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Volume 49, Number 2, April 2025

Original Articles

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Aims and Scope

Annals of Rehabilitation Medicine (*ARM*) is the official journal of the Korean Academy of Rehabilitation Medicine. It is an international, peer-reviewed open access journal, which aims to be a global leader in sharing up-to-date knowledge dedicated to the advancement of care and enhancing the function and quality of life of persons with various disabilities and chronic illnesses. As the official journal of one of the largest societies of rehabilitation medicine in Asia and Oceania, more than 3,500 physiatrists regularly receive this journal's table of contents via email, and the number is continually increasing. This journal is endorsed by the International Society of Physical and Rehabilitation Medicine (ISPRM) and the Asia-Oceanian Society of Physical and Rehabilitation Medicine (AOSPRM). International members comprise approximately half the editorial board, conducting peer-reviews of submitted manuscripts or acting as handling editors by assigning peer-review tasks to other reviewers.

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Squatting Posture Grading System for Screening of Limited Ankle Dorsiflexion

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Objective: To evaluate the effectiveness of a squatting posture grading system established to screen for limited ankle dorsiflexion.
Methods: The squat posture grading system categorizes subjects' squat posture into three grades. Grade 1 is defined as being able to maintain a squatting posture with heels on the ground in full ankle dorsiflexion without effort. Grade 2 is defined as being able to perform the same position, but unable to maintain the position for more than 5 seconds or requiring trunk and leg muscle efforts to maintain the position. Grade 3 is defined as being unable to maintain the same position and falling backwards immediately if attempted to touch the ground with heels. Next, subjects' ankle dorsiflexion angles were directly measured in knee flexed and extended position by goniometer.
Results: Out of the 92 total subjects, 35 were in grade 1, 18 were in grade 2, and 39 were in grade 3. The average ankle dorsiflexion angle with knee flexed position were 23.13° for grade 1, 16.03° for grade 2, and 9.31° for grade 3. The average ankle dorsiflexion angle with knee extended position were 15.16° for grade 1, 7.92° for grade 2, and 3.40° for grade 3. Ankle dorsiflexion angles showed a significant decrease from grade 1 to 3 ($p<0.05$).
Conclusion: The squatting posture grading system defined in this study effectively graded the subjects based on the difference in their average ankle dorsiflexion angle. This system could be used as a quick screening method for limited ankle dorsiflexion.

Keywords: Squatting posture, Ankle dorsiflexion

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INTRODUCTION

Limited dorsiflexion of the ankle joint is associated with a number of common clinically observed foot conditions and lower extremity injuries, including Achilles tendonitis [1], plantar fasciitis [2], chronic ankle instability [3], and tibial stress fracture [4]. In addition, insufficient dorsiflexion of the ankle joint induces unnecessary movement of the metatarsophalangeal joint, resulting in premature heel-off during gait, which can lead to strain in the midfoot and forefoot, which in turn contributes to foot and ankle injuries [5]. Therefore, grading the dorsiflexion angle of the ankle joint and screening for limitations in each grade could be useful for prevention and treatment of foot and ankle injuries. Assessing and preventing the potential for foot and ankle injuries is important not only in individual clinical assessments but also for sports medicine physicians who need to evaluate large groups before physical activities, such as competitions, in outdoor or gym settings. However, direct measurement of the dorsiflexion angle is time-consuming, labor-intensive, and requires adequate space and equipment. Therefore, direct

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measurement may be unsuitable as a screening test in situations like these. A simpler method that can be quickly administered to large groups in outdoor settings or similar environments may thus be necessary.

A squat requires full dorsiflexion of the ankle and full flexion of the knee and hip. Flexibility of the ankle joint and calf muscles in particular are important factors in performing and maintaining the position [6]. This posture requires full heel contact with the floor. Ankle dorsiflexion limitations can result in limited anterior tibial tilt, placing the center of gravity posteriorly, which can lead to poor postural stability and excessive effort to maintain the posture. Therefore, assessing squatting posture performance has the potential to be an indirect way to screen ankle dorsiflexion limitations and calf muscle flexibility. Furthermore, as a screening test, the squatting posture has the advantage of being easy to instruct and can be performed quickly in the context of a large-scale physical examination.

Previous studies have identified an association between squatting posture and ankle joint range of motion. Kasuyama et al. [6] found a significant difference in ankle dorsiflexion flexibility indirectly using the weight-bearing lunge between subjects who could and could not squat, but did not directly measure dorsiflexion angle of the ankle joint. Dill et al. [7] found an association between ankle joint range of motion measured in the weight-bearing lunge maneuver and the degree of dorsiflexion angle of the ankle joint in the squat. Rabin and Kozol [8] evaluated the usefulness of scoring performance of the overhead squat and forward arm squat positions to screen ankle dorsiflexion limitations.

However, the previous studies mentioned above all measured dorsiflexion angle of the ankle joint indirectly using a weight-bearing lunge, which is simpler and has higher inter-rater reliability, but only reflects ankle flexibility at knee flexed position and is potentially inaccurate compared to measurements using a goniometer. Actually, Hankemeier and Thrasher [9] found that angles measured using this method differed from those using a passive ankle dorsiflexion and goniometer by approximately 3-fold and showed only moderate correlation (r=0.621–0.681).

In this study, we defined the squatting posture grading system and aimed to prove the its usefulness for screening calf muscle flexibility by directly measuring the dorsiflexion angle of the ankle joint using a goniometer, including not only the knee flexed position but also the knee extended position.

METHODS

Subjects

A total of 92 adolescents and adults participated in this study. Twenty-five subjects were healthy volunteers, sixty-seven subjects were athletes with intellectual disabilities who participated in Special Olympics Game. During the recruitment process, participants with musculoskeletal disorders in the last 6 months, surgical history, pain, or stiffness were excluded through screening, including medical interviews and physical examinations. All participants had a level of functionality that allowed them to perform daily activities as well as exercises such as running and jumping. This study was approved by Institutional Review Board of Gachon University Gil Hospital (No. GFIRB2023-141). In accordance with the hospital's ethical guidelines, the participants were provided with verbal information, which included the purpose and procedures of the study, before inclusion in this study. When fully understood, an informed consent to participate in the study was obtained from all subjects.

Definition of squatting posture and grading system

Squatting posture is defined as follows: standing barefoot, feet shoulder-width apart and next to each other, heels touching the ground, hips lowered so that the femur is tilted below the parallel line, hips and knees in full flexion [10]. The upper limbs should not touch the body, the ground, or any other objects.

The grading system defined in this study categorizes subjects' squatting posture into three grades. Grade 1 was designed to identify candidates with sufficient flexibility, which is defined as being able to maintain a squatting posture with heels on the ground in full ankle dorsiflexion in a comfortable relaxed state without effort. Grade 2 was designed to identify candidates with partially limited flexibility, defined as those who can achieve a position but are unable to maintain it for more than 5 seconds or require excessive effort from body and leg muscles, such as excessive contraction of the abdominal or pre-tibial muscles, to keep the body's center of gravity in the middle of the foot. Grade 3 was designed to identify candidates with severely limited flexibility. Grade 3 corresponds to limited flexibility, which is defined as being unable to maintain the same position and falling backwards immediately if attempted to touch the ground with heels (Fig. 1).

Fig. 1. Examples of squat posture for grade 1 and 3. (A) Examples of squatting posture for grade 1, with heels on the ground in full ankle dorsiflexion. (B) A representative example of a failed squatting posture for grade 3-the heel is not touching the ground. (C) Another example of a failed squatting posture for grade 3-the hip is not in full flexion and the femur is not tilted below the parallel line.

Procedure

All subjects performed the squatting posture as defined above, following the examiner's demonstration of the movement, and were categorized according to the above grading system. Next, the subjects' dorsiflexion angle of the ankle joint was measured. With the subject lying supine, one examiner manually immobilized the subject's ankle in maximum dorsiflexion, and the other examiner measured the dorsiflexion angle of the ankle joint using a goniometer. The bilateral dorsiflexion angle of the ankle joint was first measured with the hip and knee flexed to 90°, and measured again with the knee and hip fully extended. To prevent bias, the evaluator who assigned grades and the person who measured the angles were different individuals, and they were blinded to each other's results during the evaluation process.

The dorsiflexion angle of the ankle joint was measured by a single examiner using a goniometer with the axis at the intersection of the fibula and the extension line at the 5th metatarsal bone. The stationary arm was fixed parallel to the fibula and the moving arm was parallel to the 5th metatarsal bone line (Fig. 2).

In addition, a tripod sign was checked to determine if the subjects had hamstring tightness. This is a test in which the examiner extends the subject's knee to full extension in a seated position, and the subject's pelvis and trunk extend backward in response to the shortening of the hamstring, if subjects have hamstring tightness [11]. It was recorded positive when at least one of the left and right sides showed a positive sign (Figs. 3, 4).

Statistical analysis

The demographic data of the continuous parameters is described by the mean±standard deviation. A chi-square test and one-way ANOVA were used for group analysis of sex/age/height/weight/body mass index (BMI). ANOVA and t-tests were conducted to analyze the association between dorsiflexion angle of the ankle joint, the grade, and the presence of tripod sign. A chi-square test was used to compare the positive rate for the tripod sign of the subjects in each grade. The significance level of all statistical analyses was set at $p<0.05$ and analyzed using SPSS version 29.0.1.0. for Windows (IBM Corp.).

RESULTS

General characteristics

A total of 92 subjects participated, and their baseline characteristics are summarized in Table 1. Seventy-six were male and 16 were female, with age of 26.0±9.7 years, height of 169.6±12.0 cm, and weight of 70.0±15.9 kg. In the case of height, grade 2 was significantly higher than grade 1 and grade 3 ($p=0.01$), but there were no significant differences in other variables.

Squatting posture grade and dorsiflexion angle of the ankle joint

All participants attempted the specified squatting posture as defined above, and during this process, no pain or noticeable stiffness in the hip or knee joints was observed. Consequently,

Fig. 2. Schematic presentation of measurement of dorsiflexion angle. (A) Measurements with hip and knee flexed to 90°. (B) Measurements with hip and knee fully extended. (C) Measurements using a goniometer.

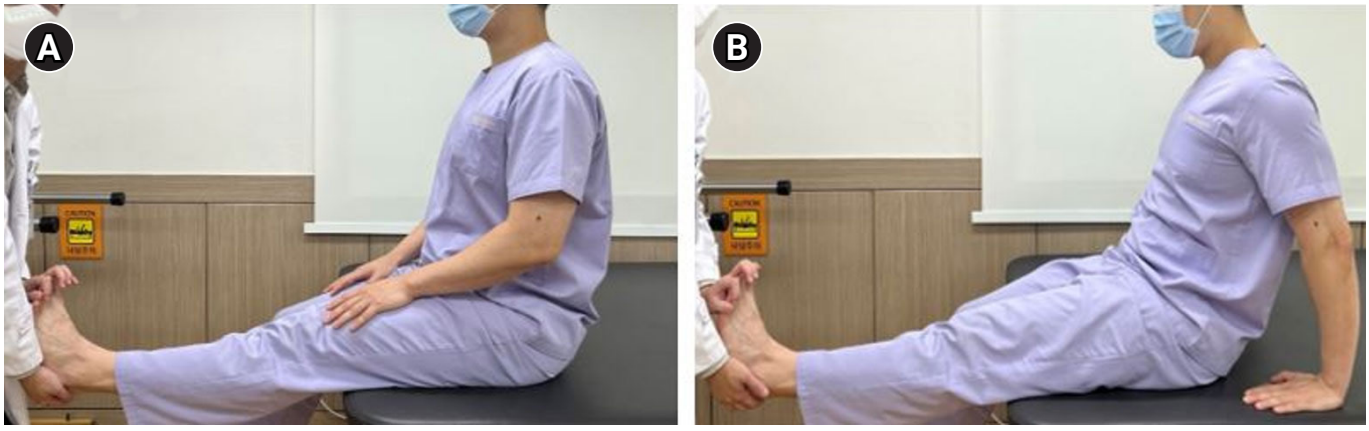

Fig. 3. Schematic presentation of tripod sign. (A) Negative tripod sign. (B) Positive tripod sign.

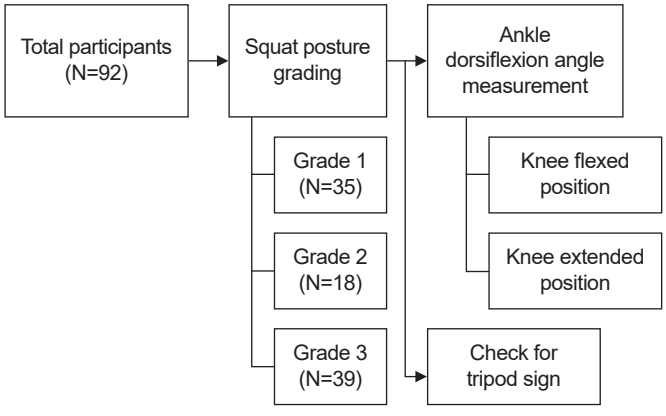

Fig. 4. Flow of the study.

of the 92 total subjects, 35 were in grade 1, 18 were in grade 2, and 39 were in grade 3. The left, right and average dorsiflexion angles of the ankle joint measured in the knee flexed and fully extended positions for subjects in each grade are shown in Table 2. The dorsiflexion angle of the ankle joint in knee flexed position was 23.13°±6.02° for grade 1, 16.03°±4.44° for grade 2, and 9.31°±6.11° for grade 3. The left, right, and average dorsiflexion angles of the ankle joint were all significantly different for each grade ($p<0.005$) and decreased towards grade 3.

The dorsiflexion angles of the ankle joint in knee extended position were 15.16°±5.45° for grade 1, 7.92°±4.41° for grade 2, and 3.40°±5.72° for grade 3. The left, right, and average dorsiflexion angles of the ankle joint were all significantly different for each grade ($p<0.005$) and decreased towards grade 3, which is the same result as the knee flexed position. There was no

Table 1. Baseline characteristics of study groups

	Total	Grade 1	Grade 2	Grade 3	p-value
Number	92	35	18	39	
Sex, male/female	76/16	28/7	15/3	33/6	0.87
Age (yr)	26.0±9.7	27.0±11.3	25.0±5.1	25.0±10.1	0.84
Height (cm)	169.6±12.0	167.3±14.0	178.2±6.4	168.0±10.1	0.02*
Weight (kg)	70.0±15.9	68.2±17.7	72.2±13.2	70.0±15.1	0.78
BMI (kg/cm^2)	24.6±5.7	24.5±6.9	24.0±3.1	25.0±5.0	0.93

Values are presented as number only or mean±standard deviation.
BMI, body mass index.
*Significant difference (p<0.05).

Table 2. Mean and standard deviation of ankle dorsiflexion angles of study groups

		Knee flexed position (°)		p-value	Knee extended position (°)		p-value
Grade 1	Right ankle	23.34±5.70	23.13±6.02		15.29±5.49	15.16±5.45	
	Left ankle	22.91±6.31			15.03±5.42		
Grade 2	Right ankle	16.17±4.72	16.03±4.44	<0.005*	8.17±4.31	7.92±4.41	<0.005*
	Left ankle	15.89±4.15			7.67±4.50		
Grade 3	Right ankle	9.15±6.44	9.31±6.11		3.28±5.61	3.40±5.72	
	Left ankle	9.46±5.77			3.51±5.82		

Values are presented as mean±standard deviation.
*Significant difference (p<0.05).

significant difference between left and right dorsiflexion angles of the ankle joint in knee flexed position, knee extended position and each grade. The dorsiflexion angle of the ankle joint measured in knee flexed position were significantly higher than when measured in knee flexed position for all grades (p<0.005).

For each grade, the maximum, minimum, and median of the dorsiflexion angle of the ankle joint measured in knee flexion and knee extension is plotted (Fig. 5). In knee flexion, grade 1 had a maximum of 41.0°, a minimum of 16.0°, and a median of 21.5°; grade 2 had a maximum of 25.0°, a minimum of 11.0°, and a median of 14.8°; and grade 3 had a maximum of 21.5°, a minimum of -4.5°, and a median of 10.0°. In knee extension, grade 1 had a maximum of 30.0°, a minimum of 6.5°, and a median of 15.0°; grade 2 had a maximum of 16.5°, a minimum of 3.0°, and a median of 6.3°; and grade 3 had a maximum of 15.5°, a minimum of -7.5°, and a median of 4.5°.

The results of calculating the sensitivity and specificity for limited ankle dorsiflexion to verify the performance of the grading system as a screening test are summarized in Table 3. Limited ankle dorsiflexion was defined based on the actual measured dorsiflexion angle of the ankle joint, with cut-off values set at less than 18.5° in the knee flexed position and less than 11.5° in the knee extended position [12]. Grade 1 was considered negative, and grades 2 and 3 were considered positive for the screening test. In the knee flexed position, the sensitivity was 91.0% and the specificity was 81.1%. In the knee extended position, the sensitivity and specificity were 86.2% and 79.4%, respectively.

Tripod sign

The percentage of positive tripod sign in each grade is summarized in Table 3. The positive rate was 17% in grade 1, 28% in grade 2, and 64% in grade 3, respectively, and showed a significant difference when comparing the three groups simultaneously (p<0.005). When comparing between the two groups, there was no significant difference between grade 1 and 2, but grade 3 showed a significantly higher tripod sign than grade 1 and 2 (p<0.005).

Therefore, to investigate the influence of hamstring tightness, groups were segregated based on the presence of the tripod sign, and additional analysis was performed to explore the relationship between grade and dorsiflexion angle of the ankle joint. In the group showing a negative tripod sign, the dorsiflexion angles of the ankle joint in the knee-flexed position were 23.52°±6.00° for grade 1, 16.38°±4.86° for grade 2, and 10.88°±5.70° for grade 3, with an overall average of 18.85°±7.76°. While in the knee-extended position, they were 15.64°±5.23° for grade 1, 9.19°±4.34° for grade 2, and 4.92°±5.14° for grade 3, with an overall average

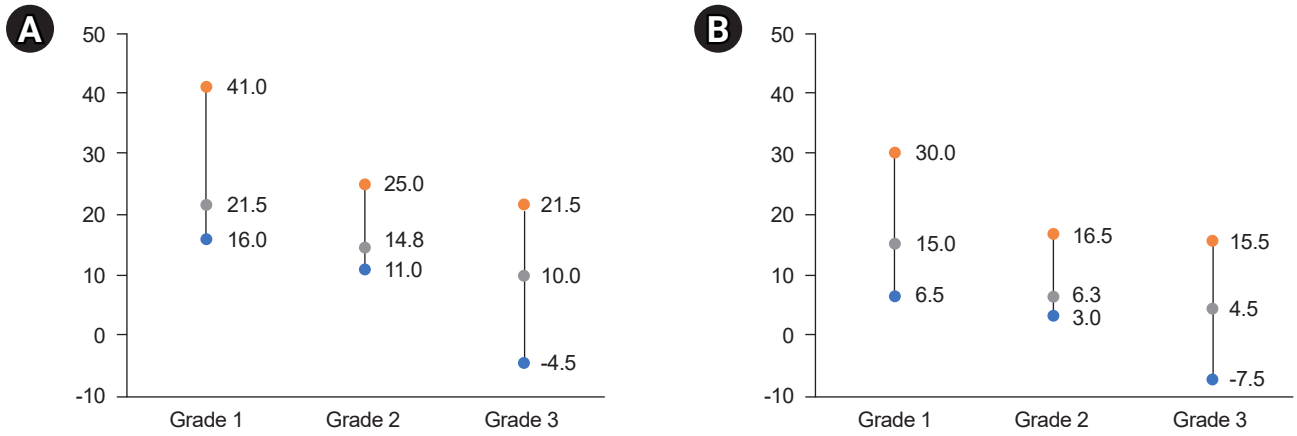

Fig. 5. Maximum, minimum and median of ankle dorsiflexion angle. (A) Maximum, minimum, and median of ankle dorsiflexion angle in knee flexed position. (B) Maximum, minimum, and median of ankle dorsiflexion angle in knee extended position. Orange, maximum; gray, median; blue, minimum.

Table 3. Confusion matrix with sensitivity and specificity

	Knee flexed position		Knee extended position	
	DF angle<18.5°	DF angle≥18.5°	DF angle<11.5°	DF angle≥11.5°
Grade 2 or 3	TP=50	FP=7	TP=50	FP=7
Grade 1	FN=5	TN=30	FN=8	TN=27
Sensitivity (%)	91.0		86.2	
Specificity (%)	81.1		79.4	

Values are presented as number only.
DF, dorsiflexion; TP, true positive; FP, false positive; FN, false negative; TN, true negative.

of 11.58°±6.76°. In the group exhibiting a positive tripod sign, dorsiflexion angles of the ankle joint in the knee-flexed position were 21.25°±4.40° for grade 1, 15.10°±2.06° for grade 2, and 8.52°±5.98° for grade 3, averaging 11.47°±7.23° overall. In the knee-extended position, these angles were 12.83°±4.64° for grade 1, 4.60°±1.46° for grade 2, and 2.63°±5.60° for grade 3, totaling 4.56°±6.29° across all grades. In each group divided by the presence of the tripod sign, similar to the overall findings, dorsiflexion angles of the ankle joint varied significantly across grades, decreasing progressively with grade 3 ($p<0.005$; Table 4).

Furthermore, a regression analysis was conducted to determine which variable, between limited ankle dorsiflexion and the presence of hamstring tightness, has a greater influence on the determination of the squatting posture grade. Limited ankle dorsiflexion was defined based on the actual measured dorsiflexion angle of the ankle joint, with cut-off values as same as above. The results are shown in Table 5, indicating that the limited ankle dorsiflexion contributes more significantly to grade determination in both postures.

Subgroup analysis of a group with intellectual disabilities

The group with intellectual disabilities had a slightly higher proportion of grade 3 at 43.3% compared to the normal group's 40.0%, but the difference was not significant. The average dorsiflexion angles of the ankle joint in the knee-flexed position and knee-extended position were 15.28° and 8.19°, respectively, which were smaller than the normal group's 17.48° and 10.26°, but again, the difference was not significant.

A subgroup analysis was conducted on the subjects with intellectual disabilities, who constitute the majority of the study population. Among the total of 67 individuals, 26 were grade 1, 12 were grade 2, and 29 were grade 3. The dorsiflexion angles of the ankle joint in knee flexed position was 23.56°±6.92° for grade 1, 15.79°±4.22° for grade 2, and 7.66°±5.62° for grade 3. The dorsiflexion angles of the ankle joint in knee extended position were 14.88°±6.30° for grade 1, 8.58°±4.10° for grade 2, and 2.03°±5.62° for grade 3. The average dorsiflexion angles of the ankle joint were all significantly different for each grade ($p<0.005$) and decreased towards grade 3 in both positions. A

Table 4. Mean and standard deviation of ankle dorsiflexion angles by presence of tripod sign and grades

Tripod sign	Grade	No.	Knee flexed position (°)	p-value	Knee extended position (°)	p-value
Negative	Grade 1	29	23.52±6.00		15.64±5.23	
	Grade 2	13	16.38±4.86	<0.005*	9.19±4.34	<0.005*
	Grade 3	13	10.88±5.70		4.92±5.14	
	Total	55	18.85±7.76		11.58±6.76	
Positive	Grade 1	6	21.25±4.40		12.83±4.64	
	Grade 2	5	15.10±2.06	<0.005*	4.60±1.46	<0.005*
	Grade 3	26	8.52±5.98		2.63±5.60	
	Total	37	11.47±7.23		4.56±6.29	

Values are presented as mean±standard deviation.
*Significant difference (p<0.05).

Table 5. Multiple linear regression analysis for the association between presence of ankle dorsiflexion angles, tripod sign and grades

Position	Variable	β	t	p-value	F	Adjusted R^2
Knee-flexed	Limited ankle dorsiflexion	1.20	8.62	<0.005*	58.45*	0.56
	Tripod sign	0.35	2.52	0.01*		
Knee-extended	Limited ankle dorsiflexion	1.07	6.73	<0.005*	40.21*	0.46
	Tripod sign	0.36	2.32	0.02*		

*Significant difference (p<0.05).

similar analysis was performed based on the presence or absence of the tripod sign. The results are shown in Supplementary Table S1. Regardless of the presence or absence of the tripod sign, there were significant differences in the dorsiflexion angle of the ankle joint for each grade, which decreased progressively towards grade 3.

DISCUSSION

This study aimed to demonstrate the effectiveness of our newly developed squatting posture grading system for evaluation of limited ankle dorsiflexion and calf muscle flexibility. Grade 1 corresponds with sufficient flexibility, grade 2 means partially limited flexibility, and grade 3 indicates a severely limited flexibility of dorsiflexion angle of the ankle joint of the subjects in our grading system. In this study, the dorsiflexion angle of the ankle joint decreased stepwise as the squatting posture grade increased from 1 to 3. Furthermore, a significant difference was observed in the mean dorsiflexion angles of the ankle joint among the groups in each grade. This statistical significance was also observed in the subgroup with intellectual disabilities.

We also found that the squatting postures were easy to perform for all subjects, even including those with intellectual disabilities. The subjects followed the instructions and demonstrations easily, and their grades were assessed promptly. These characteristics make this grading system appropriate for screening test for ankle and calf muscle flexibility.

The dorsiflexion angle of the ankle joint depends on the flexibility of the soleus and gastrocnemius. The limitation of ankle dorsiflexion in the knee extended position results from decreased flexibility of the soleus and gastrocnemius, while the limitation of dorsiflexion in the knee-flexed position results from decreased flexibility of the soleus [13]. Measuring the dorsiflexion angle of the ankle joint in knee flexed position is a way to evaluate the tightness of the soleus alone in which the position the gastrocnemius is relaxed [14].

Considering that the squatting posture used in this study is performed with the knees fully flexed, it was thought that the performance of this posture would have less to do with tightness of the gastrocnemius and more to do with tightness of the soleus. Based on the above paragraph, theoretically, subjects with isolated gastrocnemius tightness should perform well in the squatting posture with this system and would have limitations in ankle dorsiflexion in the knee extended position, but no limitations should be observed in the knee flexed position. However, in this study, a group with this characteristic was not clearly observed. Also, the actual dorsiflexion angle of the ankle joint measured in this study showed a decreasing pattern toward grade 3 in both the knee flexed and knee extended positions and the influence of soleus tightness cannot be excluded in both positions. Therefore, a caution should be taken when interpreting the results of applying this grading system to subjects with

isolated gastrocnemius tightness which was not validated in this study. However, it is clear that tightness in soleus sufficiently causes limited ankle dorsiflexion and decreased flexibility in the calf muscles, so this system could still be considered a valid screening method.

In general, the average dorsiflexion angle of the ankle joint is known to range from 8° to 26° in various positions, with the dorsiflexion angle of the ankle joint being greater when the knee is flexed than when the knee is extended [15]. In previous studies measuring passive dorsiflexion angle of the ankle joint during knee flexion and extension, Kim et al. [16] reported an average passive dorsiflexion angle of the ankle joint of 11° during knee extension and 17° during flexion in a supine position. DiGiovanni et al. [17] reported a passive dorsiflexion angle of the ankle joint of 13° during knee extension and 22° during flexion in a supine position. In our study, the average dorsiflexion angle of the ankle joint was 8.7° in the knee extended position and 15.8° in the knee flexed position, which is within a similar range to the previous studies mentioned above.

Meanwhile, several studies have shown that limitations in dorsiflexion angle of the ankle joint are associated with a variety of foot and ankle injuries, but the criteria for such limitations vary in the literature. In a study linking ankle dorsiflexion restriction to forefoot and midfoot pain, DiGiovanni et al. [17] defined the restriction as an dorsiflexion angle of the ankle joint measuring less than 5° with the knee extended and less than 10° with the knee flexed. Tabrizi et al. [18] found that in a group of children and adolescents with ankle fractures or sprains, the mean dorsiflexion angle of the ankle joint was 5.7° with the knee extended position and 11.2° with the knee flexed position, compared to 12.8° with the knee extended position and 21.5° with the knee flexed position measured in the control group. In a study analyzing the correlation between Achilles tendinitis and heel cord tightness, Kaufman et al. [12] defined heel cord tightness as a dorsiflexion angle of the ankle joint measuring less than 11.5° with the knee extended and less than 18.5° with the knee flexed.

In this study, the average dorsiflexion angle of the ankle joint was 23.13° in knee flexed position and 15.16° in knee extended position for grade 1, 9.31° in knee flexed position and 3.40° in knee extended position for grade 3, respectively, which is in a similar range to the cut-off values in the above studies, suggesting that our squatting posture grading system has the potential to replace direct dorsiflexion angle of the ankle joint measurement and, by extension, screening groups with foot and ankle injuries or pain.

Additionally, based on Kaufman et al. [12], the cut-off values for dorsiflexion angle of the ankle joint to determine the presence of heel cord tightness in the study population were set at 18.5° in the knee-flexed position and 11.5° in the knee-extended position. Accordingly, the sensitivity and specificity were calculated, revealing a sensitivity of 91.0% in the knee-flexed position and 86.2% in the knee-extended position. These values were significantly considerable, indicating the effectiveness of the screening test.

Similar to this study, Rabin scored performance of the overhead squat and forward arm squat positions to analyze the relationship between squatting posture and dorsiflexion angle of the ankle joint. However, all subjects in study of Rabin were able to perform the overhead squat and forward arm squat positions, which are more difficult than the squatting posture in this study. The mean dorsiflexion angle of the ankle joint was 27.9° measured using a weight-bearing lunge, which is similar to the dorsiflexion angle of the ankle joint in squatting posture grade 1 in this study. It is suggested that Rabin and Kozol [8] included only subjects with a normal level of calf muscle flexibility. Contrary to Rabin and Kozol [8], we used a relatively easy squatting posture, including a large number of subjects with low to high calf muscle flexibility, and categorized calf muscle flexibility into three grades.

Previous studies have shown an association between limited range of motion of ankle and hamstring tightness, which is thought to be due to tight hamstrings causing an overall contraction of the posterior leg musculature [19]. In this study, the percentage of hamstring tightness identified by the tripod sign was 17% in grade 1, 28% in grade 2, and 64% in grade 3, with no significant difference between grade 1 and grade 2, but a significant difference between grade 1 and grade 3 and also between grade 2 and grade 3. The relationship between hamstring tightness and the performance of the squatting posture, as defined in this study, remains unclear. In cases of hamstring tightness, flexion of the lumbar spine may accompany the squat exercise due to the tension exerted on the ischial tuberosity [20]. However, this aspect was not included as an evaluation factor in the squatting posture grading system used in this study. Moreover, the length of the hamstrings did not change significantly throughout the squat performance, which is likely attributable to the bi-articular structure characteristic of this muscle [21]. Additionally, considering the possibility that hamstring tightness could act as a confounding variable, additional analyses

were conducted based on its presence or absence. In both cases, a significant difference in the dorsiflexion angle of the ankle joint according to the grade was confirmed. Considering the previously mentioned evidence and results, hamstring tightness, under the individual characteristic of overall posterior leg musculature flexibility deficiency, is associated with limited ankle dorsiflexion. However, it is unlikely to be significantly related to the performance and grading of the squatting posture.

The majority of the subjects were people with intellectual disabilities in this study. It is known that people with intellectual disabilities have higher rates of abnormal foot conditions such as limited ankle range of motion and flat feet [22]. Since this study was aimed to compare groups with and without decreased calf muscle flexibility rather than determining the proportion in the overall population, we included a larger number of subjects with intellectual disability than the number of subjects with normal cognition to ensure that we had a sufficient number of subjects with limited dorsiflexion angle of the ankle joint. In addition, subjects with intellectual disabilities were able to follow the postures presented in this study without difficulty despite their cognitive function. This can also be regarded as a necessary characteristic for quick and general screening method. However, in this study, the group consisting of the subjects tended to have smaller dorsiflexion angles of the ankle joint compared to the group of normal subjects, although the difference was not significant. This is presumed to be due to the fact that the participants in this study were athletes with relatively high athletic abilities, as they participated in the Special Olympics Games, and exclusions were made during the recruitment process based on prior medical history through interviews.

The height was significantly higher in grade 2 than in grades 1 and 3. However, the total number of subjects in this study was not large, especially the number of subjects in grade 2 was small (N=18), hence it is possible that the subjects in this group were taller than the other groups by chance. However, according to Kasuyama et al. [6], unlike our study, significant differences in body weight were observed between the possible squatting and impossible squatting groups. Nevertheless, in the additional discriminant analysis and discussion conducted in that study, body weight showed significance, yet the strength of its association was very weak. Similarly to our study, BMI, which is strongly correlated with weight, did not demonstrate significant differences.

Furthermore, following the classification method used in Kasuyama et al. [6], we categorized our study population into groups that could be considered as the "possible squatting group," corresponding to grade 1, and the "impossible squatting group," corresponding to grades 2 and 3. We did not observe significant differences in height between the reclassified groups. While the difference in weight did not reach statistical significance, with respective means of 66.08 and 70.64 kg and a p-value of 0.12, there was a possibility of some degree of difference. Therefore, further research is needed to determine how exactly body weight influences squat posture and to what extent.

This study has several limitations. First, there is heterogeneity in the overall population. However, it is important to consider that this study initially included many individuals with intellectual disabilities to secure a large number of subjects with heel cord tightness. In addition, there was a lack of evaluation of other joints such as the hip and knee, which are related to the performance of the squatting posture. Lastly, due to the limitations of the testing environment, it was not possible to secure more than one evaluator, thereby preventing the assessment of interrater reliability. Nevertheless, considering the simplicity of the evaluation method and the clear distinctions between grading levels, it is presumed that there will not be significant differences between evaluators or in repeated measurements.

Conclusion

The squatting posture grading system defined in this study effectively graded the subjects based on the difference in their average dorsiflexion angle of the ankle joint. Grade 1 corresponds with sufficient flexibility, grade 2 corresponds with partially limited flexibility, and grade 3 corresponds with severely limited flexibility of dorsiflexion angle of the ankle joint of the subjects. In addition, the squatting postures in this system were easy to perform and could be graded quickly, suggesting that this grading system has the potential to be an effective screening method for limitations in ankle dorsiflexion and decreased calf muscle flexibility.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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None.

AUTHOR CONTRIBUTION

Conceptualization: Lee JK. Data curation: Kim JY, Na H. Methodology: Lee JK. Formal analysis: Kim JY. Investigation: Kim JY, Na H. Project administration: Lee JK. Software: Park KD. Resources: Lim OK. Visualization: Na H. Supervision: Lee JK. Validation: Kim JY, Lee JK. Writing – original draft: Kim JY. Writing – review and editing: Lee JK. Approval of final manuscript: all authors.

SUPPLEMENTARY MATERIALS

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Korean Translation and Psychometric Properties of Self-Report Instrument for Mobility Measuring for Adults With Lower Limb Amputation

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Objective: To assess mobility in prosthetic limb users, the Prosthetic Limb Users Survey of Mobility (PLUS-M) was developed as a brief item bank. The PLUS-M exhibits good reliability and has been translated into more than 15 languages; however, a Korean translation is not yet available. Therefore, this study translated the 44 items of PLUS-M into the Korean language and analysed the psychometric properties of the PLUS-M/Short Form 12 (PLUS-M/SF-12) instrument through official procedures.
Methods: The process of Korean translation began with a consultation with the developer of the PLUS-M and included the first and second compatibility verification, back-translation, back-translation verification by the developer, and the final approval of the Korean version. This study tested validity using different instruments such as Activities-specific Balance Confidence scale, 2-Minute Walk Test, Timed Up and Go Test to assess various characteristics related to mobility. The translated version PLUS-M was then sent to two physical therapists working at Incheon Hospital and one prosthetist working at a Rehabilitation Engineering Center for them to assess the appropriateness of term use and understanding of the instrument.
Results: The study found excellent internal consistency and test-retest reliability of the PLUS-M/SF-12 Korean version questionnaire, indicating its reliability and predictability across repeated measurements.
Conclusion: This study provided a tool to assess the mobility of individuals with lower limb amputations.

Keywords: Amputee, Validity, Patient reported outcome measures, Psychometrics

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INTRODUCTION

Whether owing to trauma, disease, or infection, amputation of the lower limb leads to a significant loss in physical function that results in limited mobility and a reduced quality of life for affected individuals [1]. The goal of rehabilitation following an amputation is to assist the patient in using and adjusting to a prosthesis, regaining the ability to walk, and returning to their previous level of physical activities of daily living (ADL). Rehabilitation specialists strive to enhance the quality of patients'

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lives by maximising their ability to perform daily activities while wearing a prosthesis and helping them improve overall quality of life [2]. Measures of mobility in patients using lower limb prostheses commonly focus on physical activities [2]. For example, the 2-Minute Walk Test (2MWT) assesses walking distance over 2 minutes, while the Timed Up and Go Test (TUG) records the time required for patients to rise from a chair, walk 3 m, and walk back to the chair and sit down [3]. Despite their usefulness in evaluating an individual's physical functions, these measures provide limited information as a tool for measuring real world ADL [4].

Patient-reported outcome measures (PROMs) assess patient mobility based on their actual experiences [5] and provide essential information that cannot be obtained in hospitals or laboratories; therefore, PROMs can be used in clinical settings and studies [6]. Several PROMs have been developed including the Locomotor Capability Index and Prosthesis Evaluation Questionnaire-Mobility Subscale; however, these questionnaires have poor psychometric reliability and validity [7,8]. The recently developed Prosthetic Limb Users Survey of Mobility (PLUS-M) is a brief item bank that measures mobility and exhibits good reliability [9,10]. This survey has been translated into more than 15 different languages and is widely used to evaluate mobility in individuals with lower limb amputations worldwide [11]. However, the PLUS-M has yet to be translated into Korean in a standardised manner given the Korean sociocultural context and studied for its psychometric properties for the official use of the PLUS-M in Korea [12].

Therefore, this study aimed to develop a Korean version of PLUS-M, obtain official certification, and analyse the psychometric properties of the PLUS-M/Short Form 12 (PLUS-M/SF-12). This study provided an instrument that can accurately assess the mobility of individuals with lower limb amputations.

METHODS

Study process

This prospective study analysed the psychometric properties of the Korean version of PLUS-M. It was approved by the Korea Workers' Compensation & Welfare Service Incheon Hospital (KCIRB-2023-0003-002) on July 29, 2023 (Table 1).

Study instruments

PLUS-M

The PLUS-M contains 44 items and is available in the following two formats: a 12-item version and 7-item short form which can be completed in 3 to 5 minutes. The development of the PLUS-M followed strict psychometric methodology and there is a strong correlation between the total 44-item version and the short forms. Individuals with lower limb amputations should respond to each question while wearing their prostheses and those who use canes, crutches, or walkers should respond as if they were using their walking aids. Each item is scored using a 5-point Likert scale.

Table 1. Study process and period

Stage	Process	Period	Study participants
PLUS-M English-Korean translation			
1	PLUS-M translation agreement with the original version author	January, 2023	Original version author
2	PLUS-M Korean translation began	February, 2023	One rehabilitation physician One researcher
3	1st and 2nd English-Korean translation Compatibility verification	February, 2023	Two physical therapists One prosthetist & orthotist
4	Reverse translation	March, 2023	One translation specialist
5	Reverse translation verification	April, 2023	Original version author
6	3rd English-Korean translation Compatibility verification	May, 2023	Two rehabilitation physicians One professor from the Department of Prosthetics and Orthotics
7	PLUS-M translation completion	June, 2023	Original version author
Analysis of psychometric properties of PLUS-M/SF-12			
1	IRB approved	July, 2023	
2	Survey and data analysis	August to December, 2023	

PLUS-M, Prosthetic Limb Users Survey of Mobility; SF-12, Short Form 12; IRB, Institutional Review Board.

Korean translation

Permission from the developer and translation of PLUS-M into Korean

Permission to proceed with the translation study was obtained in consultation with the developer of PLUS-M (Brain J. Hafner, Department of Rehabilitation Medicine, University of Washington, Seattle, WA, USA). A rehabilitation specialist and researcher of physical therapy separately translated the instrument. For any inconsistency between the translations, data were compared to select the most suitable translation.

First and 2nd English-Korean translation compatibility verification

The translated PLUS-M was sent to two physical therapists working at Incheon Hospital and one prosthetist working at a Rehabilitation Engineering Center. Their task was to assess the appropriateness of term use and understanding of the instrument. Any unclear or unnatural items were sent to the rehabilitation specialist and researcher for correction.

Back translation and verification to the back translation

We requested a back translation from a native Korean speaker (whose mother tongue was English and was fluent in both English and Korean) from Editage (https://www.editage.co.kr). The PLUS-M translated into Korean and PLUS-M translated back to English were sent to the developer who verified the compatibility of the translated information. When necessary, any revision was reflected on the translated PLUS-M.

Third English-Korean translation compatibility verification

Two rehabilitation specialists and one professor from the Department of Prosthetics and Orthotics were asked to assess the suitability of the translated Korean version of the PLUS-M in comparison to the original. After incorporating the final revisions, the translated Korean version of the PLUS-M was approved by the developer. The entire translation process was conducted according to the guidelines from previous studies [13,14].

Analysis of psychometric properties (verification of psychological reliability and validity)

Study participants

Notices were posted on the bulletin boards at the Rehabilitation Center of Incheon Hospital. Brochures were also made available at the reception desk of the orthotic room at a Rehabilitation Engineering Center. Additionally, advertisements were placed on the bulletin board of the Korea Amputee Association Website to recruit research participants. The translated version PLUS-M was sent to two physical therapists working at Incheon Hospital and one prosthetist working at a Rehabilitation Engineering Center for them to assess the appropriateness of term use and understanding of the instrument.

The inclusion criteria were as follows: patients who had undergone unilateral lower limb amputation at least 1 year prior, used a prosthesis indoors, could respond to questionnaires, and voluntarily decided to participate in this study and signed informed consent before the study began.

The exclusion criteria were as follows: patients who had bilateral lower limb amputations, had cognitive impairment, wore a prosthesis for aesthetic purposes, or had limited indoor ADL; as well as individuals who fulfilled the above criteria were selected as study subjects.

Variables measured

Data collected from every participant included demographic and general variables (age, sex, level, cause and time since amputation and type of prosthetic equipment), findings for functional performance tests (TUG and 2MWT), questionnaires assessing mobility in individuals with lower limb amputations (Activities-specific Balance Confidence [ABC] scale, PLUS-M/SF-12), and one-on-one interviews. Scores obtained from 12 items of the PLUS-M/SF-12 questionnaire were converted to T-scores based on the scoring criteria proposed by the developer (Supplementary Material 1) [15].

(1) ABC scale

The ABC scale measures confidence in performing various activities and consists of 16 items regarding specific activities and requires the patient to rate his/her "confidence for performing each activity without falling or losing balance." Participants are asked to answer their levels of confidence in performing certain activities, with a score from 0% to 100%. The total score is reached by adding all the scores together [16-18].

(2) TUG

The TUG evaluates walking ability, functional mobility, balance, and the capability to perform tasks related to walking. The test begins with the participant seated in a chair with armrests, measuring the time taken for the participant to stand up from the chair, walk a distance of 3 m, turn, walk back to the chair, and sit down upon the rater's starting signal. The participant is then

asked to repeat the course 3 times. The mean TUG score in this study was calculated using all scores. This test demonstrates high reliability with consistent results when performed multiple times by the same rater (intra-rater reliability of 0.99) and similar results when performed by different raters (inter-rater reliability of 0.98) [19].

(3) 2MWT

The 2MWT assesses walking distance over a predetermined time to evaluate functional ambulation ability and physical strength in clinical settings. The American Thoracic Society recommends a 6-Minute Walk Test (6MWT) for evaluating ambulation ability and physical strength. However, the 6MWT may not be a useful under certain circumstances owing to time constraints. Therefore, the 2MWT is commonly used as an alternative test. 2MWT has a strong correlation with the distance walked in the 6MWT and excellent test-retest reliability with an intraclass correlation coefficient (ICC) of 0.97 [20,21].

Outcome measures of efficiency

Construct validity

To assess construct validity, the correlation between the questionnaire assessing mobility in individuals with lower limb amputations, functional performance tests (TUG, 2MWT), and PLUS-M/SF-12 was analysed.

Reliability test (test-retest reliability)

We calculated the ICC between 2 completions at a 2-week interval. For any participant who was unable to make the second visit due to personal circumstances, the survey was administered via e-mail and Naver Office Form.

Internal consistency

We calculated the Cronbach's coefficient for internal consistency.

Face validity and usefulness

At the end of each visit, the investigator conducted an individual interview with participants on the content of the PLUS-M/SF-12 and its form.

Floor and ceiling effect

Among the participants scoring the lowest or highest T-scores, 15% or more indicated a significant floor or ceiling effect [22].

Data analysis

Statistical analyses were performed using SAS ver. 9.4 (SAS Institute Inc.). The participants' general characteristics were analysed using descriptive statistics and all correlation calculations. Partial correlation coefficients were classified into the following five categories: r≥0.91, very high; 0.90–0.71, high; 0.70–0.51, moderate; 0.50–0.31, low; and <0.31, negligible [23]. The ICC was classified as <0.40, poor; 0.40–0.59, fair; 0.60–0.74, good; and 0.75–1.00, excellent [24]. $p<0.05$ was considered statistically significant.

RESULTS

PLUS-M Korean version

In this study, the PLUS-M was translated into Korean. Table 2 shows the original English PLUS-M/SF-12 and the translated Korean version used for assessing psychometric properties (Supplementary Material 2). Before the developer's final ap-

Table 2. Korean version of PLUS-M/SF-12

Item	Original English version	Korean version
1	Are you able to walk a short distance in your home?	집안에서 짧은 거리를 걸을 수 있습니까?
4	Are you able to step up and down curbs?	도로 가장자리의 경계석(연석)을 오르내릴 수 있습니까?
7	Are you able to walk across a parking lot?	주차장을 가로질러 걸을 수 있습니까?
14	Are you able to walk over gravel surfaces?	자갈길을 걸을 수 있습니까?
19	Are you able to move a chair from one room to another?	의자를 방에서 다른 방으로 옮길 수 있습니까?
20	Are you able to walk while carrying a shopping basket in one hand?	한 손에 장바구니를 들고 걸을 수 있습니까?
21	Are you able to keep walking when people bump into you?	혼잡한 곳에서 사람들과 가볍게 부딪혀도 계속 걸어갈 수 있습니까?
26	Are you able to walk on an unlit street or sidewalk?	불빛이 없는 도로나 보도를 걸을 수 있습니까?
31	Are you able to keep up with others when walking?	다른 사람들과 보행속도를 맞춰 함께 걸을 수 있습니까?
35	Are you able to walk across a slippery floor?	미끄러운 바닥에서 걸을 수 있습니까?
37	Are you able to walk down a steep gravel driveway?	가파른 자갈길을 내려갈 수 있습니까?
44	Are you able to hike about 2 miles on uneven surfaces, including hills?	언덕이 포함된 울퉁불퉁한 길에서 3 km 정도 산책할 수 있습니까?

PLUS-M/SF-12, Prosthetic Limb Users Survey of Mobility/Short Form 12.

proval, three patients with lower limb amputation inspected the translation in advance to ensure that the translated information was understandable.

Psychometric validation of PLUS-M/SF-12

General characteristics of participants

Out of 40 initial patients who agreed to participate in the study, 8 dropped out due to personal reasons. The final analysis included 32 male participants with unilateral lower limb amputations resulting from trauma. Their average age, height, and weight was 52.22 years, 170.7 cm, and 73.7 kg. On average, the time since amputation was 7.25 years. Of the participants, 18 (56.2%) had transfemoral amputations and 14 (43.8%) had transtibial amputations. Additionally, 10 participants (31.2%) had right-sided amputations and 22 (68.8%) had left-sided amputations. Among all participants, nine (28.1%) used single-point/four-point canes or crutches, whereas 11 (33.4%) were employed (Table 3).

Participants were graded from K-Level 0 to 4 based on the amputee's ability to perform activities and ambulation levels. All lower limb prosthetic products were rated according to the recommended activity levels. A user with Level 0 could not have the ability or potential to amblate, Level 1 could walk in the household, but could not perform outdoor activities. Level 2 could walk in limited outdoor walk, Level 3 could walk in free outdoor walk and Level 4 could walk in high functional ability outdoor walk. The level of activity increases with grade number [25]. Patients who required a prosthetic foot could select a prosthetic type based on their level of activity. The class of prosthetic foot increases with the amputee's level of activity [26]. Of the participants who used lower limb prosthetic equipment, 4 (12.5%) used a prosthesis suitable for K-Level 2, while 28 (87.5%) used a prosthesis suitable for K-Level 3, 4. Overall, 12 participants (66.6%) used microprocessor-controlled knees, which are designed for individuals with lower limb amputations and require a high level of activity (Table 4).

Table 3. General characteristics of the participants

Characteristic	Value (n=32)
Age (yr)	52.22±13.86 (22–73)
Height (cm)	170.7±5.7 (160–184)
Weight (kg)	73.7±14.9 (58–130)
Duration of time since amputation (yr)	7.25±6.58 (1–26)
Sex, male	32 (100)
Cause of amputation	
Traumatic	32 (100)
Ischemic	0 (0)
Tumour, Infection	0 (0)
Level of amputation	
Transfemoral	18 (56.2)
Transtibial	14 (43.8)
Affected side	
Right/left	10 (31.2)/22 (68.8)
Occupation	
Yes/no	11 (33.4)/21 (65.6)
Use of assistive device	
Yes/no	9 (28.1)/23 (71.9)

Values are presented as mean±standard deviation (minimum–maximum) or number (%).

Construct validity

Data from 32 participants were analysed. PLUS-M/SF-12 Korean version had a high correlation with the ABC scores ($r=0.88$, $p<0.05$). PLUS-M/SF-12 Korean version exhibited a moderate correlation with 2MWT ($r=0.59$, $p<0.05$), but a weak correlation with TUG ($r=0.40$, $p<0.05$) (Fig. 1).

Test-retest reliability

The ICC calculated for the 32 participants who completed the Korean version of PLUS-M/SF-12 twice was 0.91 (95% confidence interval [CI], 0.82–0.95), which was excellent.

Internal consistency

The internal consistency of PLUS-M/SF-12 Korean version was analysed. Cronbach's a was 0.95 at the first test and 0.95 at the second test, which demonstrated significantly excellent internal consistency.

Face validity and usefulness

The participants understood all items well and evaluated that the PLUS-M/SF-12 Korean version appropriately included all items necessary for assessing lower limb amputees' mobility. However, some comments were as follows: the evaluation for-

Table 4. Basic prosthetic equipment features of participants

Prosthetic equipment feature	Value
Prosthetic foot (n=32)	
Prostheses suitable for K-Level 2	4 (12.5)
Prostheses suitable for Level 3, 4	28 (87.5)
Prosthetic knee (n=18)	
Microprocessor-controlled knee	12 (66.7)
Hydraulics	6 (33.3)
Pneumatics	0 (0)

Values are presented as number (%).

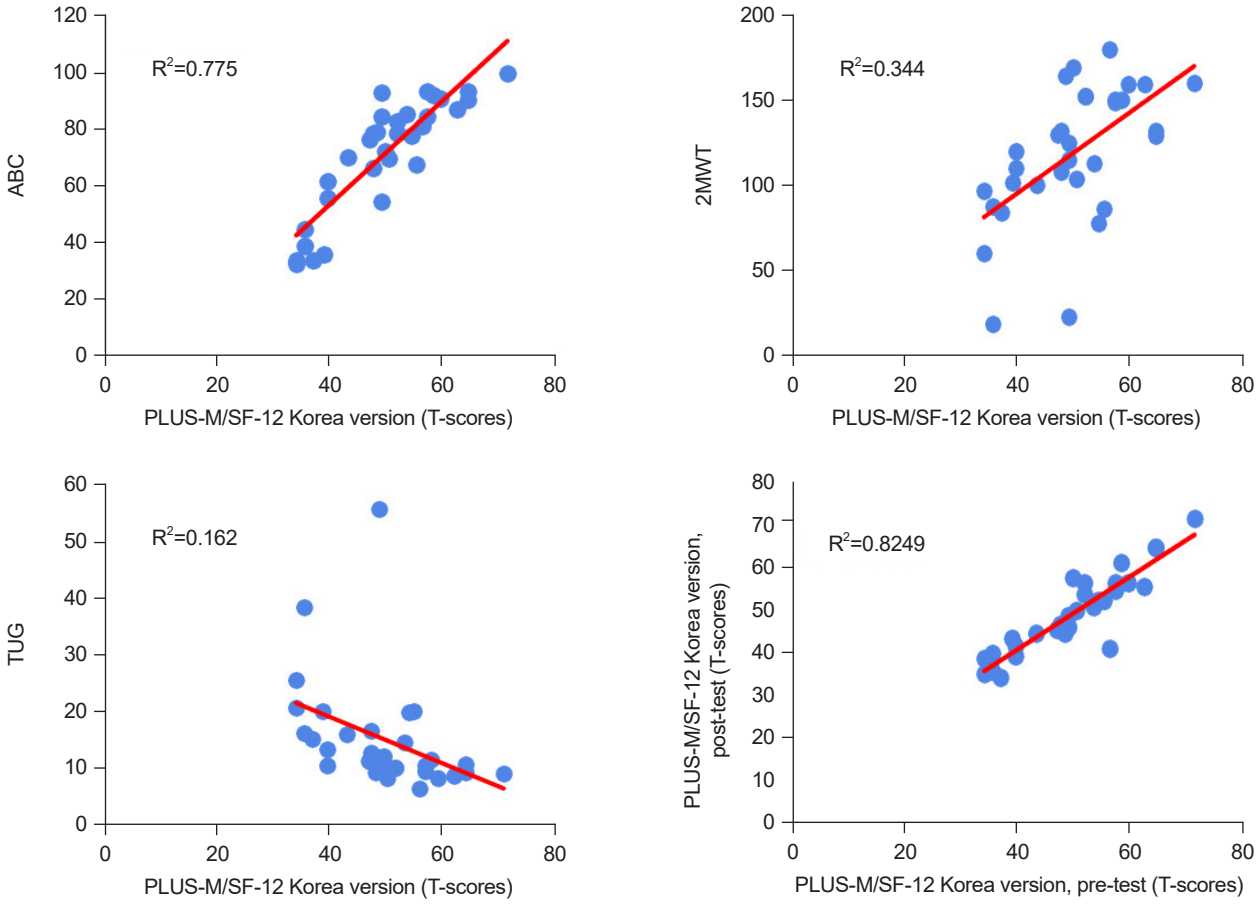

Fig. 1. Correlation graph for each test instrument. ABC, Activities-specific Balance Confidence; 2MWT, 2-Minute Walk Test; TUG, Timed Up and Go Test; PLUS-M/SF-12, Prosthetic Limb Users Survey of Mobility/Short Form 12.

mat did not consider variables such as skin conditions on the residual limb and physical strength; previously unexperienced questionnaire items; insufficient definition about certain situations (e.g., without lights and slippery); a lack of items that evaluate the use of public transportation.

Floor and ceiling effect

No significant floor and ceiling effect was observed. No participant received the lowest T-score, but only one participant (3.1%) received the highest T-score.

DISCUSSION

This study translated the PLUS-M into Korean to account for cultural differences. The tool was demonstrated to have good reliability and validity.

Assessments aid in making clinical decisions and are essential for selecting appropriate therapeutic interventions and increasing therapeutic effects [27]. Those using self-reported instruments are highly suitable for measuring health outcomes since they reflect an individual's experience, perception, and opinion. These instruments have great value in a clinical setting in terms of patient screening, health outcome monitoring, facilitation of communication between patient and clinician, provision of information on therapeutic decision, and evaluation of therapeutic effect [28]. Furthermore, self-reported data are used to provide important information on health care policy and service payment [29]. This study translated the 44 items of PLUS-M into Korean and analysed the psychometric properties of the PLUS-M/SF-12 instrument through official procedures.

This study evaluated internal consistency to determine whether the items within each measurement category measure the same characteristics in survey-based studies. The "first PLUS-M/SF-12" and "second PLUS-M/SF-12" validations in-

dicated excellent internal consistency among the questions, suggesting that the questionnaire is highly reliable. Test-retest reliability was assessed using the ICC to examine the stability of the questionnaire across repeated measurements. The analysis revealed a correlation coefficient of 0.91 (95% CI, 0.82–0.95), indicating excellent reliability. The overall results indicate that this questionnaire produces consistent outcomes, and are similar to those reported by Karatzios et al. [11], who evaluated the psychometric properties of the French version of the PLUS-M/SF-12. This implies that the Korean version of PLUS-M/SF-12 has excellent stability, consistency, and predictability. Accordingly, this study demonstrated that the Korean version of PLUS-M/SF-12 has greatly excellent reliability and efficacy as a psychometric instrument, which implies that it has great potential to be used in research and clinical settings.

This study tested validity using different instruments, such as ABC, 2MWT, and TUG, to assess various characteristics related to mobility in individuals with lower limb amputation [30-32]. The PLUS-M/SF-12 scoring guidelines indicate that the percentage (0.2%–98.4%) represents percentiles converted to T-scores. These T-scores show the proportion of individuals who scored lower than the patients in the sample population. In the present study, the average T-score for participants' PLUS-M/SF-12 was 50 points, suggesting that approximately 51.9% of the sample population has lower mobility compared to the study participants. Consequently, this indicates that the participants' ambulation level is higher than the average level (Supplementary Material 1). There was a strong correlation between the PLUS-M/SF-12 and ABC scores. Similar results were found by Hafner et al. [10], who analysed the correlation between the original version of PLUS-M/SF-12 and other instruments (Korean version r=0.88 vs. original r=0.81). This suggests that balance is a component of physical function and is closely linked to the ability to walk. The PLUS-M/SF-12 shows a moderate correlation with 2MWT but a low correlation with the TUG. With regards to 2MWT, participants performed the test in a different environment from their usual living conditions. The low correlation with TUG may be due to a high ceiling effect because the average time was 15.6 seconds (n=32), with nine participants (28.1%) having an average time of less than 10 seconds.

The higher the score of PLUS-M/SF-12, the longer the distance of 2MWT, the higher the score of ABC, and the shorter the time of TUG, the better the mobility. The hypothesis regarding the gradual correlation between the PLUS-M/SF-12 scores and comparable instruments has been validated. The lower the TUG score or the higher the 2MWT and ABC scores, the stronger the correlation. Finally, based on feedback obtained from individual interviews, it is advisable to consider adding variables related to physical condition, specifying the situation in questions, and including items related to the use of public transportation in the assessment questions.

Study limitations

Sample composition: All the study participants had undergone amputation as a result of a traumatic incident. Notably, because traumatic amputations account for less than 10% of the total amputee population as per epidemiological data, the study sample may not fully reflect the characteristics of the broader amputee population. This lack of representation can potentially impact the study results. Furthermore, the study's sample is exclusively male, deviating from the demographic norm.

Sample size: Although the calculated number of participants was 50, only 32 (64.0%) were included in the actual analysis. Accordingly, future research should recruit more participants and expand the sample size to increase the generalisation of the study results.

Criteria for use of PLUS-M: The PLUS-M is recommended for skilled individuals who have at least 1 year of experience using prosthetic equipment. However, the rehabilitation goals of inpatients may not cover all the activities described in the PLUS-M/SF-12. It is important to consider this when interpreting the study results.

Cultural and empirical differences: Some of the questions may be difficult to understand due to cultural and lifestyle differences between Eastern and Western countries. The participants could assume a similar situation or make a judgement based on their own experiences.

Conclusion

It is important to curate a reliable instrument that can assess the health of individuals with lower limb amputations, as the prevalence of this condition is increasing globally. The PLUS-M is a reliable and valid self-reported questionnaire survey. It is an effective tool for monitoring the mobility of individuals with lower limb amputations in clinical settings, as well as for improving communication between patients and rehabilitation specialists, evaluating therapeutic interventions, and enhancing the patients' condition. This study translated the PLUS-M into Korean to account for cultural differences and demonstrated

the reliability and validity of the translated instrument through psychometric verification procedures. Developing new language versions of the instrument in the future will open opportunities for collaboration and advancement of new research in rehabilitation and prosthetic assistive devices for individuals with lower limb amputations.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

Conceptualization: Kim JH, Lee G. Methodology: Kim JH. Formal analysis: Kim JH. Funding acquisition: Jo S. Investigation: Kim JH, Jo S. Writing – original draft: Kim JH. Writing – review and editing: Lee G. Supervision: Lee G. Approval of final manuscript: all authors.

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SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.5535/arm.240087.

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Effect of Extracorporeal Shock Wave Therapy on Post-Laminectomy Lumbar Epidural Fibrosis

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Objective: To investigate the effectiveness of radial extracorporeal shock wave therapy (rESWT) on pain, lumbar range of motion (ROM) and F-wave minimal latency and F-chronodispersion in patients with post laminectomy epidural fibrosis.
Methods: Sixty patients complaining of low back pain and sciatica secondary to lumbar post laminectomy epidural fibrosis were allocated to one of the two equal groups (study and control groups). Pain intensity, lumbar ROM, and F-wave latency and F-chronodispersion were assessed pre- and posttreatment using visual analogue scale (VAS), Back ROM II device, and Neuro-MEP-Micro electromyography device, respectively.
Results: Posttreatment mean values showed statistically significant decrease in VAS mean scores in both groups, with more significant decrease posttreatment in favor of the study group. There was statistically significant increase in all lumbar ROM mean scores and statistically significant decrease in F-minimal latency and F-chronodispersion for both peroneal and tibial nerves in the study group only posttreatment. Also, the results showed that significant positive moderate correlation between VAS scores and F-chronodispersion for peroneal nerve, strong negative correlation between right side bending scores and F-wave minimal latency for peroneal nerve and moderate negative correlation between left side bending scores and F-wave minimal latency for peroneal nerve after treatment.
Conclusion: It was concluded that rESWT is a new and convenient modality, that would be beneficial if added to the conventional physical therapy protocols in managing patients with lumbar post-laminectomy epidural fibrosis.

Keywords: Extracorporeal shock wave therapy, Laminectomy, Back pain, Range of motion

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INTRODUCTION

Lumbar laminectomy is the most common surgical procedure used in treating symptoms of lumbar radiculopathy caused by disc herniation. It is characterized by decompression of the neural structures passing through the intervertebral foramen and the spinal canal [1-3]. Although lumbar laminectomy improved patient's symptoms after surgery, recent systematic reviews reported that the improvement was not at the satisfactory level either after surgery or at 5 years follow up [4]. One of the most common complications after lumbar laminectomy is epidural fibrosis developed as a result of abnormal excessive healing

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tissues in the area of excision. It was found that the rate of fibroblasts' proliferation is the main factor responsible for developing epidural fibrosis, as it is transformed into myofibroblasts causing adhesions into the dura mater and nerve root leading to recurrent back and leg pain [1,5].

Epidural fibrosis constitutes 24% of all failed back surgery syndrome (FBSS) cases or post laminectomy syndrome (PLS), and is thus claimed as one of the major causes of FBSS with high incidence per year. Being resistant to treatment, chronic pain caused by epidural fibrosis could affect social function, work efficiency and activities of daily living. It may cause depression, anxiety, disability and consequently deterioration in patient's quality of life Therefore, it is important to find treatment options for decreasing pain in these patients [6]. Recently, the number of researches studied the mechanism and management of epidural fibrosis after lumbar surgery has been increased [1]. As epidural fibrosis is a part of PLS, treatment should target the source of pain, thus both conservative approaches as physiotherapy and pain medications and invasive approaches such as lumbar steroid injections, percutaneous endoscopic adhesiolysis, and re-operation for managing PLS could be used [7]. Yet, as surgical options have showed high morbidity and low success rate, they should not be prioritized to conservative approaches in treatment unless in cases of impaired bowel and bladder function, progressive weakness or interactable pain [3]. Systematic reviews of studies investigating pharmaceutical management using opioids and/or non-surgical management of PLS have shown that there was a non-significant improvement either in pain or patient's function, thus eventually resulting in re-operation [8,9]. New non-invasive and safe treatment method, including radial extracorporeal shock wave therapy (rESWT) have recently been proposed, studied and implemented in clinical practice [1,10].

rESWT is now widely used in many musculoskeletal conditions such as frozen shoulder, plantar fasciitis, lateral epicondylitis, tendon calcification, hypertrophic wounds, scar tissues [10,11]. Also, rESWT showed an impact on in neuropathic pain caused by sciatica, post herpetic neuralgia and mild to moderate carpal tunnel syndrome [12,13]. It has been recently used as alternative treatment in case of low back pain (LBP) and sciatic neuralgia [14,15]. Previous studies showed that rESWT (low energy waves) has no adverse effects or complications, if the contra-indications are considered. Shock waves are acoustic pressure pulses, produced by electrohydraulic, electromagnetic and piezoelectric sources, can penetrate through tissues in a wave like manner [16]. The physiological mechanism through which it produces its effect would involve affecting cell activity through its regeneration and anti-inflammatory effect. The application of rESWT reduces inflammatory cytokines and increases collagen fibers, tendons and soft tissue flexibility and improves local blood flow. Thus, it has been recommended in cases of fibrosis and adhesions [17,18]. In an animal study, it was concluded that the rESWT reduces epidural fibrosis developed following intentional laminectomy in rats [1]. To the best of our knowledge, the effect of rESWT on epidural fibrosis secondary to lumbar laminectomy in humans has not been investigated in previous clinical study. So, the current study aimed to investigate the effect of rESWT on pain and limited lumbar range of motion (ROM) due to post-laminectomy epidural fibrosis.

METHODS

Research design

The current study employed pretest/posttest randomized controlled study design. The patients were referred from the Orthopedic Surgery and Neurosurgery Departments of Cairo University Hospital and General Hospital. The study was conducted from January 2023 to April 2024 in the Outpatient Clinic of the Faculty of Physical Therapy, Cairo University. Before participation in the current study, every patient received an explanation of the aim and procedures of the study and signed a consent form prior to their enrollment. This study was approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University (approval number: P.T.REC/012/004382). The study was registered at the Clinical Trial Registry (NCT05887024).

A total of sixty-nine patients of both sexes with lumbar epidural fibrosis were assessed for recruitment eligibility in the current study. Four patients declined participation, and five patients did not fulfill the inclusion/exclusion criteria and hence were excluded. The selected patients were allocated by computerized block randomization. A diagram of patients' retention and randomization throughout the study was shown in (Fig. 1). Patients were randomly assigned to either the study group (n=30) that received rESWT in addition to conventional physical therapy program in the form of transcutaneous electrical nerve stimulation (TENS), electric heating packs and McKenzie back exercises, or the control group (n=30) that received conventional physical therapy program only. Every patient was assessed before and after treatment.

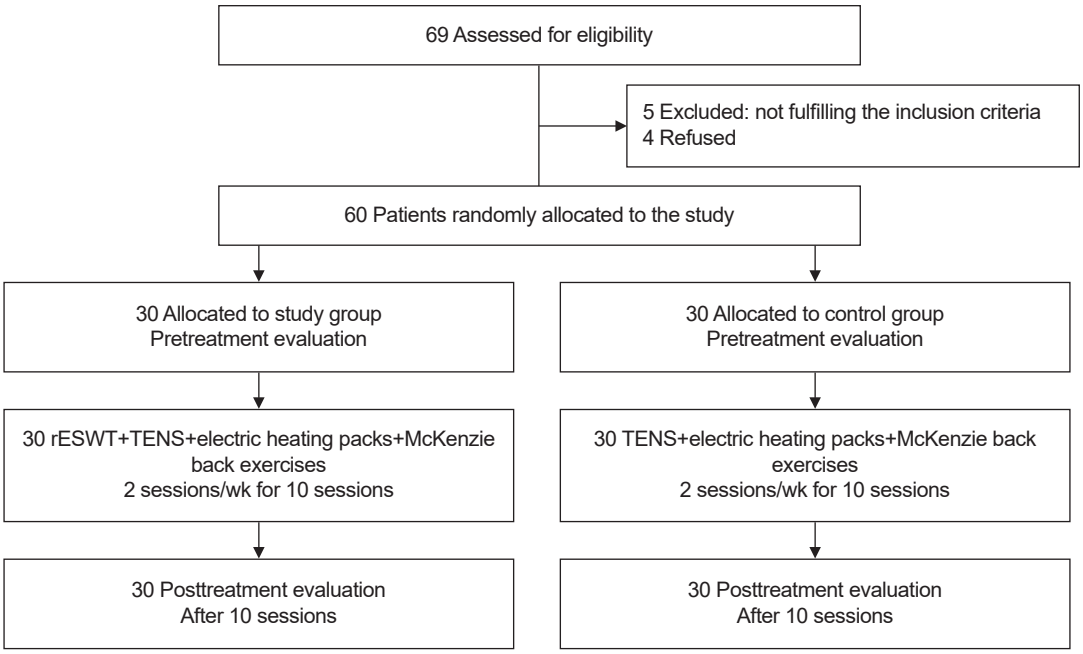

Fig. 1. Flow chart of participants. rESWT, radial extracorporeal shock wave therapy; TENS, transcutaneous electrical nerve stimulation.

All recruited patients should fulfill the inclusion criteria, which include: (1) patients had lumbar laminectomy surgery at the level L4–5, L5–S1; (2) six week to six month post operatively, as epidural fibrosis takes this duration to be matured [19]; (3) constant back pain or pain aggravated by movement; (4) restricted lumbar ROM; (5) tenderness at the site of incision; (6) epidural fibrosis confirmed by contrast magnetic resonance imaging (MRI); (7) age ranged from thirty to fifty years [20]; and (8) body mass index (BMI) less than 30 kg/m^2. Patients having any of the following criteria were excluded from the current study: (1) past history of vertebral fracture; (2) spinal cord compression; (3) spinal tumor; (4) spondylolisthesis; (5) diabetic neuropathy; (6) pregnancy; and (7) vascular diseases [16,20].

Research procedure:

Pain intensity, lumbar ROM, and F-wave minimal latency and F-chronodispersion (Fc) of tibial and peroneal nerves were measured for all recruited patients before and after treatment using visual analogue scale (VAS) [20,21], the Back ROM II device (BROM II; Fabrication Enterprises), and Neuro-MEP-Micro electromyography device (Neurosoft Company), respectively. The BROM II is designed to measure the back flexion/extension ROM using the BROM F/E (flexion/extension) unit with an L-shaped arm inserted in the distal part of the unit to measure separation distance between T12 and S1 during movement. It, as well, measures the rotation and lateral flexion ROM using the BROM R/L (rotation/lateral flexion) unit, including it magnetic reference and belt [22]. Routine measurement for both F-wave minimal latency and Fc was applied using Neuro-MEP-Micro electromyography device. It was reported that F-wave study has a sensitivity of 70% in lumbosacral radiculopathy patients [23]. The study group received rESWT using the MEDISON MB3000 shockwave instrument (SN.2012.12), in addition to conventional physical therapy program in form of TENS: EME (Therapic 9400) [24], Electric heating pack [25], and McKenzie back exercises were used [20].

Procedures for data collection

After screening of eligible patients, demographic and anthropometric data in form of name, age, gender, height, weight, BMI and occupation were recorded. BMI was calculated for each participant. Patients were asked to mark a point on a 10 cm line (VAS) indicating their pain intensity in relation to zero end, and the score was calculated using a ruler measuring the distance between the patients mark and the zero point [26]. Assessment of lumbar ROM (flexion, extension, lateral flexion and rotation) was measured using BROM II device [24]. The procedures to obtain F-wave minimal latency and Fc were the same as pro-

cedures for routine motor conduction studies for peroneal and tibial nerves using distal stimulation except with that the cathode was placed proximally, the recording electrodes for peroneal nerve were placed at the extensor digitorum brevis muscles, active electrode (G1) at dorsal lateral foot on the muscle belly, reference electrode (G2) placed distally at the 5th metatarsal joint, stimulating electrode placed lateral to tibialis anterior tendon, with the cathode placed proximally, ground electrode placed between recording ant stimulating electrodes. The stimulating electrodes for tibial nerve placed at the abductor hallucis brevis, G1 positioned 1 cm proximal and 1 cm inferior to navicular prominence, G2 placed at the 1st metatarsal joint, stimulating electrode placed at above and posterior to medial malleolus. Ground electrode placed between stimulating and recording electrodes. To obtain F-wave minimal latency and Fc, ten supramaximal stimuli were applied [27]. Every patient in the study group received 10 sessions of rESWT, 2 sessions/week. The patients were requested to assume the prone lying position, and the radial shockwave applicator (probe) was applied on the incisional line of the surgery which is in line with the vertebral column (level L4–5 & L5–S1) using conducting gel (in the center of back in line with the spine). During session time, the probe is moved along the incisional line (linear movement & direct contact). The used parameters were; 5,000 pulses/10 Hz/3 bar. Penetration depth of rESWT is 3.0 to 3.5 cm in human tissues [28]. Energy flux density is 0.10–0.15 mJ/mm^2. Low energy waves were used, which is safe for neural and muscular tissues and not causing any adverse effects. After each session the skin was checked for any undue changes like hyperemia, or allergy [16].

The conventional TENS was applied along the course of the sciatic nerve using four electrodes, which were placed as follows; on back region, lateral gluteal area, lateral popliteal fossa and posterior ankle joint [20], with the application parameters as follows; 120 Hz pulse frequency, 100 μs pulse duration and 20 minutes session duration. The amplitude was increased gradually till the patient starts to feel comfortable tingling sensations. Electric heating pad was applied on the incisional site for 20 minutes [29]. McKenzie back exercises were explained to all patients, which include a gradual progressive back exercises in the form of raising head and chest and back from prone lying position, bridging exercises, raising one arm and one opposite leg simultaneously from prone lying position, treatment duration was ten minutes [20].

Data analysis

The sample size for this study was calculated using the G*Power program 3.1.9 (G power program version 3.1). Sample size calculation based on F-tests (MANOVA: special effects and interactions), type I error (α)=0.05, power (1-β error probability)=0.90, effect size f^2 (V)=0.2456983, and Pillai V=0.3944748, with a total sample size for 54 participants for 2 independent groups comparison for major variable outcomes (pain intensity level, lumbar ROM in flexion, extension, right and left lateral rotation, and right and left side bending, F-wave minimal latency and Fc of peroneal and tibial nerves). Considering a 10% drop out rate, the minimum sample size of the current study was determined to be 60 patients (30 patients per group). Demographic and anthropometric data were analyzed using descriptive statistics and expressed as mean and standard deviation. MANOVA was used to compare within and between groups effects on VAS, lumbar ROM (flexion, extension, lateral flexion and rotation, F-minimal latency and Fc for both peroneal and tibial nerves). Post-hoc tests using the Bonferroni correction were conducted for subsequent multiple comparisons. The level of significance for all statistical tests was kept at $p<0.05$. Pearson's correlation coefficient was performed to compute the relation and direction between VAS with Fc for peroneal nerve and between lumbar ROM with F-minimal latency for peroneal nerve.

RESULTS

Sixty patients with LBP and sciatica due to lumbar post-laminectomy epidural fibrosis from both genders, were recruited in the current study. The mean of patients' age in the study group and control group were 43.03±5.07 and 44.23±3.55 years, respectively. Patients' weight, height and BMI in the study group were 69.43±5.00 kg, 165.17±6.12 cm, and 25.47±2.22 kg/m^2, respectively and 69.03±3.81 kg, 163.73±6.43 cm, and 25.82±2.24 kg/m^2 in the control group, respectively. Patients demographic data showed no statistically significant difference between both groups. The study group included 16 male patients (53.3%) and 14 female patients (46.7%), while in control group, they were 14 male patients (46.7%) and 16 female patients (53.3%; Table 1).

Mixed ANOVA was conducted to investigate the effect of rESWT on main the variable outcomes (pain intensity level, and lumbar ROM). There was a significant interaction effect of groups and time (Wilks' lambda value=0.163, η^2=0.837, F-value=80.699, p=0.0001). Moreover, there was a significant

Table 1. Comparison mean values of patients general characteristics between both groups

	Study group (n=30)	Control group (n=30)	p-value	Significance
Sex				
Male	16 (53.3)	14 (46.7)	0.606	NS
Female	14 (46.7)	16 (53.3)		
Age (yr)	43.03±5.07	44.23±3.55	0.293	NS
Weight (kg)	69.43±5.00	69.03±3.81	0.729	NS
Height (cm)	165.17±6.12	163.73±6.43	0.381	NS
Body mass index (kg/m^2)	25.47±2.22	25.82±2.24	0.541	NS

Values are presented as number (%) or mean±standard deviation.
NS, not significant.

of main effect of tested groups (Wilks' lambda value=0.163, η^2=0.837, F-value=80.842, p=0.0001). Also, there was a significant main effect of time (Wilks' lambda value=0.073, η^2=0.927, F-value=199.441, p=0.0001).

Pain intensity showed a statistically significant reduction of mean VAS scores of both groups posttreatment compared to pretreatment (p=0.0001). Pretreatment comparison between groups, showed non-significant difference between groups (p=0.226), while posttreatment scores showed a statistically significant decrease between groups in favor of the study group (p=0.0001; Table 2).

The results of this study regarding lumbar ROM showed there was no statistically significant difference in lumbar ROM in all directions posttreatment in control group, and a statistically significant increase in the posttreatment mean values of all lumbar ROM scores in all directions, in the study group (p=0.0001). Between groups comparison showed non-significant difference in pretreatment mean values of all lumbar ROM scores, and a statistically significant increase in all ROM scores between both groups posttreatment in favor of the study group (p=0.0001; Table 2).

F-wave minimal latency for both peroneal and tibial nerves results showed a significant decrease at posttreatment compared with pretreatment in study group only (p=0.0001). However, there was a non-significant difference at posttreatment compared with pretreatment in control group (p=0.701, p=0.498) for both peroneal and tibial nerves respectively. Between groups comparison showed a non-significant difference in pretreatment mean values (p=0.163, p=0.053) for peroneal and tibial nerves respectively, and a statistically significant decrease posttreatment between both groups in favor of the study group (p=0.0001) for both nerves. For Fc (peroneal and tibial) results showed a significant decrease at posttreatment compared with pretreatment in the study group only (p=0.0001) for both nerves. However, control group showed non-significant difference at posttreatment compared to pretreatment (p=0.445, p=0.277) for peroneal and tibial nerves, respectively. While there was a statistically significant decrease between both groups posttreatment in favor of the study group (p=0.0001) for both nerves (Table 3). The results of the correlational analyses between clinical and electrophysiological studies revealed that there was significant positive moderate correlation between VAS scores and Fc peroneal scores (r=0.37, p=0.044; Table 4). And strong negative correlation between right side bending and peroneal F-minimal latency (r=-0.50, p=0.005; Fig. 2). Moreover, a significant negative moderate correlation between left side bending and peroneal F-minimal latency (r=-0.42, p=0.019; Fig. 3).

DISCUSSION

Epidural fibrosis, the most common cause of PLS, develops following lumbar laminectomy due to excessive healing process [1,4]. Epidural fibrosis leads to recurrent or persistent back pain and leg pain due to compression on the nerve root or dura mater [30]. Paraspinal muscles dissection and bone resection is currently believed to produce migration of fibroblasts to the epidural space, and in conjunction with the differentiation of myofibroblasts, accumulation of fibronectin and the increase in extracellular components eventually causes the development of fibrosis. Additionally, TGF-1β secreted from fibroblasts increase the formation of fibrosis [1]. Therefore, this study was conducted to investigate the effect of rESWT on pain, lumbar ROM and electrophysiological parameters in patients with epidural fibrosis.

The results of the current study showed a significant reduction in pain intensity reflected as a decrease in the posttreatment VAS scores in both groups with more significant decrease in the study group.

Several mechanisms could explain the observed reduction in pain intensity in favor of the study group. The first one is that

Table 2. VAS and lumbar ROM of the study and control group

	Study group	Control group	MD (change)	p-value
VAS				
Pretreatment	7.63±0.99	7.93±0.53	0.30	0.226
Posttreatment	2.73±1.01	6.80±1.12	4.07	0.0001*
MD (change)	4.90	1.13		
p-value	0.0001*	0.0001*		
Flexion				
Pretreatment	9.77±3.63	9.93±3.15	0.16	0.871
Posttreatment	27.13±4.39	12.20±4.49	14.93	0.0001*
MD (change)	17.36	2.27		
p-value	0.0001*	0.290		
Extension				
Pretreatment	6.17±1.48	6.27±1.63	0.10	0.840
Posttreatment	14.33±1.09	7.63±2.91	6.70	0.0001*
MD (change)	8.16	1.36		
p-value	0.0001*	0.271		
Right lateral flexion				
Pretreatment	12.23±5.28	12.57±3.75	0.34	0.769
Posttreatment	29.90±4.38	15.83±3.91	14.07	0.0001*
MD (change)	17.67	3.26		
p-value	0.0001*	0.059		
Left lateral flexion				
Pretreatment	13.23±5.76	13.83±4.12	0.60	0.628
Posttreatment	30.10±4.97	17.00±4.17	13.10	0.0001*
MD (change)	16.86	3.17		
p-value	0.0001*	0.064		
Right rotation				
Pretreatment	3.50±1.03	3.57±1.16	0.07	0.835
Posttreatment	9.07±1.08	5.10±1.18	3.97	0.0001*
MD (change)	5.57	1.53		
p-value	0.0001*	0.119		
Left rotation				
Pretreatment	3.27±2.22	3.43±1.16	0.16	0.666
Posttreatment	8.90±1.15	5.03±1.12	3.87	0.0001*
MD (change)	5.63	1.60		
p-value	0.0001*	0.115		

Values are presented as mean±standard deviation.
VAS, visual analogue scale; ROM, range of motion; MD, mean difference.
*Significant ($p<0.05$).

rESWT has an anti-inflammatory effect which could reduce peri-neural compression [13,31]. This explanation was supported by the findings of Haberal et al. [1], Kaya Şimşek et al. [10], Lee et al. [17], and Zhou and Yang [18] who found that rESWT application is effective in stimulating nitric oxide synthase and stimulating production of nitric oxide, which have anti-inflammatory effect in musculoskeletal disorders.

The second mechanism is that rESWT produces analgesic effect, that is possibly referred to improved local capillary blood circulation, that in turn reduces muscle tension and stiffness, which in turn alleviates pain. Also, rESWT can reduce the flow of excessive stimuli affecting nociceptors and stimulation of nerves which result in changes of free radicles around the cell, increasing cell permeability, inhibiting transmission of pain signals, increasing pain threshold and promoting cell angiogenesis through its piezoelectric, mechanical and cavitation effect [32]. This explanation was supported by a study of Hausdorf et al. [33] who stated that rESWT selectively destroys non-myelinated nerve fibers and reduces the level of substance P in the dorsal root ganglia that eventually reduces pain in musculoskeletal tissues.

The third mechanism is that rESWT has anti-fibrotic effect due to its role in reduction of TGF-1β, collagen and fibronectin

Table 3. F-wave minimal latency and F-chronodispersion

	Study group	Control group	MD (change)	p-value
F-wave minimal latency (peroneal)				
Pretreatment	56.72±2.82	58.33±2.98	1.61	0.163
Posttreatment	50.82±3.42	58.03±2.97	7.21	0.0001*
MD (change)	5.90	0.30		
p-value	0.0001*	0.701		
F-wave minimal latency (tibial)				
Pretreatment	56.45±5.16	59.34±3.55	2.89	0.053
Posttreatment	51.81±4.95	58.56±3.80	6.75	0.0001*
MD (change)	4.64	0.78		
p-value	0.0001*	0.498		
F-chronodispersion (peroneal)				
Pretreatment	10.58±1.97	10.46±1.87	0.12	0.792
Posttreatment	5.19±1.60	10.09±1.94	4.90	0.0001*
MD (change)	5.39	0.37		
p-value	0.0001*	0.445		
F-chronodispersion (tibial)				
Pretreatment	12.14±2.89	12.09±1.77	0.05	0.933
Posttreatment	6.15±2.53	11.44±1.76	5.29	0.0001*
MD (change)	5.99	0.65		
p-value	0.0001*	0.277		

Values are presented as mean±standard deviation.
MD, mean difference.
*Significant (p<0.05).

Table 4. Correlation between VAS and F-chronodispersion

	VAS		
	r-value	p-value	Significance
F-chronodispersion (peroneal)	0.37	0.044*	Significant

Strong correlation (±0.50 to ±1), medium correlation (±0.30 to ±0.49), and small correlation (<±0.29).
VAS, visual analogue scale.
*Significant: (p<0.05).

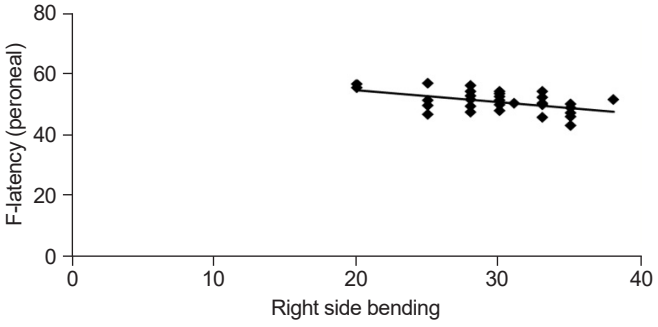

Fig. 2. Scatter plot for the bivariate correlation between right side bending and peroneal F-latency.

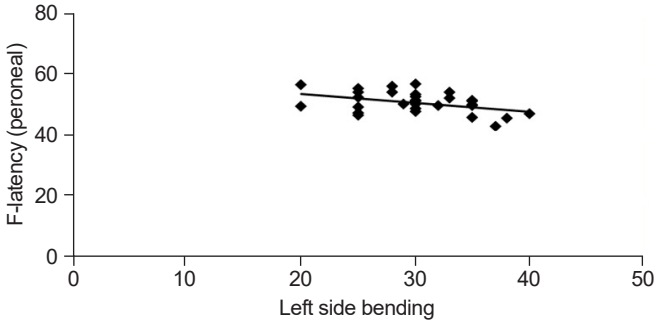

Fig. 3. Scatter plot for the bivariate correlation between left side bending and peroneal F-latency.

levels, which play a crucial role in developing fibrotic tissues [1,10,17,18]. This explanation was supported by the findings of Zhao et al. [34] who induced a trophic wound model in rabbits and could thus conclude that low as well high energy rESWT reduced fibroblastic density which plays a crucial role in developing scar tissue. Also, Haberal et al. [1] investigated the effect of rESWT on post laminectomy epidural fibrosis on rats and concluded that rESWT application decreased fibrosis after laminectomy.

In the current study, control group showed significant reduction in pain intensity, which concur with the findings of Sharaf

et al. [20], who concluded that conventional physical therapy program (TENS, hot packs and McKenzie exercises) has an effect on managing pain in PLS patients. The significant decrease of pain intensity in the control group posttreatment compared with pretreatment might be attributed to the role of TENS and hot packs in reducing pain through the activation of gate control theory [24]. Nevertheless, McKenzie exercises might reduce pain through two mechanisms. Firstly, increasing level of serotonin opioids which decreases pain [4,19]. Secondly, Back pain in patients with PLS might be also attributed to back muscle weakness due to incision. Weakness of superficial trunk muscles is one important risk factor for LBP [35] and strengthening of these muscles is often associated with significant reduction of chronic LBP. So, the second explanation might be attributed to the role of McKenzie exercises in improving back muscle strength. Abdi et al. [36] claimed back extension exercise to cause significant reduction of back pain after lumbar surgery, which support the findings of the current study.

In the current study the lumbar ROM showed a significant increase in lumbar ROM in all directions posttreatment compared to pretreatment in the study groups. The significant increase of all lumbar ROM in the study group might be attributed to significant reduction of pain in the study group. This explanation is based on the fact that back pain is the cause of limited lumbar ROM. Also, the significant increase in all lumbar ROM in the study group could be explained as an effect of anti-fibrotic effect produced by rESWT, which leads to breakdown of adhesions. This explanation was confirmed by El Naggar et al. [37] who emphasized the role of rESWT in reducing the fibrotic density, thus improving ROM.

F-wave is one of late responses which stimulate the motor peripheral nerve, the stimulus propagates up towards the alpha motor neuron of the anterior horn cells of the spinal cord and then pass distally in the efferent fibers towards the recorded muscle (extensor digitorum brevis or abductor hallucis longus). F-wave pass along fibers of the nerve root L5 or S1. So, any damage or lesion caused by compression on nerve root could be affect the F-wave parameters [38]. Regarding the results of F-wave minimal latency and Fc. There was a significant decrease at posttreatment compared to pretreatment in study group. The control group showed non-significant decrease either within or between groups.

The significant improvement in F-minimal latency and Fc might be attributed to decreases of compression on nerve root caused by epidural fibrosis. This explanation was supported by that rESWT can reduce the fibrotic density which could cause compression on nerve root, causes prolongation of either F-wave minimal latency and Fc [1]. This compression is caused by the migration of fibrous tissues to the dura and surrounding nerve roots, which is the main cause of recurrent radiculopathy [39].

The results regarding correlation between VAS and peroneal Fc showed a significant positive correlation between VAS and peroneal Fc. The correlation might be attributed to that prolongation of Fc is due to compression on nerve root caused by epidural fibrosis, which is in turn cause of pain after lumbar laminectomy [39]. Also, the negative correlation between lumbar ROM of side bending and peroneal F-wave minimal latency might be attributed to the impact and/or relation of lumbar side bending on the intervertebral foramen dimensions (width, height and area). The degree of change in the foraminal area is strongly correlated to spinal segmental motion [40]. As mentioned before the prolongation of F-minimal latency is due to proximal nerve compression which leads to proximal focal demyelination on nerve root [23].

Limitations

The study has some limitations, blinding of the physiotherapist that applying interventions (second author) was not possible. However, the author responsible for collecting data (second author) was blinded to group allocation. The surgeon who did the operation was not the same person, and this might affect treatment results. Future studies are recommended to be conducted on post laminectomy epidural fibrosis patients operated by same surgeon. It is recommended to conduct further studies to determine the long-term effect of rESWT on pain and lumbar ROM, measurement of fibrosis density posttreatment by contrast MRI. Lack of sham group in this study is one of the limitations, that could be recommended for future studies. As most of FBSS patients are over 50 years, it is recommended to apply study targeting this population.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

Conceptualization: Rashad UM. Data curation: Abousenna MH, Rehab NI. Methodology: Abousenna MH. Project administration: Rashad UM, Rehab NI. Investigation: Elsamman AK. Supervision: Rashad UM, Elsamman AK, Rehab NI. Validation: Rashad UM. Visualization: Rashad UM. Writing – original draft: Abousenna MH. Writing – review & editing: Rashad UM, Rehab NI. Approval of final manuscript: all authors.

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Original Article

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Effect of Soft Surface Stepping Exercise on Physical Activity Among Community-Dwelling Elderly: A Prospective Randomized Controlled Trial

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Objective: To investigate the effects of modified stepping exercises over six weeks on functional mobility and individual lower extremity muscle strength in community-dwelling older individuals.

Methods: This prospective randomized controlled trial design was conducted in thirty-two older adults who completed a modified stepping exercises program (n=16 for soft-surface stepping exercise; n=16 for firm-surface stepping exercise). These exercises were practiced for 50 minutes/day, three days/week, over six weeks. They were assessed for their functional mobility relating to levels of independence at baseline, after 4 weeks, after 6 weeks of intervention, and at 1 month after the last intervention sessions.

Results: Both groups showed significant improvements in functional mobility, lower extremity muscle strength, and walking speed after 4 and 6 weeks of intervention, as well as at the one-month follow-up. However, the soft-surface stepping exercise group exhibited significantly greater improvements in dynamic balance (p=0.035) and lower extremity muscle strength (p=0.015) compared to the firm-surface stepping exercise group after 6 weeks of intervention. Additionally, the soft-surface group demonstrated superior gains in hip flexor (p=0.041), hip extensor (p=0.047), hip adductor (p=0.026), and hip abductor strength (p=0.046), with these enhancements maintained at the one-month follow-up.

Conclusion: Soft-surface stepping exercise that involves whole-body movements offers a promising alternative to promote independence and safety among community-dwelling older adults. This study underscores the need for future research to evaluate the sustained impact of these benefits post-intervention, particularly during a retention period following the intervention.

Keywords: Sensory integration; Postural balance; Range of motion, articular; Gait

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INTRODUCTION

The growing worldwide population of elderly individuals can be attributed to advancements in healthcare. The aging process leads to the decline of the somatosensory, visual, and vestibular systems responsible for maintaining balance [1]. Additionally,

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the functional capacity of all bodily systems declines, increasing the likelihood of a high risk of falls [2]. Falls prevention among older people is an important global public health concern. The majority of falls among older people occur while walking [3,4]. The second most common cause of mortality from non-intentional injuries worldwide is falls, and research indicates that 40% of community-dwelling seniors aged 65 and over experience falls annually [5]. Physical inactivity and functional ability deficits, such as compromised balance and decreased lower limb muscular strength, have been recognized as autonomous factors that contribute to falls and fall-related injuries, including head injuries and hip fractures, in the elderly population [6,7].

Several studies have shown a correlation between impaired stepping ability and falls among older individuals [8-10]. Multi-directional steps are essential for activities of daily living (ADL) because, while walking indoors, 35%–50% of all steps consist of those that change the direction of movement, i.e., non-straight steps [11]. Normal individuals should be able to take steps in multiple directions to perform ADL safely. Previous studies have shown that step training with multiple directions has been shown to enhance balance and walking ability in elderly individuals and those diagnosed with Parkinson's disease [12-14]. The square step-up training, in which patients perform step-up exercises in many directions on a box, enhanced lower extremity strength and balance ability more than the general walking exercise group [15]. A more specific form of balance training for fall prevention is step training. A recently published meta-analysis by Okubo et al. [16] found that volitional and reactive step-up training can remarkably reduce fall rates by 50%. Training elderly women to perform bench steps with increasing step heights simultaneously enhances their functional capacity, thigh strength, and force-velocity characteristics of the knee extensors [17]. This exercise pattern also improves lower body strength, balance, and agility in the elderly. Besides, this exercise is an aerobic exercise and, thus, can improve cardiorespiratory fitness [18]. For exercise adherence, the evidence indicates that this exercise, as a dichotomous approach, provides a practical, time-efficient, and low-threshold program for the elderly. This activity offers many advantages simultaneously by using a dichotomous strategy.

Compared to training methods conducted on a stable support surface, functional training with unstable support is advantageous for increasing exercise difficulty due to the induction of unexpected proprietary sensory information and reaction forces in multiple directions [19]. A further study demonstrated that exercising on foam and sand improves this system's function due to the proprioceptive system's involvement, increases ankle strength and improves sensory information processing in sudden perturbations. Moreover, previous studies reported the effects of unstable surfaces [20,21], but overall improvements in lower-extremity muscle strength, power, and balance were similar. A practical and safe alternative training program to mitigate intrinsic fall risk factors in older adults [22,23].

Some previous studies have demonstrated the effectiveness of step-up training in enhancing functional activity, gait, and balance across various patient populations. However, insufficient studies have applied combining stepping exercises in various directions on unstable or uneven surfaces simultaneously. Therefore, this study aimed to compare the effects of modified stepping exercises on an unstable surface for 6-weeks on overall physical function, including walking, functional strength of lower limbs, and balance ability in community-dwelling older individuals.

METHODS

Study design and setting

This randomized controlled was condunted in rural community and sub-district health promotion hospitaltrial Phayao, Thailand. Complies with the CONSORT (Consolidated Standards of Reporting Trials) guidelines statement for transparent reporting, which was registered in the Clinical trail NCT06505083. The study protocol was approved by the Human Research Ethics Committee at the University of Phayao Review Board (protocol code: HREC-UP-HSST 1.2/101/66; approval date: 8/06/2023). Before participating in any study-related procedures, each participant provided informed consent by signing a consent form. To protect participants' privacy, each record in the database was assigned a unique alphanumeric code. The study was conducted by the principles outlined in the Declaration of Helsinki.

Participants

Participants were recruited from a local community in Thailand between June 2023 and March 2024. Eligibility criteria included age 65 years and older, absence of regular exercise (defined as twice per week for one week), willingness to understand the study purpose and procedures accurately, and voluntary participation. Additionally, eligible participants were required to walk over at least 10 m without assistive devices independently, and

the participants who demonstrated a single leg stand (SLS) test duration of less than 10 seconds indicated a higher predictive fall risk among older adults [24]. Exclusion criteria encompassed individuals exhibiting signs or symptoms that might impede walking or study participation, such as unstable medical conditions, inflammation in the lower extremity joints (with a pain scale rating of more than 5 out of 10 on a visual analog scale), and sequelae of neurological deficits. Participants diagnosed with dementia, depression, severe cardiovascular disease, or mental illness were also excluded. Moreover, the included participants did not have confirmed dementia and attained a total score of 24 or more on the Thai version of the Mini-Mental State Examination.

Ultimately, 32 participants who fully comprehended the study's purpose and content and consented to participate were selected as target participants (Fig. 1). Participants were randomly allocated to either the experimental group (n=16), undergoing unstable stepping exercises, or the control group (n=16), engaging in stable stepping exercises, utilizing a computer-generated permutation block randomization design. The design of this study is a single-blind, randomized controlled trial (subjects blind). All data were measured by the same physical therapist before, after the 4-week, after the 6-week intervention and 1 month follow-up. Detailed study explanations were provided to all participants, and written informed consent was obtained before their involvement. Participants were assured of their right to withdraw from the study at any time. Demographic characteristics, including weight, height, age, and sex, were collected through participant interviews, and body mass index (BMI) was calculated using the formula: BMI=weight (kg)/height $(m)^2$.

Sample size

The sample size estimation was based on an effect size of treatment measured with the Timed Up and Go test (TUGT) of 8.1 seconds for people with elderly [25]. The analysis was based on a one-sided paired t-test at 80% power with a significance level of 0.025, 12 participants per group are needed. Considering a 20% dropout rate, the sample size of 16 participants per group was estimated using G*Power 3.1.

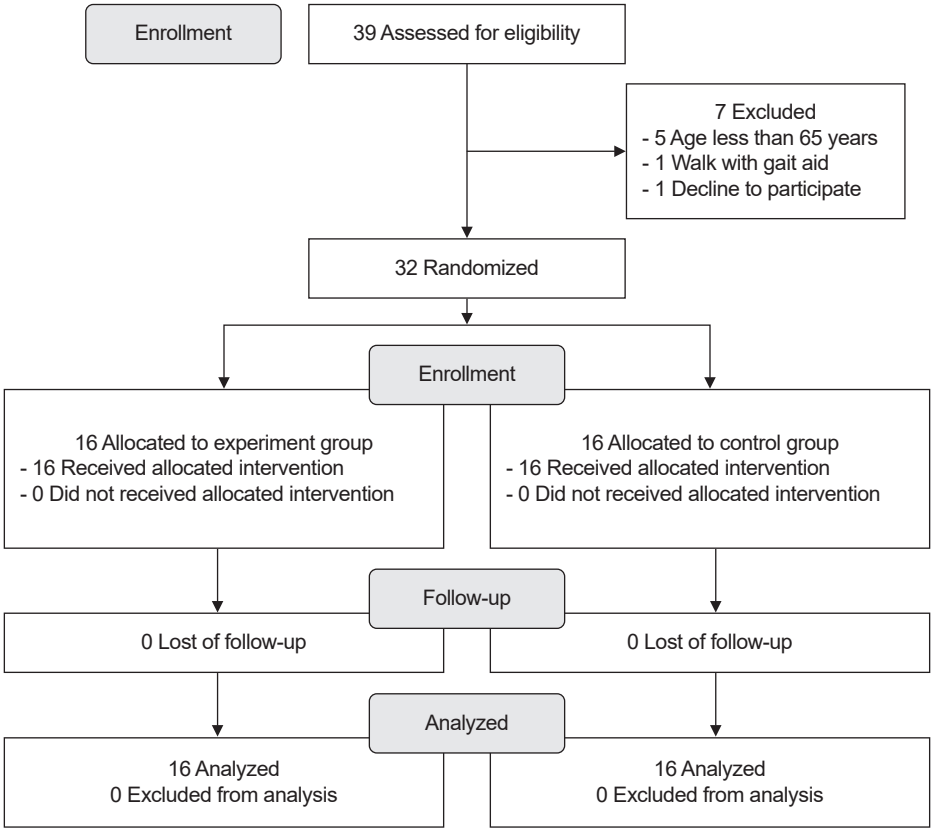

Fig. 1. Study flowchart.

Experimental procedure

The training in the modified stepping exercise both groups had three components; a 10-minute warm-up and stretching session, a 30-minute session of modified stepping exercise (The exercise program was divided into two phases. Participants were required to exercise continuously for 15 minutes, followed by a rest period of no more than 5 minutes. They then resumed exercising for another 15 minutes. This cycling was maintained for three weeks. From weeks 4 to 6, participants were instructed to exercise continuously for 30 minutes without taking any breaks between sessions), and a 10-minute cool-down with stretching to reduce exercise fatigue and prevent accidents. To achieve the desired level of intensity for this exercise, it is recommended to use a modular approach similar to resistance training, namely at 60% of the one-repetition maximum [17,25]. The research used the Aroma Mechanic Metronome model AM-707 BK, which operates at a tempo of 80 beats per minute (bpm), to control each of the participants' rhythmic frequencies. However, no guidelines are available about the number of bench-stepping repetitions required to achieve hypertrophy and strength gains. Therefore, we selected the number of repetitions based on previous studies using multi-joint resistance exercises such as the leg press [26]. The intervention program for both groups involved performing step-up on a wooden box with dimensions of 45 cm×30 cm×18 cm. For the experimental group, foam pads with a thickness of 2 inches (45 cm×30 cm×16 cm) were added to the step box, creating a soft, unstable surface for step-up training (Fig. 2). In contrast, the control group performed step-up directly on a wooden box of the same size, providing a stable, firm surface for training. The step-up exercise was performed three times per week for six weeks, totaling 18 sessions. The detailed, multi-directional step-up training procedure was as follows: Participants performed step-up and step-down movements in three directions: forward, right side, and

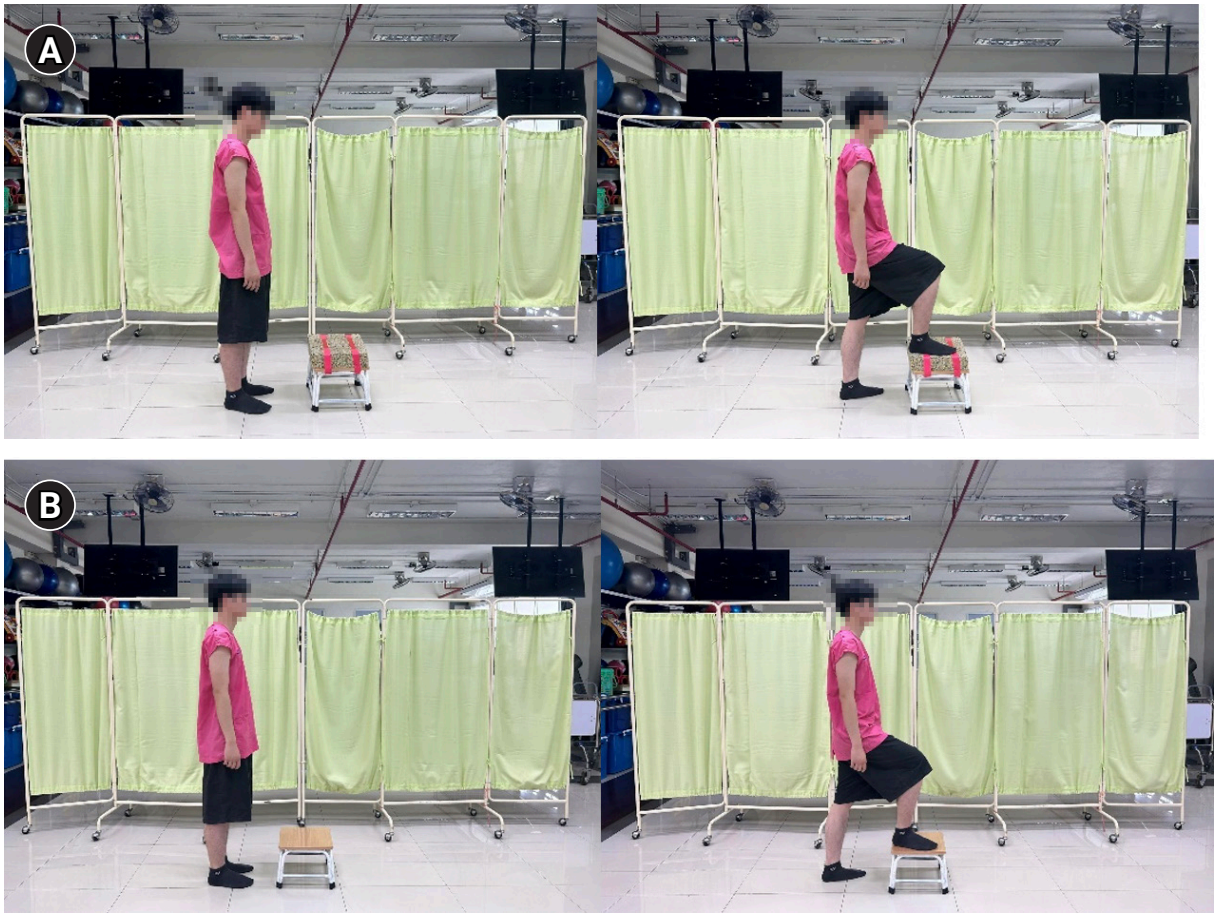

Fig. 2. Modified stepping exercise. (A) Soft-surface stepping exercise. (B) Firm-surface stepping exercise.

left side. They were instructed to step onto and off the box at a consistent speed during each trial. Each participant was closely monitored throughout the training sessions by a physical therapist to ensure proper technique, provide support, and minimize fatigue or errors. Adequate rest periods were provided between trials. The participants from each group conducted their exercise programs in separate villages under the supervision of a physical therapist.

Outcome measures

Participants had an evaluation of their functional mobility, which is essential for achieving independence, including the TUGT, Five Times Sit-to-Stand test (FTSST), 10 Meter Walk Test (10MWT), and individual muscle strength: hand-held dynamometer, and back-leg-chest test in a random sequence by a group of assessors who had excellent inter-rater reliability (intraclass correlation coefficients [ICCs]=0.88–0.99). The measurements were executed three times, including before training (pre-test), after 4-week training (intermediate test), after 6-week training (post-test), and after one month (follow-up).

Measurements

TUGT

The study participants were instructed to sit on a chair (46 cm height) without an armrest [27]. They were instructed to get up from the chair on command, walk at a comfortable pace, walk around the cone marked 3 m ahead, and return to a seated position on the original chair. The stopwatch was started as soon as the paticipants lifted their buttocks off the chair, and it was stopped at the point where the paticipants sat back in the chair after completing walking. The total time each paticipants took to complete the task was noted as the final score [28].

FTSST

The FTSST is a simple and quick test initially designed to be a proxy measure of lower-limb strength. The test requires a paticipants to stand up and sit down five times as quickly as possible from a chair with a seat 43 cm high. The time taken to complete the test (the FTSST scores) is recorded with a stopwatch. Excellent test-retest reliability of FTSST scores (ICC=0.933) has been reported in people with chronic stroke and community-dwelling older adults (ICC=0.89–0.96). Several other studies have demonstrated the reliability or validity or both of FTSST scores in specific paticipants populations, including Parkinson's disease [29] and renal pathologies and participants with rheumatoid arthritis and balance disorders [30].

10MWT

The 10MWT was used to evaluate gait ability. This test generally evaluates the gait velocity of patients with neurological damage and shows high inter-rater and intra-rater reliability (r=0.89–1.00) [31]. In the present study, the paticipants were instructed to individuals perform three 10-m overground walk trials timed with a stopwatch in each comfortable and maximum speed to characterize our participant sample. For comfortable walking speed, individuals were instructed to "walk at a speed that feels the most comfortable," and for maximum speed, individuals were instructed to "walk at the fastest speed you feel safe" walk 10 m; the time taken for 4 m, excluding the first 3 m and the last 3 m, which take into account acceleration and deceleration, was measured in units of seconds [28].

Individual isometric muscle strength

The strength of maximum isometric voluntary contraction of the paticipants's hip flexor, extensor, adductor, abductor, knee flexor, extensors, and ankle dorsiflexion, plantar flexors (in kilograms) was measured using a Nicholas handheld dynamometer (HHD) (model 01,160; Lafayette Instrument Company). The Nicholas HHD is a digital force gauge measuring forces from 0.0 to 199.99 kg. The measurement protocol was described by Magalhães et al. [32]. The make test, operationally defined as a maximal effort exerted against a stationary HHD, was used to quantify the isometric force production. For the knee flexors and extensors, the participants were seated in a high chair with hip and knee flexion fixed at 90°, and the dynamometer was placed on the anterior aspect of the tibia at 5 inches proximal from the tip of medial malleoli. The portable dynamometer was positioned across the medial and lateral malleolus of the foot to measure the strength of the hip adductor and abductor muscles. In this position, participants were lying supine on a yoga mat. During the test, the examiner manually stabilized the body parts proximal to the tested limb segment. The participants assumed the prone position on a yoga mat while the researcher positioned a hand heal dynamometer at the posterior ankle joint to assess the hip extensor and knee extensor. The individuals were lying supine on a yoga mat while their ankle dorsiflexors and plantar flexors were assessed. The portable dynamometer was positioned on either the top or bottom side of the foot, specifically above the metatarsophalangeal joint. During the test, the examiner manually stabilized the body parts proximal

to the tested limb segment. The participants assumed the prone position on a yoga mat while the researcher positioned a hand heal dynamometer at the posterior ankle joint to assess the hip extensor and knee extensor. Each paticipants completed three trials in which maximal force was generated for 2–3 seconds in three actions with each leg testing. A 5-minute rest interval was inserted between each measurement. A composite leg strength score was calculated by dividing the mean left and right-side strength score (mean scores in the three actions, divided by 2) by body weight (kg). The average value of three trials was used for data analysis [33].

Back-leg-chest dynamometer

A calibrated back-leg-chest dynamometer (BLCD) (the Takei 5402 Back Muscle Digital Dynamometer) measures isometric muscle strength, recorded in kilograms of force. There is excellent test-retest reliability (ICC=0.98) for leg extension strength [34]. The dial ranges from 0 to 300 kg (0 to 660 lb) in 10 kg (10 lb) increments. For the test, the length of the chain was adjusted to the participants' height by asking the paticipants to stand on the base of the BLCD with extended knees. Subsequently, the handle was positioned at the height of the intra-articular space of the knee joint. For the test, participants had to stand on the base, with knees and hips flexed slightly, while the lower back had to maintain an appropriate lordotic curve. Participants were asked to lift in a vertical direction by providing continuous isometric contractions of the knees, hips, and lower back extensors while holding the handle. Participants were asked to increase the pull safely gradually and reach the maximal force in three seconds while keeping this pull for another two seconds. After the demonstration and a familiarization trial, three trials were performed, with rest periods of 30 seconds between trials [35]. The maximal strength for the three trials was used for further analysis.

Statistical analysis

Descriptive statistics were used to describe the participants' demographics and the study's findings. The Shapiro-Wilk test was used to verify the normality of the acquired data. Independent t-tests (for continuous data) and chi-square tests (for categorical data) were used to determine differences between the intervention and control groups at baseline. A 4×2 mixed-model ANOVA, with time (pre-test, 4-week, 6-week, and 1 month follow-up) as a within-subjects vaiable and group (soft-surface stepping and firm-surface stepping) as a between-subjects variable, was used to analyze the effects of interventions on the outcome meaures and to identify significancant group-by-time interactions. Significant interction effects were compared using post hoc Bonferroni pairwies comparison. To determine the effect size of the time×group interaction, the partial eta squared (ηp^2) was calculated, which was interpreted considering the ηp^2 values of 0.01, 0.06, and 0.14, which correspond to effect sizes small, moderate, and large, respectively. The level of significant difference was set at a p-value of <0.05. Analyses were performed with SPSS (version 29 for Windows; IBM Corp.).

RESULTS

Baseline participant characteristics and adherence

A total of 32 participants were divided equally into an experimental group of 16 people and a control group of 16 participants. Table 1 provides a concise summary of the key characteristics of the research participants. There were no significant differences in the sex, age, body weight, height, BMI, and vital sign features of the participants through the groups at the beginning of the study (p>0.05). The training sessions had a 90%

Table 1. Baseline descriptive of all participants, exercise group, and control group

Variable	Soft surface stepping exercise (n=16)	Firm surface stepping exercise (n=16)	p-value
Age (yr)	70.69±5.51	71.42±5.12	0.321
Sex, female/male	9 (56.25)/7 (43.75)	10 (62.50)/6 (37.50)	0.527
Weight (kg)	54.58±9.64	54.56±9.53	0.991
Height (cm)	154.76±9.68	157.86±7.70	0.134
Body mass index (kg/m^2)	22.72±3.07	21.83±0.36	0.216
Systolic blood pressure (mmHg)	133.47±19.20	130.02±16.89	0.419
Diastolic blood pressure (mmHg)	74.07±13.68	71.92±9.22	0.420
Heart rate (beats/minute)	78.02±11.64	77.25±12.56	0.781

Values are presented as mean±standard deviation, and the data comparisons were executed using the t-test for independent samples. Values are presented as the number (%), and the data among the groups were compared using the chi-square test.

attendance rate, and all participants completed their allocated progression program.

Functional and walking ability

Significant within-group improvements in functional outcomes were observed in the soft-surface stepping exercise group, specifically in TUGT, BLCD, and FTSST at week 4, week 6, and the one-month follow-up (TUGT: $F_{3,13}$=5.12, p=0.015; BLCD: $F_{3,13}$=21.94, p<0.001; FTSST: $F_{3,13}$=22.75, p<0.001, respectively). Conversely, the firm-surface stepping exercise group showed significant within-group improvements in TUGT and FTSST only at week 6 and the one-month follow-up (TUGT: $F_{3,13}$=6.56, p=0.006; FTSST: $F_{3,13}$=8.22, p=0.003). Additionally, BLCD significantly improved in both groups at week 4 and week 6; however, no significant improvement was observed at the one-month follow-up in the firm-surface stepping exercise group ($F_{3,13}$=8.00, p=0.003). Regarding walking speed, the 10MWT showed significant improvements only at week 6. In the soft-surface stepping exercise group, both preferred ($F_{3,13}$=4.11, p=0.029) and fast walking speeds ($F_{3,13}$=3.51, p=0.046) improved significantly. Similarly, in the firm-surface stepping exercise group, significant improvements were observed in both preferred ($F_{3,13}$=3.78, p=0.038) and fast walking speeds ($F_{3,13}$=4.68, p=0.020) (Table 2). The between-group analysis (time×group interaction) revealed that the soft-surface stepping exercise had a large effect size on the

Table 2. Comparison of functional ability and walking ability within-group at pre-test, 4 weeks, 6 weeks, and 1 month (follow-up) and between groups (soft surface stepping and firm surface stepping exercise)

Outcome	Soft surface stepping exercise within-group difference	Firm surface stepping exercise within-group difference	Between groups difference p-value (95% CI)	Partial eta squared (ηp^2)
TUGT (s)				
Pre-test	10.89±2.50 (9.56–12.22)	10.87±2.10 (9.76–11.99)	0.985 (-1.65 to 1.68)	0.000
4 wk	8.55±1.38 (7.812–9.28)*	9.31±1.16 (8.56–10.06)	0.133 (-1.77 to 0.24)	0.074
6 wk	8.11±1.09 (7.75–8.69)**	9.06±1.18 (8.35–9.78)*	0.035 (-1.83 to -0.07)	0.140
1 mo (follow-up)	8.49±1.52 (7.63–9.25)*	8.88±1.66 (7.99–9.76)**	0.465 (-1.53 to 0.76)	0.015
BLCD (kg)				
Pre-test	46.07±13.03 (39.12–53.01)	40.23±9.95 (34.93–45.54)	0.165 (-2.54 to 14.20)	0.063
4 wk	59.97±15.21 (51.86–68.08)**	51.30±12.80 (44.48–58.12)*	0.091 (-1.47 to 18.82)	0.092
6 wk	63.46±14.17 (55.91–71.01)**	52.15±10.25 (46.68–57.61)**	0.015 (2.38 to 20.24)	0.182
1 mo (follow-up)	58.94±14.68 (51.12–66.77)*	49.06±14.67 (41.24–56.87)	0.066 (-0.71 to -20.48)	0.108
FTSST (s)				
Pre-test	12.64±2.12 (11.51–13.77)	12.02±2.70 (10.93–13.13)	0.416 (-0.90 to 2.12)	0.022
4 wk	10.24±2.70 (8.80–11.68)*	10.99±1.96 (10.08–11.89)	0.351 (-2.38 to 0.87)	0.029
6 wk	9.35±1.52 (8.54–10.15)**	10.09±1.39 (9.35–10.83)**	0.158 (-1.79 to 0.30)	0.065
1 mo (follow-up)	9.21±1.38 (8.47–9.94)**	10.09±1.44 (9.32–10.86)*	0.087 (-1.89 to 1.13)	0.094
Walking ability (m/s)				
10MWT prefer speed				
Pre-test	1.05±0.19 (0.95–1.15)	0.89±0.39 (0.68–1.10)	0.170 (-0.07 to 0.37)	0.062
4 wk	1.20±0.19 (1.10–1.31)	1.13±0.22 (1.01–1.25)	0.345 (-0.08 to 0.22)	0.030
6 wk	1.32±0.22 (1.20–1.44)*	1.25±0.24 (1.13–1.38)*	0.666 (-0.12 to 0.19)	0.006
1 mo (follow-up)	1.31±0.24 (1.18–1.44)	1.14±0.16 (1.05–1.22)	0.132 (-0.29 to 0.21)	0.074
10MWT fasted speed				
Pre-test	1.39±0.11 (1.33–1.45)	1.34±0.20 (1.24–1.45)	0.107 (-0.02 to 0.27)	0.084
4 wk	1.51±0.31 (1.35–1.68)	1.42±0.22 (1.30–1.53)	0.931 (-0.20 to 0.22)	0.000
6 wk	1.69±0.23 (1.57–1.81)*	1.56±0.19 (1.46–1.66)*	0.697 (-0.13 to 0.19)	0.005
1 mo (follow-up)	1.43±0.23 (1.30–1.55)	1.34±0.15 (1.26–1.42)	0.206 (-0.05 to 0.23)	0.053

Values are presented as mean±standard deviation (95% CI).
For the difference between groups at each time point analyzed using the 4×2 mixed-model analysis of variance.
The data comparisons within the group were analyzed at pre-test, 4 weeks, 6 weeks, and after 1 month follow-up.
CI, confidence interval; TUGT, Timed Up and Go test; BLCD, back-leg-chest dynamometer; FTSST, Five Times Sit-to-Stand test; 10MWT, 10 Meter Walk Test.
*Significant improvement from baseline levels (p<0.05).
**Significant improvement from baseline levels (p<0.01).

TUGT (ηp^2=0.140, p=0.035) and leg muscle strength (BLCD) (ηp^2=0.182, p=0.015), indicating greater improvements in balance ability and lower limb muscle strength compared to the firm-surface stepping exercise group after the 6-week intervention. However, no significant differences were observed for the FTSST and walking speed (10MWT) (Table 2).

Isometric muscle strength

Participants in the soft-surface stepping exercise group demonstrated significant improvements in muscle strength across multiple muscle groups, including the hip extensors ($F_{3,13}$=12.56, p<0.001), hip adductors ($F_{3,13}$=14.07, p<0.001), hip abductors ($F_{3,13}$=32.37, p<0.001), knee extensors ($F_{3,13}$=84.13, p<0.001), ankle dorsiflexors ($F_{3,13}$=16.27, p<0.001), and ankle plantarflexors ($F_{3,13}$=8.05, p=0.003) from baseline (pre-test) to 4 weeks, 6 weeks, and one month post-intervention (p<0.05). Notably, significant changes were observed between 4 and 6 weeks in the hip extensors, hip adductors, hip abductors, and knee extensors (p<0.05) (Table 3). Additionally, ankle plantarflexor strength significantly increased between 6 weeks and the one-month follow-up (p<0.05). Furthermore, significant improvements in hip flexor and knee flexor strength were observed after 6 weeks of intervention ($F_{3,13}$=17.09, p<0.001 and $F_{3,13}$=21.36, p<0.001, respectively). The firm-surface stepping exercise group showed significant improvements in muscle strength from baseline to 6 weeks and one month post-intervention in the hip flexors ($F_{3,13}$=5.83, p=0.009), hip extensors ($F_{3,13}$=8.43, p=0.002), hip abductors ($F_{3,13}$=6.11, p=0.008), knee flexors ($F_{3,13}$=18.93, p<0.001), ankle dorsiflexors ($F_{3,13}$=16.06, p<0.001), and ankle plantarflexors ($F_{3,13}$=5.94, p=0.009) (Table 3). While the knee extensors ($F_{3,13}$=26.70, p<0.001) showed significant improvements from baseline to 4 weeks, 6 weeks, and one month post-intervention, the hip adductors showed a trend toward significance ($F_{3,13}$=3.10, p=0.064). Additionally, significant improvements in ankle dorsiflexor strength were observed between 4 and 6 weeks (p<0.05) (Table 3).

The 4×2 mixed-model analysis of variance revealed a significant time×group interaction for hip flexors (approximately 2 kg, ηp^2=0.122, p=0.041), hip extensors (ηp^2=0.126, p=0.047), hip adductors (ηp^2=0.155, p=0.026), and hip abductors (ηp^2=0.127, p=0.046), indicating greater improvements in isometric lower limb muscle strength in the soft-surface stepping exercise group compared to the firm-surface stepping exercise group after the 6-week intervention. However, no significant time×group interactions were observed for knee flexors, knee extensors, ankle dorsiflexors, or ankle plantarflexors (p>0.05) (Table 3).

DISCUSSION

This study explored the effectiveness of modified stepping exercises with soft and firm surfaces for six weeks to improve older elderly on parameter of muscle strength, gait, balance ability, and lower extremity muscle strength. The results of this study indicate significant within-group improvements in functional performance and muscle strength following the intervention, with significant changes observed at weeks 4, 6, and the one-month follow-up (p<0.05) in both the soft-surface and firm-surface stepping exercise groups. However, the group×time interaction analysis revealed that the soft-surface stepping exercise group exhibited a large effect size on both the TUGT and BLCD, as well as on hip flexor, hip extensor, hip adductor, and hip abductor strength. The results of thisstudy suggest that the soft-surface group experienced greater improvements in balance and lower limb muscle strength compared to the firm-surface group after 6 weeks of intervention.

To the best of our knowledge, this is the first study to demonstrate the effectiveness of soft-surfac stepping in improving balance and overall muscle strength in elderly. Stepping exercise is a conveniently dynamic cardiovascular workout. It is safe with no adverse consequences and enhand to improve physical fitness among older adults after 12 weeks of training [36,37]. Our data confirm the benefits of a modified stepping exercise with a soft surface, demonstrating its effectiveness in improving balance ability and overall muscle strength after just four weeks of training. In the present study, participants who underwent soft-surface stepping exercise training demonstrated significant improvements in balance ability, as measured by the TUGT, compared to those in the firm-surface stepping exercise group. Notably, the soft-surface group showed significant improvements within 4-weeks, with continued progress observed at six weeks and the one-month follow-up. The effect size (η^2) for the TUGT was 0.140 lage effect sizes. In contrast, participants in the firm-surface stepping exercise group exhibited significant improvements only at 6-weeks and the one-month follow-up. Moylan and Binder [38] reported that the movement of step-up during alternate single leg step up-down and lateral up-down would help to improve coordination of lower limbs and anticipatory postural adjustments of motor planning during multidirectional steps to maintain the body's center of gravity on unstable or soft surfaces. In addition, the repetitive stepping

Table 3. Comparison of isometric muscle strength within-group at pre-test, 4 weeks, 6 weeks, and 1 month (follow-up) and between groups (soft surface stepping and firm surface stepping exercise)

Outcome	Soft surface stepping exercise within-group difference	Firm surface stepping exercise within-group difference	Between groups difference p-value (95% CI)	Partial eta squared (ηp^2)
Isometric muscle strength (kg)				
Hip flexors				
Pre-test	9.04±2.08 (7.93–10.15)	10.20±3.74 (8.21–12.20)	0.283 (-3.35 to 1.01)	0.038
4 wk	11.81±4.76 (9.27–14.36)	13.01±3.20 (11.30–14.72)	0.410 (-4.13 to 1.73)	0.023
6 wk	16.52±3.42 (14.7–18.5)**	14.11±3.58 (12.20–16.01)**	0.041 (0.05 to 4.93)	0.122
1 mo (follow-up)	14.51±5.44 (11.61–17.41)**	13.65±3.66 (11.69–15.60)*	0.602 (-2.48 to 4.21)	0.009
Hip extensors				
Pre-test	8.19±3.12 (6.52–9.85)	9.05±3.26 (7.23–10.89)	0.078 (-4.35 to 0.24)	0.100
4 wk	11.76±3.87 (6.52–9.85)*	10.90±3.89 (8.83–12.97)	0.533 (-1.93 to 3.66)	0.013
6 wk	16.81±3.56 (9.70–18.71)**[a]	14.11±4.31 (11.81–16.41)**	0.047 (0.06 to 7.48)	0.126
1 mo (follow-up)	14.39±4.80 (11.84–16.95)**	14.58±4.80 (12.02–17.14)**	0.602 (-5.48 to 3.23)	0.009
Hip adductors				
Pre-test	7.57±3.08 (5.93–9.22)	9.68±3.41 (7.86–11.49)	0.078 (-4.45 to 0.24)	0.100
4 wk	11.34±2.62 (9.57–13.14)**	10.31±3.92 (8.50–12.07)	0.390 (-1.38 to 3.44)	0.025
6 wk	14.90±3.69 (13.62–16.98)**[b]	12.10±3.01 (10.02–13.38)*	0.026 (0.36 to 5.23)	0.155
1 mo (follow-up)	12.18±3.89 (10.36–14.46)*	12.49±3.90 (10.22–14.32)	0.822 (-3.12 to 2.50)	0.002
Hip abductors				
Pre-test	7.35±1.99 (6.29–8.42)	8.84±2.05 (7.75–9.94)	0.055 (-0.06 to 5.12)	0.117
4 wk	11.12±3.46 (9.27–12.96)*	9.52±2.61 (8.13–10.90)	0.149 (-0.60 to 3.81)	0.068
6 wk	15.32±2.94 (13.75–16.88)**[b]	12.79±4.14 (10.58–14.98)**	0.046 (-2.95 to -0.03)	0.127
1 mo (follow-up)	14.04±3.63 (12.10–15.97)**	13.75±4.59 (11.30–16.19)**	0.842 (-2.69 to 3.27)	0.001
Knee flexors				
Pre-test	8.41±1.59 (7.57–9.26)	8.38±2.09 (7.62–9.14)	0.939 (-1.48 to 1.59)	0.000
4 wk	11.14±3.58 (9.23–13.04)	10.27±3.57 (8.98–11.56)	0.175 (-0.81 to 4.27)	0.060
6 wk	14.67±3.37 (12.88–16.47)**	13.38±4.00 (11.94–14.82)**	0.067 (-0.19 to 5.35)	0.107
1 mo (follow-up)	13.15±2.86 (11.62–14.68)**	12.46±2.68 (11.49–13.43)**	0.152 (-0.53 to 3.27)	0.067
Knee extensors				
Pre-test	9.15±1.52 (8.34–9.97)	10.12±1.96 (9.07–11.16)	0.130 (-2.24 to 0.30)	0.075
4 wk	15.06±3.51 (13.19–16.93)**	14.46±4.84 (11.87–17.03)*	0.691 (-2.45 to 3.65)	0.005
6 wk	19.68±4.72 (17.17–22.20)**[a]	17.22±3.99 (15.09–19.34)**	0.122 (-0.69 to 5.61)	0.078
1 mo (follow-up)	17.28±4.21 (15.03–19.52)**	17.86±5.05 (15.17–20.55)**	0.723 (-3.94 to 2.76)	0.004
Ankle dorsiflexors				
Pre-test	6.43±1.36 (5.70–7.15)	6.80±1.24 (6.13–7.46)	0.430 (-1.31 to 0.57)	0.021
4 wk	9.05±2.84 (7.54–10.56)*	8.67±2.34 (7.42–9.91)	0.680 (-1.49 to 2.26)	0.006
6 wk	13.42±5.16 (10.67–16.17)**	12.12±3.51 (10.25–13.99)**[a]	0.412 (-1.88 to 4.48)	0.023
1 mo (follow-up)	13.03±4.25 (10.82–15.23)**	12.48±4.04 (10.33–14.64)**	0.708 (-2.40 to 3.50)	0.005
Ankle plantarflexes				
Pre-test	8.31±1.91 (7.29–9.33)	8.61±1.93 (7.58–99.64)	0.664 (-1.68 to 1.09)	0.006
4 wk	11.12±2.69 (9.68–12.55)*	9.66±2.78 (8.18–11.15)	0.143 (-0.52 to 3.42)	0.070
6 wk	14.33±5.86 (11.21–17.46)*	13.05±4.03 (10.92–15.20)**	0.477 (-2.35 to 4.91)	0.017
1 mo (follow-up)	13.72±3.02 (12.11–15.32)**[c]	13.42±4.82 (10.84–15.99)*	0.834 (-2.60 to 3.20)	0.001

Values are presented as mean±standard deviation (95% CI).
For the difference between groups at each time point analyzed using the 4×2 mixed-model analysis of variance.
The data comparisons within the group were analyzed at pre-test, 4 weeks, 6 weeks, and after 1 month follow-up.
CI, confidence interval.
*Significant improvement from baseline levels (pre-test) ($p<0.05$).
**Significant improvement from baseline levels (pre-test) ($p<0.05$).
[a]Significant improvement between 4-week with 6-week ($p<0.05$).
[b]Significant improvement between 4-week with 6-week ($p<0.01$).
[c]Significant improvement between 4-week with 1 month (follow-up) ($p<0.05$).

exercise with various dynamic stepping patterns would also enhance proprioception (the sense of body position in space) [38,39]. Kaewjoho et al. [23] reported that a six-week Thai dancing intervention performed on a soft surface significantly improved balance ability in healthy older adults compared to exercises performed on a firm surface. Therefore, soft surface stepping exercise had greater improvement at within 6 weeks afer training. Previous studies have shown that stepping exercises can improve physical performance, particularly balance abilities in the elderly, after an extended duration of 8 weeks of exercise [39]. Accoding to Sarinukul et al. [25] reported that eight weeks of stepping exercise improved TUGT and quality of life in healthy elderly paticipants, in which significant improvements from baseline were also evident at 8 weeks. A key strength of this study is the observed mean TUGT improvement of 2.34 seconds, which is clinically meaningful for older adults at high risk of falls, as indicated by an SLS test duration of less than 10 seconds. This improvement surpasses the established threshold for a meaningful reduction in fall risk, underscoring the practical relevance of our intervention despite the statistical limitations imposed by multiple comparison corrections.

However, the participants in these earlier studies were healthy adults, while the majority of participants in this study were older adults with a higher fall risk (as indicated by a SLS test result of less than 10 seconds). It is anticipated that the older adults in this study may show greater improvements than their healthy counterparts due to the higher fall risk at baseline. The within-group analysis in this study showed that walking speed, both preferred and fast speeds, demonstrated greater improvements in the soft-surface stepping exercise group at 6-weeks and one month after training. These improvements may be attributed to the enhanced range of motion and increased torque generation in the lower limb, which contribute to better walking speed efficiency. According to Mansfield et al. [40] reported that step box training serves to augment the deficiencies of stair walking training. Utilizing a step box for stepping training is purportedly beneficial in enhancing muscle mass in the paralyzed lower limbs of stroke patients, as well as improving walking speed [41] and balance. In particular, walking on an unstable support surface such as a balance pad requires more muscle strength and movement around the ankle joint, thereby improving walking speed.

Furthermore, in the present study, overall lower limb muscle strength, as measured by the BLCD, demonstrated meaningful improvements a large effect size (η^2=0.182), while individual muscle groups showed large effect sizes (η^2=0.122 to 0.155) when assessed using HHD. These results indicated significant improvements in the soft-surface stepping exercise group. Specifically, participants exhibited greater strength gains in the hip flexors, hip extensors, hip adductors, and hip abductors, with these improvements becoming particularly pronounced at the six-week mark in between-group comparisons. However, no significant differences were observed between the groups for knee flexors, knee extensors, ankle dorsiflexors, or ankle plantarflexors. The stepping exercise involves several phases: the initial step-up (concentric phase), mid-step-up (isometric phase), and step-down (eccentric phase). During the initial step-up, hip flexors, such as the iliopsoas and rectus femoris, are activated concentrically to lift the leg toward the box. The iliopsoas primarily serves to flex the hip and raise the thigh, while the rectus femoris plays a role in both hip flexion and knee extension. In the mid-step-up (isometric phase), the hip flexors, including the iliopsoas, work isometrically to maintain the flexed position of the hip and stabilize the thigh against gravity as the body is positioned on the box. Meanwhile, the hip extensors, such as the gluteus maximus and hamstrings, contract isometrically to keep the hip extended and stabilize the pelvis. The gluteus maximus ensures the upright posture, while the hamstrings contribute to maintaining proper alignment of the knee and hip. During the step-down (eccentric phase), the hip extensors, including the gluteus maximus and hamstrings, work eccentrically to control hip flexion as the body lowers toward the ground. These muscles prevent excessive hip flexion and help stabilize the pelvis during the descent.

Hip abductors (gluteus medius), the gluteus medius plays a critical role in stabilizing the pelvis during the step-up and lateral stepping movements. It helps prevent the pelvis from dropping on the opposite side when standing on one leg. In stepping down or lateral movements, the abductor muscles contract eccentrically to control pelvic tilt. Hip adductors, these muscles also stabilize the lower body and help in controlling movement during stepping, particularly in preventing excessive lateral motion of the pelvis. The hip adductors contract during stepping to bring the legs closer together and maintain proper alignment during dynamic movements [42]. In addition, the repetitive stepping training on unstable or soft surfaces would challenge the muscles involved during stepping training. This study modified stepping exercises to include various directions, such as step-up and step-down movements, along with left and right lateral step-up and step-down motions. The findings suggest

that soft unstable, multidirectional stepping exercises are beneficial for improving overall lower limb muscle strength and coordination and muscle activation. The continuous adjustments made by the body during exercises on an unstable surface enhance motor control, improve muscle recruitment, and increase the overall muscle strength response, even after just 4 weeks of training. This mechanism has been supported by previous studies on balance and strength training on unstable surfaces, which suggest that the requirement for constant adjustments during movement promotes greater muscle engagement and neuromuscular adaptations compared to stable surfaces. Worrell et al. [43] reported that step training enhances isokinetic extensor muscle strength in healthy participants.

Comparing the outcomes of the soft surface stepping exercise group with the firm surface stepping exercise group revealed that the soft surface stepping exercise experienced greater improvements in balance ability, walking speed, and muscle strength during weeks 4–6, with these benefits persisting over time. One month follow-up, participants in this group maintained their balance ability and lower limb strength, hese sustained improvements can be attributed to the repetitive movements that enhance muscle strength, coordination, and proprioception, particularly in response to balance perturbations, resulting in quicker and safer movements during the test. Additionally, the involvement of the extensor and flexor muscle groups during sagittal plane stepping, as well as the adductor and abductor muscles during coronal plane movements, is further challenged by the unstable terrain. To confirm the effects of the soft-surface stepping exercise, a subsequent study should include a control group with no intervention, alongside implementing a randomized controlled trial design. This would allow for a more rigorous comparison and enable the assessment of recruitment and retention rates. Additionally, it would be beneficial to assess the prevalence of chronic conditions, including hypertension, diabetes, dyslipidemia, and cardiovascular diseases, as well as participants' history of falls in the 12 months prior to the study. This study is the small sample size, which may have resulted in insufficient statistical power to detect significant between-group differences. Although clinically meaningful improvements were observed, future studies with larger sample sizes are recommended to confirm these findings. Further investigation is also recommended to monitor the incidence of falls one year following the completion of the intervention, in order to better understand the long-term effects of the program.

Conclusions

Soft surface stepping exercise are comparable in perceived intensity to basic exercises, and they are moderate-intensity exercises after undergoing the program for six weeks (3 times/40–50 minutes/weeks) that increase recruitment and retention rates after the intervention program. The intervention significantly improved the participants' functional mobility, walking ability, and lower extremity muscle strength within 4-weeks and significantly increased their overall health status. Hence, the present findings suggest that using soft surface stepping exercise program might be a practical approach to enhance independence and security among community-dwelling older adults.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

Conceptualization: Kaewjoho C, Khamnon N. Data curation: Kaewjoho C, Ladawan S. Methodology: Kaewjoho C, Poncumhak P, Manoy P. Formal analysis: Kaewjoho C, Poncumhak P, Khamnon N. Funding acquisition: Kaewjoho C. Project administration: Kaewjoho C. Supervision: Khamnon N. Visualization: Ladawan S. Writing – original draft: Kaewjoho C. Writing – review and editing: Poncumhak P, Manoy P, Ladawan S, Khamnon N. Approval of final manuscript: all authors.

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Korean Version of the Confidence of Arm and Hand Movement Scale and Its Psychometric Properties

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Objective: To investigate the impact of self-efficacy in using one's upper limbs on the overall wellbeing of stroke patients, we developed the Korean version of the Confidence of Arm and Hand Movement (K-CAHM) scale by modifying the original CAHM to suit Korean cultural conditions.

Methods: This study was conducted from May 2022 to June 2023 at a rehabilitation hospital with 54 stroke patients. Participants with sufficient cognitive and verbal abilities were included, while those with severe comorbidities were excluded. For the translation and cultural adaptation of CAHM into Korean, permission was obtained from the original author. Two translators independently translated the questionnaire, followed by a consensus discussion and expert review to create K-CAHM version 1.0. After back-translation and further review, the final Korean version was completed. Reliability and validity were assessed using Cronbach's alpha, intraclass correlation coefficient (ICC), exploratory factor analysis, Bland–Altman analysis, and Pearson correlation.

Results: The K-CAHM showed good reliability (Cronbach's alpha=0.97; ICC=0.895). Bland–Altman plot analysis showed good agreement, indicating test-retest reliability. Moreover, K-CAHM showed good concurrent validity, demonstrated by its correlation with three domains of the International Classification of Functioning, Disability and Health: Fugl-Meyer assessment, the Jebsen-Taylor Hand Function Test, personal hygiene and bathing in the modified Barthel Index, and hand and stroke recovery domain in the Stroke Impact Scale.

Conclusion: The newly developed K-CAHM could complement other outcome measures, facilitating patient-centered rehabilitation in the Korean context.

Keywords: Stroke, Upper limb, Self efficacy, Self concept, Rehabilitation

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INTRODUCTION

Individuals who have experienced a stroke often have difficulty in activities of daily living (ADLs), social interactions, and other activities, without physical assistance and supervision from others. These difficulties arise from functional limitations primarily caused by impairments that affect individuals' health and overall wellbeing [1]. However, life after a stroke can be affected by factors beyond impairments. To address comprehensive stroke rehabilitation, various psychological factors—including self-efficacy, motivation, engagement, and positive enforcement—should be considered.

Among those factors, self-efficacy is a psychological construct comprising belief, confidence, and motivation. It is defined as a belief in one's ability to execute and change behaviors necessary to achieve valuable outcomes, affecting overall task performance

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from choosing an activity to completing it [2]. Self-efficacy after stroke is related to functional independence, depression, quality of life, ADL, and physical activities [3,4]. Recognizing and promoting self-efficacy is crucial for promoting and encouraging active engagement in stroke rehabilitation.

In the context of upper extremity (UE) rehabilitation, self-efficacy is associated with an individual's use of their hands in daily life; those with higher self-efficacy for UE movements use their hands more frequently [5]. Confidence in one's capacity to use the affected upper limb is highly important because it correlates with motor ability and impacts treatment outcomes [6,7]. Accordingly, an assessment tool that can measure UE self-efficacy in patients who have had a stroke would be meaningful in guiding treatment and the overall rehabilitation process, although many stroke programs objectively assess functional performance without considering the individual's functional outcomes [3,8].

To date, individuals' UE self-efficacy after a stroke has been assessed with questionnaires, including the Stroke Self-Efficacy Questionnaire (SSEQ), measure of self-efficacy for reaching, upper limb self-efficacy test (UPSET-stroke), and the Confidence in Hand and Arm Movement (CAHM) scale. The SSEQ comprises 13 items related to general perspectives after stroke, and it measures general self-efficacy related to stroke recovery rather than UE-specific self-efficacy. The self-efficacy for reaching test only assesses confidence in reaching movements, excluding other functional tasks necessary for daily life [6]. The UPSET-stroke assesses UE-specific self-efficacy in various ADL; however, it mainly examines self-efficacy in basic ADL with limited consideration for instrumental ADLs and social contexts, and its questions are not specifically described.

The CAHM scale was developed to assess self-efficacy regarding hand and arm function for people who have had a stroke [9]. It is particularly useful because it assesses an individual's perceived confidence in relation to ADL and instrumental ADL in social and individual contexts. Unlike previous tools, CAHM includes a broader range of tasks, capturing confidence in both basic and instrumental ADLs, making it a more comprehensive measure of UE-specific self-efficacy. Moreover, as self-efficacy influences motor function, rehabilitation engagement, and long-term recovery, the CAHM scale provides valuable clinical insights into both physical and psychosocial aspects of stroke rehabilitation.

Although the validity and reliability of the CAHM have been reported, the original version has not been published in any peer-reviewed article, which makes it difficult to access and use the assessment tool. Furthermore, cultural norms, values, and daily activities in Korea differ significantly from those in the region where the CAHM was originally developed. These differences can affect how patients perceive and report their abilities and challenges in UE movements. Further, the healthcare system in Korea, including stroke rehabilitation practices, may differ from those where the CAHM scale was initially implemented. These differences can impact patient experiences and expectations. Therefore, a culturally adapted version of the CAHM scale is essential to ensure it is relevant and meaningful for Korean patients. Adapting the scale to fit the Korean healthcare context ensures that it is in accordance with the rehabilitation protocols and patient management strategies. Therefore, this study aimed to translate and modify the CAHM for the Korean cultural context and confirm its reliability and validity.

METHODS

Participants

The study was conducted from May 2022 to June 2023 at a rehabilitation facility with 54 participants who had suffered strokes. The inclusion criteria were diagnosis of ischemic or hemorrhagic stroke, and adequate cognitive and verbal abilities for following instructions (Mini-Mental State Examination score≥24). Those who had severe comorbidity or disability before the stroke or other neurological disorders were excluded. This study was approved by the Institutional Review Board of the National Rehabilitation Center (approval no. NRC-2022-02-013) and registered at Clinical Research Information Service (KCT0007151). The purpose of this study was fully explained to participants, and written informed consent was obtained before enrollment. The questionnaires were self-reported.

Procedures

Translation and cross-cultural adaptation

For this study, permission to translate CAHM into Korean was obtained from the original author. First, the original questionnaire was translated independently by two translators proficient in both English and Korean. Then, a discussion was held to integrate the translations. Next, the amalgamated version was reviewed by a translation committee comprising rehabilitation experts, including physiatrists, psychologists, and occupational therapists. The Korean version of the CAHM—the K-CAHM version 1.0—was created. Subsequently, two additional transla-

tors, proficient in both English and Korean and without prior exposure to the questionnaire, reverse-translated K-CAHM version 1.0. Finally, the translation committee reviewed and integrated the original version of the questionnaire, K-CAHM version 1.0, and the reverse-translated version. Through detailed discussions, they created the final version of the K-CAHM (Supplementary Materials S1, S2). During this process, items that were not suitable for Korean culture or had different meanings in Korean were modified (Fig. 1). For readers more familiar with English, we included the English version of K-CAHM in Supplementary Material S3.

Assessment

CAHM: CAHM is a 20-item questionnaire that asks an individual to rate their confidence in performing various functional tasks involving the weaker arm or both arms on a scale of 0 to 100; a rating of 0 indicates "very uncertain/unconfident," while a rating of 100 indicates "very certain/confident."

Fugl-Meyer Assessment (FMA): The FMA is the most often-used tool to evaluate motor impairment in patients who have had a stroke [10,11]. In this study, we measured upper limb motor function using FMA.

Jebsen-Taylor Hand Function Test (JTHFT): The JTHFT was designed to assess hand dexterity and coordination. It comprises seven tasks that require individuals to perform various functional hand tasks related to ADL [12]. In this study, we used a standardized scoring system for validity verification [13].

Modified Barthel Index (MBI): The MBI is designed to assess an individual's ability to independently perform ADL. It includes 10 ADL-related tasks—personal hygiene, bathing, feeding, toileting, stair climbing, dressing, bowel control, bladder control, chair/bed transfers, and ambulation. Each task is rated on a 5-point scale, with the total score ranging from 0 to 100. The assessment focuses on actual patient performance and considers their use of assistive aids during the test. Higher scores indicate greater independence, while lower scores suggest less independence in ADL [14]. We tested the correlation between K-CAHM and each item of MBI; however, only upper limb-relevant items (personal hygiene, feeding, dressing) were reviewed for validation.

Stroke Impact Scale 3.0 (SIS): Health-related quality of life of patients who have had a stroke is assessed by SIS using eight domains: strength, hand function, ADL/instrumental ADL, mobility, communication, emotion, memory and thinking, and social participation [15,16]. Each domain's score ranges from 0 to 100, with higher scores indicating better quality of life. In addition, stroke recovery was measured by asking "how much have you recovered from the stroke." We analyzed the association of eight domains and stroke recovery of SIS with K-CAHM and used SIS-hand and stroke recovery as our variables of interest for validation.

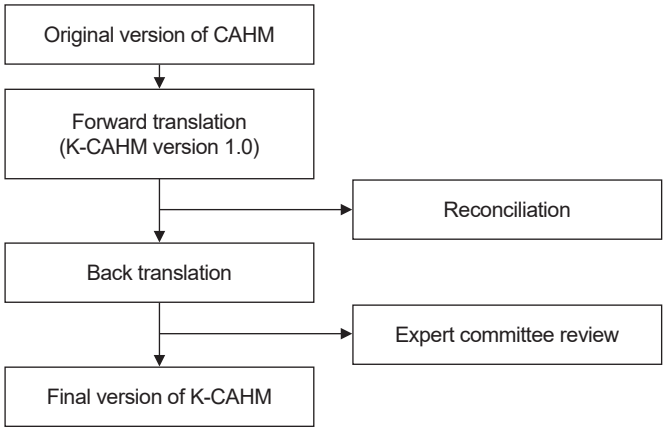

Fig. 1. Flow diagram of Korean version of the Confidence of Arm and Hand Movement (K-CAHM) development.

Reliability and validity assessment

To determine the reliability of K-CAHM, we assessed internal consistency, test-retest reliability, and agreement. The test-retest reliability was estimated by administering K-CAHM to participants who have had a stroke, twice within 7–10 days. Its validity was scrutinized by correlating it to upper limb relevant items from other measurements: FMA-upper limb, JTHFT, MBI-personal hygiene, MBI-bathing, MBI-feeding, MBI-dressing, SIS-hand, and SIS-stroke recovery. The measurements for validity verification encompass three domains of the International Classification of Functioning, Disability and Health (ICF): body function and structures, activities, and participation [17]. FMA represents body function and structure, JTHFT and MBI represent activity, and SIS indicates participation.

Statistical analysis

The absolute values and percentages were used to show the categorical variables, while the means and standard deviations were employed for the numerical variables. Internal consistency and test-retest reliability were analyzed using a Cronbach's alpha (α) and an intraclass correlation coefficient (ICC), respectively, with a 95% confidence interval (CI). A Cronbach's alpha≥0.70

was considered acceptable and ≥0.9 was considered excellent [18]. The ICC was calculated using two-way mixed-effect models. ICC values between 0.75 and 0.9 were interpreted as demonstrating good reliability and ≥0.9 demonstrated excellent reliability [19]. Bland–Altman analysis was used to quantify the agreement between the two measures of K-CAHM by plotting the difference against their mean. An exploratory factor analysis (EFA) was conducted to determine whether the scale measured a single construct or multiple dimensions. To examine the validity, a Pearson's correlation test was employed with upper-limb related outcomes. All statistical analyses were conducted using R version 4.2, and statistical significance was set at a $p<0.05$.

RESULTS

Demographic characteristics

Participants comprised 54 patients with a mean age of 62.3±11.1 years and a duration of 101.2±88.1 days after their stroke. Patients' demographic characteristics are presented in Table 1.

Translation and cross-cultural adaptation

We modified several items for cultural adequacy (Table 2). First, in the instructions, we changed "weaker hand" to "weaker arm" for clarity for patients; "the weaker hand" is repeated in many questions in CAHM. For Question 5, we removed the word "plastic sleeve" as it could be confusing. For Question 11, we modified the unit of measurement from inches to centimeters. For Questions 15 and 16, as the original terms were unfamiliar in Korea, we replaced the word "China platter" with "ceramic platter" and "Styrofoam cup" with "disposable cup." Finally, for Question 17, we specified wearing "kitchen-mitts" on both hands, as "potholders" are not used when handling a hot pot in Korean culture, and we replaced "casserole dish" with "hot pot." Moreover, we attached pictures to help patients understand the meaning of some questions (Questions 2, 4, 7, 8, 10, 11, 13, and 19) to avoid any confusion.

Table 1. Demographic characteristics

Variable	Value (n=54)
Sex	
Male	38 (70.4)
Female	16 (29.6)
Age (yr)	62.3±11.1
Months after stroke	101.2±88.1
Hemiplegic side	
Right	25 (46.3)
Left	29 (53.7)
Education (yr)	12.3±4.0
Mini-Mental State Examination score	26.7±1.9

Values are presented as number (%) or mean±standard deviation.

Table 2. Modification of the Confidence of Arm and Hand Movement items for cross-cultural adaptation

Question No.	Original version	Modified version	Reason for modification
Instruction	For convenience, we refer to it as your "weaker arm" even if it is no longer the case	For convenience, we refer to it as your "weaker arm or weaker hand," even if it is no longer the case.	We mentioned "weaker hand" because it is mentioned several times in the question.
4	Carry a cafeteria tray full of lunch food and drink from the cashier to a table?	At a fast-food restaurant, carry a tray full of food and drink from the cashier to a table.	Considering that the system of the cafeteria is unfamiliar to Koreans, we revised "cafeteria" to "fast-food restaurant" to suit Korean culture.
5	With your weaker hand, remove a credit card from its plastic sleeve in a wallet?	With your weaker hand, remove a credit card from a wallet.	We removed "plastic sleeve" since it can be confusing.
11	With your weaker hand, move a 3-inch thick telephone book from its upright position in a bookcase to a table?	With your weaker hand, move a 7.5 cm thick telephone book from its upright position in a bookcase a table.	Koreans use centimeters instead of inches.
15	Safely hand wash and dry a large heavy China platter?	Safely hand wash and dry a large heavy ceramic plate.	The term "China platter" is not familiar in Korea; therefore, we replaced it with "ceramic plate."
16	With your weaker hand, pour hot coffee into a small Styrofoam cup someone is holding?	With your weaker hand, pour hot coffee into a small disposable cup someone is holding?	In the context of Korean culture, the term "disposable cup" is more commonly used.
17	Use potholders to remove a hot casserole dish from the oven and place it on the table?	Wearing kitchen-mitts on both hands, remove a hot pot from the oven and place it on the table.	We specified wearing kitchen-mitts on both hands and mentioned hot pot, as "potholders" and "casseroles" are not used in Korean culture.

In Questions #2, 4, 7, 8, 10, 11, 13, and 19, we attached pictures to avoid any confusion among patients owing to cultural differences.

Reliability and validity

Reliability of K-CAHM

A Cronbach's alpha of 0.97 indicated the excellent internal consistency of the K-CAHM. The ICC was 0.895 with 95% CI=0.824–0.938, indicating good to excellent test-retest reliability. Additionally, Bland–Altman plots showed good agreement between the test and retest of K-CAHM, in which 51 out of 54 were within 95% limits of agreement (Fig. 2). An EFA revealed five distinct factors, with factor-specific Cronbach's alpha values ranging from 0.87 to 0.93, indicating appropriate internal consistency without excessive redundancy (Table 3).

Validity of K-CAHM

Table 4 shows the correlations between K-CAHM and other upper limb-related measures. K-CAHM demonstrated a weak correlation with FMA (r=0.387, p=0.004) and a moderate correlation with JTHFT (r=0.493, p<0.001). Additionally, it showed significant correlations with MBI-personal hygiene (r=0.315, p=0.020) and MBI-bathing (r=0.304, p=0.032), but not with MBI-feeding and MBI-dressing. Furthermore, it had a positive correlation with the SIS-hand (r=0.634, p<0.001) and SIS-stroke recovery (r=0.384, p=0.004) domains.

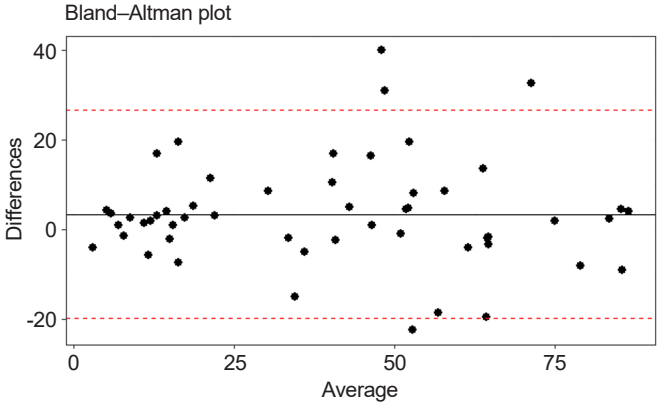

Fig. 2. Bland–Altman plot for test-retest reliability of the Korean version of the Confidence of Arm and Hand Movement.

Table 3. Exploratory factor analysis of K-CAHM

Factor		K-CAHM questionnaire	Cronbach's alpha
1	Self-regulatory self-efficacy	Q3, Q6, Q9, Q12	0.9031
2	Fine motor skills	Q2, Q5, Q7, Q8, Q10	0.8702
3	Gross motor skills	Q4, Q11, Q13, Q15, Q18	0.9188
4	Bimanual coordination	Q1, Q17, Q19, Q20	0.8946
5	Risk-sensitive task	Q14, Q16	0.9323

K-CAHM, Korean version of the Confidence of Arm and Hand Movement.

DISCUSSION

This study developed K-CAHM by modifying the original CAHM based on the cultural environment of Korea. K-CAHM showed good reliability and validity, suggesting that it can be used as an indicator to assess self-efficacy in patients who have had a stroke.

The Cronbach's alpha of 0.97 and ICC of 0.895 are comparable with those of the original CAHM (0.96 and 0.91, respectively; Lewthwaite, unpublished). Meanwhile, when Cronbach's alpha exceeds 0.95, it may indicate excessive redundancy rather than a distinct functional assessment [20]. Our Cronbach's alpha calculation yielded α=0.97, raising concerns about the scale's redundancy and homogeneity because a highly correlated scale may not effectively capture the complexity of hand function. To explore this, we conducted an EFA to examine

Table 4. Pearson correlation test of the K-CAHM and other measurement variables

Assessment	r	p-value
Body function and structure		
FMA	0.387	0.004
Activity		
JTHFT	0.493	<0.001
MBI-personal hygiene	0.315	0.020
MBI-bathing	0.304	0.032
MBI-feeding	0.085	0.541
MBI-dressing	0.178	0.385
MBI-toilet	0.145	0.292
MBI-bowel control	0.145	0.296
MBI-bladder control	0.076	0.580
MBI-ambulation	0.013	0.928
MBI-transfer	0.180	0.193
MBI-total	0.167	0.238
Participation		
SIS-strength	0.217	0.118
SIS-hand	0.634	<0.001
SIS-ADLs/IADLs	0.107	0.445
SIS-social participation	0.145	0.919
SIS-mobility	0.006	0.964
SIS-memory and thinking	0.288	0.036
SIS-emotion	0.019	0.890
SIS-stroke recovery	0.384	0.004

K-CAHM, Korean version of the Confidence of Arm and Hand Movement; FMA, Fugl-Meyer Assessment; JTHFT, Jebsen-Taylor Hand Function Test; MBI, modified Barthel Index; SIS, Stroke Impact Scale 3.0; ADLs, activities of daily living; IADLs, instrumental ADLs.

the scale's structure and reassessed reliability for each factor. The EFA identified five distinct factors, suggesting the scale measures multiple dimensions rather than a single, overly redundant construct. Factor-specific reliability values supported internal consistency without excessive overlap, ensuring strong psychometric properties. In addition, the good agreement evidenced by Bland–Altman analysis bolstered the reliability of K-CAHM. These approaches confirmed the reliability of K-CAHM and affirmed its validity in assessing weak hand function across multiple domains. Notably, the K-CAHM showed good concurrent validity, indicated by the correlation with the three domains of the ICF. This is especially meaningful because the K-CAHM considers various aspects of upper limb-related functions. FMA and JTHFT showed significant positive correlations with K-CAHM, suggesting that K-CAHM is indicative of upper limb function, including body structure/function and activities. Consistent with previous findings [5], people with stroke who had better self-efficacy tended to use their upper limbs more in daily living. Specifically, the high correlations between K-CAHM and JTHFT may be because K-CAHM mainly comprises questions that assess upper limb activities using tools. Additionally, K-CAHM significantly correlated with MBI-personal hygiene and MBI-bathing, suggesting its validity regarding upper limb activity. The non-significant findings of MBI-feeding and MBI-dressing might have come from the characteristics of K-CAHM. MBI assesses basic activities, while K-CAHM explores preparatory or more advanced activities, which require higher-level performance. K-CAHM significantly correlated with SIS-hand and SIS-stroke recovery, demonstrating its validity in the area of participation. Interestingly, K-CAHM correlated with SIS-stroke recovery, reflecting that it is indicative of confidence or subjective rating about one's recovery. Additionally, both K-CAHM and SIS 3.0 are self-report questionnaires. This significant correlation may suggest that K-CAHM could be used as self-report questionnaire. However, correlations between K-CAHM and other variables were not significant, as other items addressed tasks irrelevant to hand function, focusing on lower limb or other functions, such as bladder or bowel control. Overall, K-CAHM proved to be a valid tool to assess functions in diverse domains, including body function/structure, activity, and participation.

Cultural adaptation is crucial to ensure the validity, reliability, and relevance of measurements for the target population. Especially, confidence is inherently subjective, as it reflects an individual's perception, belief, and self-assessment of their abilities. Thus, unfamiliar elements influencing self-perception should be minimized for more reflective data collection. Notably, the items of K-CAHM are specifically described including concrete objects and actions, thereby facilitating more accurate scoring for individuals. Moreover, individuals who have experienced a stroke and are dealing with disability are likely to lose confidence. Therefore, reducing unfamiliarity allows them to be more cooperative and reflective of their confidence. Therefore, it is imperative to modify the questionnaire to reflect cultural differences, as seen in Table 2. Nevertheless, we conserved the purpose of the original CAHM. For example, in Question 1, we did not change "knife and fork" to "spoon and chopsticks," although knife and fork are not routinely used in Korean culture. We preserved the term because the intention was to measure confidence in bimanual activity or coordination, and using forks is relatively familiar. Furthermore, it is important to consider whether the task remains relevant today. For example, telephone books (Question 11), although commonplace in the past, are rarely used nowadays because online searches have replaced them. Moreover, we expected that Question 10, which involves lighting matches, could be difficult for respondents to answer since matches are less often used today than they were in the past. Nevertheless, it was hard to find an alternative task that involved bimanual coordination, dexterity, and a safety issue such as a burn. To summarize, our modification ensured that the K-CAHM accurately reflects the experiences and perspectives of individuals in the Korean cultural context, thus contributing to its overall validity and reliability.

K-CAHM reflects patients' own perspectives of their upper limb function—that is, their self-efficacy or confidence. CAHM comprises questions dealing with diverse aspects. The EFA also demonstrated five distinct factors from K-CAHM; self-regulatory self-efficacy, fine motor skills, gross motor skills, bimanual coordination, risk-sensitive task, indicating that the K-CAHM measures self-efficacy in multiple aspects.

It ascertains confidence during tasks relevant to upper limb functioning, using either the affected or both sides. CAHM includes tasks in diverse environments, not only in a private space where one is alone, but also in public areas such as a restaurant or a restroom, where one's performance can be observed by others. In addition, it measures self-efficacy when performing the most challenging tasks, especially risk-sensitive ones. Notably, it measures self-efficacy related to self-regulation, in which individuals independently identify their needs, set goals, explore resources, employ appropriate strategies, and evaluate their

outcomes [21]. Assessments of individuals' self-efficacy provide insights into their recovery potential and response to rehabilitation [22]. Self-efficacy can predict whether the affected arm is used following an intervention, even when upper limb function is retained, in people who have had a stroke [23]. Self-efficacy demonstrated a strong correlation with social reintegration and is a crucial factor in assessing performance improvement [24,25].

Moreover, the weak correlations between K-CAHM and specific MBI domains, such as personal hygiene (r=0.315) and bathing (r=0.304), suggest that self-efficacy and actual task performance are distinct constructs. This aligns with Maujean et al. [26], who found similar weak correlations between the self-efficacy scale and Barthel index, supporting the view that self-efficacy and actual function are separate aspects among individuals with stroke. Self-efficacy represents confidence in performing tasks and plays a crucial role in rehabilitation. Along with performance, self-efficacy significantly influences constructive behaviors, attitudes, and beliefs related to recovery after stroke. While actual functioning is influenced by physical ability, social factors, and psychological factors, strong self-efficacy can drive greater engagement in rehabilitation efforts and improve long-term functional outcomes.

Fostering self-efficacy is essential for empowering individuals to persist in challenging tasks and maximize their independence. This underscores the need for a multidimensional rehabilitation approach that prioritizes self-efficacy alongside physical function to enhance overall recovery. Rehabilitation should prioritize self-efficacy as a core component, alongside motor function and psychosocial adaptation, to promote sustained improvements in daily performance.

Therefore, evaluating both performance and self-efficacy provides a comprehensive perspective of an individual's rehabilitation progress. It is suggested that healthcare professionals in Korea regularly assess patients' self-confidence using K-CAHM, along with other outcome measures, to optimize rehabilitation outcomes for individuals who have had a stroke.

This study has some limitations. First, the sample size is small; thus, the findings may not be representative of the broader population of stroke patients. Second, intra-rater reliability was not verified. K-CAHM is a self-report questionnaire; therefore, our verification methods showed good reliability. Third, this study was conducted at a single rehabilitation hospital in an urban area; thus, the self-efficacy of participants in acute phase of stroke or in rural areas was not evaluated. Fourth, participants were relatively young, as their mean age was 62.3 years. Self-efficacy may be influenced by numerous personal or environmental factors; thus, future studies should include patients in different age groups; stroke phases; and environmental conditions, including residence (urban or rural), patient status (admitted, outpatient, or living in community), and type of caregiver. Fifth, the K-CAHM in this study retains certain items from the original CAHM; however, some tasks (e.g., using a telephone directory, striking a match) may no longer be relevant in modern contexts. These items were preserved for consistency in data collection, but future revisions should incorporate more applicable alternatives. For example, the telephone book task (Question 11) could be replaced with "finding a 7.5 cm-thick book," while match-striking (Question 10) could be substituted with "buttoning a shirt" or "removing a price tag from a box." These modifications require validation to ensure they maintain equivalent cognitive and motor assessment criteria.

Conclusion

K-CAHM is a reliable and valid assessment tool for evaluating self-efficacy in upper limb function among patients who have had a stroke. It can complement other outcome measures, facilitating patient-centered rehabilitation.

CONFLICTS OF INTEREST

Joon-Ho Shin is an Editorial Board member of Annals of Rehabilitation Medicine. The author did not engage in any part of the review and decision-making process for this manuscript. Otherwise, no potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

Conceptualization: Shin JH. Data curation: Kim H, Ham Y,

Shin JH. Methodology: Ham Y. Formal analysis: Kim H, Shin JH. Investigation: Kim H, Ham Y. Funding acquisition: Shin JH. Project administration: Shin JH. Resources: Shin JH. Supervision: Shin JH. Writing – original draft: Kim H. Writing – review & editing: Shin JH.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.5535/arm.240077.

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Annals of Rehabilitation Medicine

1. AIMS & SCOPE

Annals of Rehabilitation Medicine (ARM) is the official journal of the Korean Academy of Rehabilitation Medicine. It is an international, peer-reviewed open access journal, which aims to be a global leader in sharing up-to-date knowledge dedicated to the advancement of care and enhancing the function and quality of life of persons with various disabilities and chronic illnesses. As the official journal of one of the largest societies of rehabilitation medicine in Asia and Oceania, more than 3,500 physiatrists regularly receive this journal's table of contents via email, and the number is continually increasing. This journal is endorsed by the International Society of Physical and Rehabilitation Medicine (ISPRM) and the Asia-Oceanian Society of Physical and Rehabilitation Medicine (AOSPRM). International members comprise approximately half the editorial board, conducting peer-reviews of submitted manuscripts or acting as handling editors by assigning peer-review tasks to other reviewers.

The journal encompasses all aspects of physical medicine and rehabilitation, including basic, translational, clinical, and policy research, as well as rehabilitation education. Research areas covered by this journal include rehabilitation for brain disorders, spinal cord injuries, neuromuscular diseases, and dysphagia; cancer, cardiopulmonary, geriatric, pain & musculoskeletal, and pediatric rehabilitation; electrodiagnosis, orthosis & prosthesis, physical therapy, and sports medicine; and other emerging fields in rehabilitation medicine.

2. COPYRIGHTS AND CREATIVE COMMONS ATTRIBUTION LICENSE

The Korean Academy of Rehabilitation Medicine is the owner of all copyright to papers published in *ARM*, and has the right to publish, reproduce, distribute, and print the contents in other types of media. Authors of accepted papers must complete the Copyright Transfer Form. A letter of permission is required for any and all material that has been published previously. It is the responsibility of the author to request permission from the publisher for any material that is being reproduced. This requirement applies to text, illustrations, and tables. This is identical to the Creative Commons (Attribution-Noncommercial) license available at http://creativecommons.org/.

3. GENERAL GUIDELINES

The manuscript guidelines for *ARM* are based on the "Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly work in Medical Journals" published by the International Committee of Medical Journal Editors (http://www.icmje.org), and instructions which are not mentioned in the present guidelines are referred to the guidelines stated in the Recommendations. There are no fees payable to submit in this journal.

1) ARTICLE TYPES

Manuscripts include original articles, review articles, brief reports, case reports, images in this issue, and letters to the editor.

(1) Original articles

This form of publication represents original research articles reporting the results of basic and clinical investigations that are sufficiently well documented to be acceptable to critical readers.

(2) Review articles

The Editorial Board welcomes state-of-the-art review articles. The *ARM* strongly prefers systematic reviews of the literature. Invited review articles provide a comprehensive review of a subject of importance to clinicians and researchers and are commissioned by the editorial board to an invited expert in the field.

(3) Brief reports

These manuscripts are short but important reports to provide preliminary communications with less complete data sets than would be appropriate for original contributions that present novel and impactful clinical and basic research of a more preliminary nature.

(4) Case reports

Case reports are considered for publication when at least one of

the following criteria is met: (a) a rare condition is reported, (b) atypical symptoms and signs are observed, (c) new diagnostic or therapeutic methods are introduced, (d) atypical clinical and laboratory findings for populations residing in Asia and the Pacific Rim. Descriptions of clinical cases (individual or a series) should be unique, should deal with clinical cases of exceptional interest or innovation and should preferably be a first-time report.

(5) Images in this issue

This form of publication represents images (e.g.,radiographs, CT, MRI, electrodiagnostic tracings, pathology, physical examination findings, photos of a patient or medical device) that are interesting and unique.

(6) Letters to the editor

Critical comments are welcomed for providing alternative interpretations or views about articles published in *ARM*. Letters should be directly related to the published article on which it comments. Letters being considered for publication ordinarily will be sent to the authors, who will be given the opportunity to reply. Letters will be published at the discretion of the editors and are subject to abridgement and editing for style and content.

2) LANGUAGE OF MANUSCRIPT

All manuscripts must be written in clearly understandable English. Authors whose first language is not English are requested to have their manuscripts checked for grammatical and linguistic correctness before submission. Correct medical terminology should be used, and jargon should be avoided. Use of abbreviations should be minimized and restricted to those that are generally recognized. When using an abbreviated word, it should be spelled out in full on first usage in the manuscript followed by the abbreviation in parentheses. Numbers should be written in Arabic numerals, but must be spelled out when placed in the beginning of a sentence. Measurements should be reported using the metric system, and hematologic and biochemical markers should be reported in International System (SI) of Units. All units must be preceded by one space except percentage (%), temperature (°C), and degree (°).

4. RESEARCH AND PUBLICATION ETHICS

All manuscripts should be written with strict adherence to the research and publication ethics guidelines recommended by Council of Science Editors (http://www.councilscienceeditors.org/), International Committee of Medical Journal Editors (ICMJE, http://www.icmje.org/), World Association of Medical Editors (WAME, http://www.wame.org/), and the Korean Association of Medical Journal Editors (KAMJE, https://www.kamje.or.kr/en/main_en). For all studies involving human subjects, the principles embodied in the Declaration of Helsinki (https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/) should be upheld, informed consent must be obtained from all participants, and must be approved by a recognized Institutional Review Board (IRB) or research ethics committee. The editor may request submission of copies of informed consents from human subjects in clinical studies or IRB approval documents. Experiments involving animals should comply with the NIH guidelines for the use of laboratory animals (https://www.nlm.nih.gov/services/research_report_guide.html) and/or be reviewed by an appropriate committee (e.g., Institutional Animal Care and Use Committee, IACUC) to ensure the ethical treatment of animals in research. Also, studies with pathogens requiring a high degree of biosafety should pass review of a relevant committee (e.g., Institutional Biosafety Committee, IBC). *ARM* will follow the guidelines by the Committee on Publication Ethics (COPE, http://publicationethics.org/) for settlement of any misconduct.

1) REDUNDANT PUBLICATION AND PLAGIARISM

All submitted manuscripts should be original and should not be considered by other scientific journals for publication at the same time. No part of the accepted manuscript should be duplicated in any other scientific journal without the permission of the editorial board. If plagiarism or duplicate publication related to the papers of this journal is detected, the manuscripts may be rejected, the authors will be announced in the journal, and their institutes will be informed. There will also be penalties for the authors.

2) AUTHORSHIP

ARM follows the recommendations by International Committee of Medical Journal Editors (ICMJE,http://www.icmje.org/) and and the Korean Association of Medical Journal Editors (KAMJE, https://www.kamje.or.kr/en/main_en). Authorship is credited to those who have direct involvement in the study and have made significant contributions to (a) substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (b) drafting the work or revising it critically for important intellectual content; AND (c) final approval of the version to be published; AND (d) agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved as recommended by ICMJE. The primary investigator is designated the first author of

the study, unless contested by the other authors. The corresponding author is directly responsible for communication and revision of the submitted manuscript. Authors are required to include a statement of responsibility in the manuscript that specifies the contribution of every author at the end of the manuscript, in a section entitled "Author contribution". All persons who have made substantial contribution, but who are not eligible as authors should be named in the acknowledgments. In the case of change of authorship, a written explanation must be submitted. Change in either the first author or the corresponding author requires approval by the editorial board, and any changes in the other authors require approval by the editor-in-chief.

3) CONFLICT OF INTEREST

The corresponding author of an article is asked to inform the editor of the authors' potential conflicts of interest possibly influencing their interpretation of data. A potential conflict of interest must be disclosed during the online submission process on the appropriate web page. Such conflicts may be financial support or private connections to pharmaceutical companies, political pressure from interest groups, or academic problems based on the "ICMJE Uniform Disclosure Form for Potential Conflicts of Interest" (http://www.icmje.org/coi_disclosure.pdf). The editor will decide whether the information on the conflict should be included in the published paper. Before publishing such information, the editor will consult with the corresponding author. In particular, all sources of funding for a study should be explicitly stated.

4) REGISTRATION OF CLINICAL TRIAL

Clinical trial defined as "any research project that prospectively assigns human subjects to intervention and comparison groups to study the cause-and-effect relationship between a medical intervention and a health outcome" is recommended to be registered to the primary registry to be prior publication. *ARM* recommend, as a condition of consideration for publication, registration in a public trials registry. *ARM* accepts the registration in any of the primary registries that participate in the WHO International Clinical Trials Portal (http://www.who.int/ictrp/en/), NIH ClinicalTrials.gov (http://www.clinicaltrials.gov/), ISRCTN Resister (www.isrctn.org), ANZCTR (https://www.anzctr.org.au/), EudraCT Database (https://eudract.ema.europa.eu/), Clinical Trials Information System (https://euclinicaltrials.eu/), University Hospital Medical Information Network (www.umin.ac.jp/ctr/index/htm), EU Clinical Trials Register (https://www.clinicaltrialsregister.eu/) or The Clinical Research Information Service (http://cris.nih.go.kr/). The clinical trial registration number will be published at the end of the abstract.

5) PROCESS FOR MANAGING RESEARCH AND PUBLICATION MISCONDUCT

When the journal faces suspected cases of research and publication misconduct such as redundant (duplicate) publication, plagiarism, fraudulent or fabricated data, changes in authorship, an undisclosed conflict of interest, ethical problems with a submitted manuscript, a reviewer who has appropriated an author's idea or data, complaints against editors, and so on, the resolution process will follow the flowchart provided by the Committee on Publication Ethics (COPE, https://publicationethics.org/guidance/Flowcharts). The discussion and decision on the suspected cases are carried out by the Editorial Board.

6) PROCESS FOR HANDLING CASES REQUIRING CORRECTIONS, RETRACTIONS, AND EDITORIAL EXPRESSIONS OF CONCERN

Cases that require editorial expressions of concern or retraction shall follow the COPE flowcharts available from: https://publicationethics.org/guidance/Flowcharts. If correction needs, it will follow the ICMJE Recommendation for Corrections, Retractions, Republications and Version Control available from: http://www.icmje.org/recommendations/browse/publishing-and-editorial-issues/corrections-and-version-control.html.

7) ETHICS AND AUTHORSHIP IN THE USE OF GENERATIVE ARTIFICIAL INTELLIGENCE (AI)

Authorship assignment to AI is prohibited. *ARM* discourages the use of generative AI tools for the purpose of creating any types of content (including text, tables, and figures) for scientific manuscripts. If such tools are used, the authors must report their use transparently. In addition, authors who employ generative AI tools are solely responsible for all content produced and submitted. However, the use of AI tools to enhance the linguistic quality of a submission is considered acceptable and does not require specific disclosure.

5. MANUSCRIPT SUBMISSION

All submissions are made online at the journal's online manuscript submission site (http://www.e-arm.org/submission) by the corresponding author. Submitted manuscripts are initially examined for format, and then appointed a submission number. For nonbiased peer review, authors' names and institutional affiliations should not be mentioned in the text. The revised manuscript should be submitted through the same web system under the same identification numbers. The date of final review for the manuscript will be the date of acceptance for publication. If you

have any questions about the online submission process, contact the Editorial Office by e-mail at edit@e-arm.org.

1) ARTICLE PROCESSING CHARGES

Annals of Rehabilitation Medicine is an open access journal. To publish in *Annals of Rehabilitation Medicine*, authors are asked to pay an article processing charge (APC) on acceptance of their research paper. The APC for all published papers is as follows, plus VAT or local taxes where applicable. The currency KRW will be applied to the submissions from South Korea.

- Original article / Brief Reports / Unsolicited review article: 600 USD or 600,000 KRW
- Solicited article: Free
- Case report: 300 USD or 300,000 KRW
- Image in this issue: 170 USD or 170,000 KRW
- Correspondence / erratum: 100 USD or 100,000 KRW

†Note: As categorized by the World Bank, low-income countries will be eligible for a 20% discount on the updated APCs for original articles/brief reports/review articles/case reports. To find out if your country qualifies, please refer to the World Bank's classification available at https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html.

(This updated article processing charge is applied to all submissions as of Oct 1, 2023.)

6. PEER REVIEW PROCESS

1) EDITORIAL REJECT POLICY

Conformity of the submitted manuscript to the submission instructions is examined upon submission. The Editorial Board may reject the manuscript or request the author to resubmit in the following cases: 1) Topic clearly out of scope / insufficient perceptual content 2) Work clearly does not meet sufficient standards of novelty or quality 3) Manuscript incomplete or incorrectly formatted 4) Suspected plagiarism in the manuscript.

2) PEER REVIEW PROCESS

Submitted manuscripts will be reviewed by two or more peer reviewers selected from the board's database of expert reviewers. In addition, if deemed necessary, a review of statistics may be requested. Following review, the editorial board will decide whether the manuscript will be 1) accepted for publication, 2) subject to minor revision, 3) subject to major revision, or 4) rejected for publication. For manuscripts which are either subject to minor revision or subject to major revision, the corresponding author must resubmit the revised manuscript online. The revised manuscript should clearly indicate all changes by highlighting the modified text or by using a different color for the altered sections. In addition, the corresponding author must reply to both reviewers' comments point by point, and explain in detail what changes were made in the manuscript. When considered necessary, the editorial board may make changes to the structure and phrases of the manuscript without compromising the integrity of the original paper. After completion of the peer review process, the editorial board will determine acceptance for publication and notify the corresponding author by e-mail. Manuscripts which do not comply with the present guidelines will be notified for correction or withheld from publication.

When a manuscript is not resubmitted within 2 months of notification, it will be considered that the authors have withdrawn the manuscript from submission. Manuscripts accepted for publication are generally published in order of submission, depending on the category of the manuscript and the date of acceptance for publication.

7. PREPARATION OF THE MANUSCRIPT

Use Microsoft Office Word (versions after 2003) and ensure correct spelling and grammar. Setup the MS Word document for 1-inch margins on letter or A4-sized paper. The manuscript must be written in 12-point font and the sentences must be double-spaced, including tables and figure legends. Each page should be numbered in the middle of the lower margin, and all sentences must be numbered sequentially throughout the entirety of the manuscript, starting with the title page. All papers must be accompanied by a title page. The title page should contain the title of the manuscript, a short running title, the authors' names, academic degrees, respective affiliations, and ORCID. The corresponding author must be identified, and his or her contact information (postal address, e-mail, telephone and fax numbers) should be listed. The title should clearly describe the objective of the study and contain less than 20 words. The first letter of each word of the title should be in capital letters except for prepositions, articles, and conjunctions. Provide a short running title containing less than 10 words. In cases in which the authors belong to multiple affiliations, the affiliations during the study being reported should be matched to the authors' names using a superscript of Arabic numerals. Conflicts of interest, funding information, author contribution and acknowledgements (when applicable) should also be located in the title page.

1) ORIGINAL ARTICLES

Original papers should be structured in the following order: Abstract, Introduction, Methods, Results, Discussion, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures. Maximum word count is limited to 5,000 words.

(1) Abstract

A structured abstract with the headings of Objective, Methods, Results, and Conclusion must succinctly describe the paper in 250 words or less. Use complete sentences and do not number the results. At the end of the abstract, list up to 5 relevant keywords which are in accordance to the Medical Subject Headings (MeSH) in the Index Medicus (http://www.nlm.nih.gov/mesh).

(2) Introduction

Clearly present the objective of the study and its relationship to earlier work in the field. A brief background to inform the readers of the relevance of the study may be necessary. However, avoid extensive review of the literature.

(3) Methods

Describe the participants or research materials of the study, and explain in detail the inclusion and exclusion criteria for both the experimental and control groups. Describe the experimental methods in a logical and systematic manner so that they can be reproducible by another investigator. Experimental drugs should be stated in the generic name. When proprietary brands are used, include the brand name and the name of the manufacturer in parentheses after the first mention of the generic name. When using experimental devices or other products, state the brand name then follow with the name of the manufacturer, in parentheses, e.g., Flow Cytometer (Coulter Electronic Inc.). To ensure anonymity during the peer review process, the authors' affiliations or institutional setting of the study should not be revealed. Statistical analysis and criteria for determining significance should be described in enough detail to allow the knowledgeable reader with access to the original data to verify the reported results. An ethics statement should be placed here when the studies are performed using clinical samples or data, and animals.

Ensure correct use of the terms sex (when reporting biological factors) and gender (identity, psychosocial or cultural factors), and, unless inappropriate, report the sex and/or gender of study participants, the sex of animals or cells, and describe the methods used to determine sex and gender. If the study was done involving an exclusive population, for example in only one sex, authors should justify why, except in obvious cases (e.g., prostate cancer). Authors should define how they determined race or ethnicity and justify their relevance.

(4) Results

Summarize and describe logically the significant findings and trends observed in the results using text, figures and tables. Avoid extensive repetition of contents of the tables and figures in the text.

In statistical expression, mean and standard deviation should be described as mean ± SD, and mean and standard error as mean ± SE. In general, p-values larger than 0.01 should be reported to two decimal places, those between 0.01 and 0.001 to three decimal places; p-values smaller than 0.001 should be reported as $p < 0.001$.

(5) Discussion

Interpret the results in respect to the objective of the study, and describe differences with previous studies and significant findings which lead to the deduction of the conclusion. Refrain from excessive review of historic studies, textbook facts, or irrelevant references. Accentuate newly obtained observations from the study, and include significant limitations of the study.

(6) Conflicts of interest

Any potential conflicts of interest relevant to the manuscript should be described. If there are no conflicts of interest, authors should state that none exists.

(7) Funding information

All sources of funding applicable to the study should be stated here explicitly. All original articles, editorials, reviews, and new technology articles must state funding sources for the study.

(8) Author contribution

The individual contributions of the authors to the manuscript should be specified in this section.

(9) Acknowledgments

Persons who have made contributions to the study, but who are not eligible for authorship can be named in this section. Their contribution must be specified, such as data collection, financial support, statistical analysis, or experimentation. The corresponding author must inform the named contributor of the acknowledgment, and acquire consent before manuscript submission.

(10) References

- Cite only references which are quoted in the text. Limit the number of references 40.

- When quoting a reference in the text, refrain from stating the author's name, and identify references with Arabic numerals in brackets such as [1], [2-4], and [5,7,9].
- The references should be listed in order of citation in the text.
- List all authors when there are 6 or fewer; when there are 7 or more, list the first 6, followed by "et al."
- Journal names should be abbreviated according to the format listed in the Index Medicus. If the journal is not listed in the Index Medicus, refer to the list of title word abbreviations by the ISSN network (http://www.issn.org/2-22660-LTWA.php).
- For more on references, refer to the NLM Style Guide for Authors, Editors, and Publishers (http://www.nlm.nih.gov/citingmedicine).

Journals

1. Jeon JH, Jung YJ, Lee JY, Choi JS, Mun JH, Park WY, et al. The effect of extracorporeal shock wave therapy on myofascial pain syndrome. Ann Rehabil Med 2012;36:665-74.
2. Geraud G, Spierings EL, Keywood C. Tolerability and safety of frovatriptan with short- and long-term use for treatment of migraine and in comparison with sumatripan. Headache 2002;42 Suppl:S93-9.

Book & Chapter of book

3. Frontera W, Silver JK, Rizzo TD. Essentials of physical medicine and rehabilitation. 2nd ed. Saunders; 2008. p. 579-82.
4. Esquenazi A. Upper limb amputee rehabilitation and prosthetic restoration. In: Braddon RL, editor. Physical medicine and rehabilitation. 2nd ed. Saunders; 2000. p. 263-78.

Proceedings of academic conference

5. Harnden P, Joffe JK, Jones WG. Germ cell tumours V. Proceedings of the 5th Germ Cell Tumour Conference; 2001 Sep 13-15; Leeds, UK. New York: Springer; 2002.

Thesis (Dissertation)

6. Borkowski MM. Infant sleep and feeding: a telephone survey of Hispanic Americans [dissertation]. Mount Pleasant, MI: Central Michigan University; 2002.

(11) Tables

Tables should be submitted separately from the text, and each table should be created in MS Word on separate pages, using double space throughout. They should be simple, self-explanatory, and not redundant with the text or the figures. Limit 5 tables per manuscript. The title of the tables should be written in phrases, and capitalized the first letter of the first word. The title should be placed above the table, and abbreviations and footnotes should be placed under the table. Number the tables in order of appearance in the text (e.g., Table 1, Table 2). All abbreviations used in the table must be spelled-out in full under the table in the following order: abbreviation, comma, full word (e.g., RM, rehabilitation medicine;). Table footnotes should be indicated in superscripts in the following order: [a], [b], [c]… but p-values should be indicated by asterisk (e.g., *$p<0.05$, **$p<0.01$. ***$p<0.001$).

(12) Figure legends

Legends should be submitted separately from the text, and each legend should be typed on separate pages. They should be written in full sentences to describe the content of the figure, and only the first letter of the legend should be capitalized. For lengthy legends continuing beyond one line, the left margin of the following lines should start at the same point as the first line. Any symbols, marks or abbreviations made in the figure must be explained in the legend. Figures containing histologic slides should be accompanied by legends explaining tissue origin, stain method, and microscopic amplification.

(13) Figures

Figures should be uploaded online as separate files and numbered in order of appearance in the text (e.g., Fig. 1). When a single numbered figure contains 2 or more figures, the figure should be numbered with an alphabet letter following the number (e.g., Fig. 1A, Fig. 1B). Indicate focus points in the figures with markers such as arrows and arrowheads, etc. Image files must be of resolutions higher than 300 dpi, and less than 3 MB, in JPEG, GIF, TIFF, or Microsoft PowerPoint format. A single numbered figure containing more 2 or more figures such as Fig. 1A and Fig. 1B should be uploaded as a single file.

2) REVIEW ARTICLES

The abstract should contain no more than 250 words and 5 keywords. The text is structured in the order of Introduction, Main text, Conclusion, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures.

3) BRIEF REPORTS

General guidelines are the same as for the original article. The manuscript is structured in the order of Abstract, Main text, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures. A structured abstract is required and limited to 150 words, with no more than 3 keywords attached. Manuscripts

should be limited to 1,500 words of text including references and figure legends (not including abstract, tables, and figures), and no more than 10 references. The total number of figures and/or tables is limited to 3.

4) CASE REPORTS

General guidelines and order of manuscript preparation are the same as for the original article. Case reports are considered for publication only if they report rare conditions, atypical symptoms and signs, novel diagnostic or therapeutic approaches, or describe atypical findings for populations residing in Asia and the Pacific Rim. The editorial board will determine whether the case report fulfills the above criteria for acceptance of publication. The manuscript is structured in the order of Abstract, Introduction, Case report, Discussion, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures. The abstract should be nonstructured and limited to 150 words, with no more than 3 keywords attached. The introduction should briefly state the background and significance of the case. The actual case report should describe the clinical presentation and the diagnostic and therapeutic measures taken. The discussion should focus on the uniqueness of the case and should not contain extensive review of the disease or disorder. The combined number of tables and figures is limited to 5, and the number of references is limited to 10. Maximum word count is limited to 1,500 words including references and figure legends.

5) IMAGES IN THIS ISSUE

All images should be accompanied by a short description of the image and a brief and concise clinical review of the specific patient or clinical issue of no more than 500 words (excluding references) with references limited to 5. Image files must be of resolutions higher than 300 dpi for photographs, and 900 dpi for line art, waveforms, and graphs, in JPEG, GIF, TIFF, or Microsoft PowerPoint format. Images should make up a single figure, although they may contain more than one frame. The manuscript does not have an abstract.

6) LETTERS TO THE EDITOR

Letters should not have an abstract, tables, figures, and data supplements. Letters must be limited to roughly 500 words of text and no more than 5 references, 1 of which should be to the recent *ARM* article. Letters may have no more than 3 authors.

7) REPORTING GUIDELINES FOR SPECIFIC STUDY DESIGNS

For the specific study design, such as randomized control studies, studies of diagnostic accuracy, meta-analyses, observational studies, and non-randomized studies, it is recommended that the authors follow the reporting guidelines listed in the following table.

Initiative	Type of study	Source
CONSORT	Randomized controlled trials	http://www.consort-statement.org
STARD	Studies of diagnostic accuracy	http://www.stard-statement.org
PRISMA	Preferred reporting items of systematic reviews and metaanalyses	http://www.prisma-statement.org
STROBE	Observational studies	http://www.strobe-statement.org
MOOSE	Meta-analyses of observationa studies in epidemiology	http://www.consort-Statement.org/resources/downloads/other-instruments/moose-statement-2000pdf

8. SUBMISSION APPLICATION & COPYRIGHT TRANSFER

All submitted manuscripts must be accompanied by the official Submission Application & Copyright Transfer Form of the Korean Academy of Rehabilitation Medicine. The Submission Application & Copyright Transfer Form must contain the title of the manuscript, date of submission, names of all authors, authors' affiliations, and written signatures. Note the corresponding author and provide his/her affiliation, e-mail, telephone and fax numbers, and mailing address.

For the copyrights of the contributions published in *ARM*, see Creative Commons (Attribution-Noncommercial) at http://creativecommons.org.

9. MANUSCRIPTS AFTER ACCEPTANCE

ARM is published in English bi-monthly on the last days of February, April, June, August, October, and December.

1) FINAL VERSION UPLOAD

When accepted for publication, the authors' institutional affiliations should be inserted into the text of the final revised manuscript and uploaded to the online submission system. Files containing figures should be of the highest resolution (at least 300 dpi for color figures, and 900 dpi for line art and graphs) should be also be uploaded in JPEG, GIF, or TIFF format, and must be named according to the figure number (e.g., Fig. 1.jpg).

2) GALLEY PROOF

Galley proofs will be sent to the corresponding author for final corrections. Corrections should be kept to a minimum, must be returned within 2 days, otherwise publication may be delayed. Any fault found after the publication is the responsibility of the authors. We urge our contributors to proofread their accepted manuscripts very carefully. After the publication, if there are critical errors, they should be corrected as Corrigendum or Erratum.

3) PUBLICATION

The editorial board retains the right to request minor stylistic and major alterations that might influence the scientific content of the paper. The final manuscript will be published following final approval by the editor-in-chief.

Checklist for Authors

Annals of Rehabilitation Medicine

General

☐ All elements of the manuscript are printed in English and double-spaced with 1-inch margins at top, bottom, and sides. Right margins are unjustified.

☐ All pages are numbered in the following order: title page, structured or standard abstract, body of the text, conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), references, legends, and tables.

☐ The text is consecutively line numbered.

☐ The Submission Application & Copyright Transfer Form is signed by the guarantor at original submission.

Abstract (applied to original articles, review articles, brief reports, and case reports)

☐ A structured abstract with the headings of Objective, Methods, Results, and Conclusion (A nonstructured abstract for case reports) must succinctly describe the paper.

☐ At the end of the abstract, relevant keywords are listed.

References

☐ All references have been checked for accuracy and completeness.

☐ Cite only references which are quoted in the text. Limit the number of references 40 for original articles, 10 for brief reports and case reports, and 5 for images in this issue and letters to the editor.

☐ Are numbered consecutively in the order they are cited in the text; all listed references have been cited in the text.

☐ Do NOT parenthesize the superscript numerals, and hyphenate (-) when citing 3 or more references in consecutive order.

☐ The format prescribed by the "Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals (ICMJE Recommendations)" has been followed. Examples provided under Instructions for Authors have been uploaded.

☐ List all authors when there are 6 or fewer; when there are 7 or more, list the first 6, followed by "et al."

☐ Journal names should be abbreviated according to the format listed in the Index Medicus. If the journal is not listed in the Index Medicus, refer to the list of title word abbreviations by the ISSN network (http://www.issn.org/2-22660-LTWA.php).

Figure Legends

☐ Figure legends are provided for each figure.

☐ Figure legends are numbered and presented together in numeric order following reference page(s).

Tables

☐ Each table is headed by a title and numbered in Arabic numerals on a separate page.

☐ The title of the tables should be written in phrases, and capitalized the first letter of the first word.

☐ There are less than 5 tables in the text of original articles.

☐ Tables are cited in numeric sequence in the text.

Figures

☐ Each is numbered with an Arabic numeral and cited in numeric sequence in the text.

☐ Photographs of recognizable persons should be accompanied by a signed release from the patient or legal guardian authorizing publication. Masking eyes to hide identity is not sufficient.

Credits & Permissions

☐ In addition to the notice of informed consent and releases to publish photographs of recognizable persons, submit with the manuscript written permission to use non-original material (quotations exceeding 100 words, any table or illustration) from copyright holder of the original. No article will be accepted as a submission to Archives without all required permissions. Credit the source in a text or table footnote or in a legend.

A more complete description of each item that must be checked is provided under the appropriate heading in the Instructions for Authors.

I have reviewed this Checklist and have complied with its requirements.

Every author took a certain role and made contribution to the study and the manuscript. In case of publication, I agree to transfer all copyright ownership of the manuscript to the Korean Academy of Rehabilitation Medicine to use, reproduce, or distribute the article.

☐ Agree ☐ Disagree