Asian Journal of Physical Therapy

Volume 1 | Number 2023 Article 1

2023

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Recommended Citation

Goda, Akio; Nakano, Hideki; Iwai, Hisami; Suruga, Kento; Watanabe, Mai; and Murata, Shin (2023) "Reproducibility and Validity of Muscle Strength in Hip Abduction with Flexion While Seated in Older Adults Who Need Nursing Care," *Asian Journal of Physical Therapy*: Vol. 1: No. 2023, Article 1.
Available at: https://digitalcommons.lmunet.edu/ajpt/vol1/iss2023/1

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Abstract

Objective: This study aimed to determine the usefulness of the strength of the muscles in hip abduction with flexion while seated (SMHAF-S) in older adults who need nursing care. To achieve this, we examined the reproducibility and validity of a method to measure the SMHAF-S in older adults who need nursing care using a hand-held dynamometer. **Methods:** This cross-sectional study enrolled 40 older women who needed nursing care in September 2021 and completed the SMHAF-S and underwent quadriceps muscle strength, grip strength, 10-s chair stand test for frail older adults (FCS-10), one-legged stance test (OLST), and timed-up-and-go (TUG) test. The reproducibility of the SMHAF-S was examined by determining the intraclass correlation coefficient (ICC). The validity of the relationship between the SMHAF-S and quadriceps muscle strength and other measurement items was examined by calculating Pearson's correlation coefficients. **Results:** In this cohort (age 83.6±5.2 years), the reproducibility of the SMHAF-S was excellent (ICC 0.91). Significant correlations were found between the SMHAF-S and quadriceps muscle strength, grip strength, FCS-10, OLST, and TUG test results ($p<0.05$). **Conclusion:** The SMHAF-S is a highly reproducible measurement method that reflects lower limb muscle strength and whole-body muscle strength, balance, and walking ability in older adults who need nursing care.

Keywords: muscle strength, hip abduction, flexion, older women, validity, reproducibility

Introduction

Japan, which faces a super-aging population, the number of older people certified as requiring support or care under the long-term care insurance system is increasing, and the growing costs for social security for older people have become a major social issue.[1] Among the factors that necessitate nursing care for older adults (age ≥65 years), 37.3% of care certifications are attributable to "frailty due to aging," "fracture/fall," and "joint disease,"[2] all of which are associated with lower limb muscle strength and function. A meta-analysis revealed that muscle weakness was the most common fall risk factor.[3] Therefore, regular muscle strength measurement for older persons who require long-term care is needed to monitor the changes in lower limb muscle strength over time, and it is crucial to maintain muscle strength to prevent the worsening of the level of care required.

Lower limb muscle strength is closely related to the ability to stand and move,[4] and is essential for older adults to live comfortably without inconvenience in their daily lives. However, muscle strength decreases with age,[5] and muscle weakness is more likely to occur in the lower limbs than in the upper limbs.[6] Thus, the deterioration of lower limb muscle strength in older adults is a problem that cannot be overlooked. Establishing a simple method to evaluate lower limb muscle strength is desirable for early detection of lower limb muscle weakness and initiating interventions for muscle strength maintenance and improvement.

Quantitative evaluation using a hand-held dynamometer (HHD) has been implemented as a simple method for evaluating lower limb muscle strength in older adults.[7] Kato et al. reported a method for assessing quadriceps muscle strength by fixing the HHD with a belt (the belt method).[8] However, the evaluation of knee joint extensor muscle strength using the belt method failed to demonstrate potential maximal muscle strength when the individual had pain in the knee joint.[9] Therefore, developing a lower limb muscle strength measurement method that can quantify the maximal muscle strength regardless of whether the individual has pain in the knee joint is desirable.

Matsumoto et al.[10] developed an HHD-based method to measure the strength of the muscles in hip abduction with flexion (SMHAF) with the individual in the supine position that has shown significant correlations between the SMHAF in the supine position and quadriceps muscle strength and physical function in healthy community-dwelling older persons.[11,12] However, this measurement method requires transferring a wheelchair user to a bed, which obligates time-consuming preparation for the measurement. Furthermore, securing a measurement environment in some facilities is difficult because space should be secured for the individual to lie on their back during the SMHAF measurement. Therefore, to resolve these drawbacks, we developed a novel method for measuring SMHAF while sitting (SMHAF-S).[13] This would enable clinically meaningful *in situ* measurement without changing the patient's position, even for patients who use wheelchairs. However, no study has evaluated the SMHAF-S measurement method in frail older individuals, as the other studies were conducted in healthy young people.[13] In frail older adults at high risk of falling, it would be clinically meaningful if it were found that easily measurable hip flexor strength in the sitting position is an indicator that reflects lower limb muscle strength and physical function, as it would enable earlier detection of fall risk in older adults and proactive preventive intervention. Therefore, this study aimed to examine the reproducibility and validity of the SMHAF-S in older adults with long-term care certification.

Methods

The participants were 47 older women certified as requiring long-term care and had used Day Care Facility A in September 2021. Of the 47 potential participants, only 40 were eligible for inclusion in this study based on the eligibility criteria (Mini-Mental State Examination [MMSE] scores≥20 and ability to perform all measurements[14]).

Participants were informed verbally and in writing of the purpose of the measurement and the publication of the results following the Declaration of Helsinki, and all participants provided written consent before the measure was conducted. The university's research ethics committee approved this study to which the principal investigator belongs (Ethical Review No. 21-17).

After collecting information about demographic characteristics (age, height, weight), nursing care needs level (support level 1 or 2, care level 1–5; "care" represents a more severe level of care than "support"; and higher numbers indicate a more severe level of care),[15] and MMSE scores, we measured quadriceps strength, grip strength, 10-s Chair Stand test for Frail Elderly (FCS-10), one-legged stance test (OLST), and the Timed Up and Go (TUG) test, in addition to SMHAF-S, in all participants. Furthermore, a manual muscle tester (Moby MT-100: Sakai Medical Co., Ltd.) was used to measure the SMHAF-S, with the participant in the sitting posture and the trunk in a vertical position, both upper limbs flexed, and the arms crossed in front of the chest, the foot on the floor, and with the hip and knee joints in approximately 90° flexion. Two belts attached to the pull sensor of the manual muscle tester were attached to the distal thigh on each side, and the length of the belts was adjusted such that the pull sensor was in close contact with the knee (Figure 1). The measurer held the foot and instructed the participant to "open your knees with full force while keeping your ankles together." The maximum isometric muscle force was measured twice during the hip abduction with flexion movement. The maximum value was divided by the body weight [kilogram force (kgf)/kg], and the value was used for analysis.

Figure 1. *Testing position for SMHAF-S assessment*

The quadriceps muscle strength was measured using a single-leg strength-measuring table (T.K.K. 5715: OG Wellness Co., Ltd.). The participant was positioned in a chair with the trunk in the vertical position and the lower leg in the drooping position. A foot belt was attached to the distal portion of the lower leg, and the isometric maximal muscle force was measured twice on each side during the knee extension. The maximum measured value was divided by the body weight and included in the analysis as the quadriceps muscle strength (kgf/kg).

Grip strength was measured using a grip strength tester Grip D (T2177: TOEI LIGHT). With the participant standing with both upper limbs hanging downward, the isometric maximum muscle force was measured twice on each side when grasping the grip strength tester. The maximum value was divided by the body weight to obtain the grip strength (kgf/kg).

The FCS-10 was measured according to the method of Murata et al.[16] During the measurement period of 10 seconds, the number of times that the individual stood up (cycles) from a seated position in a chair without armrests and with both upper limbs on the knees was measured. The individuals stood up from the starting position at the "start" signal, straightened to an upright posture, sat down immediately, and repeated the same action for 10 seconds. However, motions not completed at the end of 10 seconds (i.e., cycle from standing to sitting) were not counted. The FCS-10 was measured only once.

For the OLST, the maximum time (seconds) that the individual could hold the open-eyed, one-legged standing posture was measured once on each side, and the highest value was used in the analysis. Participants were instructed to stand barefoot, place both upper extremities lightly to the side, and gaze at a mark 2 meters before them.

For the TUG test, the measurement was initiated with the individual in the 90-degree hip flexion position and the 90-degree knee flexion position when seated in a chair. The time (seconds) required to stand up, walk to a cone placed 3 m from the front of the chair, and return and sit down in the chair was measured. Before the measurement, the participant was verbally instructed to complete the task as quickly as possible.[17] The TUG test was performed only once.

For the statistical analysis, the reproducibility of the SMHAF-S was examined by determining the intraclass correlation coefficient (ICC) (1,1) from the two measurements performed by one measurer. To interpret the ICC, we adopted the criteria proposed by Landis et al. (0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1.00, almost perfect).[18] Moreover, the validity of the SMHAF-S was examined by determining the Pearson's product rate correlation coefficient to ascertain the correlation with other measurement indices. To interpret the correlation coefficients, we adopted the criteria proposed by Chan (0.31–0.60, fair; 0.61–0.80, moderately strong; and 0.81–1.00, very strong).[19] Statistical analysis was performed using the SPSS (version 22, IBM, NY, USA), with a significance level of 5%.

Results

Participant Characteristics

Table 1. *Variables measured for all participants*

Variables	Mean ± SD
SMHAF-S 1st measurement (kgf/kg)	0.20 ± 0.09
SMHAF-S 2nd measurement (kgf/kg)	0.21 ± 0.08
Quadriceps strength (kgf/kg)	0.36 ± 0.13
MMSE (pts)	26.05 ± 2.95
Grip strength (kgf/kg)	0.37 ± 0.09
FCS-10 (cycles)	4.51 ± 1.82
OLST (s)	6.77 ± 9.06
TUG (s)	10.52 ± 3.34

Note. SMHAF-S = Strength of the Muscles in Hip Abduction with Flexion While Sitting, MMSE = Mini-Mental State Examination, FCS-10 = 10-s Chair Stand test for Frail Elderly, OLST = One-legged Stance Test, TUG = Timed Up and Go Test; kgf/kg = Kilogram-force/Kilogram, pts = Points, s =Seconds

In this study cohort, the mean ± SD age, height, and weight were 83.6 ± 5.2 years, 146.4 ± 5.7 cm, and 50.1 ± 10.1 kg, respectively. The breakdown of the certified nursing care needs of the participants was as follows: 20 participants required Support Level 1, 10 required Support Level 2, 6 required Care Level 1, 3 required Care Level 2, and 1 required Care Level 3. Table 1 shows the results of each assessment item. The ICC of the two SMHAF-S measurements was 0.91 (95% confidence interval: 0.83–0.95; p<0.01).

The results of the correlation analysis are presented in Table 2. Significant correlations were found between SMHAF-S and quadriceps strength, grip strength, FCS-10, OLST, and TUG test results. Similarly, quadriceps strength significantly correlated with grip strength, FCS-10, OLST, and TUG test results.

Table 2. *Correlation between SMHAF-S and the assessment items*

Variables	SMHAF-S (kgf/kg)	Quadriceps strength (kgf/kg)
Quadriceps strength (kgf/kg)	0.54†	-
MMSE (pts)	−0.05	0.22
Grip strength (kgf/kg)	0.32*	0.48†
FCS-10 (cycles)	0.50†	0.56†
OLST (s)	0.36*	0.55†
TUG (s)	0.58†	0.33*

Note. Values are Pearson's correlation coefficient; SMHAF-S = Strength of the Muscles in Hip Abduction with Flexion While Sitting, MMSE = Mini-Mental State Examination, FCS-10 = 10-s Chair Stand test for Frail Elderly, OLST = One-legged Stance Test, TUG = Timed Up and Go Test; kgf/kg = Kilogram-force/Kilogram, pts = Points, s =Seconds

** p<0.05*

†p<0.01

Discussion

This study examined the reproducibility and validity of measuring the SMHAF-S in 40 older women with long-term care needs certifications. The results showed significant fair correlations between the SMHAF-S and quadriceps strength and grip strength, FCS-10, OLST, and TUG test results. These results suggest the validity of the SMHAF-S as a lower limb muscle strength measurement method. In addition, the reproducibility of the two SMHAF-S measurements, which was indicated by an ICC of 0.91, demonstrated excellent reproducibility. Overall, this measurement method was confirmed to have high reproducibility and fair validity in older women who require nursing care.

Both SMHAF-S and quadriceps strength were significantly correlated with grip strength. Grip strength measurements have been reported to indicate overall muscle strength in older adults[20] because the tension in the abdominal and back muscles increases when grip strength is maximized, and the truncal muscles are connected to those of the lower limbs. In addition, a previous study reported a correlation between quadriceps muscle and grip strength.[20] In this study, we found a significant correlation between grip strength and the SMHAF-S, which suggests that the SMHAF-S is an index that reflects lower limb muscle strength and whole-body muscle strength in older women who require nursing care.

The FCS-10 test is where frail older people repeatedly stand up from a sitting position. The quadriceps,[21] gluteus maximus,[22] and hamstrings[23] are involved in this movement. The sitting hip abduction with flexion motion can be considered a combined motion of hip extension, abduction, and external rotation with the feet on the ground and involves muscles such as the gluteus medius, tensor fasciae latae, sartorius, rectus femoris, and biceps femoris,[24] which overlap with the lower limb muscle forces that are recruited during the standing motion. Therefore, it is suggested that the SMHAF-S reflects the strength of the lower limb muscles that mediate the rising motion.

Furthermore, significant correlations were found between the SMHAF-S and quadriceps muscle strength and the results of the OLST and TUG tests. The OLST evaluates the balance function in the standing posture, and a significant relationship exists between OLST and lower limb muscle strength in older adults.[25] Moreover, the TUG test evaluates the walking ability and dynamic balance, including standing, sitting, and changing direction in addition to walking. Quadriceps muscle strength correlates with the results of the OLST and TUG tests.[25,26] In this study, the correlation between the SMHAF-S and the results of the OLST and TUG test was attributed to the fact that the lower limb muscle groups that are involved in hip abduction with flexion movements (gluteus medius, tensor fasciae latae, sartorius, rectus femoris, and biceps femoris[24]) act to stabilize the pelvis in the one-legged standing position and promote postural control during quick rise and change of direction in the TUG test. The results suggest that the gluteus medius, tensor fasciae latae, sartorius, rectus femoris, and biceps femoris have a facilitatory effect on pelvic stabilization in the one-legged stance as well as on postural control during quick rise and change of direction during the TUG test, thereby contributing to a prolonged OLST and shorter TUG time. Therefore, SMHAF-S and quadriceps muscle strength may be related to dynamic balance and applied walking ability.

However, in this study, the correlations between SMHAF-S and other measures were not strong (fair: 0.31–0.6). Previous studies have reported that a disability (e.g., knee pain) affects the strength of the correlation between lower extremity muscle strength and physical function.[27] Although we could not examine the participants' medical history in this study, it is possible that differences in the participants' disability levels affected the low correlation coefficients between the SMHAF-S and physical function. Therefore, in the future, it may be helpful to examine the individuals stratified by their disability level.

This study had some limitations. First, due to limitations of the measurement environment, we could not measure SMHAF in the supine position[11]; therefore, we did not compare the SMHAF-S with the SMHAF in the supine position. In the future, it will be necessary to measure the SMHAF-S in combination with the SMHAF in the supine position to clarify the advantages and disadvantages of the SMHAF-S. Second, the relationship between the SMHAF-S and lower limb muscle activity during hip abduction with flexion movement in a sitting position is unclear.[24] Therefore, in the future, measuring muscle potentials during SMHAF-S measurements will be necessary to clarify the effects of different hip flexion angles on muscle activity. Third, this study is limited to examining the intra-rater reliability of the SMHAF-S. Thus, in the future, inter-rater reliability should also be assessed. Fourth, since only women were included in this study, it is unclear whether this study's findings apply to men. Therefore, further studies are needed to examine the applicability of the findings to men. Finally, the degree of correlation between this study's SMHAF-S and other measures was not substantial. Thus, future studies should increase the number of cases and add other measurement indices to validate the SMHAF-S for a more multifaceted validation.

Conclusion

These findings suggest that the SMHAF-S measurement method examined in this study has excellent reproducibility and, similar to quadriceps muscle strength, is an index that reflects lower limb muscle strength, whole-body muscle strength, balance ability, and walking ability. Based on these results, the SMHAF-S can be a simple and convenient index that provides information on the individual's complex physical functions. Despite some limitations, we believe that this study will be helpful for therapists working in busy clinical settings.

Conflicts of Interest

The authors declare no conflict of interest.

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