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Sedentary Behavior Strongly Associated with the Number of Steps Taken by Frail Older Adults: A Cross-Sectional Study

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Abstract

Objectives: *This study examined factors related to the number of steps taken by frail older adults.*

Methods: *This cross-sectional study involved 35 frail older adults aged 84.7 ± 5.9 years who attended a day-care center in Japan. The number of steps taken and time spent sitting were measured in 24 hours for 6 days using an accelerometer, knee extension strength, modified falls efficacy scale, timed up and go test, short physical performance battery, functional independence measure, and the Fillenbaum's instrumental activities of the daily living screener. The factors contributing to the number of steps taken were investigated using stepwise multiple regression analyses.*

Results: *The mean number of steps taken per day (standard deviation) by all participants was 1,446.6 (886.2). In the stepwise multiple regression analyses, the number of steps taken was significantly affected by the time spent sitting (β = -0.674) and the short physical performance battery (β = 0.298).*

Conclusions: *The study results suggest that less sedentary activity and improved lower extremity function may increase the number of steps taken by frail older adults.*

Key words: *Number of daily steps; Sedentary behavior; Accelerometer; Japanese frail older adults.*

Introduction

The number of daily steps taken decreases with age. In healthy older adults over 65 years, fewer than 5,000 steps per day results in reduced activities of daily living (ADL)[1]. Furthermore, fewer than 2,000 steps per day leads to becoming bedridden[2].

It has been shown that in older adults, the number of daily steps taken decreases due to medical conditions, physical factors, and cognitive factors. Depressive symptoms and worsening knee osteoarthritis (OA) are associated with a decline in the number of daily steps taken by older adults[3]. Reduced muscle strength[4, 5], balance[5], walking ability[6], ability to stand up and sit down using a chair[7], and fear of falling[6] are factors that reduce the number of steps taken in community-dwelling older adults.

Frail older adults take fewer steps than healthy older adults. Our previous study suggested that the number of steps taken per day by frail older adults who attend day-care centers was around 1,500[8]. It is inferred that these populations are older, and their cognitive and physical functions are reduced as compared to healthy older adults. Also, their inactivity has further increased due to reduced domestic and social roles such as parenting and work[9]and the lack of spontaneity[10]. However, the factors that predict the number of daily steps taken by frail older adults have not been clearly demonstrated.

Sedentary behavior, which is defined as "all arousal behaviors with energy consumption of 1.5 METs or less in sitting and lying positions"[11], is a risk factor for mortality and several morbidities among older adults regardless of physical activity level[12, 13]. Patel *et al.* showed an association between time spent sitting and mortality in 123,216 middle-aged and older adults aged 50 to 74 years (mean age, males 63.6 years, females 61.9 years). As a result, they reported that the length of time spent sitting was associated with mortality regardless of the amount of physical activity undertaken[14].

A recent report by Hamer *et al.* examined the factors related to sedentary behavior in 6,228 community-dwellingmiddle aged and older adults (aged 64.9 ± 9.1 years) and found that more extended periods of time spent sitting is associated with lower muscle strength, independent of physical activity[15]. Meanwhile, in community-dwelling frail older adults (aged 74.2 ± 9.8 years),it is reported that both reducing the time sedentary behavior and increasing the physical activity may prevent frailty syndrome as a potential marker in screening of frailty[16].In other words, in frail older adults, it is inferred that physical activity and sedentary behaviordemonstratea trade-offrelationship. Therefore, we hypothesized that sedentary behavior and physical activity in frail older adults are closely related and that more extended time spent sitting may negatively impact the number of steps taken by frail older adults. The purpose of this study was to clarify the factors related to the number of steps taken by frail older adults.

Materials and Methods

Study Design and Participants

This study was a cross-sectional study of frail older adults attending a day-care center. This study was analyzed usingthe baseline data from the our previous study, which was the intervention study to increase the number of steps taken by frail older adults attending the day-care center in Japan[17].The participants were recruited from three centers; two were located in Osaka prefecture and one in Shiga prefecture. The inclusion criteria were as follows: 65 years or older, able to walk indoors by themselves (regardless of the use of a walking aid), able to understand the purpose of the study, and provided consent. The exclusion criteria were as follows: pacemaker implantation and a Mini-Mental State Examination score under 24. In total, 35 participants who met the criteria (mean age 84.7 ± 5.9 years, 27 females, 77.1%) were included in the analysis. A verbal explanation of the purpose of this study was provided, and written informed consent was obtained. This study was conducted with the approval of the research ethics committee of Osaka Prefecture University (2019-119), initiated after registration with the Research Ethics Committee of University Hospital Medical Information Network Center (registration number: UMIN000023191).

Procedure

From September 2016 to March 2018, all participants had their height and bodyweight measured and underwent the Mini-Mental State Examination (MMSE). Additionally, we collected participants age, the frequency that they attended the day-care center per week, marital status, and cohabiting family. Subsequently, we investigated participants objective physical activity, sedentary behavior, fear of falls, physical function, activities of daily living (ADL), and instrumental ADL (IADL).

Assessment

The number of daily steps taken and time spent sitting were measured. A wrist-worm three-axis accelerometer (UP2; Jawbone Inc., San Francisco, CA) was used for 8 days. This device can measure the number of steps taken and the length of sedentary periods using proprietary algorithms[18]. Additionally, it connects to the device on which the UP2-dedicated application is installed using Bluetooth. The weight of the accelerometer is approximately 20 g, it is water-resistant for up to 1 m, and has a battery life of 10 days. Therefore, it is not necessary to remove it before bathing every day. The reliability and validity of this device have been reported in many studies. A systematic review showed a high validity of the step count measured[19]. Furthermore, the step count measurement was found to be accurate for walking undertaken in laboratory and free-living conditions[20, 21]and at the optimal walking pace of older adults[22]. The mean number of steps taken was calculated using the accelerometer data of 6 days, with the first and last days at the time of the three evaluations excluded.

The Modified Falls Efficacy Scale (MFES) was measured to assess participant's fear of falling. The

MFES is a 14-item scale based on the Falls Efficacy Scale developed[23] and further modified by Hill *et al.*[24]. The subjects were asked to give a score from 0 (no confidence) to 10 (complete confidence). The lower the total score, the stronger their fear of falling. The MFES has a total score of 140 points.

Physical function was measured by knee extension muscle strength, the timed up and go (TUG) test, and the Short Physical Performance Battery (SPPB). Knee extension muscle strength was assessed using a manual holding-type dynamometer (Anima Co., Ltd.; μ-Tas F-100, Tokyo, Japan) in a seated position. The force sensor was placed 10 cm above the lateral malleolus. The isometric knee extension muscle strength under the maximum effort with the knee joint 90° bent was measured twice on each side, with the maximum value taken as representative. The muscle torque value was calculated by multiplying the lever arm length (distance between the lateral knee joint line and the point of force application) to determine the body weight ratio (Nm/kg). Then, the muscle torque value was divided by the participant's weight[25]. As for the TUG, participants were asked to stand up from a chair, walk 3 m at an optimal speed, turn at a designated spot, return to the seat and then sit back down. The time taken to complete the task was recorded by a physical therapist using a stopwatch. The time was measured from the moment the physical therapist clinician said 'go' to the moment the participant sat back down on the chair. This measurement was carried out twice, with the minimum value was taken as representative. The TUG has been reported to have high reliability and validity as an assessment of balance in frail older adults[26]. The SPPB was used to assess overall physical performance[27]. The SPPB is comprised of three tests: a hierarchical assessment of standing balance, a short walk, and standing from a seated position. Specifically, it measures standing time on both feet, semi-tandem and tandem positions, maximum walking speed over a 4 m distance, and standing/sitting time five times. Each test was scored from 0 (worst performance) to 4 (best performance). Additionally, a total score was obtained for the entire battery that was the sum of all 3 tests, which varied between 0 and 12[28]. This assessment has been used by international working groups and reported to be reliable and valid as an indicator of the physical performance of frail older adults[29, 30].

The Functional Independence Measure (FIM) and the Fillenbaum's IADL (FIADL) screener[31] were used to assess ADL and IADL, respectively. The FIM scores ranged from 18–126, with higher scores indicating higher activity levels. The FIADL consists of the following five items: 1) can you get to places out of walking distance?, 2) can you go shopping (groceries/ clothing)?, 3) can you prepare your own meals?, 4) can you do your housework?, and 5) can you handle your own money? Participants received 1 point when they could perform the task without assistance. When some kind of assistance was needed, they received 0 points. More than 4 points is reflective of high independence in IADL[32].

Statistical Analysis

Data are expressed as a mean (standard deviation) or frequency (percentage). The Shapiro-Wilk test was used to examine the normality of variables. By applying Spearman's rank-order correlations, the associations between the number of steps taken and the measured variables, i.e., age, gender, sitting time, knee extension strength, TUG, SPPB, MFES, FIM, and FIADL, were assessed. A stepwise multiple regression analysis was performed to determine the correlation between the number of steps taken and the measured variables. To confirm the existence of multicollinearity between the input variables, the variation inflation factor (VIF) was calculated. SPSS version 25 for Windows (IBM Corporation, Armonk, USA) was used for all analyses. A p-value ofless than 5% was considered statistically significant.

Table 1. Characteristics of the study participants (N = 35)

Characteristics	Mean (SD)
Age (years)	84.7 (5.9)
Females, *n* (%)	27 (77.1)
Height (cm)	148.6 (8.1)
Weight (kg)	49.7 (10.7)
BMI (kg/m^2)	22.5 (4.7)

MMSE (scores)	27.2 (1.8)
Frequency per week attending day-care center (times/week)	2.4 (1.3)
Married, *n* (%)	32 (91.4)
Cohabiting family, *n* (%)	26 (74.3)
Number of steps (steps/day)	1,446.6 (886.2)
Sitting time (hour/day)	6.1 (1.3)
MFES (scores)	93.4 (28.3)
Knee extension strength (Nm/kg)	0.9 (0.3)
TUG (sec)	16.2 (6.5)
SPPB (scores)	7.5 (2.7)
FIM (scores)	115.3 (7.0)
FIADL (scores)	2.6 (1.6)

Data are presented as a mean (standard deviation; SD) or frequency (percentage). BMI: body mass index; MMSE: mini-mental state examination; TUG: timed up and go; SPPB: short physical performance battery; MFES: modified falls efficacy scale; FIM: functional independence measure; FIADL: Fillenbaum's instrumental activities of daily living

Results

Table 1 summarizes the characteristics and outcome measures of participants in this study. The MMSE score of participants was 27.2 (1.3 SD) points. The mean number of steps taken and time spent sitting was 1,446.6 (886.2 SD) steps/day and 6.1 (1.3 SD) hours, respectively. The ADL that were performed with minimal assistance had an average FIM score of 115.3. However, the low FIADL scores of 2.6 suggested that the majority of participants were dependent in IADL. The frequency with which participants attended the day-care center was 2.4 times/week.

The correlations between the number of steps taken and the outcomes measured are shown in Table 2. The number of steps taken significantly correlated with time spent sitting, SPPB, and FIM.

Table 3 shows the results of the multiple regression analyses. The stepwise multiple regression analyses indicated that the time spent sitting (β = -0.674) and SPPB (β = 0.298) were independent determinants of the number of steps taken. The adjusted R^2 was 0.627. As VIF was 1.045, the possibility of multicollinearity was low.

Table 2. Correlation between the number of steps taken and the outcomes measured

	Number of steps (steps/day)	
	correlation coefficient	*P-value*
Age (years)	0.068	0.698
Gender (0 = Females, 1 = Males)	-0.135	0.440
Sitting time (hour/day)	- 0.783	<0.01
MFES (scores)	0.253	0.142
Knee extension strength (Nm/kg)	0.222	0.200
TUG (sec)	-0.273	0.113
SPPB (scores)	0.406	0.016
FIM (scores)	0.352	0.038
FIADL (scores)	0.179	0.303

TUG: timed up and go; SPPB: short physical performance battery; MFES: modified falls efficacy scale; FIM: functional independence measure; FIADL: Fillenbaum's instrumental activities of daily living

Table 3. Stepwise multiple regression analyses to detect independent variables of the number of steps taken by frail older adults (N = 35)

Factors	B	SE	β	*P*-value
Sitting time	-457.801	74.99	-0.674	< 0.001
SPPB	98.566	36.463	0.298	0.011
Adjusted R^2		0.604		

B: regression coefficient; SE: standard error of regression coefficient; β: standard partial regression coefficient; SPPB: short physical performancebattery

Discussion

This study suggested that the number of steps taken by frail older adults attending a day-care center was affected by sitting time and SPPB. In particular, time spent sitting had a more significant effect on the number of steps taken than SPPB. This study shows that in frail older adults, the number of daily steps taken is strongly affected by sedentary behavior. Contrastingly, in middle and older adults, it is reported that physical activity and sedentary behavior were independent of each other[13-15].

Sedentary behavior has been reported to be any waking behavior with an energy expenditure of ≤1.5 METs that is undertaken in a seated or reclined position[33]. In a previous study, the majority of older adults in their 70s spent more than 5 hours watching television, regardless of gender[34]. Healy *et al.* also found that more than 60% of 10,012 Americans, including older adults, watched television for at least 2 hours a day in all age groups[35]. Patel *et al.* showed that the length of time spent sitting was associated with mortality regardless of the amount of physical activity undertaken in middle-aged and older adults[14]. Gianoudis *et al.* reported that more extended periods of time spent sitting by older adults (mean age 67.5 years) increased the risk of sarcopenia by 33%, which was independent of physical activity and other lifestyle and confounding factors[36]. Therefore, it is recommended that strategies are implemented that aim to reduce the time spent sitting and increase the physical activity of community-dwelling older adults.

In the present study, the number of steps taken by frail older adults was significantly affected by the time spent sitting. The results of the frequency per week attending day-care center (2.4 mean), the FIM (115.3 mean), and the FIADL (2.6 mean) in our study showed that the participants rarely went out and had low IADL, even though their ADL at home were independent. The decreased frequency of going out and loss of higher ADL abilities may further increase the time spent sitting. This suggests that reducing the time spent sitting might lead to increased daily activity.

The SPPB, which comprehensively assesses balance ability, walking speed, and lower limb muscle strength as an index for evaluating lower limb function in older adults, was also one factor that contributed to the number of steps taken by frail older adults. In a previous study of community-dwelling older males (mean age 74.1 years), the SPPB was significantly associated with Gait Speed, Stair Climb, and lower extremity strength among high physical activity groups[37]. Another study suggested that the low-activity group had a mild to moderately greater risk for mobility-related disability and dependency in ADL than the high-activity[38]. In frail older adults, decreased SPPB, a composite assessment of lower limb physical function, influenced a lower number of steps through reduced physical function and mobility.

This study had some limitations. First, because of the small number of participants, the results cannot be applied generally to all frail older adults. Second, we did not investigate the medical conditions that could affect the number of steps taken, such as depression and knee pain due to knee OA. In the future, such medical conditions should be considered. Finally, we did not consider the influence of seasonal variation on the number of steps taken. However, the LSA indicated that most of the participants spent the majority of their time inside and generally went out only to attend the day-care center.

Conclusion

Our findings suggest that less time spent sitting, and higher levels of physical performance may help to increase the number of steps taken by frail older adults who attend a day-care center in Japan. For frail older adults, changing daily sedentary habits may be efficacious for increasing the number of steps taken and lead to a more independent life.

Conflict of Interrest: The authors have no conflicts of interest to declare.

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