Research Report

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The Effects of Wall Squat Exercise using Elastic Band on Leg Strength, Gait, and Plantar Pressure in Chronic Stroke Patients

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Background Squat exercises effectively strengthen leg muscles in stroke patients but pose challenges due to balance issues and fall risks. Wall squat exercises provide greater stability by utilizing the wall, making them a safer alternative while maintaining similar muscle-strengthening benefits. Additionally, applying an elastic band at the knees may activate the gluteus medius muscle, potentially improving walking ability.

Purpose This study aimed to investigate the effects of wall squat exercises using an elastic band on leg muscle strength, gait, and plantar pressure in chronic stroke patients.

Study design Comparative, repeated measures design

Methods The study included 23 chronic stroke patients randomly assigned to either the experimental group (n=11), performing wall squats with an elastic band, or the control group (n=12), performing wall squats without a band. Both groups completed 10 sets of 10 repetitions, three times per week for six weeks. Outcomes measured before and after the intervention included leg muscle strength assessed with a manual muscle tester, gait performance evaluated using the 10-Meter Walk Test, and plantar pressure measured with an FDM-T treadmill. Two-way repeated measures ANOVA was used to compare differences between groups over time.

Results The experimental group using an elastic band showed greater improvements in leg muscle strength compared to the control group, particularly on the paralyzed side, which contributed to enhanced walking ability. Additionally, walking speed and stability improved. Plantar pressure analysis revealed a more balanced distribution between the forefoot and hindfoot, reducing asymmetrical weight distribution.

Conclusions The findings confirm that wall squat exercises using an elastic band are an effective rehabilitation method for stroke patients, improving leg muscle strength and walking ability. The resistance provided by the band played a key role in strengthening the gluteus medius, leading to improved gait stability. Furthermore, the more balanced plantar pressure distribution contributed to better weight distribution, enhancing overall walking stability. These results suggest that elastic band-assisted wall squat exercises can be a safe and effective intervention for stroke rehabilitation, offering a practical approach to improving functional mobility. Therefore, incorporating this exercise into stroke rehabilitation programs can help enhance the overall physical function of patients.

Key words Elastic band; Gluteus medius; Strengthening; Stroke; Wall squat

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INTRODUCTION

Stroke is a central nervous system disease with a high incidence and mortality rate worldwide, and is caused by a disruption of blood supply to brain neurons due to cerebral hemorrhage or cerebral infarction.[1] Stroke causes complex motor, sensory, cognitive, and emotional impairment,[2] which leads to asymmetrical postural alignment and a decreased ability to maintain symmetrical weight bearing.[3] Fear of falling reduces the confidence of stroke patients, interferes with their daily lives, and lowers their quality of life.[4] Therefore, the process of restoring balance is essential for returning to daily life, and this can contribute to preventing falls and improving function.[5]

One of the most significant losses after stroke is the loss of walking ability, which is a major goal of rehabilitation treatment.[6] Walking is a basic method of locomotion that is achieved through the coordination of multiple joints and muscles, and the feet play an important role in bearing weight as the only support surface of the body.[7,8] However, the upright posture is inherently unstable because it requires maintaining a high center of pressure on a relatively small base of support.[9] To compensate for this instability, the muscles of the waist and legs are activated to provide stability.[10] Some studies have reported that walking problems in stroke patients further deteriorate physical function, disrupting independent and functional movements and ultimately limiting social participation.[11] Strengthening exercises for the lower extremities are necessary to improve the walking function of stroke patients.[12] A study that performed strength-enhancing exercises showed that the strength of the paralyzed leg significantly improved in chronic stroke patients, and functional performance, walking speed, and stair climbing ability were improved.[13]

The squat, a representative closed-chain exercise,[14] contributes to the development of thigh muscle groups and strengthens the quadriceps muscle by activating multiple joints through weight support.[15] It has been reported that squat exercise is effective in improving muscle activity and central pressure movement in stroke patients, which can be linked to balance training to prevent the use of affected sides.[16] However, squat exercise is difficult to maintain posture and center of gravity, so the weight load is transferred to the lower back and knee joints, which can cause injury.[17] To compensate for this, the wall squat exercise was proposed. The wall squat exercise can be performed safely without the risk of back or knee injuries because it transfers body weight to the wall, and is a suitable exercise for beginners.

In addition, elastic bands are inexpensive, easy to carry, have a low risk of injury, and can provide resistance at various angles, making them suitable for improving muscle strength and body balance.[18,19] One study reported that bridge exercise using an elastic band promoted muscle activity in the middle gluteus medius muscle compared to bridge exercise without an elastic band.[20] In addition, elastic band exercise helps prevent muscle strength decline and improve balance and walking ability.[21] Another study reported that the results of applying elastic band exercise for 12 weeks to patients with hemiplegia due to stroke showed a positive effect in preventing decline in physical strength in daily life and balance ability due to decline in leg muscle strength and in preventing falls.[19]

Neurological and functional impairments are closely related to stable walking speed, and it has been reported that hip strength plays an important role.[22] The hip abductor muscles stabilize the hip joint posture during walking and are essential for independent walking and balance recovery.[23,24] It was reported that balance and walking were improved as a result of performing hip-joint abductor strengthening exercises in stroke patients.[25] Plantar pressure is an important indicator of the qualitative status of balance and gait, and measures the pressure applied to the entire foot during daily life.[26] Plantar pressure outside the normal range can cause physiological disorders and musculoskeletal damage, and that repeated imbalanced weight bearing causes postural misalignment.[27] Most stroke patients have a higher level of pressure on the paralyzed side than on the paralyzed side. More weight is supported on the non-paretic side,[28] which increases the instability of body balance and postural control, causing various problems.[29] Therefore, biofeedback using a plantar pressure sensor has the potential to contribute to improving gait in stroke patients.[30]

For stroke patients, squat exercise is an effective exercise to strengthen leg muscles, but it can be a burdensome exercise due to the difficulty in maintaining balance and the risk of falling. As an alternative, applying wall squat exercise can increase stability by using the wall, thereby reducing the risk of falling, and can expect muscle strengthening effects similar to those of regular squats. In particular, applying elastic bands to the knees can more effectively activate the gluteus medius muscle, which plays an important role in walking, and is expected to have a positive effect on improving walking ability. Therefore, in this study, we analyzed the effects of wall squat exercise using elastic bands on leg muscle strength, walking, and plantar pressure in chronic stroke patients and aimed to suggest a safer and more effective intervention method.

METHODS

Participants

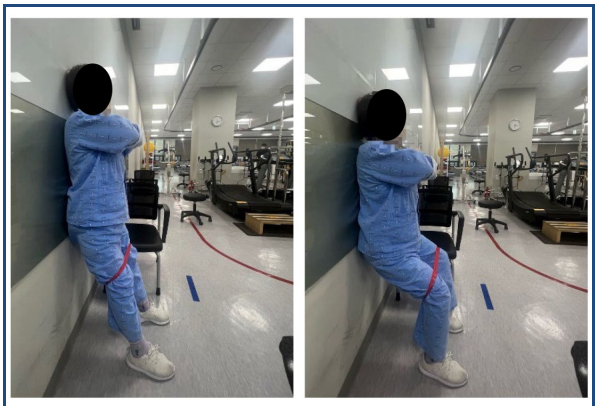
The subjects of this study were 30 chronic stroke patients admitted to Daegu Hospital. The 30 subjects were randomly divided into an experimental group (n=15) and a control group (n=15), but some dropped out due to discharge during the intervention process, resulting in 11 subjects in the experimental group and 12 subjects in the control group. Before participating in this study, all subjects received a sufficient explanation of the purpose of the study and gave written consent. The study was conducted after obtaining approval from the Daegu University Institutional Review Board (Approval Number: 1040621-202407-HR-058). The general characteristics of the subjects are as follows (Table 1).

Procedure

Both the experimental and control groups used the wall squat exercise method.[31] The experimental group performed wall squats with an elastic band 5 cm above their knees (Figure 1), while the control group performed wall squats in the same way as the experimental group without using an elastic band (Figure 2). One set consisted of 10 repetitions of sitting and standing up against the wall, and a total of 10 sets were performed. The exercise was performed 3 times a week for a total of 6 weeks with a 15-second rest period between sets.

Manual muscle test

In this study, the leg muscle strength was evaluated using a manual muscle tester (Model 01165, Lafayette, USA) on the knee extensors, knee flexors, and hip abductors of the non-paretic and paretic sides. The muscle strength measurement positions were selected from the positions listed in the muscle strength examination textbook.[32] The pressure that appears during the maximum isometric contraction of each muscle was measured, and the average



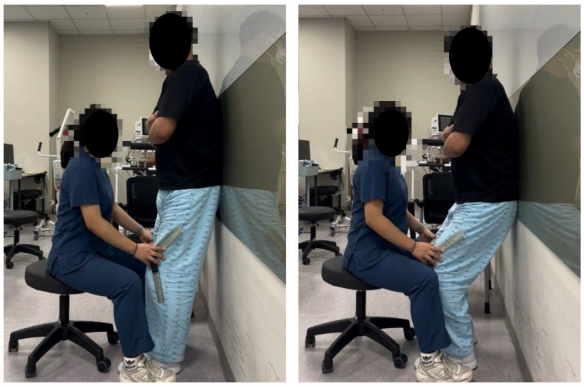
(A) **(B)**

Figure 1. Wall squat exercise with elastic band: (A) starting position and (B) squatting position.

Table 1. General characteristics of subjects

		EG (n=11)	CG (n=12)	χ^2	*p*
Gender	Male	8(72.73%)	10(83.33%)	.379	.538
	Female	3(27.27%)	2(16.67%)		
Paretic side	Left	6(54.55%)	7(58.33%)	.034	.855
	Right	5(45.45%)	5(41.67%)		
Type of stroke	Infarction	8(72.73%)	8(66.67%)	.100	.752
	Hemorrhage	3(27.27%)	4(33.33%)		
Age (years)		58±9.19	54.17±12.57	20.996	.226
Height(cm)		168.09±6.86	171.81±7.22	17.657	.281
Weight(kg)		70.59±11.38	75.92±14.87	20.996	.337
Time since onset(month)		11.12±5.52	13.31±6.61	23.000	.344
MMSE-K(score)		27.27±2.15	27.08±2.19	7.838	.250
FAC(score)		3.27±0.65	3.42±0.67	1.017	.601
FMA-LE(score)		31.45±1.86	31.45±2.01	1.626	.898

M±SD: mean ± standard deviation.
EG: wall squat with elastic band.
CG: wall squat without elastic band.
p <.05.
MMSE-K: mini mental state examination-Korean version.
FAC: functional ambulation category.
FMA-LE: Fugl-Meyer assessment for lower extremity.



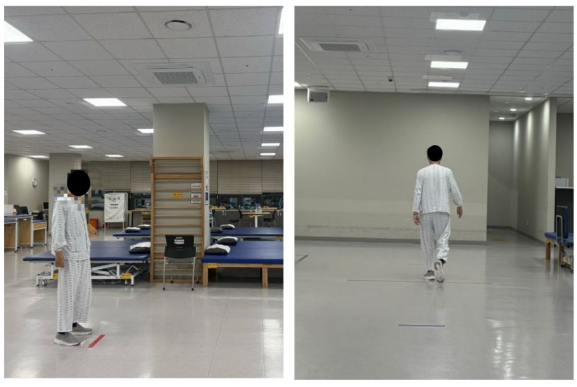
(A) (B)

Figure 2. Wall squat exercise without elastic band: (A) starting position and (B) squatting position.

of three measurements was recorded. A 15-second rest was taken between each measurement to exclude muscle fatigue. The maximum force value was used to evaluate muscle strength in this study.

10m walking test

The 10m Walking Test (10MWT) was used to evaluate walking performance. The time taken by the subject to walk 10 m, excluding the 2 m acceleration section at the starting point and the 2 m deceleration section at the final destination, while the subject walked a total distance of 14 m was measured. The subjects repeated the measurement three times in total at a safe but fast speed, and the average value was calculated. In order to minimize the subject's fatigue, the time interval between each measurement was measured again after a 30-second rest using a stopwatch (Figure 3).



(A) (B)

Figure 3. 10-Meter walk test: (A) starting position and (B) walking phase.

Plantar pressure test

In this study, the Zebris FDM-T Treadmill (Zebris, Germany) was used as an evaluation tool to measure the plantar pressure of the subjects in a standing position before and after exercise. In this study, for measurement, the subjects were instructed to stand upright on the treadmill, look straight ahead, and maintain a standing posture for 30 seconds (Figure 4). In this study, the average pressure ratio values of the forefoot, hindfoot, and entire foot were used to evaluate the plantar pressure of the paretic and non-paretic sides.

Data analysis

All statistical analyses of the data collected in this study were performed using the SPSS (statistical package for the social sciences) version 23.0 for window software (SPSS Inc., Chicago). Data processing on the general characteristics of the research subjects was described using descriptive statistics. In order to compare the differences between groups over time, two-way repeated measures ANOVA was used, and the significance level was set at α =.05. In order to check for interaction, the Bonferroni test was performed, and the significance level was set at α =.017.

RESULTS

Manual muscle test

As a result of the manual muscle strength test of the control group and the experimental group, the muscle strength level increased in both groups, and in particular, the results of the experimental group were better, but no statistically significant results were found (Table 2).

Figure 4. Measure of foot pressure on Zebris FDM-T treadmill.

Table 2. Changes in knee extensor, knee flexor, and hip abductor strength pre- and post-intervention in the experimental and control groups (Unit: lbs)

			Time			*F*	*p*
			Pre-test	Post-test			
Muscle strength of knee extensor	NP	EG	28.95±9.77	33.53±11.67	Time	6.176	0.021*
					Group	0.294	0.593
		CG	26.64±6.67	32.38±7.88	Time×group	0.078	0.783
	P	EG	21.35±6.52	27.45±10.94	Time	6.685	0.017*
					Group	0.010	0.923
		CG	23.01±7.10	25.20±7.63	Time×group	1.488	0.236
Muscle strength of knee flexor	NP	EG	19.11±3.81	23.14±4.50	Time	44.220	0.000*
					Group	0.701	0.412
		CG	17.03±2.84	22.48±5.48	Time×group	1.006	0.327
	P	EG	26.24±7.82	27.75±8.46	Time	2.099	0.162
					Group	3.447	0.077
		CG	20.77±6.22	24.73±5.75	Time×group	0.422	0.523
Muscle strength of hip abductor	NP	EG	17.97±6.35	19.07±4.64	Time	0.165	0.689
					Group	0.920	0.348
		CG	16.48±7.23	16.04±5.26	Time×group	0.915	0.350
	P	EG	14.66±6.21	20.92±4.98	Time	27.689	0.000*
					Group	0.615	0.442
		CG	15.04±4.48	17.43±4.84	Time×group	5.560	0.028*

M±SD: mean ± standard deviation.
NP: non-paretic side.
P: paretic side.
EG: wall squat with Elastic band.
CG: wall squat without Elastic band.
p<.05.

There was a difference in the strength of the hip joint abductor muscles on the paretic side between the two groups at each time point (p<.05), and there was no statistically significant difference in the change in each group at each time point

Table 3. Muscle strength of paretic hip abductor (Unit: lbs)

	Pre	Post	Difference value	T	Change rate (%)	*P*
EG	14.66±6.21	20.92±4.98	6.26±1.23	-4.01	42.70%	0.002*
CG	15.04±4.48	17.43±4.84	2.39±0.36	-3.61	15.86%	0.004
t	-.170	1.705				
p	.867	.103				

M±SD: mean ± standard deviation.
EG: wall squat with Elastic band.
CG: wall squat without elastic band.
p<.0025.

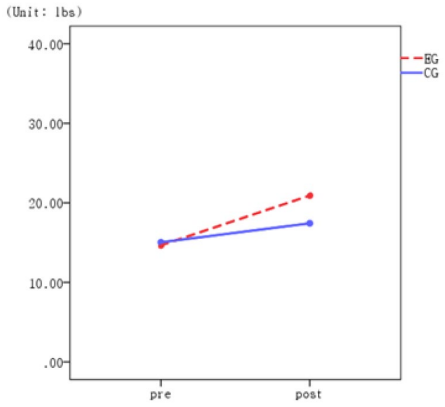


Figure 5. Comparison of paretic-side hip abductor strength between groups.
(EG: elastic band group, CG: control group)

(p>.05). There was a significant difference in the interaction between the time point and the group (p<.05). (Table 3 and Figure 5)

10m walking tests

As a result of the 10-meter walking test of the control group and the experimental group, walking time was shortened in both groups, but statistically significant results were not found (Table 4).

Plantar pressure

As a result of the plantar pressure measurement test of the control group and the experimental group, no statistically significant results were found (Table 5).

DISCUSSION

In this study, we analyzed the effects of wall squat exercise using elastic bands on leg muscle strength, gait, and plantar pressure in patients with chronic stroke. As a result of the study, both the experimental group with elastic bands and the control group without elastic bands showed significant improvements in leg muscle strength and walking ability, but more significant improvements were observed in the experimental group.

It was confirmed that wall squat exercise using elastic bands is effective in strengthening leg muscle strength. In particular, the improvement in leg muscle strength on the paralyzed side was remarkable, which is consistent with previous studies. In a study, resistance exercise using elastic bands was reported to be effective in strengthening leg muscle strength.[33] And in a study, resistance exercise using elastic bands was reported to be effective in improving muscle strength in stroke patients.[34] In this study, it appears that resistance exercise using elastic bands induced an increase in leg muscle strength. These findings support that elastic band–based resistance training is a viable method for improving lower limb strength in chronic stroke.

In comparison, the general squat exercise quadriceps muscle thigh It was reported that it is effective in increasing the strength of the biceps femoris.[14] However, in this study, the activity of the middle gluteus muscle was increased more effectively by adding an elastic band, which also had a positive effect on walking stability. Therefore, it is suggested that wall squat exercise using an elastic band may be a more effective approach to improving leg muscle strength than simple squat exercise.

In addition, the experimental group showed improvement in time reduction in the 10-meter walk test compared to the control group. This is similar to what was reported in the study, and means that the elastic band contributed to im-

Table 4. Walking time using 10-meter walk test (Unit: second)

		Time			F	P
		Pre-test	Post-test			
				Time	4.215	0.053
	EG	15.18±6.90	13.34±7.73			
10MWT				Group	5.203	0.033*
	CG	24.43±13.11	22.80±10.72			
				Time*Group	0.016	0.899

M±SD: mean ± standard deviation.
10MWT: 10-meter walk test.
EG: wall squat with elastic band.
CG: wall squat without elastic band.
p<.05.

Table 5 Plantar pressure distribution ratio (Unit: %)

			Time			*F*	*P*
			Pre-test	Post-test			
Fore-foot pressure	NP	EG	44.55±18.35	47.36±12.86	Time	0.321	0.577
					Group	0.185	0.671
		CG	43.08±13.22	44.00±17.22	Time×group	0.083	0.776
	P	EG	49.55±15.38	46.91±14.75	Time	0.039	0.846
					Group	1.254	0.275
		CG	56.67±18.55	58.00±30.55	Time×group	0.357	0.556
Back-foot pressure	NP	EG	55.45±18.35	52.64±12.86	Time	0.321	0.577
					Group	0.185	0.671
		CG	56.92±13.22	56.00±17.22	Time×group	0.083	0.776
	P	EG	50.45±15.38	53.09±14.75	Time	0.039	0.846
					Group	1.254	0.275
		CG	43.33±18.55	42.00±30.55	Time×group	0.357	0.556
Total foot pressure	NP	EG	50.09±11.70	51.55±9.18	Time	3.016	0.097
					Group	0.565	0.461
		CG	51.00±14.95	58.00±15.20	Time×group	1.297	0.268
	P	EG	49.91±11.70	48.45±9.18	Time	3.016	0.097
					Group	0.565	0.461
		CG	49.00±14.95	42.00±15.20	Time×group	1.297	0.268

M±SD: mean ± standard deviation.
NP: non-paretic side.
P: paretic side.
EG: wall squat with elastic band.
CG: wall squat without elastic band.
$p<.05$.

proving walking stability by increasing the coordination of the hip and knee joints.[21] In particular, a study reported that hip arthroplasty played an essential role in independent walking and balance recovery, and this study also confirmed that resistance exercise using elastic bands increased the activity of hip arthroplasty muscles, which had a positive effect on improving balance and walking ability.[24]

In this study, the results of plantar pressure measurement showed that the forefoot and hindfoot of the experimental group The distribution of plantar pressure changed to become more balanced. This indicates that, although stroke patients tend to have their weight shifted to the non-paralyzed side, the elastic band application exercise helped improve weight distribution to be more symmetrical. These results were also confirmed in the study, suggesting that a balanced distribution of plantar pressure is an important factor in improving walking stability.[30]

This study has several limitations. First, this study may not have ruled out the influence of other rehabilitation treatments besides exercise intervention. Therefore, future research requires a research design that more thoroughly controls the control group. Second, the number of study subjects was limited, which may limit the generalization of the study results. Future research should include more subjects to increase the reliability of the study. Third, the study period was set to 6 weeks, which may be insufficient to verify the long-term effects. Therefore, follow-up research is needed to analyze the long-term effects of wall squat exercise using elastic bands.

CONCLUSIONS

This study proved that wall squat exercise using elastic bands is effective in improving leg muscle strength, gait, and plantar pressure in stroke patients. The results showed that the experimental group using elastic bands had greater improvements in leg muscle strength than the control group, improved static and dynamic balance ability, and significantly increased walking ability. In addition, it was shown that the distribution of plantar pressure changed to be more balanced, which also contributed to improving walking stability. These results suggest that wall squat exercise using elastic bands can be an effective intervention method for the rehabilitation of chronic stroke patients, and that exercise using elastic bands can be expected to improve leg muscle strength, balance, and walking ability more than conventional wall squat exercise. Additional research and clinical application should be conducted so that this exercise method can become a standard exercise treatment in the rehabilitation process of stroke patients.

Key Points

Question How does wall squat exercise with elastic bands affect leg strength, walking, and plantar pressure in chronic stroke patients?

Findings The strength of the hip muscles on the paretic side increased, which had a positive effect on walking ability and plantar pressure distribution.

Meaning Elastic bands can promote the activation of the gluteus medius, enhancing hip joint abduction and walking stability, suggesting that they are effective for rehabilitation.

Article information

Conflict of Interest Disclosures: None.
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Ethic Approval: The study was conducted after obtaining approval from the Daegu University Institutional Review Board (Approval Number: 1040621-202407-HR-057). Informed consent for publication of the images was obtained from the patient.

Author contributions

Conceptualization: MK So, TH Kim.
Data acquisition: MK So.
Design of the work: MK So, TH Kim.
Data analysis: MK So.
Project administration: TH Kim.
Interpretation of data: MK So.
Writing – original draft: MK So.
Writing–review&editing: TH Kim.

REFERENCES

1. Belgen B, Beninato M, Sullivan PE, Narielwalla K. The association of balance capacity and falls self-efficacy with history of falling in community-dwelling people with chronic stroke. *Arch Phys Med Rehabil*. 2006; 87(4):554-561.
2. Sharp SA, Brouwer BJ. Isokinetic strength training of the hemiparetic knee: effects on function and spasticity. *Arch Phys Med Rehabil*. 1997;78(11):1231-1236.
3. Shumway-Cook A, Anson D, Haller S. Postural sway biofeedback: its effect on reestablishing stance stability in hemiplegic patients. *Arch Phys Med Rehabil*. 1988;69(6):395-400.
4. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture*. 2002;16(1):1-14.
5. Horak FB, Henry SM, Shumway-Cook A. Postural perturbations: new insights for treatment of balance disorders. *Phys Ther*. 1997;77(5):517-533.
6. Mumma CM. Perceived losses following stroke. *Rehabil Nurs J*. 1986;11(3):19-21,24.
7. Perry J, Bleck EE. Gait analysis: normal and pathological function. *Dev Med Child Neurol*. 1993;35(12):1122.
8. Saltzman CL, Nawoczenski DA. Complexities of foot architecture as a base of support. *J Orthop Sports Phys Ther*. 1995;21(6):354-360.
9. Winter DA. Human balance and posture control during standing and walking. *Gait Posture*. 1995;3(4):193-214.
10. Aruin AS, Latash ML. Directional specificity of postural muscles in feed-forward postural reactions during fast voluntary arm movements. *Exp Brain Res*. 1995;103:323-332.
11. Cederfeldt M, Gosman-Hedström G, Sävborg M, Tarkowski E. Influence of cognition on personal activities of daily living (P-ADL) in the acute phase: The Gothenburg cognitive stroke study in elderly. *Arch Gerontol Geriatr*. 2009;49(1):118-122.
12. NJ Kim. The effects of elastic band resistance exercise on the upper and lower extremity muscle activity in stroke hemiplegic patients with different durations of paralysis. *Korean Journal of Social Sports*. 2009;37: 1315-1324.
13. Teixeira-Salmela LF, Olney SJ, Nadeau S, Brouwer B. Muscle strengthening and physical conditioning to

reduce impairment and disability in chronic stroke survivors. *Arch Phys Med Rehabil*. 1999;80(10):1211-1218.
14. Palmitier RA, An K-N, Scott SG, Chao EY. Kinetic chain exercise in knee rehabilitation. *Sports Med*. 1991;11:402-413.
15. Selseth A, Dayton M, Cordova ML, Ingersoll CD, Merrick MA. Quadriceps concentric EMG activity is greater than eccentric EMG activity during the lateral step-up exercise. *J Sport Rehabil*. 2000;9(2):124-134.
16. KH Ko, BJ Kim. A comparative study on the balance of stroke patients according to knee squat exercise and squat exercise posture. *Korean Journal of Integrative Medicine*. 2022;10(4):1-9.
17. Fry A. Coaching considerations for the barbell squat-Part 1. *J Strength Cond Res*. 1993;15(2):556-569.
18. SH Kang, SS Kim. The effects of elastic band exercise and aerobic exercise on the basic physical strength and vascular health of the elderly. *Korean Journal of Physical Education*. 2017;56(1):1-10.
19. SH Yoo, SA Kong, MG Lee. The effects of 12 weeks of elastic band exercise on daily physical fitness and cardiovascular variables in hemiplegic stroke patients. *Korean Journal of Physical Education*. 2007;46(4): 447-457.
20. SA Choi, HS Cynn, CH Yi, OY Kwon, TL Yoon, WJ Choi, JH Lee. Isometric hip abduction using a Thera-Band alters gluteus maximus muscle activity and the anterior pelvic tilt angle during bridging exercise. *J Electromyogr Kinesiol*. 2015;25(2):310-315.
21. SH Ahn, JP Lee, JH Yoon, SH Kim, JG Oh. The effects of elastic band exercise on lower extremity muscle strength, balance, and gait ability in hemiplegic stroke patients. *Korean Journal of Special Sports*. 2009;17 (4):51-70.
22. Nadeau S, Arsenault AB, Gravel D, Bourbonnais D. Analysis of the clinical factors determining natural and maximal gait speeds in adults with a stroke. *Am J Phys Med Rehabil*. 1999;78(2):123-130.
23. CM Kim, JJ Eng, Whittaker MW. Effects of a simple functional electric system and/or a hinged ankle-foot orthosis on walking in persons with incomplete spinal cord injury. *Arch Phys Med Rehabil*. 2004;85(10): 1718-1723.
24. Kirker S, Simpson D, Jenner J, Wing AM. Stepping before standing: hip muscle function in stepping and standing balance after stroke. *J Neurol Neurosurg Psychiatry*. 2000;68(4):458-464.
25. Mercer VS, Chang SH, Williams CD, Noble KJ, Vance AW. Effects of an exercise program to increase hip abductor muscle strength and improve lateral stability following stroke: a single subject design. *J Geriatr Phys Ther*. 2009;32(2):6-15.
26. Dowling A, Steele J, Baur L. Does obesity influence foot structure and plantar pressure patterns in prepubescent children*? Int J Obes.* 2001;25(6):845-852.
27. Gravante G, Russo G, Pomara F, Ridola C. Comparison of ground reaction forces between obese and control young adults during quiet standing on a baropodometric platform. *Clin Biomech*. 2003;18(8): 780-782.
28. Kusoffsky A, Apel I, Hirschfeld H. Reaching-lifting-placing task during standing after stroke: coordination among ground forces, ankle muscle activity, and hand movement. *Arch Phys Med Rehabil*. 2001;82(5):650-660.
29. Geiger RA, Allen JB, O'Keefe J, Hicks RR. Balance and mobility following stroke: effects of physical therapy interventions with and without biofeedback/forceplate training. *Phys Ther.* 2001;81(4):995-1005.
30. Ma CZ-H, Zheng Y-P, Lee WC-C. Changes in gait and plantar foot loading upon using vibrotactile wearable biofeedback system in patients with stroke. *Top Stroke Rehabil*. 2018;25(1):20-27.
31. M Cho. The effects of modified wall squat exercises on average adults' deep abdominal muscle thickness and lumbar stability. *J Phys Ther Sci*. 2013;25(6):689-692.
32. Brown M, Avers D. *Daniels and Worthingham's Muscle Testing E-Book*. Saunders. 2018.
33. HS Kim, NJ Kim. Exercise physiology: the effects of elastic band exercise on daily physical fitness in stroke patients. *Korean Journal of Physical Education*. 2003;42(5):649-655.
34. NJ Kim, HS Kim, JG Oh, BH Lee. The effects of elastic band exercise on the upper and lower extremity muscle activity in stroke patients. *Exercise Science*. 2006;15(4):329-336.