Neurology Asia 2023; 28(3) : 593 – 603

Effects of virtual balance training and conservative rehabilitation on balance in chronic stroke patients

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Abstract

Objective: This study aimed to test the comparative efficacy of virtual balance training (VBT) and conservative rehabilitation (CR) relative to CR alone on balance in chronic stroke patients. *Methods:* Thirty patients with chronic stroke (>6-months post-stroke) were allocated into 2 groups (n=15) as Group CR and Group VBT. CR was performed for 60 min, 4 times a week, for 8 weeks in both groups. VBT was applied for 20 min, 4 times a week, for 8 weeks along with the CR, in Group VBT. Brunnstrom motor recovery (BMR) stage, spasticity degrees, Functional Ambulation Scale (FAS), Short Form-36 (SF-36) scale, Berg Balance Scale (BBS) in both groups were assessed before and after treatment. Mann-Whitney U, Wilcoxon signed rank tests were used to evaluate BBS data ($p<0.05$). *Results:* Although, no significant difference was observed between groups in terms of BBS scores, BMR stages, FAS scores, SF-36 scale scores, and spasticity degrees before and after treatment; significant improvements were observed in BBS scores, BMR stages, and FAS scores after treatment in both groups ($p<0.05$). Comparing the SF-36 subscale scores before and after treatment, significant differences were noted in emotional role limitation scores for Group VBT ($p=0.03$) and in pain scores for Group CR ($p=0.01$).

Conclusion: VBT along with the CR in chronic stroke patients was not superior to the CR alone, in terms of improving balance, motor recovery, ambulation level, and quality of life.

Keywords: Augmented reality, chronic stroke, conservative rehabilitation, virtual balance training.

INTRODUCTION

Stroke is one of the leading causes of death and disability worldwide.[1] The decrease in cerebral blood flow in stroke patients causes several speech and balance disorders as well as unfavorable clinical symptoms such as loss of cognitive, motor, and sensory functions.[1,2] Most survivors of stroke experience gait and postural control disorders that increase the risk of falling.[3-6] Balance is required for independence in daily activities of individuals and important for maintaining mobility and general health.[7] Severe balance disorders are also adversely affected functional recovery of patients.[8-13] For this reason, it is important to include rehabilitation techniques that enhance balance and coordination during treatment.

It has been reported that balance training exercises had moderate evidence for improved balance in stroke patients.[11,19-26] Several conventional methods, including neuro-developmental training, motor learning, and progressive resistance exercises are frequently used for improving balance after stroke.[27-29] However, since conventional balance training methods are based on the repetition of specific movements, patients may find them monotonous and thus they lose motivation.[30-35] Virtual reality (VR) are environments in which real-world events are simulated with the support of computer hardware and software.[35] Augmented reality, a form of VR, provides to sight and interact virtual images on a real-world environment.[36] Virtual balance training (VBT) is a task-specific training scheme that provides complex multi- joint movement for functional goals resulting in ensuring permanent learning.[10,32-34] It has been reported that the effect

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Date of Submission: 13 March 2023; Date of Acceptance: 28 June 2023

https://doi.org/10.54029/2023kcw

of VBT on balance functions is based on the neural reorganization mechanism created in the brain by the visual, vestibular, and proprioceptive feedback provided by this program.[37] The training can be controlled through visual, auditory, and tactile feedback.[30,38-41] The application of VR technology generates interactive simulation by organizing the information delivered to sensory organs to maximize functional recovery. VR approaches provide the motivation and cooperation of patients, which contributes to increasing functional recovery.[30]

Thera-Trainer Balo (TTB) device (Medica Medizintechnik GmbH, Hochdorf, Germany) is used for balance training by benefiting from augmented and VR applications. This device allows the allocation of visually gamified task and provides target-oriented dynamic balance training to patients who can stand in a fall-proof environment.[42,43] There were previous research articles examining the effect of VR applications on balance for stroke rehabilitation in the literature.[5,8,10,30,44,45] TTB device was used in some of these studies.[5,10,42] Effects of additional, dynamic supported standing practice on functional recovery using TTB in sub-acute stroke patients evaluated by Braun *et al*.[5] Influence of gaming assisted visual feedback on functional standing balance using TTB among acute stroke patients was investigated by James and Brammatha.[10] However, limited data was available on the effects of VR applications using TTB on chronic stroke rehabilitation. There was also a need for detailed information on the optimal use of this device.[11,46] This study aimed to test the comparative efficacy of VBT and conservative rehabilitation (CR) relative to CR alone on the clinical findings; such as standing, stepping, walking and balance measures, and daily activities in chronic stroke patients. The null hypothesis was that VBT combined with CR is superior to CR alone.

METHODS

This assessor-blinded, prospective, and randomized study was carried out in accordance with the Declaration of Helsinki Ethical Principles and approved by Clinical Research Ethics Committee (approval number, 07.10.2021/33). The clinical trial number of this study was NCT05552742. A total of 46 patients aged 20-65 years with hemiplegia due to cerebrovascular accident who presented to the Department of Physical Medicine and Rehabilitation between November 2021 and May 2022, were screened for this study. Written informed consent was provided from all participants. Thirty patients who met the following inclusion criteria were included: patients who had a cerebrovascular accident at least 6 months before the study, had the first unilateral hemiparesis attack, could stand with or without assistance, and had no contraindications for walking. Patients with a history of neurological diseases, a mini-mental test score of <24, severe spasticity at the lower extremity with grade 4 and unilateral neglect, and musculoskeletal diseases such as amputation and severe arthritis, which limits walking, were excluded from the study.

The total sample size was calculated as a minimum of 20 patients using the Berg Balance Scale (BBS) pre-post treatment change values of a previous study[30] via the G*Power 3.1 program.[47,48] The power of this study was 80% and the α-error was 0.05. Considering the possibility of patient dropout, it was planned to have 30 patients and they were split into 2 groups (n=15) by simple randomization in accordance with a list formed by an online randomizer. Group CR was received the CR program and Group VBT was received a combination of VBT and CR programs. The CR includes a patient-specific conservative program comprising exercises that strengthen the paralyzed side, increase joint range of motion, strengthen muscles, and enhance balance performance and coordination. The patients in both groups received CR for 60 min, 4 days a week, for 8 weeks. The physician who performed the assessments and the authors of this study were blinded to the use of VBT. Neither the physiotherapists who carry the interventions nor the patients were blinded.

The TTB device comprises 2 steel cylinders connected to a base plate via a mechanical joint with 2 degrees of freedom. There are helical springs on the portion of the steel cylinder that connects to the base plate. The knee support bars and the pelvis support table are connected to both parallel bars via simple hinges. Feedback regarding the slope is provided through a computer attached to the sensor placed on the base plate. It ensures task- and target-oriented dynamic standing in a fall-proof environment.[5] VBT using the TTB was applied 4 times a week for 8 weeks, and each session lasted for 20 min. The center of gravity of each patient was determined using sensors and displayed as an avatar on the screen. Circle training program was applied to the patients. Task given in this program, it was to collect objects arranged in a circle using the avatars of the patients and drop them into the storage unit on their center of gravity (Figure 1).

Figure 1. The patient undergoing virtual balance training program using TTB device.

The patients were encouraged to move their mass by swiping in all directions by an experienced physiotherapist. The patients were trained at 50% range of motion (0-6 degrees). Difficulty level set to 50%. In the difficulty assessment made at the end of every 2 weeks, if the patient rated the training as very easy, the difficulty level was increased by 10%. The difficulty level was based on the avatar's precision and time pressure when collecting objects.

Outcome measures

Patient information regarding the age, gender, hemiplegic side, stroke duration, and type of ischemia was recorded at the beginning. Primary and secondary outcomes were assessed at the beginning and the endpoint of the treatment.

Primary outcome

Primary outcome was the BBS measures. The BBS is a measurement tool to detect balance ability of an individual during a predetermined set of tasks. A high score corresponds to a high level of functionality.[5,10,49]

Secondary outcomes

Barthel index assesses functional independence in stroke patients.[50] The lower value indicates the higher dependency. The National Institute of Health Severity Scale (NIHSS) is used to assess neurologically severity of the stroke. High scores in NIHSS show more severe damage.[51] Brunnstrom motor recovery (BMR) stage is used to determine motor recovery after stroke. It is rated between 1-6. A high score indicates to a high level of motor recovery.[52] The Modified Ashworth Scale is used to assess spasticity, which is expressed using scores between 0 and 4. The higher scores represent spasticity or increased resistance to passive movement.[53]

The Functional Ambulation Scale (FAS) is a 6-point functional walking test that evaluates ambulation ability and determines the amount of human support required by patients while walking, regardless of whether they use a personal assistive device.[54] The higher scores indicate high level of independency. The SF-36 scale is used to evaluate the health status, a high score indicates a good quality of life. It comprises eight subscales: physical function, physical role limitation, pain, general health, energy, social function, emotional role limitation, and mental health. The score of each subscale varies between 0 and 100. A high score indicates a good quality of life.[55]

Statistics

The SPSS version 23 software package program (IBM Company) was used to evaluate the data. Shapiro-Wilk test was used to assess the distribution of variables. The Mann-Whitney U were used to compare quantitative variables between groups since the data were not normally distributed except for Barthel and NIHSS scores. Independent samples t-test was used for Barthel and NIHSS scores. Bonferroni-corrected Wilcoxon signed rank test was used for intra-group comparisons before and after treatment. The data of the participants who were drop out during the treatment were evaluated with the "intention to treat" analysis using the LOCF (last observation carried forward) approach. The data we obtained from the study were expressed as median (med), minimum-maximum (min-max), mean±SD. Chi-square test and McNemar test were used to compare categorical data. $p<0.05$ level was considered statistically significant.

RESULTS

A total of 30 of 46 patients who were screened met the inclusion criteria. 14 patients in Group CR and 15 patients in Group VBT completed the study. One of the patients in Group CR withdrew from the study (Figure 2). Demographic data of the patients are summarized in Table 1. No significant differences were found between the groups in terms of age, gender, stroke duration, ischemia type, and hemiplegic side.

No significant difference was observed between the groups in terms of BBS, Barthel, NIHSS, and SF-36 scores before and after treatment (Tables 2 and 3). However, significant improvements were determined in BBS, Barthel, NIHSS and SF-36 subscale scores including physical function, physical role limitation, and general health at the end of treatment in both groups ($p<0.05$). However, no significant difference was noted in the SF-36 subscale scores of energy, social function, and mental health before and after treatment. Although a significant difference was observed in the SF-36 subscale scores of emotional role limitation after treatment compared with those of before treatment in Group VBT ($p<0.05$), no significant difference was noted in Group CR. A significant difference was also observed in the SF-36 subscale scores of pain after treatment in Group CR ($p<0.05$), but no significant difference was found in Group VBT.

There were no significant differences between the BMR stages of the upper extremity, hand, and lower extremity of the groups before and after treatment. A significant improvement was observed in BMR stages of the upper extremity, hand, and lower extremities in Group CR after treatment ($p<0.05$). A significant improvement was also noted in BMR stages of the hand and lower extremity of the patients in Group VBT after treatment ($p<0.05$); however, no statistically difference was found in the motor recovery stage of the upper extremity (Table 4). There were no significant differences between FAS scores of the groups before and after treatment. Significant improvements were observed in terms of FAS scores ($p<0.05$) in both groups at the endpoint compared with baseline (Table 4).

DISCUSSION

Previous studies conducted using VBT in patients with acute and subacute stroke revealed that improvements were noted in the balance scale scores compared with the control groups and these scales can be used reliable.[5,10] Based on the findings of this study that evaluated VBT and CR programs using these scales in chronic stroke patients, the null hypothesis was rejected. Because no significant differences were found between groups in terms of BBS scores, Barthel scores, NIHSS scores, ambulation ability, BMR

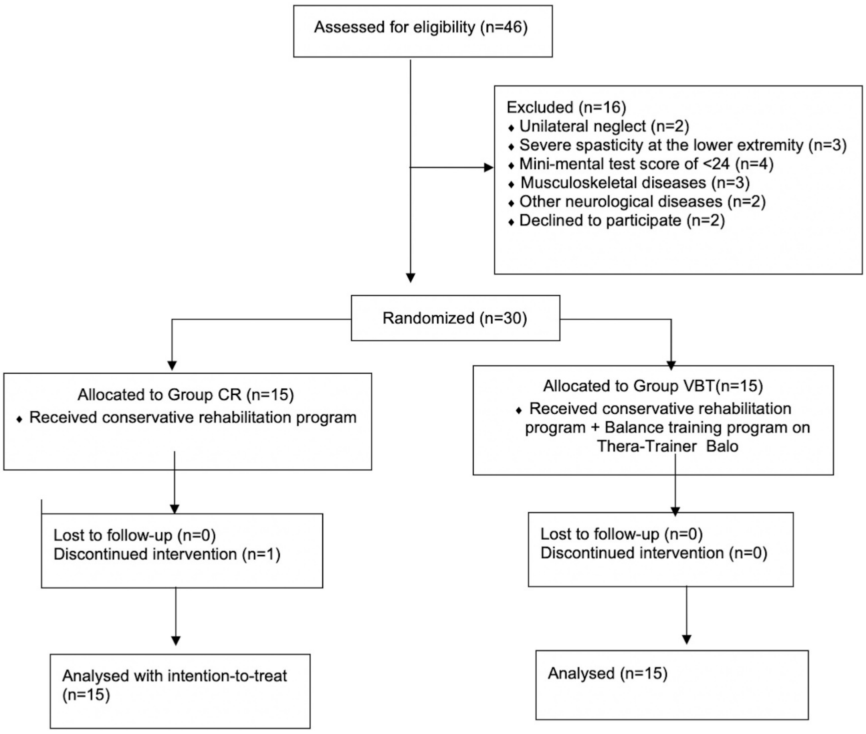

Figure 2. The flow chart of the study

Table 1: Demographic data and stroke characteristics of the groups

	Group CR Median (Min-Max)	Group VBT Median (Min-Max)	p
Age* (years)	52.5 (42-65)	61 (46-65)	0.369
Stroke duration* (months)	18 (11-52)	23 (6-92)	0.555
	Frequency	**Frequency**	
Gender**	7 women 7 men	4 women 11 men	0.362
Stroke type**	12 ischemic 2 hemorrhagic	11 ischemic 4 hemorrhagic	0.651
Hemiplegic side**	7 right 7 left	6 right 9 left	0.867

*Mann-Whitney U test and **Chi-square tests was applied. P values are defined for the comparison of differences among the groups. Level of significance α: 0.05 ($p<0.05$). Data are expressed as medians (minimum-maximum), frequency and mean. CR: Conservative Rehabilitation, VBT: Virtual Balance Training

stages, spasticity, and activities of daily living.

The effect of gaming assisted VBT on balance in acute stroke patients was investigated using TTB by a study.[10] That previous study[10] differed from the current study in terms of the frequency and duration of the conducted balance exercises. VBT was applied for 20 min, 4 sessions per week, for 8 weeks in the present study, while VBT was performed for 30 min, 2 sessions a day, for 4 days in that study. Moreover, acute stroke patients

Table 2: Berg Balance Scale, Barthel Index and NIHSS scores of the groups

	Group CR Median (Min-Max)	Group VBT Median (Min-Max)	p
Berg Balance Scale*			
BT	51.5 (16-56)	51 (13-56)	0.965
AT	54.5 (17-56)	56 (22-56)	0.123
p	0.011	0.002	
r	-0.479	-0.559	
	Mean ± SD	**Mean ± SD**	
Barthel index**			
BT	62.1 ± 8.25	64.6 ± 8.54	0.426
AT	70.7 ± 7.55	72.0 ± 7.02	0.639
p	0.001	0.001	
r	0.921	0.946	
NIHSS**			
BT	9.7 ± 2.36	9.4 ± 2.22	0.716
AT	8.9 ± 1.73	8.6 ± 1.87	0.700
p	0.003	0.001	
r	0.713	0.788	

NIHSS: The National Institutes of Health Stroke Scale. BT: Before treatment, AT: After treatment. *Mann Whitney U test and **Independent Samples t test were used for intergroup comparisons. *Wilcoxon Sign Rank Test and **Paired t Test were used for intragroup comparisons P values in column are defined for the comparison of differences among the groups. P values in row are defined for the comparison of differences within groups. Level of significance α: 0.05 ($p<0.05$). Data are expressed as medians (minimum-maximum). r: Effect size. CR: Conservative Rehabilitation VBT: Virtual Balance Training.

Table 3: Short Form-36 scores of the groups

	Group CR Median (Min-Max)	Group VBT Median (Min-Max)	p
SF-36 Physical Function			
BT	72.5 (10-95)	85 (0-95)	0.215
AT	85 (15-100)	90 (0-100)	0.371
p	0.012	0.008	
r	-0.474	-0.481	
SF-36 Physical Role Limitation			
BT	0 (0-100)	25 (0-100)	0.334
AT	100 (0-100)	75 (0-100)	0.454
p	0.006	0.005	
r	-0.515	-0.517	
SF-36 Pain			
BT	90 (0-100)	67.5 (0-100)	0.208
AT	100 (45-100)	100 (45-100)	0.961
p	0.109	0.012	
r		-0.459	
SF-36 General Health			
BT	80 (30-100)	70 (25-100)	0.776
AT	80 (35-100)	90 (30-100)	0.437
p	0.048	0.001	
r	0.374	-0.605	
SF-36 Energy			
BT	60 (20-90)	65 (20-90)	0.759
AT	57.5 (30-90)	60 (20-95)	0.614
p	0.569	0.509	
SF-36 Social Function			
BT	81.25 (12.5-100)	100 (0-100)	0.521
AT	81.25 (37.5-100)	100 (37.5-100)	0.245
p	0.417	0.167	
SF-36 Emotional Role Limitation			
BT	33.3 (33.3-100)	33.3 (0-100)	0.924
AT	100 (0-100)	100 (0-100)	0.649
p	0.030	0.079	
r	-0.411		
SF-36 Mental Health			
BT	72 (12-92)	64 (36-92)	0.569
AT	66 (12-88)	64 (36-96)	0.628
p	0.877	0.668	

SF-36: Short Form 36, BT: Before treatment, AT: After treatment. Mann Whitney U test was used for intergroup comparisons. Wilcoxon sign rank test was used for intragroup comparisons P values in column are defined for the comparison of differences among the groups. P values in row are defined for the comparison of differences within groups. Level of significance α: 0.05 ($p<0.05$). Data are expressed as medians (minimum-maximum). r: Effect size. CR: Conservative Rehabilitation VBT: Virtual Balance Training.

Table 4: Brunnstrom Motor Recovery, Ambulation and Spasticity Degrees of the groups

	Group CR Median (Min-Max)	Group VBT Median (Min-Max)	p
Upper Extremity Brunnstrom Stage			
BT	3.5 (1-6)	5 (1-6)	0.205
AT	4 (1-6)	5 (2-6)	0.320
p	0.014	0.059	
r	-0.463		
Hand Brunnstrom Stage			
BT	3.5 (1-5)	5 (1-6)	0.202
AT	4 (1-6)	5 (1-6)	0.264
p	0.008	0.034	
r	-0.500	-0.387	
Lower Extremity Brunnstrom Stage			
BT	4.5 (3-6)	5 (2-6)	0.426
AT	4.5 (3-6)	5 (2-6)	0.463
p	0.025	0.025	
r	-0.423	-0.408	
FAS			
BT	4 (2-5)	4 (0-5)	0.548
AT	5 (2-5)	4 (1-5)	0.340
p	0.025	0.034	
r	-0.423	-0.387	
Lower Extremity Plantar Flexion Spasticity Degree			
BT	2.5 (0-4)	2 (0-49	0.450
AT	2.5 (0-49	2 (0-4)	0.423
p	0.317	0.157	

FAS: Functional Ambulation Scale, BT: Before treatment, AT: After treatment. Mann Whitney U test was used for intergroup comparisons. Wilcoxon sign rank test was used for intragroup comparisons. P values in column are defined for the comparison of differences among the groups. P values in row are defined for the comparison of differences within groups. Level of significance α: 0.05 ($p<0.05$). Data are expressed as medians (minimum-maximum). r: effect size. CR: Conservative Rehabilitation VBT: Virtual Balance Training.

were included in that study, but chronic stroke patients were examined in this study. Evaluating the findings of both studies, it was seen that VBT provided significant improvements in balance performance. James and Brammatha[10] found that addition of gaming assisted visual feedback for balance training resulted in significant improvements in BBS scores compared with control group in acute stroke patients. However, no significant difference was found between BBS scores of tested groups, according to the results of the current study. One of the reasons for this difference may be due to the different experimental designs used in both studies. The single session duration of the VBT exercise performed in this study was shorter than that of previous study.[10] Another and more important reason may be the reduced recovery potential in chronic stroke patients compared to acute patients.

Balance has great importance to describe the ambulation level in patients.[8] Comparative efficacy of dynamic versus static supported standing exercises were evaluated in subacute stroke patients was examined using TTB by Braun *et al*.[5]

Significant improvements in ambulation, mobility, and independence in daily living activities were provided in both groups. Comparing the change scores (before and after treatment) of groups, FAS scores significantly higher in dynamic supported standing exercise group.[5] Evaluating the ambulation and independency levels in this study, significant improvements were observed in both groups in terms of FAS scores at the end of the treatment, and no significant difference was noted between the groups.

Effects of force platform biofeedback balance training on motor recovery and ambulation level of stroke patients were investigated by Eser *et al*.[8] CR program was applied to Group 1, whereas balance training program using a device (the Nor-Am Target Balance Training System) in addition to CR were applied to Group 2.[8] Significant improvements were found compared with the baseline in mobility status (Rivermead Mobility Index), lower extremity motor recovery (BMR), activity level (FIM) of the patients in both groups. However, no significant difference was found between the groups. Similarly, there was no significant difference between the BMR stages of groups, in the present study. Significant improvements were observed in the motor recovery stages of the hand and lower extremity at the endpoint in both groups. However, significant improvement was observed in the upper extremity after treatment compared with baseline, in Group CR. That study differs from the present study in terms of balance device preference and exercise duration (for 15 min, 5 days a week, for 3 weeks).[8] In addition, patients were included in that study regardless of whether their clinical condition was acute or chronic.[8] In the present study, VBT and CR programs provided similar motor recovery improvements at the end of the treatment, like Eser et al.'s study. Balance devices have advantages such as dynamic weight transfer and provision of visual and auditory feedback.[5,42] However, these results might be due to the fact that the coordination of higher cognitive, motor, and sensory skills plays a role in sustaining balance and posture.[56]

In a previous study[57] the CR group was compared with the balance training group, like this study. Although improvements were observed in BBS scores, no significant difference was found between the test groups, in that study.[57] This result obtained from the previous study[57] was consistent with the findings of the present study. However, these 2 studies differed in terms of stroke status in the patients studied. Unlike that study in which subacute stroke patients were evaluated, chronic stroke cases were examined in this study. The effect of virtual reality reflection therapy on balance and gait in chronic stroke patients was investigated in another study.[44] The use of the mirror therapy concept in that study differed from this study.[44] The effect of VR training on lower extremity functional status, mobility, balance, and walking speed in chronic stroke patients using Xbox Kinect system.[58] In that study,[58] it was found that VR training combined with CR was superior to CR alone in chronic stroke rehabilitations, unlike the present study.

The physical function, physical role, and general health subscales of the SF-36 scale showed significant improvements in both of groups, thus it can be said that life quality of all patients was increased in the present study. The patients in Group CR showed significant improvements in their pain subscale scores after treatment, whereas those in Group VBT showed significant improvements in their emotional role subscale scores. However, no significant difference was found between the groups in terms of SF-36 scores. The improvement in the scores of emotional role limitation subscale in Group VBT may be attributed to the positive reflection of the sensory feedback provided by the balance device. However, the absence of this difference in terms of pain may raise the question of whether positioning patient on the device and activities performed on the device increase pain.

The fact that only chronic stroke patients were evaluated in this study can be considered as a limitation. It is well known that patients with stroke have a great potential for rehabilitation during the early stages. Care must be taken when generalizing the findings for all patients with stroke because the groups in the present study included patients with chronic stroke, who may have different treatment efficacy compared with those with acute stroke. Another limitation is the lack of long-term follow-up of the patients. Besides, effects of such interventions on long-term follow-up merit consideration. Since this is a single center study, further validation is required. Small sample sizes could have limited data generated to strongly supported to our claims. Although VR show promise as option to complement traditional therapies in rehabilitation of the neurological disorders, theoretical and practical challenges keep such as lack of technical standards, different VR concepts, economic applicability. Hence, its clinical utility remains sub-optimal and the technology is not yet mature for routine clinical care.[59]

In conclusion, evaluating the balance scale scores, motor recovery, ambulation level, functional independency, and quality of life of the patients, the VBT program along with CR was not superior to the CR alone, in chronic stroke patients. VBT can be a valuable contribution to stroke rehabilitation in terms of increasing patient cooperation with treatment. In the future, large-scale studies using dynamic balance exercise systems with different duration, intensity, and frequency should be considered.

DISCLOSURE

Conflict of interest: None

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