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Original Article

Relationships between physical, cognitive, and social frailty and locomotive and non-locomotive physical activity of moderate to vigorous intensity

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Abstract. [Purpose] The purpose of this study was to examine the relationships between physical, cognitive, and social frailty and locomotive and non-locomotive physical activity of moderate to vigorous intensity in community-dwelling older adults and to explore effective intervention methods for preventing frailty. [Participants and Methods] Participants were 82 community-dwelling Japanese older males and females. Measurement items included basic information (age, gender, height, weight, body mass index, and the number of underlying diseases), physical activity, and assessment of physical, cognitive, and social frailty. Associations of physical, cognitive, and social frailty with physical activity were analyzed by group comparisons and multivariate analyses. [Results] The comparisons of physical activity indices for each frailty type revealed that physical frailty was associated with the number of steps and locomotive physical activity of moderate to vigorous intensity, whereas cognitive frailty and social frailty were not. Two overlapping types of frailty were associated with locomotive physical activity. When adjusted for age and gender, step counts and locomotive physical activity were each associated with physical frailty. [Conclusion] Future interventions to increase step counts and locomotive physical activity of moderate to vigorous intensity may be effective for preventing physical frailty; however, interventions other than simple physical activity need to be considered for the prevention of cognitive and social frailty.
Key words: Frailty, Physical activity, Moderate to vigorous physical activities (MVPA)

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INTRODUCTION

Frailty is a state of increased vulnerability to stress and enhanced susceptibility to ill health due to a decline in a physiological reserve capacity in old age[1)]; it is a precursor to the state of needing long-term care. Thus, if frailty can be prevented, then a longer healthy life expectancy and lower healthcare costs can be anticipated. The concept of frailty includes not only physical but also mental and psychological aspects, such as cognitive dysfunction and depression, as well as social issues such as living alone and economic deprivation[2)]. In recent years, these components of frailty have become known as physical, psychiatric/psychological, and social frailty, respectively, and each increases the risk of falls and impairment of basic activities of daily living (ADL)[1–6)]. Early intervention for frailty is important, and methods to address frailty need to be considered from the perspective of extending healthy life expectancy.

Physical activity (PA) is important for frailty prevention. In Japan, the Ministry of Health, Labour and Welfare (MHLW) recommends that older adults engage in PA of moderate to vigorous intensity, which includes walking as well as other daily

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activities such as work and housework, as a way to prevent lifestyle diseases[7]. WHO also recommends that older adults aged ≥65 years engage in at least 150 minutes of PA of moderate to vigorous intensity throughout the week[8]. A systematic review of the association between PA and health revealed an association between PA and all-cause mortality[9], and in this context as well, PA of moderate to vigorous intensity is considered important for health.

An increase in PA has been shown to contribute to the prevention and improvement of physical frailty. A previous study in the United States examined the association between physical frailty and PA measured by accelerometers in 2,317 males and females aged ≥50 years; an increase in PA was found to be associated with a decrease in the prevalence of physical frailty in both males and females[10]. A Japanese study examining the association between PA and frailty targeting 819 males and females aged 65–75 years reported that PA and a higher step count were associated with a lower prevalence of physical frailty[11]. These studies suggest that an increase in PA in daily life may have a positive effect on physical frailty.

PA needs to be evaluated according to the types of PA. The reason for this is that, while locomotive PA, i.e., walking, is a representative PA, complex activities such as housework (e.g., cleaning, doing laundry) that involve movements of the upper body are also performed in daily life. Therefore, non-locomotive PA should be evaluated apart from locomotive PA, and tri-axial accelerometers are useful to this end. Oshima et al.[12] classified PA into locomotive PA and non-locomotive PA using tri-axial accelerometry, and found that non-locomotive PA was also involved in increasing PA. Tanaka et al.[13] compared locomotive PA and non-locomotive PA by age and gender in 989 males and females aged 18–92 years and found that the durations of non-locomotive PA and total PA of moderate to vigorous intensity were significantly shorter in both males and females aged ≥70 years compared with other age groups. Therefore, evaluating PA by type may be useful for exercise prescription during frailty intervention, such as selecting the types of activities and setting target values. However, to date, no study has analyzed both locomotive PA and non-locomotive PA in relation to physical frailty. Moreover, no study also have comprehensively assessed the relationships between PA and frailty, or more specifically, physical, cognitive, and social frailty. Understanding the characteristics of PA in terms of its effect on each type of frailty may help in developing future strategies for frailty prevention.

The present study aimed to investigate relationships between physical, cognitive, and social frailty and locomotive and non-locomotive PA as measured by a 3-axis accelerometer in community-dwelling older adults

PARTICIPANTS AND METHODS

This cross-sectional study was conducted from July 5, 2021, to November 30, 2021, for community-dwelling older adults. Participants were verbally informed of the purpose and content of the study and were explained that participation in the study was voluntary; that they would not be subject to disadvantages if they did not respond to the questionnaire; that the study could be terminated even after they consented to cooperate and without any repercussions; and that participants would not be identified because data would be processed anonymously. Individuals who agreed to participate in the study signed a consent form. This study was approved by the Ritsumeikan University Ethics Review Committee for Medical Research Involving Human Subjects (review number: BKC-LSMH-2021-011).

Using G*Power 3.1 software (Heinrich Heine University, Düsseldorf, Germany), the sample size for frailty assessments was calculated with a power of 80%, alpha error of 0.05, and effect size of 0.40 (large). The number of participants required for this study was determined to be 80. To account for potential dropouts, we recruited 82 community-dwelling older adults (20 males and 62 females; mean age ± standard deviation: 74.0 ± 6.2 years) living in Usa City, Oita Prefecture, Japan. All participants provided consent to participate in this study. The exclusion criteria were as follows:

1) Those with active or suspected infections by a coronavirus (COVID-19).
2) Those who had difficulty answering the questionnaire due to cognitive decline.
3) Those who were certified as requiring long-term care (need for long-term care levels ≥1).
4) Those with a history of mental illness.
5) Those who had undergone orthopedic surgery or had movement restrictions.
6) Those deemed by a physician as ineligible to participate due to illness.

Data from the 82 participants were subjected to analysis (Fig. 1).

Measurement items included basic information (age, gender, height, weight, BMI, and the number of underlying diseases), PA, physical frailty assessment, cognitive frailty assessment, and social frailty assessment. Confounding factors that were presumed to be related to frailty were also elicited from previous studies[1–6].

Active Style Pro (Omron Corporation, Kyoto, Japan: HJA-350IT), an activity meter equipped with a 3-axis acceleration sensor, was used to evaluate the number of steps and PA. Active Style Pro recognizes movements by the amplitude and duration of acceleration waveforms; movements involving no change in upper body inclination are classified as walking activity, and movements with a change in inclination are classified as daily living activity[14]. Participants were asked to wear the device on their waist from waking to bedtime, except when they were bathing or engaged in other in-water activities. The PA meter was worn for at least 10 hours a day for at least 7 days in accordance with previous studies[15, 16]. The intensity of PA was classified according to activity meter data, as follows: sedentary behavior (1 to 1.5 metabolic equivalents (METs)), light-intensity PA (LPA: 1.6 to 2.9 METs), and PA of moderate to vigorous intensity (MVPA: more than 3 METs).

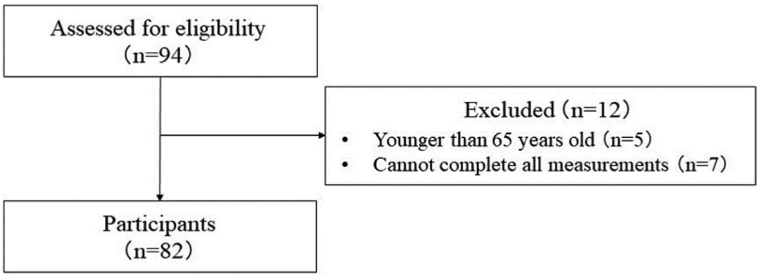

Fig. 1. Flowchart of the participant selection process.

Physical frailty was assessed using the Japanese version of the Cardiovascular Health Study (J-CHS) criteria[17], which include the following five items: weight loss, fatigue, decreased PA, decreased grip strength, and decreased walking speed. Participants who met three or more of these criteria were considered to have physical frailty; those meeting only one or two criteria were considered to have physical prefrailty (i.e., one stage before physical frailty).

Cognitive frailty was defined as a combination of subjective cognitive decline and physical prefrailty[18]. Participants who answered "Yes" to the Geriatric Depression Scale 15 (GDS15) No. 10 question ("Do you feel you have more problems with memory than most?") were considered to have subjective cognitive decline[18]. Cognitive decline (e.g., mild cognitive impairment) has been assessed by objective measures as well as subjective ones, with variation among studies. Some reported the use of a clinical dementia rating (CDR) of 0.5[19]. The prevalence of cognitive frailty reportedly varies by population, ranging from 1.0% to 39.7%[19]. In the present study, participants with subjective cognitive decline, as well as physical prefrailty, were considered to have cognitive frailty, because the combination of objective cognitive decline and physical frailty would have resulted in a much lower prevalence rate. In a previous study, the prevalence of cognitive frailty defined as physical frailty with objective cognitive decline was 1.2%[20, 21]. Assessing subjective cognitive function is also less burdensome for participants, which is another advantage given their old age.

Social frailty was defined as meeting two or more of the following five items (prefrailty if one item): "I go out less frequently than last year (yes)", "I visit friends (no)", "I think I am useful to friends and family (no)", "I live alone (yes)", and "I have a conversation with someone every day (no)"[22].

Confounding factors included the presence or absence of an exercise habit (at least 2 days per week, average exercise time of at least 30 minutes), years of education (6–9 years, 10–13 years), work status, financial comfort, marital status (married, bereaved/separated, never married), falls (in the past year), and hospitalization (in the past year), all of which were considered to be associated with frailty.

Each frailty was classified physical frailty into three groups (physical frailty, physical prefrailty, and robust), cognitive frailty into two groups (cognitive frailty and robust), and social frailty into three groups (social frailty, social prefrailty, and robust). Participants were further divided into four groups according to the number of overlapping frailties (three frailties, two frailties, one frailty, and robust). Numerical values and scores of each assessment item were compared between groups using the χ^2 test, Kruskal–Wallis test, and the Mann–Whitney U test after cross-tabulation. Based on the results of these tests, multinomial logistic regression analysis using the forced entry method was conducted, in which physical, cognitive, or social frailty was used as the dependent variable, and factors extracted from each evaluation item were used as independent variables. Prior to the multinomial logistic regression analysis, correlations between items were examined using Spearman's rank correlation coefficients to avoid multicollinearity. SPSS version 27 for Windows (IBM, Armonk, NY, USA) was used for data analysis, with the statistical significance level set at 5%.

RESULTS

Characteristics of the 82 participants are shown in Table 1. For physical frailty, 8 (9.8%) participants were classified as frailty, 37 (45.1%) as prefrailty, and 37 (45.1%) as robust. For cognitive frailty, 26 (31.7%) participants were classified as frailty, and 56 (68.3%) as robust. For social frailty, 22 (26.8%) participants were classified as frailty, 25 (30.5%) as prefrailty, and 35 (42.7%) as robust (Table 1).

The comparison of PA indices among the physical frailty, prefrailty, and robust groups revealed that physical frailty was associated with step counts ($p<0.05$) and locomotive MVPA ($p<0.05$) (Table 2). On the other hand, cognitive frailty and social frailty were not associated with any PA indices (Tables 3 and 4). Multiple comparisons of variables that showed significant associations indicated that physical frailty had a significant negative impact on step counts and locomotive MVPA compared to being robust.

The comparison of physical activity indices by the number of overlapping types of frailty revealed an association between frailty overlaps and locomotive MVPA ($p<0.05$). Multiple comparisons revealed that two overlapping types of frailty had a significantly negative effect on locomotive MVPA compared with robust (Table 5).

Table 1. Participant characteristics

Age (years)	74.0 ± 6.2
BMI (kg/m^2)	23.4 ± 3.4
Step counts (steps/day)	6,044.8 ± 3,082.7
SB (METs • h)	4.8 ± 1.8
Locomotive LPA (METs • h)	1.5 ± 0.8
Non-locomotive LPA (METs • h)	6.0 ± 2.3
Locomotive MVPA (METs • h)	0.8 ± 0.7
Non-locomotive MVPA (METs • h)	2.3 ± 1.3
Total locomotive PA (METs • h)	2.3 ± 1.2
Total non-locomotive PA (METs • h)	8.3 ± 3.3
Total activity (METs • h)	10.6 ± 4.1
Number of underlying diseases (persons)	None: 34, One: 41, Two: 6, Three: 0, Four: 1
Gender (persons)	Male: 20, Female: 62
Years of education (persons)	6–9 years: 4, 10–13 years: 78
Financial comfort (persons)	Comfortable: 37, Not comfortable: 45
Family (persons)	Living alone: 10, Living with someone: 72
Work (persons)	Employed: 22, Not employed: 60
Marriage (persons)	Married: 54, Bereaved/separated: 23, Never married: 5
Exercise habits (persons)	Yes: 52, No: 30
Falls (persons)	Yes: 19, No: 63
Hospitalization (persons)	Yes: 17, No: 65
Physical frailty (persons)	Robust: 37, Pre-frail: 37, Frail: 8
Cognitive frailty (persons)	Robust: 56, Frail: 26
Social frailty (persons)	Robust: 35, Pre-frail: 25, Frail: 22
Number of frailty overlaps (persons)	Robust: 16, One type of frailty: 27, Two types of frailty: 27, Three types of frailty: 12

Data are presented as mean ± standard deviation or number. BMI: body mass index; SB: sedentary behavior; LPA: light-intensity physical activity; MVPA: moderate to vigorous physical activity.

Finally, multinomial logistic regression analysis with the forced entry method was performed using age, gender, step counts, and locomotive MVPA as independent variables and physical frailty as the dependent variable. Multinomial logistic regression analysis with step counts and locomotive MVPA entered as independent variables were also performed. Before conducting these analyses, the analysis of internal correlations revealed significant correlations between each variable, but since the r-value never exceeded 0.8, the results of the correlation matrix for the items that showed significant differences in between-group comparisons were considered to have low multicollinearity. The multivariate analyses revealed that physical frailty was significantly associated with step counts (odds ratio: 0.999, 95% confidence interval: 0.998–0.999) and locomotive MVPA (odds ratio: 0.057, 95% confidence interval: 0.004–0.906) when step counts and locomotive MVPA were each entered as independent variables ($p<0.05$ for both). When both step counts and locomotive MVPA were entered as independent variables, no association was observed between physical frailty and any of the variables.

DISCUSSION

The purpose of this study was to examine relationships between physical, cognitive, and social frailty and locomotive and non-locomotive MVPA in community-dwelling older adults to explore effective intervention methods for frailty prevention. The comparisons of PA indices for each frailty type revealed that physical frailty was associated with the number of steps and locomotive MVPA, whereas cognitive frailty and social frailty were not. There was an association between two overlapping types of frailty and locomotive MVPA. When adjusted for age and gender, step counts and locomotive MVPA were each associated with physical frailty, and when both step counts and locomotive MVPA were included as variables, no association with physical frailty was observed.

Previous studies on the prevalence of physical, cognitive, and social frailty in community-dwelling older adults in Japan reported a prevalence of 11.3% for physical frailty and 56.9% for physical prefrailty in 4,745 community-dwelling older adults aged ≥65 years[23)]; a prevalence of 13.8% for cognitive frailty in 5,076 community-dwelling older persons aged ≥65 years[24)]; and a prevalence 11.1% for social frailty and 24.8% for social prefrailty in 4,425 community-dwelling older persons aged ≥65 years[25)]. In the present study, the prevalence of physical frailty/prefrailty was 9.8%/45.1%, which is similar

Table 2. Comparison of physical activity indices among the physical frailty, prefrailty, and robust groups

	Physical frailty[1)]				
Evaluation item	a. Robust (n=46)	b. Prefrailty (n=61)	c. Frailty (n=13)	p[2)]	Multiple comparisons
Age (years)	71.0 (68.0, 77.0)	73.0 (70.0, 79.0)	76.0 (68.5, 81.0)		
BMI (kg/m²)	23.5 (21.7, 24.8)	22.8 (21.7, 25.3)	22.2 (19.3, 23.3)		
Number of underlying diseases	0.0 (0.0, 1.0)	1.0 (0.0, 1.0)	1.0 (0.5, 1.0)		
Step counts (steps/day)	6,555.3 (4,997.0, 8,480.5)	4,996.8 (3,032.5, 7,631.2)	3,790.6 (2,212.7, 4,204.0)	*	a>c, a>b
SB (METs • h)	4.3 (3.4, 5.7)	4.2 (3.6, 5.2)	4.8 (4.1, 5.5)		
Locomotive LPA (METs • h)	1.4 (1.0, 1.9)	1.4 (1.1, 1.9)	1.1 (0.7, 1.6)		
Non-locomotive LPA (METs • h)	5.5 (4.2, 7.6)	5.6 (3.9, 7.1)	6.1 (4.9, 8.1)		
Locomotive MVPA (METs • h)	0.9 (0.6, 1.4)	0.6 (0.3, 0.9)	0.4 (0.2, 0.5)	*	a>c, a>b
Non-locomotive MVPA (METs • h)	2.3 (1.8, 3.3)	2.1 (1.3, 2.4)	2.1 (1.3, 2.7)		
Total locomotive PA (METs • h)	2.3 (1.8, 3.0)	2.0 (1.5, 2.9)	1.2 (1.1, 2.0)		
Total non-locomotive PA (METs • h)	7.8 (6.1, 11.2)	7.9 (5.0, 9.4)	8.5 (6.3, 10.4)		
Total activity (METs • h)	9.9 (8.6, 13.6)	10.0 (7.3, 11.8)	10.1 (7.0, 12.0)		
Male (n (%))	10 (21.7)	9 (14.8)	1 (7.7)		
Have an exercise habit (n (%))	25 (54.3)	22 (36.1)	5 (38.5)		
Have 10–13 years of education (n (%))	37 (80.4)	34 (55.7)	7 (53.8)		
Employed (n (%))	11 (23.9)	11 (18.0)	0 (0.0)		
Financially comfortable (n (%))	15 (32.6)	16 (26.2)	6 (46.2)		
Living alone (n (%))	3 (6.5)	5 (8.2)	2 (15.4)		
Married (n (%))	27 (58.7)	23 (37.7)	4 (30.8)		
Have had a fall (n (%))	7 (15.2)	10 (16.4)	2 (15.4)		
Have been hospitalized (n (%))	7 (15.2)	10 (16.4)	0 (0.0)		

Data are presented as median (interquartile range). BMI: body mass index; SB: sedentary behavior; LPA: light-intensity physical activity; MVPA: moderate to vigorous physical activity.
[1)]Comparison among the three physical frailty groups was performed using the Kruskal–Wallis test.
Multiple comparisons were performed using the Mann–Whitney U test with Bonferroni's correction ($p<0.05/3=0.017$) to account for multiplicity (with significant differences between groups). For the nominal scale, the χ^2 test and Fisher's direct method were used.
[2)]*: $p<0.05$,***: $p<0.001$.

to the previously reported rates. However, the prevalence of cognitive frailty and social frailty/prevalence was higher at 31.7% and 26.8%/30.5%, respectively, possibly because the present study was conducted from April to December 2021, i.e., during the COVID-19 pandemic, when restrictions were imposed on going out and socializing. This might explain why the prevalence of cognitive frailty and social frailty/prevalence was higher in the present study than in the previous study.

Physical frailty, but not cognitive frailty or social frailty, was associated with step counts and locomotive MVPA. Regarding the association between physical frailty and the amount of PA, several studies have reported similar findings. One study reported that total MVPA duration, bouted MVPA (MVPA longer than 10 minutes), and step counts, but not LPA or MVPA of less than 10 minutes, were significantly associated with a lower prevalence of physical frailty in elderly people[11)]. Another study reported that MVPA, total PA, number of steps, postural change, and lower energy expenditure was associated with physical frailty. Objective measures of PA were also reported to be associated with frailty regardless of the definition of frailty[26)]. There are a number of other studies reporting the association between physical frailty and PA[27–31)], consistent with the results of the present study. However, the present study is unique in that MVPA was classified into locomotive MVPA and non-locomotive MVPA, and their associations with physical frailty were each examined. Therefore, the finding that locomotive MVPA is associated with physical frailty is novel and of importance. Moreover, the multivariate analyses adjusting for age and gender revealed that step counts and locomotive MVPA were independently associated with physical frailty. Therefore, interventions to increase step counts and locomotive MVPA may be effective for preventing or improving physical frailty.

Regarding the relationship between cognitive frailty and the amount of PA, some studies reported an association between cognitive frailty and low PA[3, 32)]. In these studies, however, questionnaires were used to determine scores for the level of independence in instrumental activities of daily living (IADL), or to obtain responses regarding the presence of daily PA, but the amount of PA performed during the day was not investigated. By contrast, the present study, using accelerometers to measure the amount of PA for the first time, found no association between cognitive frailty and the amount of PA. Thus, the present study is the first to suggest that cognitive frailty is not related to quantified PA. In this regard, studies reporting an

Table 3. Comparison of physical activity indices between the cognitive frailty and robust groups

	Cognitive frailty[1)]		
Evaluation item	Robust (n=69)	Frailty (n=51)	p[2)]
Age (years)	74.0 (70.0, 78.5)	72.0 (67.0, 79.0)	
BMI (kg/m^2)	23.0 (20.7, 25.2)	23.4 (20.7, 25.2)	
Number of underlying diseases	1.0 (0.0, 1.0)	1.0 (0.0, 1.0)	
Step counts (steps/day)	5,539.5 (3,888.9, 7,788.7)	5,227.1 (4,075.7, 8,201.8)	
SB (METs • h)	4.3 (3.6, 5.7)	4.4 (3.4, 4.8)	
Locomotive LPA (METs • h)	1.3 (0.9, 1.9)	1.5 (1.1, 2.0)	
Non-locomotive LPA (METs • h)	5.6 (4.2, 7.5)	6.6 (4.1, 7.1)	
Locomotive MVPA (METs • h)	0.7 (0.4, 1.2)	0.5 (0.4, 1.1)	
Non-locomotive MVPA (METs • h)	2.1 (1.7, 2.7)	2.1 (1.0, 2.7)	
Total locomotive PA (METs • h)	2.2 (1.5, 2.9)	2.1 (1.4, 3.1)	
Total non-locomotive PA (METs • h)	7.8 (5.9, 10.3)	8.9 (4.7, 9.9)	
Total activity (METs • h)	9.9 (8.3, 12.7)	11.0 (7.5, 11.9)	
Male (n (%))	15 (21.7)	5 (9.8)	
Have an exercise habit (n (%))	36 (52.2)	16 (31.4)	
Have 10–13 years of education (n (%))	53 (76.8)	25 (49.0)	
Employed (n (%))	16 (23.2)	6 (11.8)	
Financially comfortable (n (%))	28 (40.6)	9 (17.6)	
Living alone (n (%))	6 (8.7)	4 (7.8)	
Married (n (%))	40 (58.0)	14 (27.5)	
Have had a fall (n (%))	10 (14.5)	9 (17.6)	
Have been hospitalized (n (%))	12 (17.4)	5 (9.8)	

Data are presented as median (interquartile range). BMI: body mass index; SB: sedentary behavior; LPA: light-intensity physical activity; MVPA: moderate to vigorous physical activity.
[1)]Comparison between the two cognitive frailty groups was performed using the Mann–Whitney U test. For nominal measures, the χ^2 test and Fisher's direct method were used.
[2)]*: p<0.05, **: p<0.001.

association between cognitive function and PA, but not cognitive frailty, were acknowledged, with results similar to those of the present study. With respect to the association between cognitive function and PA level, a previous study that examined the association between MVPA and cognitive function in Japanese males and females aged 40–69 years reported that the group with higher MVPA had a lower risk of dementia than the group with lower MVPA[33)]. On the other hand, a previous study targeting males and females aged 70–89 years in the United States reported that a 24-month moderate-intensity PA program did not improve cognitive function compared with a health education program[34)]. In addition, a systematic review examining the effectiveness of PA interventions to slow cognitive decline and delay the onset of cognitive impairment and dementia in adults without a diagnosis of cognitive impairment concluded that evidence of effectiveness in preventing dementia was insufficient for all PA interventions[35)]. In other words, although previous studies have found an association between PA and cognitive function, the evidence is still insufficient.

Regarding the relationship between social frailty and the amount of PA, no association was observed between social frailty and the indices of PA calculated by accelerometers. Previous studies on social frailty and PA using questionnaires reported that low PA was associated with social frailty. In addition, social frailty was also reported to be significantly less likely than robust to go out of home or out-of-town places[36)]. In other words, individuals with social frailty may be less physically active than those without social frailty, or active only to the minimum extent necessary to survive. In contrast to previous studies, no association was observed between social frailty and the amount of PA in the present study. This discrepancy may be explained by the different methods used to assess PA, since previous studies all used questionnaires to calculate the amount of PA. One study evaluated social frailty and PA in 596 older adult Japanese participants using the Aid for Decision-Making in Occupation Choice tool, in which participants were asked to select meaningful activities from among 95 activities and rate their satisfaction with the selected activities on a 5-point scale. That study found an association between social frailty and satisfaction scores for activities that participants considered important in their daily lives[37)]. In other words, the socially frail may not be satisfied with their daily activities. Thus, social frailty may be associated with the kind of PA that individuals find meaningful and satisfying, such as leisure time activity, but not with PA that could be objectively calculated using an accelerometer. Further verification of the relationship between social frailty and PA is necessary in the future, for example, by considering the level of satisfaction with PA, rather than objectively quantified PA.

Table 4. Comparison of physical activity indices among the social frailty, prefrailty, and robust groups

Evaluation item	Social frailty[1)] a. Robust (n=38)	b. Prefrailty (n=27)	c. Frailty (n=55)	p[2)]	Multiple comparisons
Age (years)	75.0 (70.0, 78.0)	72.0 (70.0, 79.0)	74.0 (67.0, 80.0)		
BMI (kg/m^2)	23.5 (21.9, 24.9)	23.2 (21.9, 24.5)	22.6 (20.6, 25.9)		
Number of underlying diseases	1.0 (0.0, 1.0)	1.0 (0.0, 1.0)	1.0 (0.0, 1.0)		
Step counts (steps/day)	6,426.5 (4,778.3, 9,090.8)	4,997.0 (4,003.8, 7,144.0)	4,760.1 (2,838.8, 7,446.3)		
SB (METs • h)	4.3 (3.4, 5.3)	4.5 (4.0, 6.3)	4.1 (3.6, 5.2)		
Locomotive LPA (METs • h)	1.4 (1.1, 2.0)	1.3 (1.0, 1.9)	1.3 (0.6, 1.6)		
Non-locomotive LPA (METs • h)	6.1 (4.2, 8.0)	6.2 (4.7, 7.1)	5.3 (3.5, 6.5)		
Locomotive MVPA (METs • h)	0.8 (0.4, 1.4)	0.6 (0.3, 0.9)	0.5 (0.3, 1.0)		
Non-locomotive MVPA (METs • h)	2.4 (1.8, 3.5)	2.2 (1.9, 2.4)	1.8 (1.1, 2.2)		
Total locomotive PA (METs • h)	2.5 (1.8, 3.5)	2.0 (1.5, 2.7)	1.9 (1.2, 2.8)		
Total non-locomotive PA (METs • h)	8.5 (5.9, 11.3)	7.9 (6.6, 9.7)	7.0 (4.5, 9.9)		
Total activity (METs • h)	11.2 (8.7, 14.2)	9.4 (8.6, 11.9)	9.3 (7.0, 11.5)		
Male (n (%))	9 (23.7)	3 (11.1)	8 (14.5)		
Have an exercise habit (n (%))	27 (71.1)	12 (44.4)	13 (23.6)		
Have 10-13 years of education (n (%))	32 (84.2)	25 (92.6)	21 (38.2)		
Employed (n (%))	11 (28.9)	4 (14.8)	7 (12.7)		
Financially comfortable (n (%))	19 (50.0)	14 (51.9)	4 (7.3)	*	
Living alone (n (%))	2 (5.3)	2 (7.4)	6 (10.9)	*	
Married (n (%))	25 (65.8)	17 (63.0)	12 (21.8)		
Have had a fall (n (%))	7 (18.4)	7 (25.9)	5 (9.1)		
Have been hospitalized (n (%))	8 (21.1)	5 (18.5)	4 (7.3)		

Data are presented as median (interquartile range). BMI: body mass index; SB: sedentary behavior; LPA: light-intensity physical activity; MVPA: moderate to vigorous physical activity.
[1)]Comparison among the three social frailty groups was performed using the Kruskal–Wallis test.
Multiple comparisons were performed using the Mann–Whitney U test with Bonferroni's correction ($p<0.05/3=0.017$) to account for multiplicity (with significant differences between groups). For the nominal scale, the χ^2 test and Fisher's direct method were used.
[2)]*: $p<0.05$,**: $p<0.001$.

Table 5. Comparison of physical activity indices by the number of overlapping types of frailty using the Kruskal–Wallis test

Evaluation item	Number of overlapping types of frailty[1)] a. Robust (n=16)	b. One type of frailty (n=27)	c. Two types of frailty (n=27)	d. Three types of frailty (n=12)	p[2)]	Multiple comparisons
Step counts (steps/day)	6,656.1 (5,410.8, 1,0943.7)	5,878.3 (4,587.2, 8,158.2)	4,320.2 (3,151.1, 6,582.9)	4,600.4 (3,237.5, 6,783.8)		
SB (METs • h)	5.1 (4.1, 6.4)	4.0 (3.4, 5.1)	4.4 (3.7, 6.1)	4.4 (3.4, 4.6)		
Locomotive LPA (METs • h)	1.5 (1.1, 2.1)	1.3 (0.9, 1.9)	1.3 (0.8, 1.6)	1.5 (1.2, 2.0)		
Non-locomotive LPA (METs • h)	6.7 (5.1, 7.8)	5.0 (4.2, 7.1)	5.5 (4.1, 7.9)	6.6 (4.2, 7.1)		
Locomotive MVPA (METs • h)	1.1 (0.8, 1.9)	0.7 (0.4, 1.0)	0.4 (0.3, 1.0)	0.5 (0.4, 0.9)	*	a>c
Non-locomotive MVPA (METs • h)	2.8 (1.8, 3.9)	2.3 (1.9, 2.7)	1.9 (1.4, 2.2)	2.1 (1.4, 2.9)		
Total locomotive PA (METs • h)	2.8 (2.0, 3.6)	2.3 (1.6, 3.0)	1.8 (1.2, 2.3)	2.1 (1.4, 2.9)		
Total non-locomotive PA (METs • h)	9.5 (6.7, 11.7)	7.5 (6.2, 9.6)	7.3 (5.1, 10.1)	8.9 (5.4, 9.4)		
Total activity (METs • h)	11.7 (9.5, 15.5)	9.7 (8.6, 12.4)	8.9 (7.3, 11.9)	11.0 (7.5, 11.3)		

Data are presented as median (interquartile range). BMI: body mass index; SB: sedentary behavior; LPA: light-intensity physical activity; MVPA: moderate to vigorous physical activity.
[1)]Comparison between the four groups was performed using the Kruskal–Wallis test (with significant differences between groups).
Multiple comparisons were performed using the Mann–Whitney U test with Bonferroni's correction ($p<0.05/4=0.013$) to account for multiplicity.
[2)]*:$p<0.05$.

In the present study, an association was observed between locomotive MVPA and two overlapping types of frailty. Only a few studies have examined the association between concurrent physical, cognitive, and social frailty and adverse events. A longitudinal study of 2,375 community-dwelling older adults aged ≥55 years reported that, compared with a robust group with no cognitive impairment, a frail with cognitive impairment group had a 12 to 13 times higher prevalence and incidence of functional impairment, 5 to 27 times higher prevalence and incidence of reduced quality of life, and 5 times higher risk of death[21)]. Moreover, a longitudinal study that followed 2,406 community-dwelling older adults for 3 years reported that a combination of physical and social frailty measures could more accurately identify individuals at increased risk of functional impairment than physical or social frailty alone[38)]. Furthermore, two or more overlapping physical frailty, cognitive frailty, and social frailty were reported to have adverse effects on the risk of falls, ADL impairment, and Ikigai among community-dwelling Japanese older adults[39)]. Although these studies suggest the negative effect of two or more overlapping types of frailty on adverse events, none of them compared the amounts of PA measured by accelerometers according to the number of overlapping types of frailty, as in this study. Future studies on this topic are warranted to assess the effect of each type of frailty on long-term care prevention from the perspective of prognosis prediction for adverse events.

The limitations and challenges of the present study include the anticipated effects of the COVID-19 pandemic, such as restrictions on going out and socializing, which might have negatively affected both frailty and PA measurements. Moreover, since the sample size was small, a future study with a larger sample size will be necessary to examine further the relationships between physical, cognitive, and social frailty and the amount of PA. Furthermore, cognitive frailty was defined as a combination of subjective cognitive decline and physical prefrailty based on previous studies. This definition was adopted because the prevalence of cognitive frailty was expected to be low if objective cognitive decline was used instead, and also, the burden on participants was relatively low. However, in future studies, assessing objective cognitive decline might be necessary to provide more reliable results. Finally, the causal relationship between each type of frailty and the amount of PA needs to be verified by conducting longitudinal studies in the future.

In conclusion, the present study examined relationships between physical, cognitive, and social frailty and locomotive and non-locomotive MVPA to explore effective methods for future frailty prevention, and found that physical frailty, but not cognitive or social frailty, was associated with step counts and locomotive MVPA. The associations remained unchanged in multivariate analyses adjusted for age and gender. Future interventions to increase step counts and locomotive MVPA may be important for preventing physical frailty, although interventions other than simple PA will need to be considered for the prevention of cognitive and social frailty.

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