (SD) a	71.7 (1.3)	71.8 (1.4)	71.9 (1.4)	0.720	71.7 (1.3)	71.7 (1.3)	72.1 (1.5)	71.9 (1.5)	0.224
Male sex	56 (41.8)	67 (44.1)	95 (50.2)	0.241	50 (34.0)	58 (50.4)	51 (55.4)	54 (52.9)	0.002
BMI, kg/m^2, N (%)†									
<18.5	4 (3.0)	6 (3.9)	6 (3.2)	0.080	5 (3.4)	4 (3.5)	4 (4.3)	2 (2.0)	0.903
18.5–24.9	45 (33.6)	71 (46.7)	71 (37.6)		58 (39.5)	41 (35.7)	42 (45.7)	40 (39.2)	
≥25	76 (56.7)	71 (46.7)	108 (58.1)		78 (53.1)	67 (58.3)	44 (47.8)	57 (55.9)	
Smoking status, N (%)									
Current	8 (6.0)	15 (9.9)	11 (5.8)	0.878	7 (4.8)	9 (7.8)	8 (8.7)	9 (8.8)	0.431
Past	44 (42.8)	50 (32.9)	66 (34.9)		47 (32.0)	49 (42.6)	30 (32.6)	33 (32.4)	
Never	74 (55.2)	79 (52.0)	102 (54.0)		85 (57.8)	55 (47.8)	48 (52.2)	56 (54.9)	
Drinking status, N (%)									
Never	66 (49.3)	71(46.7)	95 (50.3)	0.553	79 (53.7)	53 (46.1)	39 (42.4)	53 (52.0)	0.125
Occasional drink	13 (9.7)	16 (10.5)	19 (10.1)		21 (14.1)	9 (7.8)	15 (16.3)	6 (5.9)	
Heavy drink	39 (29.1)	50 (32.5)	64 (33.9)		36 (24.5)	45 (39.1)	32 (34.8)	36 (35.3)	
Working status, N (%)									

* Kruskal–Wallis test was used for age, and Chi-squared test was used for others.

† BMI, Body mass index; GDS, Short-term Geriatric Depression Scale

	Physical activity volume (N = 475)				Daily walking time (N = 456)				
Current	33 (24.6)	33 (21.7)	68 (36.0)	0.025	36 (24.6)	26 (22.6)	21 (22.8)	45 (44.1)	0.008
Retired	73 (54.5)	91 (59.9)	101 (53.4)		82 (55.8)	67 (58.3)	66 (66.3)	51 (50.0)	
Never	12 (9.0)	15 (9.9)	13 (6.9)		15 (10.2)	15 (13.0)	4 (4.3)	5 (4.9)	
Living alone, N (%)	17 (12.7)	18 (11.8)	22 (11.6)	0.797	20 (13.6)	9 (7.8)	13 (14.1)	12 (11.8)	0.558
Depressive symptom, GDS score ≥6, N (%)[†]	25 (18.7)	27 (17.8)	40 (21.2)	0.828	24 (16.3)	31 (27.0)	16 (17.4)	19 (18.6)	0.450
Comorbidity index, median (range) [a]	1 (0–3)	1 (0–4)	1 (0–5)	0.566	1 (0–5)	1 (0–3)	1 (0–5)	1 (0–4)	0.631

[*] Kruskal–Wallis test was used for age, and Chi-squared test was used for others.

[†] BMI, Body mass index; GDS, Short-term Geriatric Depression Scale

Table 2 presents the ORs and 95% CI for frailty incidence according to PA volume and daily walking time. Compared with participants who practiced low PA volume, those who practiced moderate PA volume tended to decrease the risk of frailty after adjusting for the covariates (age, sex, BMI, smoking status, drinking status, working status, living arrangement, depressive symptoms, and comorbidity index). Although high PA volume also tended to decrease the risk of frailty incidence, the OR of subsequent frailty was approximately 1.00 after complete adjustment. The trend for ORs of subsequent frailty by PA volume resembled a U-shaped curve, although neither the linear trend nor quadratic trend was statistically significant. A daily walking time of 0.5–1 h/d was significantly associated with a decreased risk of frailty than that in walking for ≤0.5 h/d (OR, 0.35; 95% CI, 0.12–0.98). Moreover, longer daily walking durations, such as 1–2 h/d or >2 h/d, decreased the risk of frailty by 39% and 18%, respectively. Adjusting the regression models exclusively for age and sex or all covariates did not impact the final results. Similar to that seen concerning PA volume, the trend for the ORs of subsequent frailty by daily walking time also resembled a U-shape curve.

Table 2
Association between physical activity and frailty after three years of follow-up

	Sample size	Frailty case	OR (95% CI) *†	OR (95% CI) *‡
Physical activity volume (MET-minutes/week) §				
Low	134	16	1.00	1.00
Moderate	152	11	0.57 (0.25–1.28)	0.61 (0.26–1.45)
High	189	18	0.77 (0.38–1.58)	0.85 (0.38–1.88)
P for linear trend			0.757	0.666
P for quadratic trend			0.352	0.494
Daily walking time (h/d)				
≤0.5	147	19	1.00	1.00
0.5–1	115	6	0.39 (0.15–1.01)	0.35 (0.12–0.98)
1–2	92	8	0.63 (0.26–1.53)	0.61 (0.23–1.63)
>2	102	11	0.81 (0.36–1.81)	0.82 (0.34–1.97)
P for linear trend			0.925	0.795
P for quadratic trend			0.624	0.567

*Continuous physical activity volume and daily walking time were analyzed using the logistic regression model to calculate P-values for the linear trend or P-values for the quadratic trend.

†Adjustment for age and sex;

‡Adjustment for age, sex, body mass index, smoking status, drinking status, working status, living arrangement, depressive symptoms, and comorbidity index.

§MET, Metabolic Equivalent of Task; CI, Confidence interval; OR, Odds ratio

Sensitivity analyses for the associations of frailty incidence with PA volume and daily walking time by excluding participants with a history of cancer, stroke, or heart disease did not change the association substantially (Table 3).

Table 3
Sensitivity analysis for the associations between physical activity and frailty after three years of follow-up by excluding participants with disease history of cancer, stroke and heart diseases

	Sample Size	Frailty ase	OR (95% CI) *†	OR (95% CI) *‡
Physical activity volume (MET-minutes/week) §				
Low	121	13	1.00	1.00
Moderate	136	9	0.58 (0.24–1.42)	0.64 (0.25–1.65)
High	165	17	0.96 (0.44–2.07)	1.15 (0.48–2.74)
P for linear trend			0.441	0.394
P for quadratic trend			0.613	0.946
Daily walking time (h/d)				
≤0.5	134	17	1.00	1.00
0.5–1	105	6	0.44 (0.17–1.18)	0.42 (0.15–1.23)
1–2	77	4	0.37 (0.12–1.15)	0.40 (0.18–1.36)
>2	88	11	0.98 (0.43–2.24)	1.02 (0.40–2.60)
P for linear trend			0.684	0.512
P for quadratic trend			0.591	0.563

*Continuous physical activity volume and daily walking time were analyzed using the logistic regression model to calculate P-values for the linear trend or P-values for the quadratic trend. Sensitivity analysis was conducted by excluding the participants with heart disease, stroke, or cancer at baseline.

†Adjustment for age and sex;

‡Adjustment for age, sex, body mass index, smoking status, drinking status, working status, living arrangement, depressive symptoms, and comorbidity index.

§MET, Metabolic Equivalent of Task

Discussion

This study was conducted to investigate the association between PA and subsequent incident frailty in community-dwelling older adults. We found a significant association of incident frailty after 3 years of follow-up with walking for 0.5–1 h/d but not with PA volume. The association of frailty incidence with both PA volume and daily walking time both presented U-shaped curves, although they were statistically insignificant.

To the best of our knowledge, this is the first study to investigate the association between daily walking time and incident frailty in older adults living in the community. The WHO guidelines on PA and sedentary behaviors [25] recommend multicomponent PA for older adults to maintain their physical fitness. Studies from the UK [10] and Finland [11] reported that both moderate (e.g., washing the car or gardening) and vigorous (e.g., tennis or swimming) leisure-time PAs reduced the risk of frailty in older adults by 41–69%. Moreover, a study of the Finnish population reported that vigorous leisure-time PA in midlife could lower frailty risk in the older stages of life by up to 77% [12]. Decreased frailty risk was also observed in Chinese [9], Japanese [13], and Mexican [14] older adults who practiced PA at higher frequencies. In the US, no associations were observed between PA intensity and subsequent frailty among older adults who exercised instead of getting involved in sedentary activities [16]; however, moderate or vigorous PA reduced frailty risk by >40% in Spanish older adults [17]. Our study found that daily walking, a regular moderate-intensity PA (3.3 estimated METs), decreased the risk of frailty in Japanese older adults by >60%. Consistent with our study, a regular frequency of moderate PA was associated with a low risk of frailty incidence in European older adults [15]. Walking—a simple, safe, easily accessible, and effective PA modality for older adults—promotes physical performance and fitness [26], prevents cardiovascular disease [27], and decreases mortality risk [28]. Not only does our finding support that PA could prevent or delay the onset of frailty in community-dwelling older adults but it also yields new evidence to integrate walking into older adults' daily routines and to keep them physically active to delay frailty and adverse health outcomes.

Our study observed no significant association between PA volume and frailty prevention. Consistent with our findings, a study from the US did not find this association either [16]. However, we observed a U-shaped curve for the association of frailty with PA volume as well as daily walking time, although the associations were insignificant. In our study, walking for 0.5–1 h/d, but not longer, could decrease subsequent frailty risk in Japanese adults aged 70–74 years. This is the first study to conceive a non-beneficial effect of high-level PA on frailty development. Contrary to our findings, previous studies reported a linear relationship between PA intensity and frailty incidence in adults aged 50–60 years who were more likely to sustain higher physical capacity [10, 12, 19]. A study from Japan reported the prospective association between frailty and walking >5,000 steps/d, approximately 50 minutes of activity, but it suggested that walking for >1 h/d was not related to the prevention of frailty [18]. The human body develops dysfunctions with aging, including physical and cognitive impairment, and likely experiences a series of chronic conditions, which, to some extent, justify the recommendation for performing high level (intensity or volume) of PA. The Physical Activity Guidelines for Americans highlight the importance of regular PA for older adults with or without chronic conditions and indicate tailored levels of PA based on their physical capacity [29]. Consequently, higher levels of PA might not provide additional benefits for older adults concerning frailty, and it is suggested that older adults should consider customizing their PA levels according to their physical capacity or the physician's suggestions to avoid unnecessary injury caused by excessive PA. Maintaining a physically active lifestyle through moderate daily walking is more likely to decrease low-grade inflammation, increase muscle mass and strength required to maintain movement, accelerate metabolic processes to adapt to glucose and fatty acid metabolism, regulate cardiopulmonary fitness to efficiently carry oxygen and nutrients throughout the body, and enable neurological function to coordinate multiple systems, consequently enhancing the physical capacity [30].

This study has some limitations. First, the relatively small sample size may have possibly weakened the statistical power of the association of interest, but we obtained the clear trend of the association for both PA volume and daily walking time. Second, PA was assessed using a self-reported questionnaire rather than an objective assessment tool such as an accelerometer. However, this study obtained results consistent with those of a study that measured PA using accelerometers [18]. Third, PA was assessed only at the baseline, and PA levels were likely to change with age; but our participants were in narrow age range of 70-74 years. Fourth, the follow-up period in this study was relatively short (3 years). Nonetheless, a previous study demonstrated that PA had an equivalent impact on frailty risk over both short- and long-term follow-up periods [17]. Finally, it might be difficult to statistically generalize the results to all older populations domestically or globally, because our study population came from only three towns in Hokkaido, Japan. But the median of daily walking time (51min/d, equal about 5000step/d) of our participants approximated the value (5730 steps/d) reported for the old adults aged 65-74 years by Japan National Health and Nutrition Survey 2019 [31]; and the incidence rate 9.5% of the frailty in three year also closed to the global frailty incidence 13.5% [32]. The main strength of our study is that the age of our study population was limited to 70–74 years, which could reduce the effect of age on the association of interest.

Conclusions

The longitudinal association between daily walking time and frailty was an approximate U-shaped curve and walking for 0.5–1 h/d decreased the risk of frailty among community-dwelling older residents more significantly than longer walking times. Incorporating moderate regular walking levels into the daily lives of older adults may delay the onset of frailty and improve successful aging. Further studies are needed to investigate the impact of longer daily walking times (higher PA levels) on the risk of frailty among older adults.

Abbreviations

ATTACH: JAGES at the Taisetsu community Hokkaido

BMI: Body mass index

CI: Confidence interval

GDS: Geriatric Depression Scale

GDS-15: Short-term Geriatric Depression Scale

IPAQ: International Physical Activity Questionnaire

JAGES: Japan Gerontological Evaluation Study

MET: Metabolic Equivalent of Task

OR: Odds ratio

PA: Physical activity

WHO: World Health Organisation

Declarations

Ethics approval and consent to participate: Responding to the questionnaire was considered to indicate informed consent. This study was approved by the Ethics Review Committee of Hokkaido University Graduate School of Medicine (NO. 14-024).

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and/or analysed during the current study are not publicly available because of privacy concerns but are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Figures

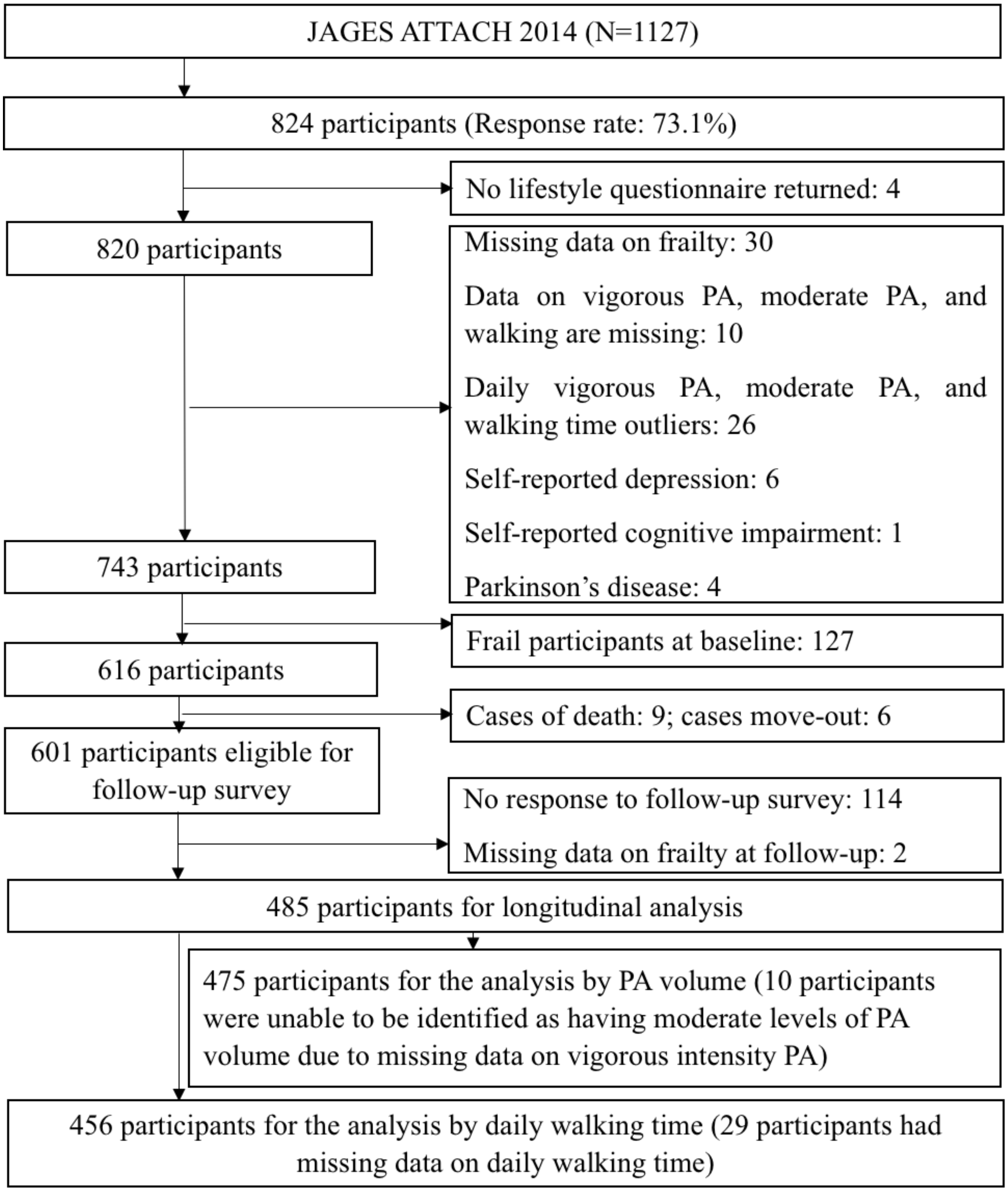

Figure 1

Flowchart of the study population PA, Physical activity; JAGES ATTACH, The Japan Gerontological Evaluation Study at Taisetsu community Hokkaido

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