Effects of a Task-Oriented Exercise Program on Balance in Patients with Hemiplegia Following Stroke

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Abstract

Background: One of the most common disabilities after stroke is impaired balance, so improving balance is essential for performing daily activities through rehabilitation. A task-oriented exercise program is an effective approach to improving balance.

Objectives: The aim of this study was to investigate the effects of a task-oriented exercise program on balance in patients with hemiplegia following stroke.

Methods: This randomized clinical trial was conducted between October 2015 and January 2016, and 20 Iranian patients with hemiplegia following stroke were randomly assigned to experimental (n = 10) and control groups (n = 10). The experimental group received a 4-week task-oriented exercise program, and the control group received 4-week conventional physiotherapy, respectively. The patients were evaluated before and after the exercise intervention. Clinical measures included the Berg Balance Scale (BBS) while laboratory measures included the plantar pressure distribution, the center of pressure path length (COP path length), and the center of pressure confidence ellipse area (COP area).

Results: Significant improvement was observed in the BBS after completion of the exercise program in both the experimental and the control groups (50.5 ± 1.08 and 46.8 ± 3.96 , $P < 0.05$, respectively). Significant improvement was showed in the COP path length and area after the task-oriented exercise program (171.14 ± 52.15 and 65.44 ± 69.79 , $P < 0.01$, respectively). The COP area also improved after completion of conventional therapy (114.9 ± 88.99 , $P < 0.05$), but the COP path length in the conventional therapy group and the plantar pressure distribution in both groups were not improved significantly after treatment ($P > 0.05$). The BBS, COP path length, and COP area improved significantly in the experimental group compared to the control group following intervention ($P < 0.05$).

Conclusions: A task-oriented exercise program is associated with an improvement in balance in patients with hemiplegia following stroke.

Keywords: Stroke, Hemiplegia, Balance, Exercise Therapy

1. Background

Sudden loss of neurological function in a stroke due to interruption of blood supply to the brain can lead to disability in adults (1). Approximately 90% of patients who have survived following a stroke have difficulties in motor control and balance functions (2, 3). Hemiparesis or hemiplegia is one of the most common symptoms secondary to stroke, especially on the opposite side of the lesion that can cause deficiencies in movement, sensation, speech, cognition, perception, and balance (3).

Balance is defined as the ability to maintain the image of the center of gravity of the body in the range of stability including the three main components of stability, symmetry and dynamic stability are affected following

stroke (4, 5). Postural sway in hemiplegic patients following stroke increases twofold and symmetry of weight bearing decreases, so that the weight bearing on the healthy leg increases as much as 61% to 80% of body weight (4, 5). The location of the COP under each foot replicates the neural control of the leg muscles. In previous studies, the COP has been used as a good index to study the balance of individuals (6-8). Most studies used the center of pressure path length (COP path length) and the center of pressure confidence ellipse area (COP area) during static standing to measure postural sway as well as plantar pressure distribution by using the pressure distribution platform to analysis the asymmetry in weight distribution in subjects with stroke (9-11).

Several studies showed that among a variety of thera-

peutic interventions, a task-oriented exercise program as a new strategy focuses on functional retraining in subjects with stroke by using multi-system interactions, including the musculoskeletal, cognitive, and neurological systems (2, 12-16). This kind of exercise focuses on performing a functional task in accordance with the following principles: repetition in practice; gradual increase in the complexity of tasks by breaking the task down into several parts, starting with the simplest form of exercise; training based on the individual's goals and personal needs; and using verbal and visual feedback during practice (2, 17, 18). This type of motor learning exercise emphasizes skill education via functional activities and is associated with neuroplasticity changes in the cerebral cortex, brain stem, cerebellum, and spinal cord (17, 19).

Some other studies have demonstrated that postural sway improves in patients with stroke after a task-oriented exercise program (12, 20-22). However, there is controversy about the effectiveness of a task-oriented exercise program on stance symmetry (1, 12). Although different rehabilitation approaches have been used to improve balance and function in patients with stroke, the effectiveness of a specific task-oriented exercise program has not been well investigated (10, 12). Also, there is limited information regarding the effect of exercise programs on balance improvement in patients with sub-acute stroke (23). Therefore, the aim of this study was to compare the effects of a task-oriented exercise program and of conventional physiotherapy on balance in patients with recent strokes.

2. Objectives

The objective of this study was to evaluate the effect of a task-oriented exercise program on balance in patients with hemiplegia following stroke.

3. Methods

3.1. Sample and Procedure

This was a randomized clinical trial, registered in the Iranian registry of clinical trials (IRCT) under the IRCT number of 2015100224297N1. The study was conducted between October 2015 and January 2016. Twenty-six patients with hemiplegia following stroke ranging in age from 45 to 70 were referred from outpatient clinics of neurology and physiotherapy at Asadabady and Razi hospitals affiliated with Tabriz University of Medical Sciences. The number of participants was calculated through a pre-experimental power analysis ($\alpha = 0.05$, $1 - \beta = 0.8$, effect size = 2.8, standard deviation = 5) based on changes in the berg balance scale (12). The sample size was estimated as 10 subjects per

group. Written informed consent was obtained from all of the patients before the study, and the protocol was approved by the Tabriz University of Medical Sciences ethics committee.

The inclusion criteria for all subjects comprised hemiplegia following stroke that had occurred in the past 3 months, observational clear asymmetry in weight bearing, the ability to walk 10 m independently without an assistive device, and having the berg balance scale (BBS) in the range of 30 - 40 to ensure that participants had basic up-right control (24). Subjects were excluded from the study if they had impaired vision, the existence of any neurological or orthopedic diseases affecting postural function (such as poliomyelitis and deformations), and other diseases that would prevent the patients from participating in the study.

3.2. Study Design

After screening, 6 patients were excluded from the study, and the remaining 20 eligible patients were randomly allocated to the experimental group (10 subjects), which performed the task-oriented exercises, and to the control group (10 subjects), which performed conventional physiotherapy. A randomization procedure was performed by a person who was not involved in the assessment or interventions of this study. The independent person prepared the sealed envelopes, and then folded and placed numbered cards in sealed envelopes. Before starting the exercise program sessions, each patient picked up one of the sealed envelopes in the order in which they entered the study. All subjects were tested before initiating the exercise programs and after the end of the 4-week interventions. The participants in both groups were assessed and treated by the same physiotherapist.

3.3. Intervention

In the experimental group, the patients performed the following task-oriented exercise program: 1) sitting on a chair and reaching for objects in all directions at a distance of more than arm's length, 2) stepping forward, backward, and sideways on the exercise step, 3) performing flexion and extension of the affected knee, with the affected foot located on the exercise step and the unaffected foot off the step, 4) stepping over obstacles with different heights, 5) standing up from a chair, walking four steps forward, touching a stool, and then returning to the chair, 6) sitting on a Swiss ball while doing a range of motion and balance exercises in the trunk and upper extremities, 7) double leg standing for 10 seconds, 8) tandem standing, or placing the heel of one foot in front of the other foot, for 10 seconds, 9) standing up from a chair without using the arms, and 10) tandem walking forward and backward (12, 20).

The four last exercises were performed in different situations while the somatosensory and vision were manipulated as follows: 1) with open eyes and a hard surface, 2) with open eyes and a soft surface, 3) with closed eyes and a hard surface, and 4) with closed eyes and a soft surface (20). The difficulty level of the exercises was determined by increasing the number of repetitions, increasing the height of the exercise step from 10 to 20 cm, and adding 2- to 4-pound weights around the ankle. Increases in the exercise step height and ankle weight were determined based on a subject's ability to perform the movements and the number of repetitions completed in the allotted time without any assistance. Each session subject performed exercises 1 to 5 in 20 minutes and the rest of the exercises in 30 min, so that the total treatment time was 50 minutes (12). The task-oriented exercise program was performed in front of a mirror in order to use visual feedback to be sure of the accuracy of various movements, and to facilitate the movement of the hemiplegic side using the image of the healthy side in the mirror. During the exercise program, verbal feedback was used in order to perform correct movements, to maintain proper posture, and to be aware of warning signs (i.e., dizziness, pain, chest discomfort) (12).

For the control group, the patients received 50 minutes of traditional physiotherapy, including mat exercises, a range of motion exercises, and walking education (4, 25). Both groups were matched in the number of exercises and time allocated to each session. There were adequate rest intervals between exercise repetitions in both groups, so that the participants did not become fatigued.

3.4. Outcome Measures

A physiotherapist expert in neurological physiotherapy evaluated balance performance using clinical and laboratory measures before and after intervention.

3.4.1. Clinical Outcome Measure

A valid and reliable Persian version of the BBS was used for clinical measurement of balance (24, 26, 27). This scale quantifies balance and consists of 14 different items. Each item consists of 5 points, from 0 (needs maximum help) to 4 (independent). The total score of the scale is 56. Data was analyzed based on the total score.

3.4.2. Laboratory Outcome Measures

A pedobarograph system (FDM-S, Zebris, Germany) with a size of $70 \times 40 \times 2.5$ cm, 2560 capacitive sensors with sensory areas of 54×34 cm, and a frequency of 50 Hz was used to measure the postural sway parameters, including COP path length and COP area, and symmetry in weight bearing, which is assessed on the basis of the planar pressure distribution. The validity of this system has

been proven in several studies (19, 28). The pedobarograph system has a high intra-class correlation coefficient ($ICC > 90\%$), indicating good repeatability and reliability (29, 30). In order to assess the static balance, the patients were instructed to double leg stand on the platform with bare feet and arms along the body for 20 seconds, while the patients looked out of a target that was installed in two meters at the front wall. Three successful trials were recorded with rest intervals of 1 to 2 minutes.

3.5. Statistical Analysis

The independent t-test and chi-square test were used to compare group quantitative and qualitative demographic variables, respectively. According to the Shapiro-Wilk normality test, the distribution of the clinical and laboratory variables was not normal and nonparametric statistics were used for data analysis. The Wilcoxon signed-rank test was used to identify statistically significant differences between the evaluation before and after intervention. Inter-group differences were assessed with the Mann-Whitney U test. The level of statistical significance was chosen as 0.05.

4. Results

Demographic characteristics of the patients are presented in Table 1. There were no significant differences in demographic characteristics between the experimental and control groups ($P > 0.05$).

The results showed no significant differences in the baseline before treatment between the two groups with respect to the clinical and laboratory measures ($P > 0.05$) (Table 1).

According to the result, before intervention, the mean BBS score was 37.4 in the control group and 37.7 in the experimental group. After intervention, the mean BBS score increased to 46.8 in the control group and to 50.5 in the experimental group, with significant improvements in both groups ($P < 0.05$). When the improvements in the BBS score were compared between the two groups, greater improvement was observed significantly after the task-oriented exercise program ($P < 0.05$) (Figure 1).

After intervention, in the experimental group the mean COP path length decreased from 231.44 to 171.14 and the mean COP area decreased from 65.44 to 47.61, and according to the Wilcoxon signed-rank test, the reduction was significant ($P < 0.05$). In the control group, the mean COP path length decreased from 301.81 to 266.86, without a significant difference ($P > 0.05$). However the mean COP area decreased from 114.9 to 91.91, with a significant difference ($P < 0.05$) (Figures 2 and 3). Significant differences were also shown between the two groups in COP path length and COP area following intervention ($P < 0.05$).

Table 1. Baseline Description of the Demographic Characteristics of the Sample^a

Characteristics	Experimental Group (n = 10)	Control Group (n = 10)	P Value
Age, y	58.9 ± 26.8	59.6 ± 7.16	0.84 ^b
Height	161.30 ± 12.27	161.30 ± 7.08	> 0.99 ^b
Weight, kg	77.60 ± 15.68	68.20 ± 9.64	0.13 ^b
Time since stroke (days)	32.80 ± 16.71	32.5 ± 15.78	0.96 ^b
Gender (male/female)	8/2	7/3	0.6 ^c
Hemiplegic side (left/right)	6/4	9/1	0.12 ^c
Type of stroke (ischemic/hemorrhagic)	10/0	10/0	> 0.99 ^c
BBS	37.7 ± 2.71	37.4 ± 3.27	0.9 ^d
COP Pl, mm	231.44 ± 101.03	301.81 ± 106.47	0.11 ^d
COP area, mm ²	65.44 ± 69.79	186.5 ± 113.3	0.49 ^d
N-A P%	85/31 ± 84/9	14/34 ± 52/6	0.82 ^d

Abbreviations: BBS, berg balance scale; COP Pl, center of pressure path length; COP, area center of pressure confidence ellipse area; N-AP%, plantar pressure distribution of normal-affected side.

^aValues are expressed as mean ± SD.

^bIndependent t-test; Intergroup qualitative variables test.

^cChi-square test;

^dMann-Whitney U test.

In the current study, despite an increase in plantar pressure distribution from 44.92 to 49.89 in the affected leg and a decrease from 54.76 to 50.29 in the normal leg after the task-oriented exercise program, no significant difference was observed after intervention in the experimental group ($P > 0.05$). In the control group, the changes in plantar pressure distribution did not improve significantly after intervention ($P > 0.05$). The results of the study on improvement of plantar pressure distribution were not significant between the two groups after intervention ($P > 0.05$). However, a positive trend toward symmetry in weight bearing was shown following intervention in the experimental group compared with what was observed in

the control group (Table 2).

5. Discussion

The results of this study revealed a greater increase in the BBS score and a greater reduction in postural sway parameters (COP path length and COP area) following a task-oriented exercise program in comparison with conventional physiotherapy in patients with hemiplegia following stroke. Improvement in functional balance measured with the BBS in the current study following intervention was in agreement with previous studies; for example, Fernandes et al. (31) studied the effect of task-oriented

Figure 1. Comparison of Intragroup and Intergroup Changes in the BBS Score in the Experimental and Control Groups Before and After Intervention

Figure 2. Comparison of Intragroup and Intergroup Changes in COP Pl in the Experimental and Control Groups Before and After Intervention

Table 2. Comparison of Intragroup and Intergroup Changes in the Experimental and Control Groups^{a,b}

Variables	Experimental Group			Control Group			P Value ^c
	Post-Training	Pre-Training	P Value ^c	Post-Training	Pre-Training	P Value ^d	
NP (%)	54.76 ± 16.22	50.29 ± 3.56	0.38	53.25 ± 17.08	54.57 ± 7.22	0.72	0.07
	62.7 (36.39 - 67.24)	50.13 (47.57 - 53.78)		59.49 (38.1 - 67.68)	56.09 (48.51 - 58.75)		
AP (%)	44.92 ± 15.64	49.89 ± 3.92	0.33	46.72 ± 17.06	45.43 ± 7.2	0.72	
	37.29 (32.75 - 63.6)	49.86 (46.21 - 52.53)		40.51 (32.30 - 61.84)	43.9 (41.25 - 51.47)		

^aData are expressed as mean ± SD and median (range).^bNP, plantar pressure distribution of normal side; AP, plantar pressure distribution of affected side.^cMann-Whitney U test.^dWilcoxon signed-rank test.

training and strengthening of the affected lower limb on balance in 16 male adults less than 1 month after stroke. In their study the BBS was increased significantly after 12 weeks of intervention. Ahn et al. (1) studied 30 patients randomly divided into either a set-task program or a selective-task program. In this study, BBS improved significantly after the selective-task program. Leroux et al. (12) published a research article in 2006 reporting on their study on improvement of balance and mobility in 10 subjects with stroke after the same type of task-oriented exercise program as our study. The subjects showed significant improvement in the BBS after completing the exercise program. According to Salbach et al. (14), task-oriented walking exercises for 6 weeks performed by 91 subjects one year post-stroke improved walking, but surprisingly no change in the BBS score was shown. The performance of task-oriented exercises by subjects with chronic stroke, without the effect of spontaneous central nervous system recovery following training, was probably responsible for a lack of improvement in the BBS. Since, walking is not a part of the BBS scale, walking exercises have little effect on the

BBS score (14). In our study, the greater improvement in the BBS score in the experimental group compared to the control group might be associated with the similarity of the task-oriented exercise program to the BBS items.

The COP path length and the COP area have been used to assess steadiness (11, 21). Steadiness is defined as the ability to maintain a stable standing position with minimal movement (10, 11). The result of this study about the COP path length and COP area was similar to some previous studies that evaluated postural sway in patients with stroke (1, 5, 12, 31). For example, Tsaklis et al. (10) examined the effects of learning weight transfer on balance and weight distribution in 9 male patients with chronic stroke after 4 weeks. Their study showed a significant improvement in BBS and COP displacement. They confirmed the findings of Seo et al. (21), who reported a significant change in sway area, but not for sway path, in both intra-group and intergroup measurements following dual-task balance training in 40 patients with stroke for 4 weeks. Bayouk et al. (20) mentioned that a task-oriented exercise program with sensory manipulation improved COP parameters after a 4-week intervention in 8 patients with stroke. In contrast, Leroux et al. (12) reported no significant changes in COP parameters, but a trend toward improvement of COP displacement was indicated. However, our results showed that the addition of multisensory training to the task-oriented exercises in patients with hemiplegia led to a significant decrease in the COP parameters.

In the present study, we found that more weight, assessed by plantar pressure distribution, was shifted to the affected leg after task-oriented exercises, although statistical improvement was not observed. Plantar pressure distribution is considered an indication of symmetry, which is defined as maintaining equal weight distribution between the feet in the upright position (10, 11). Functional activities such as sitting down and standing up from a chair in compliance with equal weight on both feet, reaching objects, standing with equal weight bearing on both feet, sitting on a Swiss ball, and stepping up are parts of task-oriented ex-

Figure 3. Comparison of Intragroup and Intergroup Changes in COP area in the Experimental and Control Groups Before and After Intervention

ercises, which lead to a greater focus on adequate weight bearing and muscle activation in the affected leg (10, 32). Similar to our results, Leroux et al. (12) also did not report a significant improvement in loading symmetry. In their research, asymmetry in weight bearing is attributed to the absence of normal sensory input.

Tsaklis et al. (10) observed that weight shift training improved COP displacement, but not weight distribution, in subjects with chronic stroke. They explained that the lack of improvement in weight distribution might be related to developing and using a slightly asymmetrical body posture for several years, so more treatment sessions might be needed to adapt to a correct position.

In patients with hemiplegia secondary to stroke, proprioceptive deficits in the ankle joint, muscle weakness, and unequal weight bearing on the lower limbs are associated with an increase in postural sway (33). Therefore, as we observed in our study, a regular and targeted task-oriented exercise program, by strengthening the major muscle groups of the lower extremities as well as improving proprioception and increasing weight bearing on the affected foot, had positive effects on postural stability (11, 27, 31). Patients with stroke were able to select the pertinent sensory information for balance control more efficiently after adding multisensory training to task-oriented exercises (34, 35).

In the current study, another possible reason for achieving greater improvement in the clinical and laboratory measures of balance was associated with the spontaneous recovery in function and movement that often occurs in the first 3 months following stroke. More spontaneous recovery usually occurs during the 3 months after a stroke, and also the recovery rate is faster in the first month after a stroke, but a plateau is observed in recovery 3 to 6 months following a stroke. During this period of time, the functional ability of patients who received rehabilitation care is highly achieved (21, 24, 36, 37).

5.1. Trial Strengths and Limitations

There is limited information about the effect of similar task-oriented exercises with our intervention on both clinical and laboratory measures in comparison with the control group in sub-acute Iranian patients with stroke. However, there are some limitations to the present study. First, the number of participants in this study was too small to generalize the results to the entire population of subjects with hemiplegia following stroke. Second, nonbinding of the present study may have resulted in bias. Lastly, there was no follow-up in our study. So, the long-term effects of the task-oriented exercise program on balance remain unclear.

5.2. Conclusion

In conclusion, task-oriented training might improve clinical and laboratory measures in patients with hemiplegia following stroke. Therefore, task-oriented training can be used as an effective treatment for patients with hemiplegia following stroke.

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References

1. Ahn M. H. A. C., Kim MC. Effect of Selective-Task vs Set-Task Program on Balance and Weight Bearing of Stroke Patient. *J Phys Ther Sci*. 2011;**23**:707-11.
2. Harvey RL. Improving poststroke recovery: neuroplasticity and task-oriented training. *Curr Treat Options Cardiovasc Med*. 2009;**11**(3):251-9. [PubMed: [19433020](#)].
3. Vearrier LA, Langan J, Shumway-Cook A, Woollacott M. An intensive massed practice approach to retraining balance post-stroke. *Gait Posture*. 2005;**22**(2):154-63. doi: [10.1016/j.gaitpost.2004.09.001](#). [PubMed: [16139751](#)].
4. 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. [PubMed: [11276182](#)].
5. Tyson SF, Hanley M, Chillala J, Selley A, Tallis RC. Balance disability after stroke. *Phys Ther*. 2006;**86**(1):30-8. [PubMed: [16386060](#)].
6. DAW. Human balance and posture control during standing and walking. *Gait posture*. 1995;**3**(4):193-214.
7. Carpenter M. G. F. J., Winter DA, Peysar GW. Sampling duration effects on center of pressure summery measures. *Gait Posture*. 2001;**13**(1):35-40.
8. Karlsson A, Frykberg G. Correlations between force plate measures for assessment of balance. *Clin Biomech (Bristol, Avon)*. 2000;**15**(5):365-9. [PubMed: [10758298](#)].
9. Pereira LCBA, Martins EF. Relationships between body symmetry during weight-bearing and functional reach among chronic hemiparetic patients. *Braz J Phys Ther*. 2010;**14**(3):259-66.
10. Tsaklis PV, Grooten WJ, Franzen E. Effects of weight-shift training on balance control and weight distribution in chronic stroke: a pilot study. *Top Stroke Rehabil*. 2012;**19**(1):23-31. doi: [10.1310/tsr1901-23](#). [PubMed: [22306625](#)].
11. Nichols DS. Balance retraining after stroke using force platform biofeedback. *Phys Ther*. 1997;**77**(5):553-8. [PubMed: [9149764](#)].
12. Leroux A, Pinet H, Nadeau S. Task-oriented intervention in chronic stroke: changes in clinical and laboratory measures of balance and mobility. *Am J Phys Med Rehabil*. 2006;**85**(10):820-30. doi: [10.1097/01.phm.0000233179.64769.8c](#). [PubMed: [16998429](#)].

13. Eng JJ, Chu KS. Reliability and comparison of weight-bearing ability during standing tasks for individuals with chronic stroke. *Arch Phys Med Rehabil.* 2002;**83**(8):1138-44. [PubMed: [12161837](#)].
14. Salbach NM, Mayo NE, Wood-Dauphinee S, Hanley JA, Richards CL, Cote R. A task-orientated intervention enhances walking distance and speed in the first year post stroke: a randomized controlled trial. *Clin Rehabil.* 2004;**18**(5):509-19. [PubMed: [15293485](#)].
15. Marigold DS, Eng JJ. The relationship of asymmetric weight-bearing with postural sway and visual reliance in stroke. *Gait Posture.* 2006;**23**(2):249-55. doi: [10.1016/j.gaitpost.2005.03.001](#). [PubMed: [16399522](#)].
16. Rensink M, Schuurmans M, Lindeman E, Hafsteinsdottir T. Task-oriented training in rehabilitation after stroke: systematic review. *J Adv Nurs.* 2009;**65**(4):737-54. doi: [10.1111/j.1365-2648.2008.04925.x](#). [PubMed: [19228241](#)].
17. Hubbard IJPMW, Neilson C, Carey LM. Task-specific training: evidence for and translation to clinical practice. *Occup Ther Inter J Rehabil Res.* 2009;**16**(3-4):175-89.
18. Bayona NA, Bitensky J, Salter K, Teasell R. The role of task-specific training in rehabilitation therapies. *Top Stroke Rehabil.* 2005;**12**(3):58-65. doi: [10.1310/BQM5-6YGB-MVJ5-WVCR](#). [PubMed: [16110428](#)].
19. Kitamura J, Nakagawa H. Visual influence on contact pressure of hemiplegic patients through photoelastic sole image. *Arch Phys Med Rehabil.* 1996;**77**(1):14-8. [PubMed: [8554467](#)].
20. Bayouk JF, Boucher JP, Leroux A. Balance training following stroke: effects of task-oriented exercises with and without altered sensory input. *Int J Rehabil Res.* 2006;**29**(1):51-9. doi: [10.1097/01.mrr.0000192100.67425.84](#). [PubMed: [16432390](#)].
21. Seo KKH, Han J. Effects of dual-task balance exercise on stroke patients' balance performance. *J Phys Ther Sci.* 2012;**24**(7):593-5.
22. Renner CIEOJ, Ludwig R, Brendel C, Kwakkel G, Hummelsheim H. Group therapy task training versus individual task training during inpatient stroke rehabilitation: A randomised controlled trial. *Clinic Rehabil.* 2015.
23. Wevers L, van de Port I, Vermue M, Mead G, Kwakkel G. Effects of task-oriented circuit class training on walking competency after stroke: a systematic review. *Stroke.* 2009;**40**(7):2450-9. doi: [10.1161/STROKEAHA.108.541946](#). [PubMed: [19461035](#)].
24. Salavati M, Negahban H, Mazaheri M, Soleimani M, Hadadi M, Seifidashti L, et al. The Persian version of the Berg Balance Scale: inter and intra-rater reliability and construct validity in elderly adults. *Disabil Rehabil.* 2012;**34**(20):1695-8. doi: [10.3109/09638288.2012.660604](#). [PubMed: [22380626](#)].
25. Chen IC, Cheng PT, Chen CL, Chen SC, Chung CY, Yeh TH. Effects of balance training on hemiplegic stroke patients. *Chang Gung Med J.* 2002;**25**(9):583-90. [PubMed: [12479619](#)].
26. Azad AEM, Taghizadeh GH. Effect of intensive task-oriented balance practice on functional balance and mobility in chronic stroke patients. *Modern Rehabil.* 2013;**7**(3):48-53.
27. Negahban H, Rezaie S, Goharpey S. Massage therapy and exercise therapy in patients with multiple sclerosis: a randomized controlled pilot study. *Clin Rehabil.* 2013;**27**(12):1126-36. doi: [10.1177/0269215513491586](#). [PubMed: [23828184](#)].
28. Nakhaee Z, Rahimi A, Abaee M, Rezasoltani A, Kalantari KK. The relationship between the height of the medial longitudinal arch (MLA) and the ankle and knee injuries in professional runners. *Foot (Edinb).* 2008;**18**(2):84-90. doi: [10.1016/j.foot.2008.01.004](#). [PubMed: [20307417](#)].
29. Soltani N, Rahimi A, Naimi SS, Khademi K, Saeedi H. Studying the Balance of the Coper and Non-Coper ACL-Deficient Knee Subjects. *Asian J Sports Med.* 2014;**5**(2):91-8. [PubMed: [25834702](#)].
30. Hong SH, Im S, Park GY. The effects of visual and haptic vertical stimulation on standing balance in stroke patients. *Ann Rehabil Med.* 2013;**37**(6):862-70. doi: [10.5535/arm.2013.37.6.862](#). [PubMed: [24466521](#)].
31. Fernandes BFM, Batistab F, Evangelistab I, Pratesb L, Silveira-Sérgioc J. Task-oriented training and lower limb strengthening to improve balance and function after stroke: A pilot study. *Europ J Phys.* 2015;**17**(2):74-80.
32. Dean CM, Richards CL, Malouin F. Task-related circuit training improves performance of locomotor tasks in chronic stroke: a randomized, controlled pilot trial. *Arch Phys Med Rehabil.* 2000;**81**(4):409-17. doi: [10.1053/mr.2000.3839](#). [PubMed: [10768528](#)].
33. Niam S, Cheung W, Sullivan PE, Kent S, Gu X. Balance and physical impairments after stroke. *Arch Phys Med Rehabil.* 1999;**80**(10):1227-33. [PubMed: [10527078](#)].
34. Hu MH, Woollacott MH. Multisensory training of standing balance in older adults: I. Postural stability and one-leg stance balance. *J Gerontol.* 1994;**49**(2):52-61. [PubMed: [8126353](#)].
35. Bonan IV, Yelnik AP, Colle FM, Michaud C, Normand E, Panigot B, et al. 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.* 2004;**85**(2):274-8. [PubMed: [14966713](#)].
36. Duncan P, Studenski S, Richards L, Gollub S, Lai SM, Reker D, et al. Randomized clinical trial of therapeutic exercise in subacute stroke. *Stroke.* 2003;**34**(9):2173-80. doi: [10.1161/01.STR.0000083699.95351.F2](#). [PubMed: [12920254](#)].
37. Kim CY, Lee JS, Kim HD, Kim J, Lee IH. Lower extremity muscle activation and function in progressive task-oriented training on the supplementary tilt table during stepping-like movements in patients with acute stroke hemiparesis. *J Electromyogr Kinesiol.* 2015;**25**(3):522-30. doi: [10.1016/j.jelekin.2015.03.004](#). [PubMed: [25863464](#)].