Medicina Sportiva (2022), vol. XVIII, no 1, 3430-3436
Journal of the Romanian Sports Medicine Society

Impact of upper extremity positions on balance and gait in stroke survivors: A comparative study with healthy controls

Fettah Saygili[1], Ugur Cavlak[2]
[1]*Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Turkey,* [2]*Biruni University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İstanbul, Turkey*

Abstract. *Aim*. This study aims to show how upper extremity position affects balance and gait in stroke survivors compared with healthy controls. *Material and Method*. Thirty-two stroke survivors (mean age: 52.1±10 yrs) having a score of 7 and above according to the Hodkinson Mental Test were compared with 32 healthy controls (mean age: 52.1±10 yrs). Stroke survivors were divided into two groups according to their Brunnstrom upper extremity stage: stage 1 (n=16) (group 1); stage 3 (n=16) (group 2). Healthy controls were instructed to simulate Brunnstrom upper extremity Stage 1 first (group 3) and then Stage 3 (group 4) during the assessments. The same healthy controls were evaluated twice, one day apart. Tinetti Gait and Balance Assessment Tool and Functional Reach Test were used to measure balance ability and gait characteristics of the participants in the two groups. *Results.* While stroke survivors in stage 1 (group 1) and stage 3 (group 2) were compared in terms of balance and gait characteristics, no significant differences were found ($p \geq 0.05$). The same results were also found for healthy controls (group 3 and 4) ($p \geq 0.05$). However, stroke survivors in stage 1 or stage 3 (group 1 and 2) according to Brunnstrom showed decreased balance and gait characteristics compared to healthy controls (group 3 and 4) ($p \leq 0.05$). *Discussion and Conclusion.* Although the stroke survivors showed balance and gait problems compared to the healthy controls, the findings indicate that the upper extremity position does not lead to negative effects on balance and gait characteristics in stroke survivors.
Key words: *stroke, upper extremity, position, balance, gait.*

Introduction

Depending on the location and magnitude of brain injury, stroke can cause physical dysfunctions and many disabilities. Stroke survivors often experience balance and gait problems due to reduced mobility, weakened muscle strength, abnormal posture, and cognitive dysfunction (1).

Decrease in balance is one of the most common problems in stroke survivors. Numerous experiments reporting increased postural oscillations, greater load on the intact limb, decreased muscle strength and decreased sensory information from the affected side, abnormal muscle tone, decreased stability, and cognitive problems are the main causes of balance disruption (2-5). Also, as it is known, the risk of falls in stroke survivors increased due to impaired balance. Furthermore, 70% of stroke survivors have a history of falls after discharge (6). But more importantly, it causes fear of falling in individuals with stroke and causes a significant decrease in individuals' activities and increases caregiver burden (6, 7).

One of the most important outcomes of the post-stroke rehabilitation program is the ability of individuals with stroke to ambulate independently in the community (8). However, this is not always possible because gait in stroke survivors is characterized by reduced speed, cadence, step length, asymmetry and increased energy consumption in temporal, spatial, kinematic and kinetic gait variables (10). Although rehabilitation programs emphasize regaining gait, it has been stated that 35% of stroke survivors cannot regain their walking function and 25% cannot walk without physical support (12).

It has been reported that there is a problem in the upper extremity of the stroke survivors ranging from 48%(13) to 77% [14] after stroke. Approximately 80% of people with acute stroke have upper extremity motor disorders, after 4 years, 50% of them continue to have motor problems (15). This situation limits the daily living activities of the stoke individuals and causes them to become dependent on help. Therefore, it is important to evaluate upper extremity dysfunction from the early period and to plan the most suitable treatment strategies (16).

In addition to problems such as muscle weakness, coordination disorders, movement disorders, and tonus abnormalities seen in the lower extremities after stroke, balance is also affected by upper extremity dysfunctions (16). Also, a number of studies researched the effects of upper extremity position on gait, these studies used slings for giving the position to the upper extremities (18,19). However, there is no study showing the impact of upper extremity position, which was caused by the symptoms of stroke, on balance or gait parameters in stroke survivors. That's why; this study was planned to describe the impact of upper extremity position on balance and gait in stroke survivors compared with healthy controls.

Material and Method

Participants. Between June 2017 and May 2018, 32 subjects with stroke and 16 healthy controls were included in the study. Stroke survivors who were admitted Pamukkale University Neurological Rehab. Unit were included in this study. Healthy controls were selected from patients' caregivers with the same demographic characteristics as the stroke survivors. Inclusion criteria for stroke survivors were between the ages of 30-65, who had a stroke for the first time, had a stroke diagnosis of at least 6 weeks, could walk independently (with or without a walking aid), being stage 1 or stage 3 according to the Brunnstrom upper extremity staging, having a score of 7 and above according to the Hodkinson mental test (HMT). The inclusion criteria for healthy control were to be between the ages of 30-65 and to have a score of 7 or more according to the HMT. People with multiple hemispheres lesions, other neurological diseases, orthopedic problems, or internal diseases such as diabetes, and hypertension were excluded from the study. During the study, participants who did not complete the tests or who had had missing data were also excluded from the study.

Study design. Thirty-two stroke survivors were divided into two groups; Brunnstrom stage 1 (affected upper extremity in flask extension position) (group 1) and stage 3 (affected upper extremity in spastic flexed position) (group 2). Sixteen healthy subjects were included in the control group. The participants in the control group were divided into two groups: upper limb imitating flask position (Brunnstrom stage 1) (group 3) and upper extremity imitating spastic position (Brunnstrom stage 3) (group 4). Healthy controls were instructed to simulate the Brunnstrom stage 1 and stage 3. Real stroke individuals' photographs were shown to the healthy controls so that they can simulate an upper extremity flask or spastic position. Moreover, a physiotherapist showed each position on his own body. Measurements were completed when healthy controls simulated the positions correctly. Each healthy participant simulated flask position first and then spastic position one day apart. The idea behind including healthy controls in the study was to reduce the effects of symptoms such as spasticity and muscle weakness on gait and balance to zero, thus we examined the effects of arm position purely.

Data Collection. HMT was used to detect cognitive impairments. Those having scores of 7 or higher were included in the study (20). Tinetti Gait and Balance Assessment Tool (TGBAT) was used to evaluate gait and balance. Gait and balance measurements were done in Brunnstrom stage 1 and stage 3 positions (21). The functional Reach Test (FRT) was also used to assess the limits of stability. All participants were evaluated by the same physiotherapist.

TGBAT is a simple, easily administered test that measures a subject's gait and balance. The test is scored on the subject's ability to perform specific tasks. The maximum score for the gait component is 12 points. The maximum score for the balance component is 16 points. The maximum total score is 28 points, higher scores indicate that person's balance and gait are better (22, 23).

FRT is a valid and reliable balance assessment test that measures the distance between the arm length and the maximum distance a person can reach when standing in a standing position in a standing position. In this test, the participant stands at an angle of 90 degrees between the arm and the trunk. The participant is then asked to extend forward and the maximum distance the participant can reach is measured. The measurement is made 3 times and the best measurement is recorded (24).

Ethical considerations. The approval was given by Pamukkale University Non-invasive Clinical Research Ethics Committee (Number: 36936, date: 06.06.2017).

Statistical analysis. The Statistical Package for the Social Sciences (SPSS version 23) was used to analyze the data obtained from this study. The Kolmogorov-Smirnov test was used to detect the normal distribution of the data. Mann Whitney's U-test was applied to all of the other parameters except height. A level of $p \leq 0.05$ was considered as significant.

Table I. Comparison of demographic characteristics of stroke survivors and healthy controls

Variables	**Stroke survivors** group 1+2 (n=32)		**Healthy controls** group **3+4**(n=32)		*p**
	Min-Max	Mean±SD	Min- Max	Mean±SD	
Age (years)	29-65	52.13±10.7	32-65	52.1±10.2	0.904*
Height (cm)	148-183	168.1±8.7	145-182	163.3±10.7	0.311**
Weight (kg)	50-110	77.5±13.6	58-120	77.6±15.5	0.638*
Body mass index (kg/m^2)	18.3-38.1	27.4±4.6	19.2-42.7	29.2±5.6	0.163*
Education level (years)	5-20	8.7±4.3	5-16	9.6±3.9	0.247*
HMT Score	7-10/10	8.8±1.0/10	8-10/10	9.5±0.7/10	0.003*

*HMT: Hodkinson Mental Test, * Mann- Whitney U test, **Independent Sample T test*

Results

No significant differences in terms of age, height, weight, body mass index, and educational level between the stroke survivors and the healthy controls ($p>0.05$). Although there was a significant difference in terms of HMT scores between the groups, nobody showed cognitive impairment ($p<0.05$) (Table I). When groups 1 and 2 were compared in terms of demographics, no significant differences were found ($p>0.05$), except for disease duration ($p<0.05$) (Table II). No significant differences were found in the intragroup analysis of stroke survivors (groups 1 and 2) and healthy controls (groups 3 and 4) in terms of balance and gait parameters ($p >0.05$) (Table III, IV).

Table II. Comparison of demographics and clinical characteristics of stroke survivors by group 1 and group 2

Variables	**Group 1** (n=16)		**Group 2** (n=16)		*p**
	Min- Max	Mean±SD	Min- Max	Mean±SD	
Age (years)	35-65	52.6±10.6	29–65	51.6±11.1	0.821*
Height (cm)	155-183	170.1±9.0	148-180	166.1±8.0	0.511**
Weight (kg)	58-100	80.1±12.4	50–110	74.9±14.6	0.265*
Body mass index (kg/ m^2)	18.3-38.1	27.9±5.3	22.0-36.8	27.0±4.0	0.451*
Education level (years)	5-20	7.9±4.3	5–17	9.4±4.5	0.231*
Disease Duration (month)	1.5-28	6.3±7.0	7-96	40.9±29.7	0.000*
HMT Score	7-10	8.8±1.1	7-10	8.8±1.0	0.937*

*HMT: Hodkinson Mental Test, * Mann- Whitney U test, **Independent Sample T test*

Table III. Comparison of balance and gait scores of stroke survivors by the groups

Variables	**Group 1** (n=16)		**Group 2** (n=16)		*p**
	Min-Max	Mean±SD	Min-Max	Mean±SD	
FRT(cm)	8-40	21.0±7.8	11.5-32	18.3±4.7	0.234*
Tinetti, balance score	6-16	11.2±3.5	6-16	12.1±3.1	0.482*
Tinetti, gait score	4-12	7.5±2.7	2-12	8.3±3.0	0.372*
Tinetti, total score	10-28	18,6±5.8	8-28	20.4±5.9	0.355*

*FRT: Functional Reach Test, * Mann- Whitney U test*

Table IV**.** Comparison of balance and gait scores of healthy controls by the groups

Variables	**Group 3** (n=16)		**Group 4** (n=16)		*p**
	Min- Max	Mean±SD	Min- Max	Mean±SD	
FRT (cm)	25-46	34.4±5.7	22-42	31.8±5.2	1.000*
Tinetti, balance score	16-16	16±0.0	16-16	16±0.0	1.000*
Tinetti, gait score	12-12	12±0.0	12-12	12±0.0	1.000*
Tinetti, total score	28-28	28±0.0	28-28	28±0.0	1.000*

*FRT: Functional Reach Test, * Mann- Whitney U test*

Table V. Comparison of balance and gait scores of stroke survivors with stage 1 (group 1) and healthy controls simulating stage 1 (group 3)

Variables	**Stroke Survivors** Group 1 (n=16)		**Healthy Controls** Group 3 (n=16)		*p**
	Min- Max	Mean±SD	Min- Max	Mean±SD	
FRT (cm)	8-40	21.0±7.8	25-46	34.4±5.7	0.000*
Tinetti, balance score	6-16	11.2±3.5	16-16	16±0.0	0.000*
Tinetti, gait score	4-12	7.5±2.7	12-12	12±0.0	0.000*
Tinetti, total score	10-28	18.6±5.8	28-28	28±0.0	0.000*

*FRT: Functional Reach Test, * Mann- Whitney U test*

Table VI. Comparison of balance and gait scores of stroke survivors with stage 3 (group 2) and healthy controls simulating stage 3 (group 4)

Variables	**Stroke Survivors** Group 2 (n=16)		**Healthy Controls** Group 4 (n=16)		*p**
	Min- Max	Mean±SD	Min- Max	Mean±SD	
FRT (cm)	11.5-32	18.3±4.7	22-42	31.8±5.2	0.000*
Tinetti, balance score	6-16	12.1±3.1	16-16	16±0.0	0.000*
Tinetti, gait score	2-12	8.3±3.0	12-12	12±0.0	0.000*
Tinetti, total score	8-28	20.4±5.9	28-28	28±0.0	0.000*

*FRT: Functional Reach Test, * Mann- Whitney U test*

Discussion

The study was conducted to analyze whether upper extremity position affects balance and gait in stroke survivors or not. As a result of this research, balance and gait parameters are affected in stroke survivors. However, the upper extremity position had no negative effect on balance ability and gait characteristics.

Although stroke survivors can walk independently, they have a high risk of falling in both acute and chronic periods. As known very well, the most important cause of falls in stroke survivors is balance impairment (25). We know that the balance of stroke survivors is impaired compared to healthy subjects. Stroke survivors show decreased postural stability, the inability of the lower extremities to provide adequate support, step length reduction, and inadequate compensatory responses (26). Similarly, we observed a range of disorders such as decreased support surface of stroke survivors, difficulty in standing due to insufficient postural stability, and impaired weight bearing and gait. In the light of the results obtained from our study, balance, and gait are affected by the reasons mentioned above in stroke survivors, negatively. The related literature supports our study (25-28).

In stroke survivors, some forces and moments arise due to the weight and dynamics of the arm during upper extremity movement. These forces and moments affect the standing and sitting posture as well as the ability to change positions and make various changes in balance (16). Kulcu et al. found that upper extremity dysfunction adversely affected the balance. In addition, they stated a positive relationship between Brunnstrom upper extremity stages and balance (16). Similar results have also been given in the other study by Kurt et al., which included stroke survivors between stage 1 and stage 5 according to Brunnstrom (29). In another research, stroke survivors were divided into 2 groups according to Brunnstrom's upper extremity staging as stage 1-2 (group 1) and stage 3-4 (group 2). They reported that there was a significant difference between the two groups in terms of balance (30). In parallel with the literature, in our study, the balance of stroke survivors was also found to be impaired. But unlike the previous studies, no differences in terms of balance and gait were found between Brunnstrom motor stages. We think that the main reason for this is that the above-mentioned studies used Brunnstrom's upper extremity staging to compare the functional status. In our study, we compared the impact of arm position on balance and gait parameters in stroke survivors and healthy controls.

There are a few studies that have examined the effect of upper extremity position on gait. Yavuzer et al. evaluated gait parameters in stroke survivors and healthy subjects with or without a sling with their arm flexed. In consequence, they found that there was no difference between arm sling and without arm sling measurements of healthy controls. However better results were obtained with arm sling measurements in stroke survivors (18). Hwang et al. studied the effects of arm sling on gait parameters in stroke survivors. They asked participants to wear flexion type, extension type, and elastic type. They reported that walking with an arm sling was better than without arm sling. Moreover, extension type arm sling showed more positive effects compared to the others (19). Hwang et al. claimed that gait was better when the upper limb was supported by extension type sling. In the studies, the positive effect of an arm sling on the gait cycle was shown. In our study, no sling was used. A comparison was made according to the upper extremity positions resulting from tonus disturbance. Namely, we tried to show the effect of upper extremity kinematics on balance and gait, which are mainly affected by muscle tones such as spasticity and flaccidity in stroke survivors.

During the normal gait cycle, arm swings are completely passive due to trunk movements, gravity, and inertial forces. Besides, arm swings play an important role in maintaining balance during gait as well as reducing energy consumption (31). In a person with a stroke, the unaffected arm moves more than the affected arm during gait. This may occur as a direct result of post-stroke disease or an adaptive strategy to facilitate gait. Chou et al. observed that stroke survivors placed their arms in front of their breasts or hips during walking (32). In our study, it was also observed that there was no arm swing on the affected side as a result of tonus changes in the upper extremities of stroke survivors. However, the unaffected arm moved more than the affected arm.

According to the results of our study, when stroke groups were examined on a group basis, no significant relationship was found between the FRT scores of stroke survivors according to Brunnstrom's upper extremity staging. Yet, FRT scores were lower in stroke individuals with stage 3 than those with stage 1. Huang et al. found that spasticity in the shoulder girdle is usually seen in large medial rotator muscles such as pectoralis major, latissimus dorsi, and teres major (33). Moreover, spasticity in the latissimus dorsi muscle also affects trunk movements. During measurements in our study, we observed that stroke survivors in stage 3 had spasticity and showed decreased trunk movements and lower FRT scores.

One of the most important symptoms of hemiplegia after stroke is the decrease in lower leg muscle strength. Decrease in sensory and muscle strength on the hemiparetic side greatly affects gait parameters. In our study, there were significant differences in gait and balance between stroke survivors and healthy controls. Stroke survivors showed balance disturbances and gait cycle problems. This is an expected result.

Simulating stroke survivors provide us to examine the effects of arm position purely. Because we can minimize the effects of symptoms, especially spasticity and muscle weakness, on gait and balance. But, when we examined the literature, there is no study was found in which healthy individuals simulated stroke survivors. Thus, we think that our study is important because it can open new horizons for investigators' further studies.

Limitations. There were some limitations of the study: (1) the sample size was small; (2) we could not use more sophisticated technologies to evaluate balance ability and gait parameters. In spite of the limitations, comparing the stroke survivors and healthy controls has yielded significant results.

Conclusion

In this current study, unlike in the literature, stroke survivors were examined and were compared with healthy controls in terms of balance and gait. According to the results of our study, in stroke survivors, balance and gait are affected to a great extent compared to healthy controls. Our study showed that the upper extremity position does not affect balance and gait. Even so, we should analyze stroke survivors, who have muscle tone abnormalities in the affected upper extremity, to see their needs during maintaining balance and gait. In addition, our study is one of the pioneering studies in the field of physiotherapy, where volunteers simulate patients.

Acknowledgments. The authors would like to express their special thanks of gratitude to Prof. Filiz Altug and our colleagues (Guzin Kara, Ayse Unal, Mehmet Duray, Aziz Dengiz., and Gulsum Tıkaç), who gave us the golden opportunity to do this study. *Conflict of Interest.* The authors declare that they have no conflict of interest. *Ethical Approval.* The approval was given by Pamukkale University Non-invasive Clinical Research Ethics Committee (Number: 36936, date: 06.06.2017). All procedures performed in the study involving human participants were in accordance with the ethical standards of the Institutional Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants.

References

1. Bonan IV, Yelnik AP, Colle FM, Michaud C, Normand E, Panigot B, et al. (2004). Reliance on visual information after stroke. Part II: Effectiveness of a balance rehabilitation program with visual cue deprivation after stroke: a randomized controlled trial. *Arch Phys Med Rehabil.* 85(2): 274-278.
2. Forster A, Young J. (1995). Incidence and consequences of falls due to stroke: a systematic inquiry. *BMJ.* 311(6997): 83–86.
3. Nyberg L, Gustafson Y. (1995). Patient falls in stroke rehabilitation. A challenge to rehabilitation strategies. *Stroke* 26(5): 838–42.
4. Stoker Yates J, Min Lai S, Duncan P, Studenski S. (2002). Falls in community-dwelling stroke survivors: an accumulated impairments model. *J Rehabil Res Develop.* 39(3): 385–94.
5. Geurts AC, de Haart M, van Nes IJ, Duysens J. (2005). A review of standing balance recovery from stroke. *Gait Posture*. 22(3): 267-281.
6. Watanabe Y. (2005). Fear of falling among stroke survivors after discharge from inpatient rehabilitation. *Int J Rehabil Res.* 28(2): 149-152.
7. Schmid AA, Rittman M. (2007). Fear of falling: an emerging issue after stroke. *Top Stroke Rehabil;*14(5):46-55.
8. van de Port IG, Kwakkel G, Lindeman E. (2008). Community ambulation in patients with chronic stroke: how is it related to gait speed? *J Rehabil Med.* 40(1): 23-27.
9. Szopa A, Domagalska-Szopa M, Lasek-Bal A, Żak A. (2017). The link between weight shift asymmetry and gait disturbances in chronic hemiparetic stroke patients. *Clin Interv Aging.* 12: 2055-2062.
10. Chen G, Patten C, Kothari DH, Zajac FE. (2005). Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. *Gait Posture.* 22(1): 51-56.
11. Hendricks HT, van Limbeek J, Geurts AC, Zwarts MJ. (2002). Motor recovery after stroke: a systematic review of the literature. *Arch Phys Med Rehabil*. 83(11): 1629-1637.
12. Persson HC, Parziali M, Danielsson A, Sunnerhagen KS. (2012). Outcome and upper extremity function within 72 hours after first occasion of stroke in an unselected population at a stroke unit. A part of the SALGOT study. *BMC Neurol.* 12(1): 1-6.
13. Lawrence ES, Coshall C, Dundas R, Stewart J, Rudd AG, Howard R, et al. (2001). Estimates of the prevalence of acute stroke impairments and disability in a multiethnic population. *Stroke.* 32(6): 1279-1284.
14. Langhorne P, Coupar F, Pollock A. (2009). Motor recovery after stroke: a systematic review. *Lancet Neurol.* 8(8): 741-754.
15. Geler Külcü D, Yanık B, Gülşen G. (2009). Hemiplejik hastalarda denge bozukluğu ve üst ekstremite fonksiyonları arasındaki ilişki. *FTR Bil Der J PMR Sci.* 12(1): 1-6.
16. Yavuzer G, Ergin S. (2002). Effect of an arm sling on gait pattern in patients with hemiplegia. *Arch Phys Med Rehabil.* 83(7): 960-963.
17. Hwang YI, Yoon J. (2017). Changes in gait kinematics and muscle activity in stroke patients wearing various arm slings. *J Exerc Rehabil.* 13(2): 194.
18. Dirik A, Cavlak U, Akdag B. (2006). Identifying the relationship among mental status, functional independence and mobility level in Turkish institutionalized elderly: gender differences. *Arch Gerontol Geriatr.* 42(3): 339-350.
19. Naghdi S, Ansari NN, Mansouri K, Hasson S. (2010). A neurophysiological and clinical study of Brunnstrom recovery stages in the upper limb following stroke. *Brain Inj.* 24(11): 1372-1378.
20. Tinetti ME. (1986). Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc.* 34(2): 119-126.
21. Yücel SD, Şahin F, Doğu B, Şahin T, Kuran B, Gürsakal S. (2012). Reliability and validity of the Turkish version of the Performance-Oriented Mobility Assessment I. *Eur Rev Aging Phys Act.* 9(2): 149-159.
22. Duncan PW, Weiner DK, Chandler J, Studenski S. (1990). Functional reach: a new clinical measure of balance. J Gerontol. 45(6): M192-M197.
23. Weerdesteijn V, Niet Md, Van Duijnhoven H, Geurts AC. (2008). Falls in individuals with stroke. *J Rehabil Res Dev.* 45: 1195–1214.
24. Salot P, Patel P, Bhatt T. (2016). Reactive balance in individuals with chronic stroke: biomechanical factors related to perturbation-induced backward falling. *Phys Ther.* 96(3): 338-347.
25. Lin KC, Wu CY, Chen CL, Chern JS, Hong WH. (2007). Effects of object use on reaching and postural balance: a comparison of patients with unilateral stroke and healthy controls. *Am J Phys Med Rehabil.* 86(10): 791-799.

26. Kajrolkar T, Yang F, Pai YC, Bhatt T. (2014). Dynamic stability and compensatory stepping responses during anterior gait–slip perturbations in people with chronic hemiparetic stroke. *J Biomech.* 47(11): 2751-2758.
27. Kurt EE, Delialioğlu SÜ, Özel S. (2010). İnmeli Hastalarda Dengenin Değerlendirilmesi. *Turk J Phys Med Rehab.*56: 56-61.
28. Şahin E, Baydar M, El Ö, Söylev GÖ, Akpınar BA, Şenocak Ö, et al. (2012). İnmeli Hastalarda Omuz Askisinin Statik Dengeye Etkisi. *J Neurol Sci.* 29(3): 458-466.
29. Meyns P, Bruijn SM, Duysens J. (2013). The how and why of arm swing during human walking. *Gait Posture.* 38(4): 555-562.
30. Chou CH, Hwang YS, Chen CC, Chen SC, Lai CH, Chen YL. (2014). FES for abnormal movement of upper limb during walking in post-stroke subjects. *Technol Health Care.* 22(5): 751-758.
31. Huang YC, Liang PJ, Pong YP, Leong CP, Tseng CH. (2010). Physical findings and sonography of hemiplegic shoulder in patients after acute stroke during rehabilitation. *J Rehabil Med.* 42(1): 21-26.
32. Bohannon RW. (2007). Muscle strength and muscle training after stroke. *J Rehabil Med*. 39(1): 14-20
33. Flansbjer UB, Downham D, Lexell J. (2006). Knee muscle strength, gait performance, and perceived participation after stroke. *Arch Phys Med Rehabil.* 87(7): 974-980.

Corresponding Author
Ugur Cavlak
Biruni University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation İstanbul, Turkey
E-mail address: *ucavlak@biruni.edu.tr*

Received: April 12, 2022 Accepted: May 25, 2022