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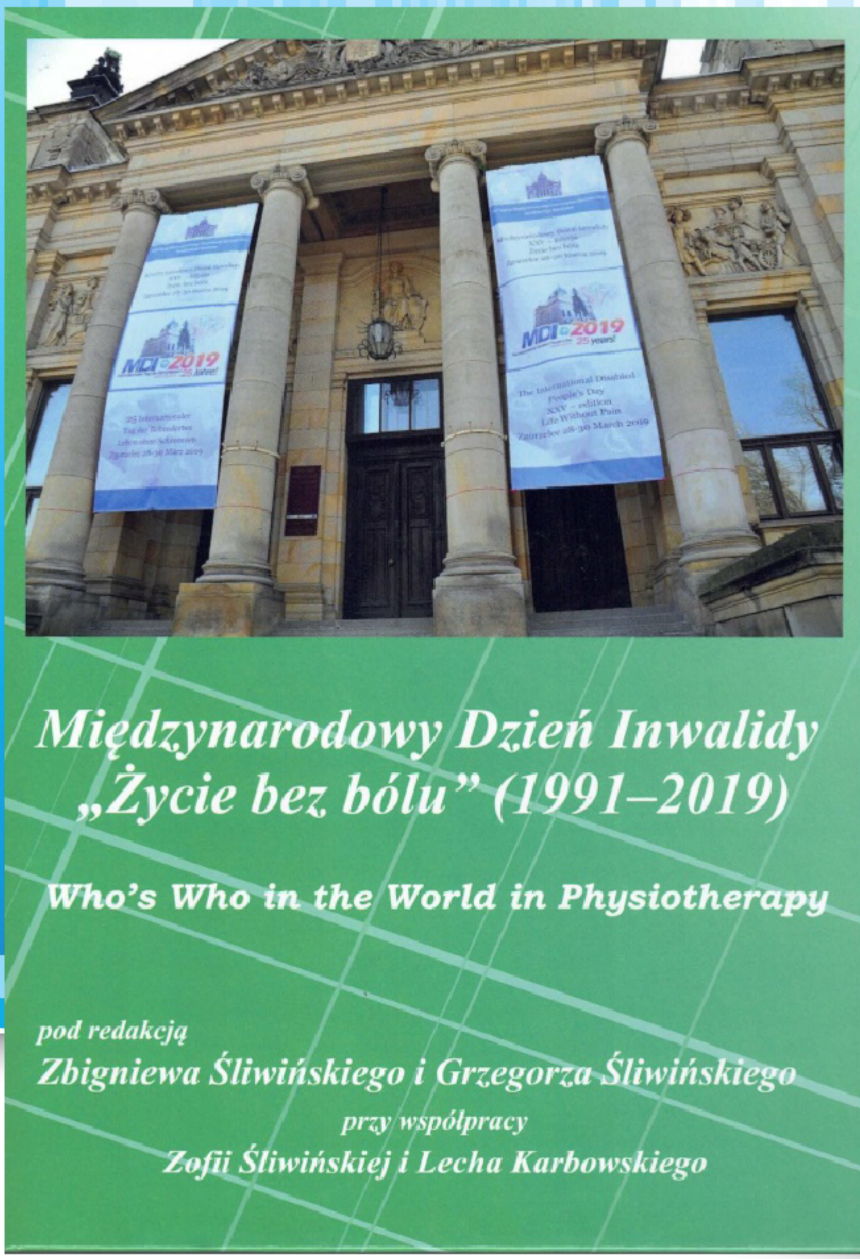

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Effects of vestibular rehabilitation on postural stability in anterior circulation stroke patients: A randomized controlled trial

Wpływ rehabilitacji przedsionkowej na stabilność postawy u pacjentów z udarem w przednim obszarze unaczynienia: randomizowane badanie kontrolowane

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Abstract

Background. Postural stability after anterior circulation stroke is considered a major cause of falling and functional dependence. Recently, special attention regarding mechanisms about standing balance recovery following stroke has been grown. Evidence supports the effectiveness of vestibular rehabilitation therapy for patients with central vestibular disorders. Objective. A randomized controlled trial was designed to investigate the effects of vestibular rehabilitation on postural stability in anterior circulation stroke patients. Methods. Thirty-six patients (27 males, 9 females) their age range from (44 to 72 years) diagnosed with anterior circulation stroke were enrolled and assigned randomly into two similar groups: experimental group (A) received vestibular rehabilitation therapy in addition to conventional treatment 3 sessions per week for six consecutive weeks, but the conventional group received only conventional treatment. All patients were assessed for postural stability using sensory organization test and berg balance scale and for gait performance using time up and go test at baseline and after 6 weeks at end of the rehabilitation process. Results. Statistical analyses using mixed design MANOVA showed that there was statistical significant difference ($p < 0.05$) in all outcome variables for both groups in favor to VR group especially in SOT5, SOT6 while there were non-significant differences between groups in SOT1 variable. Conclusion. Vestibular rehabilitation may be a promising approach if it is integrated as standard in the rehabilitation program for improving postural control after anterior circulation stroke affecting parieto insular region.

Key words:

vestibular rehabilitation, postural stability, anterior circulation stroke, parieto insular cortex

Streszczenie

Informacje wprowadzające. Brak stabilności postawy po udarze w przednim obszarze unaczynienia jest uważany za główną przyczynę upadków i zależności funkcjonalnej. Ostatnio zwrócono szczególną uwagę na mechanizmy odzyskiwania równowagi w pozycji stojącej po udarze. Dowody potwierdzają skuteczność rehabilitacji przedsionkowej u pacjentów z centralnymi zaburzeniami przedsionkowymi. Cel. Randomizowane kontrolowane badanie zostało zaprojektowane w celu zbadania wpływu rehabilitacji przedsionkowej na stabilność postawy u pacjentów po udarze w przednim obszarze unaczynienia. Metody. Trzydziestu sześciu pacjentów (27 mężczyzn, 9 kobiet) w wieku od 44 do 72 lat ze zdiagnozowanym udarem w przednim obszarze unaczynienia zostało włączonych i przydzielonych losowo do dwóch podobnych grup: grupa eksperymentalna (A) poddawana rehabilitacji przedsionkowej i leczeniu konwencjonalnemu, 3 sesje tygodniowo przez sześć kolejnych tygodni; grupa konwencjonalna była poddawana tylko leczeniu konwencjonalnemu. Wszyscy pacjenci byli oceniani pod kątem stabilności postawy za pomocą testu organizacji sensorycznej i skali równowagi Berga oraz sprawności chodu za pomocą testu „wstań i idź" na początku i po 6 tygodniach na końcu procesu rehabilitacji. Wyniki. Analiza statystyczna z wykorzystaniem metody mieszanej MANOVA wykazała, że istniała statystycznie istotna różnica ($p < 0,05$) we wszystkich zmiennych wynikowych dla obu grup na korzyść grupy VR, zwłaszcza w zakresie SOT5, SOT6, podczas gdy nieistotne różnice między grupami zaobserwowano w zakresie zmiennej SOT1. Wniosek. Rehabilitacja przedsionkowa może być obiecującym podejściem, jeśli jest zintegrowana ze standardowym programem rehabilitacji mającym na celu poprawę kontroli postawy po udarze w przednim obszarze unaczynienia wpływającym na obszar ciemieniowy wyspy.

Słowa kluczowe

rehabilitacja przedsionkowa, stabilizacja postawy, udar w przednim obszarze unaczynienia, kora ciemieniowa wyspy

Introduction

Stroke is the second moment driving cause of death accounting for 11.13% of total mortality and the main cause of long-term adult disability around world [1]. Anterior circulation strokes (ACS) either ischemic or hemorrhagic are the most prevalent of all brain insult representing for about 70%, 13% respectively of clinical cases [2]. The most common symptom after ACS is a hemiparesis. Most patients after insult have mixed complain of cognitive, motor, sensory and emotional stress leading to dependency to perform activities of daily living ADL [3]. Within all of these possible sensorimotor deficits after stroke, the loss postural stability probably has a negative effect on ADL independence and gait performance [4, 5]

Vestibular dysfunctions and impaired eye motion disorders might affect over 70% of both anterior and posterior circulation stroke patients. The resulting Visuomotor deficits and visual–perceptual impairments may have a negative influence in the recovery process and may be associated with poor functional outcomes that affect an patient's ability to deal with any sensory input obtained from the environment while performing functional task [6]

The relationship between vestibular dysfunctions and anterior circulation stroke is now the subject of a great deal of the recent researches. It was reported that central vestibular disorder is a common after stroke in the middle cerebral artery territory parieto- insular lesion as the result of ischemia or hypo perfusion to parieto- insular Vestibular Cortex (PIVC) which is considered the main region of all vestibular inputs that process vestibular information and play a crucial role in making sense of our body [7, 8]. So such deficits in this region after parieto- insular stroke will cause typical vestibular symptoms in the form of postural instability and high risk of falling which considered major cause of disability and highly correlated with functional dependence [9].

Patients after ACS lake the ability to use the vestibular input during standing posture or walking for maintaining balance due to suppression of vestibluocular reflex (VOR) and vestiblu spinal reflex (VSR) after the brain insult so, many patients limit their head rotation during walking to avoid retinal slip and blurring of vision which is considered another cause of vestibular dysfunction and disequilibrium following ACS [10,11]. Also, there is strong and clinically meaningful relationship between VOR, VSR functions and various gait parameters which could worsen walking ability, postural stability and increase risk of falling among patients [12].

Clinically, although there are already existing treatment strategies for achieving postural stability during stroke rehabilitation such as task oriented approach, biofeedback, virtual reality training, progressive resistance exercises and neuromodulation techniques, but still most patients after completing the standard rehab program experience some degree of balance impairment and functional limitation especially with external perturbation [13]. There is a moderate to strong evidence reported that vestibular rehabilitation (VR) is now considered the standardized regimen of care and the first option for patients after peripheral or central vestibular dysfunction based on a recent Cochrane review [14].

Interestingly, a recent study reported that VR especially gaze stabilization exercises can immediately improve postural stability and balance required to maintain static upright standing after only 5 min of training without requiring special instruments or costs [15]. Another study reported the effectiveness of VR on postural stability not only in geriatric patients with chronic dizziness due to central and peripheral vestibulopathy but also in a healthy young adult [16].

Surprisingly, management of central vestibular dysfunctions are not integrated and established as a standard in rehabilitation program after ACS but occasionally treated as a separate problem. Furthermore, to our knowledge there is lack in the literature about the effects of VRT after ACS including parieto insular lesion. Based on these concepts the purpose of the study was to investigate the effect of VR on postural stability in ACS patients.

Material and Methods

Study design

This is a randomized clinical trail was made at the Vestibular and Audiology unit Faculty of Medicine Azhar University and Out clinic, Faculty of Physical Therapy, Cairo University within the time between January 2019 and March 2021 to investigate the effect of vestibular rehabilitation (VR) on postural stability in anterior circulation stroke patients.

Trail registry and ethics

The study was registered in Pan African Clinical Trial Registry with the serial number: PACTR201808158196289. It was accepted by the ethics community and the review boards at the Faculty of Physical Therapy, Cairo University, Egypt, with a reference number P.T.REC/012/001995. All patients accepted to write an informed consent before participation in the study.

Participants

Thirty-six patients from both genders included in the study. All patients included have been diagnosed by a neurologist as having anterior circulation stroke mainly in middle cerebral artery (MCA) territory parieto insular lesion and confirmed by CT and/or MRI. They were participated after giving their consent form before data collection. All measurement was conducted at the base line (T0) and after 6 weeks of rehabilitation (T1). Patients were assigned in random way discussed later into two group of equal number as follow fig. 1:

Group A (experimental group) consisted of 18 patients treated with vestibular rehabilitation in the form of vestibular adaptation exercises (VORx1 and VORx2) and vestibular substitution exercises in addition to the conventional program for 60 min three sessions per week for six weeks.

Group B (Control) consisted of 18 patients received only conventional selected physical program for 60 min three sessions per week for six weeks.

Eligibility criteria for the participants

Our inclusion criteria were as follow: Patients diagnosed with first time ACS either Ischemic or hemorrhagic insult in MCA territory parieto insular lesion and confirmed by CT and or MRI (figure 1), Their age ranged from 43 to 69 yrs old [17], ability to stand unassisted for 30 seconds and ability to walk with or without support at least for 30 m [17], ability to communicate and understand instructions as indicated by a Mini-Mental Status Examination [18], mild to moderate balance impairment score of Berg Balance Scale [BBS] was ≥ 21 and ≤ 40 according to a predictive cut off value which defined as the risk of "independent safe ambulation [19], Mild to moderate motor dysfunctions according to a Fugl-Meyer score of 27 to 90 for lower limb [20] while patients exclusion from the study if they have the following criteria: Infra tentorial or post circulation stroke, vestibular symptoms like vertigo or dizziness, other neurologic problems unrelated to stroke hemiparesis which can affect balance ability, significant medical or psychiatric illness, lower limb orthopedic disorders that would affect the ability to walk safely or sever weight bearing pain, unable to provide informed consent for study participation.

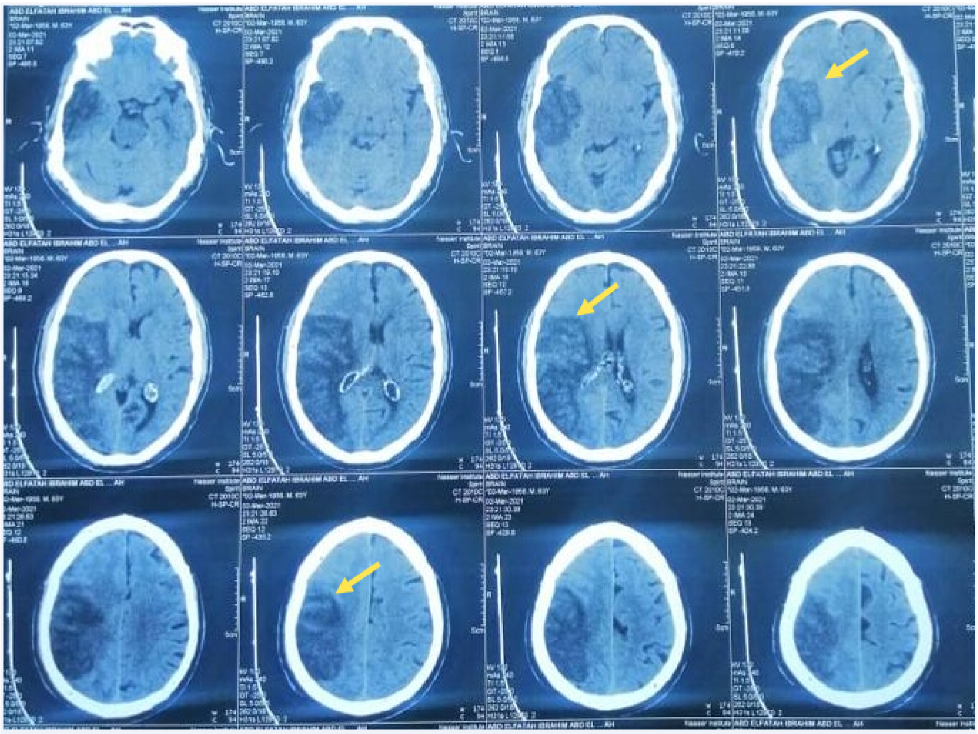

Fig 1. CT brain of patient No.3 of experimental group, yellow arrow showing MCA infarction affecting parieto insular

Sample size

The sample size was calculated by using G Power program (version 3.1.9.2) (Franz Faul, Uni Kiel, Germany). T test, error type I rate was set at 5% (p > 0.05), and the ES was 1.29 of the main outcome variable obtained from a pilot study conducted on six subjects and type II error rate was at 90% power. The proper minimum number of participants for this study was twenty eight figure 2.

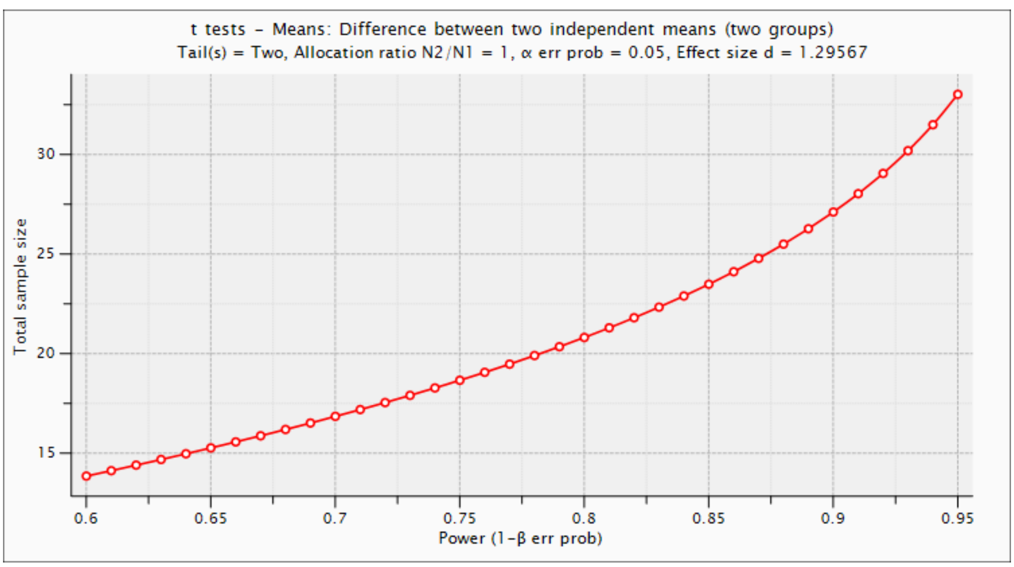

Fig. 2. Plot of sample size calculation

Randomization
Patients were assigned randomly by simple method into two groups of equal numbers. The sequence of allocation was concealed and performed by another person not involved in the study. The randomization done by random number generator using permuted blocks of different sizes placed in sealed envelope.

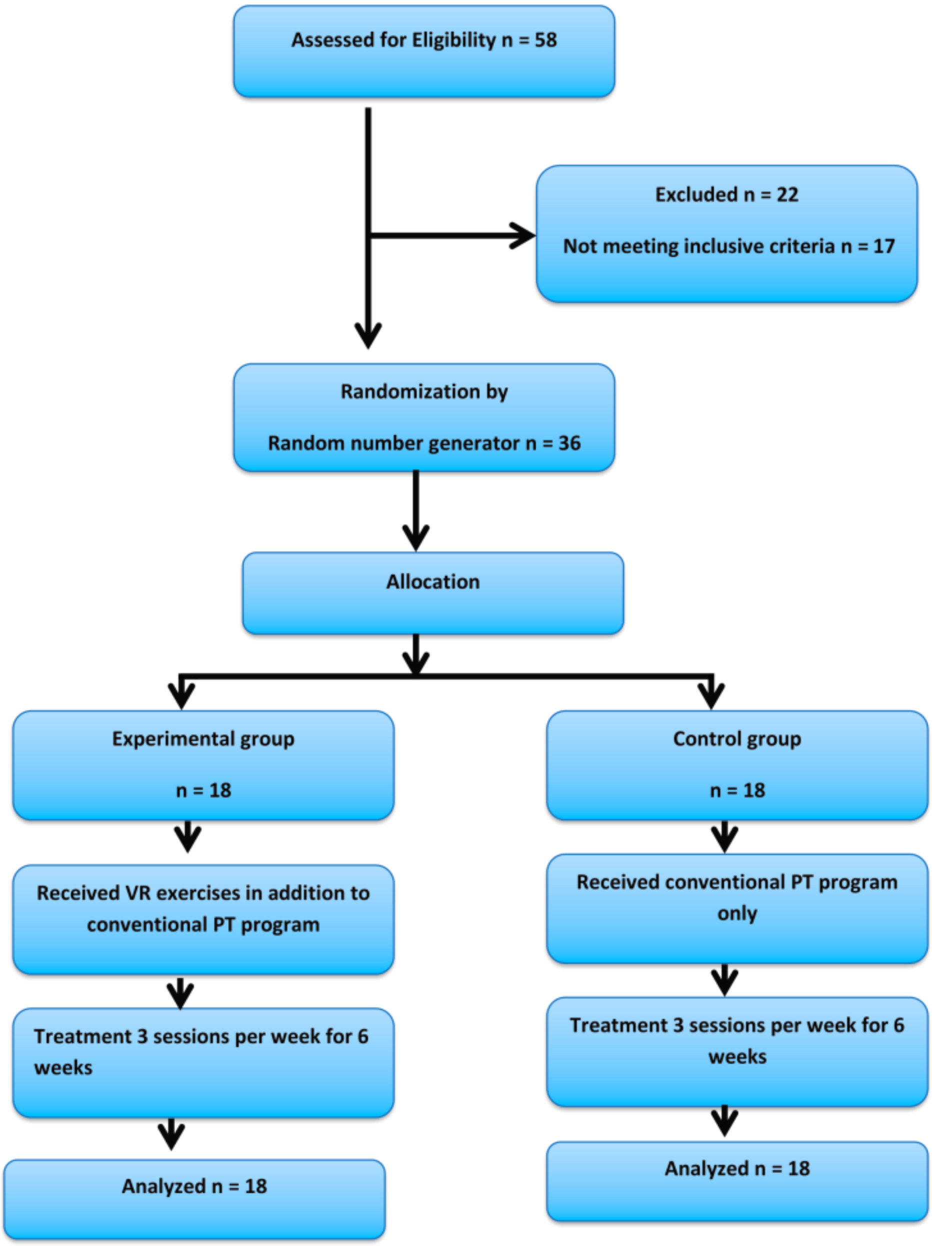

Fig 3. Flow chart of study according to consolidated standards of reproving trials, 2010

Outcome measures
Postural stability was considered as a primary outcome and was assessed at the base line (T0) and after 6 weeks of rehabilitation (T1) through:

Computerized dynamic posturography (CDP) device using the test of sensory organization (SOT) and equitest protocol
During testing, the patients stood barefoot in the upright standing position, protected by a parachute type safety harness connected to an overhead bar to avoid risk of fall, with their arms beside their body and their feet aligned on a predesigned site. A dualforce platform, with four transducer sensors, picking up any vertical or shear forces exerted due to body sway. Patients were instructed to ignore any surface or visual surround motion, remained steady and upright as possible. The SOT examine the three sensory system of balance under different

visual and supporting surface of six different stages that were administered in the study as follow: stage one: Eyes open, stable platform and background; stage two: Eyes closed, stable platform and background; stage three: Eyes open, stable platform surface and movable visual background (So the patient will rely mainly on vestibular and somatosensory information to keep balance, stage four: Eyes open and movable force plateform, stage five: Eyes closed and movable force platform, stage six**:** Eyes open, movable force platform and visual surround.

At the end of SOT each patient submitted to 18 trials of the six stages of testing, and three trials done repeatedly for each condition while each trial last ten seconds. A composite equilibrium score (ES) was shown for all six conditions representing over all stability for each patient. An ES is a measure of postural control from any degree of body sway during testing. A score of 100 indicates no sway and perfect postural control, whereas 0 indicates sway and loss of balance beyond the limits of stability [21].

Berg Balance Scale (BBS) which is an easy test of balance consists of fourteen assessment tasks based on ADL as follow: sit to stand, standing alone, sitting alone, stand to sit, transfer activity, stand with eyes closed, stand with narrow base of support, reach forward with outstretched hand, picking target from the floor, turning and looking to the shoulder, turning 360° degree to both directions to the right and left, placing foot on low stool, stand with one leg on the front, and stand on one lower limb. Each task is calculated from 0 to 4 and total score range from 0 to 56 [22]. Gait performance was considered as secondary outcome and was assessed at the base line (T0) and after 6 weeks of rehabilitation (T1) through:

Time Up and Go test (TUG) which measured the time that the patient can stand from chair and walks three meters to a wall then turn back and sit down on chair, patients perform the test three times and average times were recorded [23].

Treatment protocols

Both groups received a conventional treatment including, function mobility and basic balance exercises, strengthening exercises, flexibility exercises, rhythmic and pelvic stabilization exercises, walking and gait training exercises and climbing up and down stairs 3 sessions per week for six weeks [24].

The experimental group performed this traditional treatment for 30 min in addition to vestibular rehabilitation for 30 min, so total time was 60 min in each session, three sessions per weeks for six weeks [25]. The control group completed the conventional program only for one hour three sessions per week for six weeks.

The vestibular rehabilitation (VR) program divided into two main components: Vestibular adaptation and vestibular substitution exercises.

Vestibular adaptation exercises were performed as follow

a. Patients were instructed to sit on chair and stabilize their gaze onto fixed target on wall like (2 cm coloured dot away from patient by his arm distance) while actively moving head horizontally to right and left and vertically up and down as long as maintaining the target in focus of eyes during motion (VORx1).

b. Patients were instructed to perform the same exercises of head rotation while moving the target and the head in opposite direction simultaneously either horizontally and vertically while the patient keeps clear visual fixation on the target without retinal slip (VORx2).

The duration of these exercises was increased gradually from 1 minute to 2 minutes for each axis and each position. The exercises were progressed under more difficult and various functional conditions from sit to stand, from standing on unstable surface also from standing with wide to narrow BOS and during ambultaion, with a different cadence against mixed backgrounds, in different axes and planes also patients were instructed to keep clear visual acuity during head movements [26].

All Patients were instructed to do their exercises as home program reviewed in booklet 2–3 times per day for 20–30 minutes. During the period of home exercises, patients were contacted by mobile phone to assure their activity in the therapeutic program and to motivate them for doing their best. Patients were asked to document any symptoms that occurred during the home exercises.

Vestibular substitution exercises were performed as follow:

a. From standing position patients were advised to stand with normal BOS while rotating of trunk to both directions and weight shift from side to side from open and closed eyes. Patients begin to stand performing squat on even and uneven surface then to stand on one leg progress to March in place from open and closed eyes.

b. Ambulation training consisted of walking anterior and posterior and sideway with wide BOS and intact vision, looking forward at fixed issue on the wall. The patient then walks in strict base of support until reach to tandem walking position. All exercises were prescribed first with both hand in the front, then with both hand beside his body, and then with hands on the chest. Each position is maintained for 15 to 20 seconds before the patient doing the next exercise. Patients were instructed to reverse counting while walking. This can be achieved progressively more challenging while the patients perform the exercise during ambulation on different ground. Patients instructed to turn around while walking, firstly making a big circle but gradually decreasing it. The patient must be encouraged to roll 360 degrees in both directions. The supporting surface was modified from even to uneven levels for more challenging. The difficulty of exercises was challenged by different BOS and on unstable surfaces by elimination of vision during upright position and ambulation exercises. The center of support was changed from wide base to narrow base up to tandem stand. The progression and difficulty of stability exercises graduated from one position to another according to patient's ability level and response to training [26].

The control group received traditional program including function mobility and basic balance exercises, strengthening exercises, flexibility exercises, rhythmic and pelvic stabilization exercises, walking and gait training exercises and climbing up and down stairs 3 times per week for 6 weeks [24].

Statistical analysis

Prior to analysis, test of normality was applied using Shapiro-Wilk test, while the homogeneity of variances between groups was conducted using levene's test and 2 X 2 MIXED MANOVA was used in analysis as our data normally distributed. The Chi-square test was applied also to analyze the distributions of the nominal variables. The significant level for all statistical tests was applied $p < 0.05$. Statistical analysis was performed through the statistical package for social sciences (SPSS) version 23 for windows.

Results

Table 1 showed the physical characteristics of the participants in the current study. As revealed by Mixed design multivariate analysis of variance 2×2 (MANOVA), no significant differences ($P > 0.05$) were obtained. There were no differences between groups in weight, height and body mass index ($p > 0.05$).

Table 1. Demographic and clinical characteristics of participants

	Study group	Control group	t-value	P-value	P < 0.05
Age [years], Mean ± SD	61.72 ± 5.16	58.17 ± 10.94	1.246	0.221	NS
Weight [kg,] Mean ± SD	83.39 ± 8.07	81.78 ± 7.39	0.624	0.537	NS
Height [cm], Mean ± SD	163.61 ± 5.63	162.22 ± 7.90	0.607	0.548	NS
BMI [kg/m^2], Mean ± SD	31.23 ± 3.39	31.14 ± 2.74	0.088	0.930	NS

Data were presented as mean ± standard deviation, P-value: probability value, NS: non-significant

Overall effect: Mixed MANOVA was conducted to investigate the effect of treatment on SOT1, SOT2, SOT3, SOT4, SOT5, SOT6, CS, BBS and TUG. There was a significant interaction effect of treatment and time ($P = 0.0001$). There was a significant effect of treatment ($P = 0.0001$). There was a significant effect of time ($P = 0.0001$).

F-value of tested groups effect was 22.076, while for training periods effect was 155.646 and for interaction effect was 18.968. Wilks' Lambda value for tested groups effect was 0.232 while for training periods effect was 0.041and for interaction effect was 0.260.

The results of between groups comparison showed that all clinical measured outcomes were significantly improved but with higher score in study group than control group ($P < 0.05$) except SOT1 for both groups showed non-significant difference ($P = 0.87$) Table (2).

We noticed a significant increase in the scores values produced with all sensory organization test from SOT2 to SOT6 in both groups in favor to study group especially in condition 5 and condition 6 which were considered the ideal test to challenge vestibular cues as vision and proprioceptors inputs were absent. Also there is a significant increase in the composite score after treatment in favor also to study group. The percentage of improvement under condition 5 for the study and control groups were 72.89%, 40.67% respectively, while condition 6 showed 46.05%, 23.84%.

The results of within group comparison showed that the scores of all measured outcomes were improved for both groups ($P < 0.05$) except SOT1 showed no significant difference.

Table 2. multiple pairwise comparison of for all clinical measured outcome variables pre and post rehabilitation between study group and control group

	Time	Study Group Mean ± SD	Control Group Mean ± SD	Between groups
SOT1	Pre treatment	90.28 ± 1.07	90.61 ± 2.68	**P = 0.324**
	Post treatment	91.72 ± 1.93	90.83 ± 2.03	**P = 0.869**
	P value	**P = 0.411**	**P = 0.742**	
SOT2	Pre treatment	80.72 ± 1.40	81.50 ± 3.18	**P = 0.332**
	Post treatment	89.56 ± 1.88	87.22 ± 2.66	**P = 0.005***
	P value	**P = 0.0001***	**P = 0.0001***	
SOT3	Pre treatment	62.67 ± 2.00	62.28 ± 1.48	**P = 0.503**
	Post treatment	77.39 ± 2.06	68.17 ± 1.24	**P = 0.0001***
	P value	**P = 0.0001***	**P = 0.0001***	
SOT4	Pre treatment	83.33 ± 2.97	83.00 ± 1.41	**P = 0.638**
	Post treatment	88.67 ± 1.84	86.89 ± 1.90	**P = 0.014**
	P value	**P = 0.0001***	**P = 0.0001***	

	Time	Study Group Mean ± SD	Control Group Mean ± SD	Between groups
SOT5	Pre treatment	**33.61 ± 6.58**	35.11 ± 3.41	**P = 0.603**
	Post treatment	**58.11 ± 14.02**	49.39 ± 6.75	**P = 0.003***
	P value	**P = 0.0001***	**P = 0.0001***	
SOT6	Pre treatment	**35.83 ± 6.21**	37.50 ± 2.25	**P = 0.427**
	Post treatment	**52.33 ± 10.37**	46.44 ± 2.30	**P = 0.006***
	P value	**P = 0.0001***	**P = 0.0001***	
CS	Pre treatment	**60.00 ± 3.48**	59.50 ± 4.20	**P = 0.675**
	Post treatment	**75.11 ± 3.57**	68.00 ± 3.29	**P = 0.0001***
	P value	**P = 0.0001***	**P = 0.0001***	
BBS	Pre treatment	**32.17 ± 2.85**	31.17 ± 2.68	**P = 0.262**
	Post treatment	**44.22 ± 2.64**	38.67 ± 2.40	**P = 0.0001***
	P value	**P = 0.0001***	**P = 0.0001***	
TUG	Pre treatment	**19.56 ± 1.14**	20.11 ± 1.23	**P = 0.150**
	Post treatment	**14.61 ± 1.24**	17.17 ± 0.92	**P = 0.0001***
	P value	**P = 0.0001***	**P = 0.0001***	

SOT: sensory organization test, CS: Composite Score, BBS: Berg Balance Scale, TUG: Time Up and Go test), P-value written in bold and with asterisk if statistically significant

Discussion

The purpose of the study was to investigate the effect of vestibular rehabilitation (VR) on postural stability in anterior circulation stroke patients. Our results support the merit of adding VR in the standard rehabilitation program after anterior circulation stroke affecting parieto insular area as a complementary in the physical therapy interventions, when balance impairment is present for improving postural control and functional independence of gait.

The main findings of our study was that anterior circulation stroke patients not only presented with a significantly larger degree of body sway in the SOT conditions and equilibrium composite score in both study and control group especially when the force platform was altered and eye closed (SOT 5), and in sway-referenced platform and visual surround which producing visuovestibular conflict (SOT 6) but also in BBS, TUG test scores and to less extent regarding SOT2, SOT3 and SOT4 respectively. Our results revealed an improvement in all measurement outcomes in both groups post vestibular rehabilitation training in favor to the experimental group except SOT1 showed non-significant difference for both groups.

Parieto- Insular Vestibular Cortex (PIVC) is an important area of the brain as it is considered the core region of all vestibular inputs that process vestibular information and play a critical role in achieving postural balance and making sense of our body [27].

Interestingly, previous study conducted by Miyai et al. [7] who firstly assess twenty-five patients (13 males and 12 females) after parieto insular stroke in MCA territory using Equi test, he stated that all patients in the impaired standing balance group (ISP) can stand properly in SOT 1 while suffering from large sway and instability in SOT5, SOT6, these finding come in agreement with results of our study pre rehabilitation [7].

On the same words, Fabio and Badke, [28] who examined 10 patients with stroke using the sensory organization test observed a lower stance duration and impaired postural control during visuvestibular conflict conditions in SOT5, SOT6 which come in agreement of our study [28].

Conversely, Bonan et al. [29] and co-workers who assess forty patients with chronic hemiparesis using computerized dynamic postourography device in comparison with age matched control thus they found significant reduction in SOT5, SOT6 and composite score, these finding come in accordance with our results but still some sort of disagreement with them as our results showed also an abnormal scoring in SOT 3, SOT2 and less extent to SOT4 [29].

The possible argument for clarification of our findings pre rehabilitation that is the link between an impaired dynamic stability and balance that was presented as deficiency in equilibrium SOT scores especially in SOT5, SOT6 and a lesion involving the parieto insular vestibular cortex which responsible for processing all vestibular afferents and its major role in multisensory integration for postural control [30].

Surprisingly, a recent observational study conducted by Sang et al. [8] who shed light that Central vestibular disorder is a common scenario after stroke especially in the middle cerebral artery territory as the result of blood hypo perfusion to Parieto-Insular Vestibular Cortex (PIVC) which could worsen walking ability, postural stability and increase risk of falling after stroke [8].Another possible explanation that patients after ACS can't properly select accurate sensory input for maintaining balance especially with visuvestibular conflict and rely more on visual input for achieving stability and postural control especially due to less estimation and under stimulation of other sensory strategies [29].

Furthermore, the ability to select proper sensory input for maintaining balance was compromised in stroke patients, so they were mainly depending on visual information to control their posture [31]. This is explaining the high body sway and postural perturbation in stroke patients during visuavestibular conflict in SOT5 and 6 due to patients relay mainly on injured and non-functioning vestibular cues for maintaining balance as visual and somatosensory cues were altered in form of sway referenced surround and plateform. The same word in SOT3 and SOT2 there is a visual conflict and challenge so patients relay only in somatosensory input and inability to use vestibular input properly after parieto insular lesion that is presented to us with lowering scores in both conditions but still better than SOT5 and SOT6

On the other side, a study conducted by oliveira et al., who assess 21 hemiparetic patients and compare them with other 21 matched control using posturography, he stated that large body sway and worse performance in conditions SOT3, SOT4, SOT5 and SOT6 while there is no significant differance between groups regarding SOT1 and SOT2, these finding come in agreement with our results in all SOT conditions after parieto insular stroke pre rehabilitation except SOT1 only presented within normal score [17].

From my prospective, this contradiction in SOT2 score due to the heterogeneity of inclusive criteria between the two studies as our patients in both groups selected after lesion in specific region of brain in parieto insular while other study includes lesions in different cerebral areas such as frontal lobe, temporal lobe, internal capsule, basal ganglia, parietal lobe, insula and thalamus which is the possible explanation for contradiction.

Indeed, the relation between vesibular deficit and disequilibrium is not entirely new, a previous study conducted by Catz et al. [11] who examined 15 patients with unilateral hemispheric stroke to clarify whether the equilibrium impairment in ADL related to vestibular dysfunction and reported that postural instability after stroke due to suppression of VOR and VSR function which is presented and come in agreement with our study in a significantly lowering scores of sensory organization testing, BBS and TUG test [11].

Recently, a Cochrane review reported moderate to strong evidence to support the choice of vestibular rehabilitation (VR) as safe and effective exercise based technique in the management of patients with vestibular dysfunctions specifically for improving gaze stability, postural control and function ADL through adaptation, substitution and habituation exercises [32].

The results of current study post rehabilitation showed a significant improvement in all outcome measurements with proper postural control, balance ability and gait performance for both groups in favor for the experimental group that undergo vestibular training.

These findings come in agreement with pilot study conducted by Mitsutake et al. [33] who perform a study in a paradigm similar to us and investigate effect of VR on stroke patients after 6 weeks training, he found a significant improvement in all outcome measures regarding GST, DGI and TUG but only in the experimental group without any change in the control group [33].

The possible explanation for this argument that authors in the previous study apply very simple exercises for control group such as ROM for limbs trunk walking in and out door and climbing stairs that logically doesn't affect postural stability or gait performance while in our study we administer basic balance and posture exercises rhythmic and pelvic stabilization exercises in addition to strengthening and flexibility exercises which the main cause of improvement in control group

A key rehabilitation goal for stroke patients is to enhance walking ability in order to improve opportunities for involvement in daily activities and back to work [34]. Indeed, a study conducted by Balci et al. [24] who examine the effect of 6 weeks of VR training to 25 patients suffering from posterior circulation stroke and found significant improvement in both study and control regarding TUG test p value (0.04, 0.007) respectively. Our study come in agreement with them and revealed an improvement in TUG test for both study and control group regarding gait speed and stability in favor to experimental group [24].

In agreement of the current study, Rossi-Izquierdo et al. [35] who apply vestibular rehabilitation to 139 elderly populations to detect its clinical outcomes and effectiveness, they reported also a greater significant improvement in postural balance, gait performance and reduce falling risks [35].

In consistent also with our results Ueta et al. [36] who recruited 23 healthy volunteer without history of neurological diseases for measuring static balance from standing, with the eyes either open or closed, on the supporting surface either stable or foam rubber after administration of gaze stabilization exercises (GSE), they reported an improvement in the static balance in conditions especially challenging vestibular system and conclude that GSE which considered a mainstay of vestibular rehabilitation can be a useful exercises for patients with central, peripheral vestibular dysfunction, elderly population and stroke patients [36].

The possible mechanisms for elucidating previous findings that VR not only can enhance modification of vestibulospinal reflex, anti-gravity muscles but also increase of sensory awareness of vestibular cues for postural stability by gaze stability exercises which is considered a mainstay of VR and useful exercises that induces proper selection and sensory reweighting of vestibular sensory cues [37].

Another key to interpretation of our results post rehabilitation regarding high performance and significant improvement of experimental group over control group is that vestibular adaptation exercises can be modulating the excitability of vestibular reflex improving the VOR function through activation of vestibular nucleus and common pathway center by repetitive rotation of head result in plastic changes of VOR which in turn improve and modulate VSR function improving postural stability [15, 36].

VR is required to facilitate the movements of the head, trunk and pelvis during walking. Patients after stroke have been described to display unusual coordination of trunk and pelvic rotations as many patients limit their head rotation during walking to avoid retinal slip and blurring of vision resulting from impaired VOR function and unsteadiness of image on the fovea of retina, which can lead to changes in balance control during ambulation and risk of falling [38].

Surprisingly, Akiyoshi et al. [15] in his recent study who investigated 18 participants and reported that vestibular rehabilitation especially gaze stabilization exercises can immediately improve postural stability and balance required to maintain static upright standing after only 5 min of training due to improved VOR functions and permit free head rotation during locomotion without jumping of environment and risk of falling, these findings come in agreement and consistence with our study through improving balance and gait parameters among stroke patients post rehabilitation [15].

After deciding a proper vestibular rehabilitation approach, another basic and vital issue is to evaluate its efficacy because as it may fundamental to alter the approach of vestibular rehabilitation exercises if does not achieve its benefit and functional improvement with patients. An Equi test of computerized dynamic posturography device is considered a gold standard, valid and reliable method for assessment and treatment postural stability in ACS patients [39].

The results of current study after rehabilitation revealed that there is a significant improvement in numerical scores of all SOT conditions for both groups in favor to the study group except SOT1 showed non-significant difference in both groups. The major improvement was mainly in visuvestibular conflict conditions SOT5, SOT6 with high percent of change in favor to experimental group.

A similar study conducted by Cass et al. [40] who investigate functional outcomes of vestibular rehabilitation in 67 patients (42 males, 25 females) with vestibular disorder suffering from dizziness and impaired postural control using CDP as an objective tool for assessment before and after VR. The results revealed that about sixty percent of patients showed significant enhancement of SOT and postural control while twenty-five percent of patients recovered to normal value that is come in agreement with our results [40].

In addition, our study agreed with Black et al. [41] who recruited eighteen subjects with chronic vestibular dysfunctions and their main complain were instability, impaired balance and movement intolerance before and after VR using CDP as an objective device for evaluation. They found that all patients showed significant improvement in all SOTs conditions and overall equilibrium score [41].

Also, Morisod et al. [42] who investigated 42 patients with chronic subjective vertigo who received vestibular exercises and a post rehabilitation assessment using posturography, they showed an improvement in SOT conditions in addition to percentage of abnormal posturographic findings significantly decreased from 79% to 33% ($p < 0.001$) which come in accordance with current study [42].

In contrast, study conducted by Baydan, [43] who study the effect of VR on 100 patients diagnosed as chronic subjective dizziness, they reported that there was significant improvement in all SOTs and composite score after rehabilitation especially in SOT5 that achieved higher percent of success [43].

The results of these previous studies that used CDP as an assessment tool for vestibular dysfunctions didn't agree with that of the current study in a little issue that they mentioned an improvement in SOT1 after VR while our study showed non-significant difference in this variable for all stoke patients in both groups.

From my point of view, the possible clarification of this argument that although all patients either in these studies or our study suffer from vestibular dysfunction that clinically manifested by postural instability associated with dizziness and vertigo only in patients of previous studies while patients in our study suffer from postural instability without any degree of dizziness.

Furthermore, patients with vestibular dysfunction manifested with vertigo and dizziness were instructed to stop any vestibular suppressant drugs at least three days before testing so they feel dizzy, unsteadiness and minimal degree of swaying in SOT1 that considered non-challenging as the three sensory strategies for balance not altered while stroke patients in our study were stable without body swaying in same condition.

The reasonable explanation for my perspective that patients with vertigo in previous studies presented with peripheral or central vestibular lesion that affect either vestibular nerve or vestibular nucleus in brainstem respectively or as result of posterior circulation syndrome that indirectly affect the nucleus and manifested with dizziness, nausea, vomiting for prolonged period of time until either peripheral recovery or central compensation was achieved. On the other side all patients in our study presented with unilateral anterior circulation stroke in parieto insular vestibular cortex usually doesn't manifest with vertigo, nausea as the unaffected opposite hemisphere can suppress and masking these symptoms and if they do as -in very rare cases in literature – it is less severing and only for short time at initial onset of stroke [44].

The golden explanation from my perspective and in my own opinion that puzzle out high performance and significant improvement of experimental group over control group that most patients in study group motivated and seriously follow home program daily 2-3 times which is essential to achieve patient's goals. So along with planning and progressing exercise program, patients and caregiver education is an integral part not only limited to VR training but also in all physical rehabilitation exercises.

However, the current study has some specific limitations, each of which may shed light toward ideas of future studies. Although the sample size was calculated according to the results of a G power analysis, it seems to remains modest. It can be speculated that generalization of results would increase if the sample size would be more enlarged. Another limitation is the absences of stratification the stroke patients into more subgroups according to definite location of lesion if it is isolated and limited to insular cortex or extending to adjacent structures of operculae, subinsular area, claustrum, external capsule and dealing with them as parieto insular stroke in general which may affect outcome measure, so further studies should take this issue into account. Another limitation concerns vestibular rehabilitation training in our study lacking of patients follow up strategy after three, six and twelve months to assess long term effect of VR will be permanent or temporarily and to determine if there will be maintenance, recurrence or deteriorations in the gained results.

Conclusion

Vestibular rehabilitation may be a promising approach if it is integrated as standard in the rehabilitation program for improving postural control after anterior circulation stroke affecting parieto insular region.

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