Association of activities of daily living with the load during step ascent motion in nursing home-residing elderly individuals: An Observational Study

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The present study is an expansive analysis of our cross-sectional study that has been published previously as an article titled ‘‘Association between physical function and the load pattern during stepping-up motion in community-dwelling elderly women’’ (2016).

Objective: This study aimed to examine the association of independence in ADL with the loads during step ascent motion and other motor functions in 32 nursing home-residing elderly individuals.

Design: Independence in ADL was assessed by using the functional independence measure (FIM). The loads at the upper (i.e., pulling up) and lower (i.e., pushing up) levels during step ascent task was measured on a step ascent platform. Hip extensor, knee extensor, plantar flexor muscle, and quadriceps setting strengths; lower extremity agility using the stepping test; and hip and knee joint pain severities were measured. One-legged stance and functional reach distance for balance, and maximal walking speed, timed up-and-go (TUG) time, five-chair-stand time, and step ascent time were also measured to assess mobility.

Results: Stepwise regression analysis revealed that the load at pushing up during step ascent motion and TUG time were significant and independent determinants of FIM score. FIM score decreased with decreased the load at pushing up and increased TUG time.

Conclusions: The study results suggest that depending on task specificity, both one step up task's push up peak load during step ascent motion and TUG, can partially explain ADL's FIM score in the nursing home-residing elderly individuals. Lower extremity muscle strength, agility, pain or balance measures did not add to the prediction.

Key Words: Elderly, Activities of daily living, Step ascent motion, Load

Decline in physical function with aging causes a decline in independence in activities of daily living (ADL) in elderly individuals.[1] The declined independence in ADL leads to increased burden on caregivers, further decline in physical function, and increased need for care and medical costs in elderly individuals. Furthermore, physical function and independence in ADL of elderly residing in nursing homes decline in comparison with those of community-dwelling elderly individuals. Thus, it is important to clarify the relationships between ADL independence and physical function in order to slowdown the decline in ADL in elderly individuals residing in nursing homes.

Functional independence measure (FIM)[2] is an ADL scale used in rehabilitation. FIM has high validity[3] and intrarater and interrater reliability.[4] FIM consists of items such as motor and cognition functions, and can assess independence in general ADL. Previous studies demonstrated that FIM score is associated with lower extremity muscle strength[5,6] and balance[7,8] in patients with neurological or muscular disorders. FIM was also demonstrated to be associated with lower extremity muscle strength in community-dwelling elderly individuals.[9] Furthermore, a previous study[1] reported that stair ascent time predicts partially the decline in independence in ADL in community-dwelling elderly individuals. However, studies indicated that lower extremity muscle strength is associated with independence in ADL[5,6,9] measured muscle strength in the non-loading position, such as the lying or sitting position, while ADL involve lower extremity motion not only in the non-loading position but also in the loading position, such as the standing position. Loading during step ascent motion[10] requires far greater lower extremity strength compare to just walking[11]. Araki et al.[10] demonstrated that step ascent time increases with decreased load during step ascent motion. The loads during step ascent motion are indicators of the magnitude, timing, and duration of loading, and it could assesses physical function during body forward progression and upward push. Thus, the loads during step ascent motion, which assesses physical function, may be associated with ADL score. However, it is unclear whether the load during step ascent motion can better predict independent ADL score than other indicators such as lower extremity muscle strength,[5, 6] standing balance,[7, 8] stair ascent time,[1] and lower extremity agility or pain assessed generally in elderly individuals. Furthermore, the declined ability to load during step ascent motion and the declined independence in ADL caused by the difficulty to push upward may influence cognitive function and lead to the decline in independence in general ADL. Thus, although the loads during step ascent motion may be associated with independence in general ADL, the quantitative relationships between physical function, ADL, and cognition have not been tested.

The present study examined quantitatively the association of independence in general ADL as assessed by the FIM, with the loads during step ascent motion, measured on a step ascent platform, and lower extremity muscle strength, lower extremity agility and pain, balance, and mobility in elderly individuals residing in nursing homes.

METHODS

Participants

Thirty-two elderly individuals (9 men and 23 women, aged 83.0 ± 6.9 years) residing in 3 nursing homes in Kyoto, Japan, were included in the present study. The participants performed all measured tasks including the step accent test without using assistance devices or handrails. Subjects unable to walk without assistance were excluded. Furthermore, subjects were excluded if they had severe orthopedic, neurological, respiratory, circulatory disorders, or severe dementia.

The protocol was approved by the ethics committee of the Kyoto University Graduate School and Faculty of Medicine. The participants provided informed consent in writing. This study conforms to all STROBE guidelines and reports the required information accordingly (see Supplementary Checklist).

ADL assessment

Independence in ADL was assessed by using the FIM, which has 18 items in total.[2] The FIM consists of motor function evaluation (13–91 points), including 6 items (6–42 points) on self-care, 2 items (2–14 point) on sphincter control, 3 items (3–21 points) on transfer, and 2 items (2–14 points) on locomotion; and cognitive function (5–35 points) evaluation, which includes 2 items (2–14 points) on communication and 3 items (3–21 points) on social cognition. All subsets of the FIM were assessed. Each item was rated as 1–7 points, and the sum of the scores in each item was expressed as

18–126 points. A large point indicated a high independence in ADL.

Load during step ascent motion

For assessment of load during step ascent motion, a step ascent platform (Kyoritsu Denshi Kogyo, Osaka, Japan) was used based on a previous study.[10] The step ascent platform (step height, 15 cm; width, 70 cm; and tread depth, 35 cm) consisted of 4 electronic weighing scales placed onto the upper (right and left) and lower (right and left) levels. The loads at the upper and lower levels during step ascent task were collected using custom-made software and sampling at 100 Hz.

The starting position was standing on the lower level, with the right foot on the right and the left foot on the left weight meters. The subjects ascended as fast as possible onto the next step without using handrails, starting with the right foot. The ending position was standing on the upper level with the right foot on the right and the left foot on the left weight meters. The task of stepping up was repeated twice (Fig. 1). The first peak load at the upper level (i.e., pull up sub-phase of ascending the step) was recorded when the right foot loaded on the upper step while the last peak load at the lower level (i.e., push up sub-phase of ascending the step) was recorded when the left leg loaded on the lower step.[12] The two peaks (kg) were used for statistical analyses (Fig. 2). The mean value of each load was calculated, and each load was presented as a ratio of body weight. MATLAB version 8.3 (MathWorks, Natick, MA) was used for the data analyses.

To examine the intrarater reliability of the loads at both pulling up and pushing up during step ascent motion, the values obtained from the 2 measurements records of the 32 subjects in the present study were used for the statistical analyses.

Lower extremity muscle strength

For assessment of lower extremity muscle strength, hip extensor, knee extensor, plantar flexor, and quadriceps setting strengths were measured. The maximal voluntary isometric contraction (MVIC) of each muscle on the right side was measured twice, and the maximal value of two measurements was used for the analysis. Furthermore, the torque (Nm) was calculated by multiplying each MVIC value by the lever arm and presented as a ratio of body weight (Nm/kg).

Hip extensor muscle (Fig. 3a) and quadriceps setting strengths (Fig. 3b) (i.e., combined extensor muscle strength of the hip and knee joints, which was different from individual hip or knee extensor muscle strength) were measured by using a dynamometer (Locomo Scan; Alcare Co., Ltd., Tokyo, Japan) based on a previous study.[13] Hip extensor muscle strength was measured in the long-sitting position with the hips fixed with a belt to maintain a hip joint position of 70° flexion and the force sensor of the dynamometer placed under the popliteal fossa. The subjects were asked to press the thigh down against the force sensor without fixing the distal part of the right leg with a belt. Quadriceps setting strength was measured in the position similar to hip extension strength. The distal part of the right leg was fixed with a belt. The subjects were asked to extend the knee joint by pressing down on the force sensor at the popliteal fossa fixing the distal part of the right leg with a belt. The lever arms were determined as the length between the trochanter major and the lateral knee joint in these measurements.

Knee extensor muscle strength was measured by using a handheld dynamometer (μ Tas F-1; Anima Co., Ltd., Tokyo, Japan). Knee extensor muscle strength was measured in the sitting position with hip and knee joint positions of 90° flexion. The force sensor that was fixed with a belt placed in the height of the malleolus lateralis. The lever arm was determined as the length between the lateral knee joint and the malleolus lateralis.

Plantar flexor muscle strength (Fig. 4) was measured by using a handheld dynamometer (Mobie; Sakai Medical Co., Ltd., Tokyo, Japan) in the long-sitting position, with the hips fixed with a belt to maintain a hip joint position of 70° flexion and knee position of full extension and ankle joint position of 0° plantar flexion, and a belt connecting to the pull sensor of the dynamometer, placed around the heads of the first and fifth metatarsal bones. The lever arm was determined as the length between the malleolus lateralis and the head of the fifth metatarsal bone.

Lower extremity agility

For lower extremity agility assessment, the stepping test (step) was performed once in the standing position, using a step counter (Takei Scientific Instruments Co., Ltd., Niigata, Japan). The subjects were asked to step as fast as possible. The number of steps within 5 seconds was counted.

Lower extremity pain

For lower extremity pain assessment, the severities of bilateral hip and knee joint pains in the present were assessed by using the numerical rating scale (NRS) before the stepping test, which was expressed as 0 (no pain) –10 (worst possible pain). The subjects were assessed as “having lower extremity pain” if they had pain with a severity rating of ≥1 on the NRS in more than one joint.

Balance

For balance assessment, one-legged stance time (s) and functional reach (cm) distance were measured. One-legged stance time with eyes open was performed standing on the right lower extremity. For functional reach test, anterior reach distance was measured in the standing position keeping the right arm lifted to a horizontal position. One-legged stance time and functional reach distance were measured twice, and the greater of the two values were calculated.

Mobility

For mobility assessment, maximal walking speed (m/s), timed up-and-go (TUG) time (s), five-chair-stand time (s), and step ascent time (s) were measured. The maximal walking speed was determined over a 5-m distance. A 1-m distance to accelerate and decelerate before and after the test distance was provided. The walking time for the 5-m distance was measured once by using photoelectric tubes (TC Timing System; Brower Timing Systems, UT, USA), which could measure the walking time automatically using photoelectrons, placed 1 and 6 m from the starting line based on a previous study.[13] Walking speed was calculated from the walking time.

The TUG time was measured once as the time that the subjects stood up from the sitting position in a standard chair without arm rests, walked a 3-m distance, turned, walked back to the chair, and sat down as fast as possible. The five-chair-stand time was measured once as the time that the subjects stood up from the sitting position in a standard chair without armrests and sat down as fast as possible five times.

The step ascent time was measured twice on the above-mentioned step ascend platform. The subjects ascended as fast as possible onto a 15-cm-high step without using handrails, starting with the right foot. The starting position was standing on the lower level, with the right foot on the right and the left foot on the left weight meters. The step ascent time was measured as the time from when the load at the right lower level was less than 1 kg to the timing when the load at the left upper level reached above 1 kg. The mean value of two measurements was calculated. MATLAB version 8.3 (MathWorks, Natick, MA) was used for the data analyses.

To examine the intrarater reliability of the step ascent time measured on the step ascent platform, the values of two measurements records of 32 subjects were used for the statistical analyses.

Statistical analyses

Statistical analyses were performed by using SPSS version 21.0 (IBM Japan; Tokyo, Japan). Intraclass correlation coefficients [ICC(1.2)] were calculated to test the intrarater reliability of the loads and step ascent time measurements.

Stepwise regression analysis was used to investigate the associations between the depended variable FIM score using the loads during step ascent motion, lower extremity muscle strength, lower extremity agility and pain, balance, mobility, age, height, and sex as the independent variables. To monitor for a multicollinearity effect, the variance inflation factor (VIF) was investigated. Statistical significance was set at a *P* value of 0.05.

RESULTS

Table 1 presents the participants' characteristics, ADL, the loads during step ascent motion, lower extremity muscle strength, lower extremity agility and pain, balance, and mobility. In the reliability analysis of right and left feet loading and step ascent time measurements, the ICC (1,2) values were 0.989 for the load at pulling up, 0.902 for the load at pushing up, and 0.889 for step ascent time, which indicated a high intrarater reliability.

The stepwise regression analysis revealed that the load at pushing up of the left lower extremity during step ascent motion and TUG test were significant and independent determinants of the FIM score having a coefficient of determination $R^2 = 0.38$; that is, the FIM score decreased with the decreased the load at pushing up and also decreased with increased TUG time. As the VIF value was 1.27, the multicollinearity effect in a regression equation was not observed (Table 2).

DISCUSSION

Identifying the determinants that predict independence in ADL and the prevention of the decline in independence in ADL is important research question when attempting to better understand the needs of elderly individuals residing in nursing homes. To the best of our knowledge, this study is the first to examine the association of independence in general ADL as assessed by using the FIM, with the loads during step ascent motion measured by using a step ascent platform.

Stepwise regression analysis showed that FIM score was associated with the push up load and not with the pull up load. FIM includes the evaluation of transfer ability, bed and chair, toilet, and tub and shower. Furthermore, FIM includes items such as locomotion (i.e., walking and stair ascent motion). Previous study[10] demonstrated that the time needed to ascend one step as fast as possible was associated with the load at the lower level but was not associated with the load at the upper level, similarly to the result in the present study. The load applied on the upper step at pulling up is considered an index that includes the ability to support the body with the lower extremity while maintaining a single limb upright balance. It was confirmed that the load at the upper level was positively associated with one-legged stance time in our data. In contrast, the load applied on the lower step at pushing up can be an index for measuring the ability to push the body up and forward. Furthermore, muscle power caused by pushing-off with the trailing lower extremity was demonstrated to be important during walking.[14] Thus, it is plausible to state that the load at the lower level, which indicates pushing up ability, rather than the load at the upper level, was associated with independence in ADL.

In the present study, FIM score was associated with the load at pushing up during step ascent motion but not with lower extremity muscle strength such as hip extensor, knee extensor, plantar flexor muscle, or quadriceps setting strengths. On the contrary, various previous studies demonstrated the association of walking and stair ascent abilities and FIM score with lower extremity muscle strength. Some studies demonstrated that walking speed was associated with knee extensor[15] and plantar flexor[16] muscle strengths in community-dwelling elderly individuals. Other studies demonstrated that walking speed was associated with hip flexor, hip abductor muscle, and quadriceps setting strengths, but not with hip extensor, knee extensor, and toe grip muscle strengths,[13] and that stair ascent speed was associated with knee extensor and flexor muscle strengths[17] in community-dwelling middle-aged and elderly individuals. In addition, one study demonstrated that FIM score was associated with lower extremity muscle strength in community-dwelling middle-aged and elderly individuals.[9] The reason FIM score was associated with the load at pushing up during step ascent motion rather than with lower extremity muscle strength in the non-loading position in the present study may be that independence in ADL assessed by using the FIM, which consists of items such as transfer and locomotion (i.e., walking and stair ascent motion), involved not only lower extremity motion in the non-loading position but also that in the loading position such as the standing position.

FIM score was also associated with the TUG time in the present study. A previous study[18] demonstrated that independence in ADL as assessed by using the Barthel Index is associated with TUG time in patients with orthopedic or neurological disorders. Another study[19] demonstrated that falls are associated with TUG time in community-dwelling elderly individuals. Our data concurred with the aforementioned studies and support the incorporation of TUG when evaluation mobility of elderly individuals.

In the present study, independence in ADL was not associated with lower extremity agility and pain, balance, maximal walking speed, five-chair-stand time, or step ascent time. A longitudinal study demonstrated that stair ascent time predicts the decline in the level of independence in ADL in community-dwelling elderly individuals.[1] The none corroborating results might be caused by the differences in ADL assessment method and step ascent motion measurement between the present study (i.e., the FIM and one step ascent time) and the previous study (i.e., assessment except for the FIM and stair ascent time). Differing results also might be have been due to the difference in study participants between the present study (i.e., elderly individuals residing in nursing homes) and the previous study (i.e., community-dwelling elderly individuals). The results of the present study showed that FIM score was associated with the load at pushing up during step ascent motion and TUG time rather than with mobility such as maximal walking speed, five-chair-stand time, or step ascent time.

The FIM is used to evaluate not only motor function but also cognitive function. Cognitive function includes items such as communication (i.e., comprehension and expression) and items such as social cognition (i.e., social interaction, problem solving, and memory). A previous study demonstrated that training intervention that consists of aerobic exercise such as walking and dual task training to activate thinking and memory prevents the decline in general cognitive function and improves memory in community-dwelling elderly individuals with mild cognitive function.[20,21] In the present study, the elderly individuals with high load at pushing up may lead to maintain their cognitive function.

The present study has several limitations. First, designing a cross-sectional study, the causality of the FIM score with the load at pushing up during step ascent motion and TUG test was difficult to clarify. Whether a decrease in the load at pushing up and an increase in TUG time caused or resulted from the declined independence in FIM's ADL score is unclear. Second, though the study sample, which included elderly individuals residing in nursing homes, was comparatively small, the size was enough to meet the sample size needed in stepwise regression analysis.

In conclusion, depending on task specificity, both one step up task's push up peak load during step ascent motion and TUG, can partially explain ADL's FIM score in the nursing home-residing elderly individuals. Lower extremity muscle strength, agility, pain or balance measures did not add to the prediction. The load at the lower level during step ascent motion may be an important index to evaluate in elderly individuals residing in nursing homes. Future studies are needed to test the hypothesis that training can improve the load at pushing up during step ascent motion and can affect ADL positively in elderly individuals.

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FIGURE 1. Step ascent motion measurement on a step ascent platform.

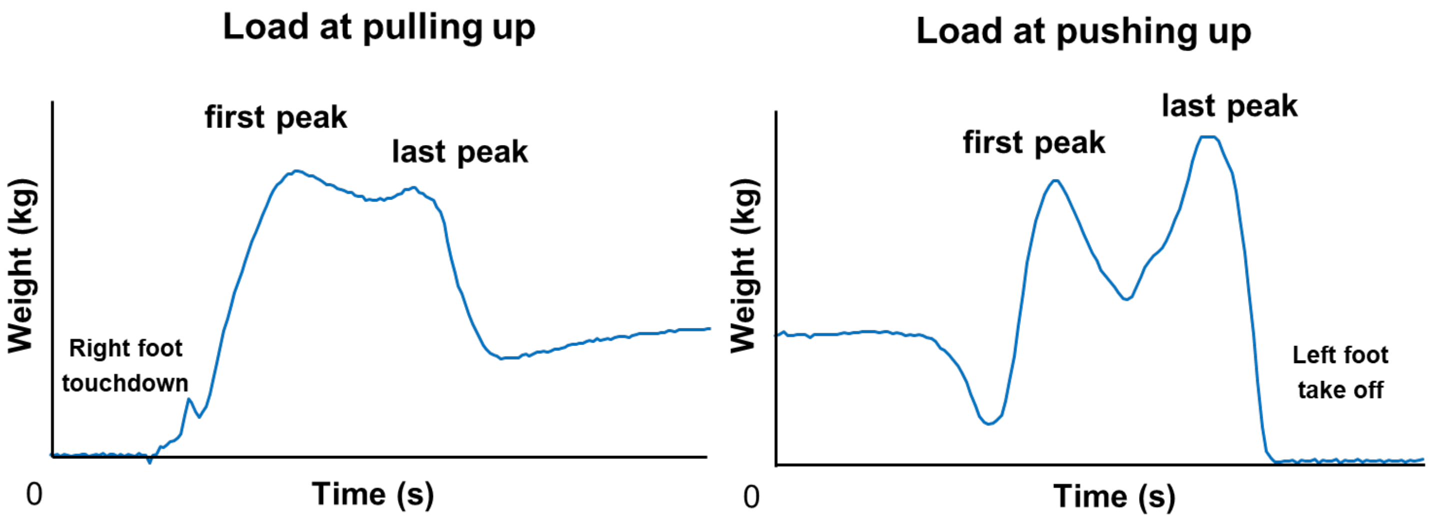
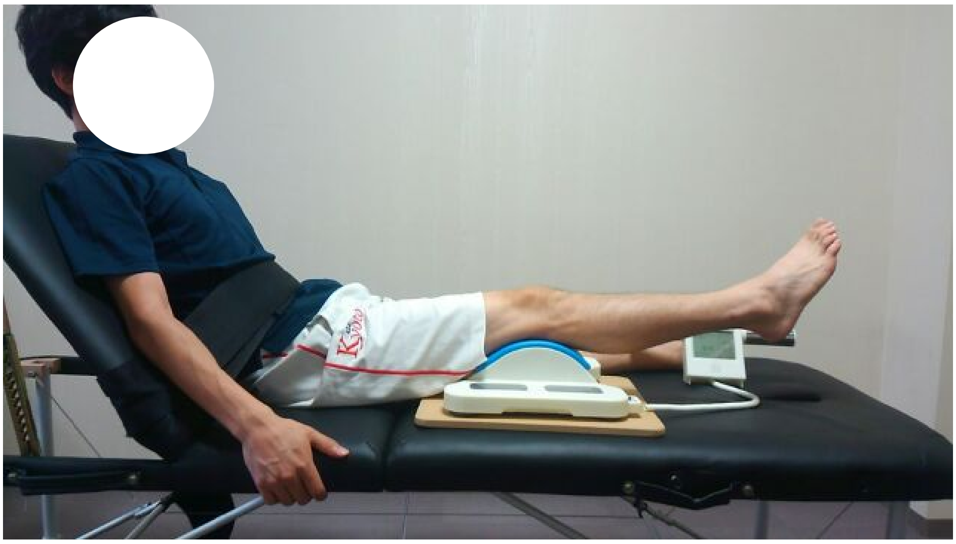


FIGURE 2. The loads at pulling up and pushing up during step ascent motion measured on a step ascent platform.

A



B

FIGURE 3. Measurement of hip extensor muscle and quadriceps setting strengths.

A, Hip extensor muscle strength. B, Quadriceps setting strength.

FIGURE 4. Measurement of plantar flexor muscle strength.