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Kertas Asli/*Original Articles*

Effects of Customized Vestibular Rehabilitation on Static balance among Adults with Benign Paroxysmal Positional Vertigo

(Kesan Rehabilitasi Vestibular Disesuaikan Ke Atas Keseimbangan Static Dalam Kalangan Dewasa Dengan Masalah Benign Paroxysmal Positional Vertigo)

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ABSTRACT

The aim of this study was to detemine the effectiveness of Customized vestibular rehabilitation (CVR) in addition to the standard Canalith repositioning maneuver (CRM) on static balance among adults with posterior canal Benign Paroxysmal Positional Vertigo (BPPV). In this randomised controlled trial, 28 adults with idiopathic unilateral posterior canal BPPV were randomized to either the control or experimental group. The experimental group (n=14, mean age: 50.71±9.88 years) received CVR in addition to CRM, and the control group (n=14, mean age: 54.36±8.55 years) received only CRM for 6 weeks. Measurements of static balance (postural sway) using a portable kinematic sensor were performed at baseline, four and six weeks after treatment for both groups while standing on firm and foam surface with eyes open (EO) and closed (EC). Only standing on foam surface with EC was observed to have a significant interaction effect, F (2, 52) =5.28, p<0.05. This suggest that the groups were affected differently by the intervention and greater improvement was demonstrated in the experimental group. Post hoc test showed that a significant difference (p<0.05) in static balance was shown between baseline and 6th week after intervention. The results of our study indicate that CVR in addition to CRM improved static balance in adults with UPC BPPV at 6th week after intervention for persons with BPPV.

Keywords: Customized vestibular rehabilitation; canalith repositioning maneuver;benign paroxysmal positional vertigo (BPPV);balance; postural sway

ABSTRAK

Matlamat kajian ini adalah untuk mengkaji keberkesanan rawatan CVR sebagai tambahan kepada CRM pada keseimbangan postur statik dalam kalangan dewasa dengan PC BPPV. Dalam kajian terkawal secara rawak in , seramai 28 orang dewasa yang telah di diagnosis dengan UPC BPPV serta dibahagikan kepada kumpulan eksperimen dan kawalan. Kumpulan eksperimen (n=14, min umur: 50.71±9.88 tahun) menerima CVR sebagai tambahan kepada CRM dan kumpulan kawalan (n=14, min umur: 54.36±8.55 tahun) menerima rawatan CRM sahaja untuk enam minggu. Keseimbangan postur statik diukur dengan menggunakan sistem pengukuran makmal mobiliti pada dasar (minggu sebelum intervensi), minggu ke-empat dan ke-enam selepas intervensi semasa berdiri di atas permukaan yang keras dan lembut dengan mata terbuka dan tertutup. Hanya berdiri di atas permukaan yang lembut dengan mata tertutup didapati mempunyai kesan interaksi yang signifikan, F (2,52) =5.28, p<0.05. Ini mencadangkan kedua-dua kumpulan terkesan dengan berbeza oleh intervensi dengan peningkatan yang ketara pada kumpulan eksperimen. Ujian post-hoc menunjukkan perbezaan yang signifikan (p<0.05) dalam keseimbangan statik diantara dasar dan minggu ke enam selepas intervensi. Hasil kajian kami menunjukkan CVR sebagai tambahan kepada CRM meningkatkan keseimbangan postur statik pada minggu ke enam selepas intervensi dalam kalangan dewasa dengan UPC BPPV.

Kata kunci: Vestibular rehabilitasi disesuaikan; manuver piawai kedudukan semula canalith; benign paroxysmal positional vertigo (BPPV);keseimbangan; postur bergoyang

INTRODUCTION

Benign Paroxysmal Positional Vertigo (BPPV) accounts for one third of peripheral vestibular disorders among adults with a lifetime prevalence of 2.4% (Bruintjes et al. 2018; Von Brevern et al. 2007). Approximately 50-75% of BPPV cases are normally idiopathic (Bruintjes et al. 2018; Parnes et al. 2003), commonly affecting the posterior canal (Von Brevern. 2013), followed by the horizontal semicircular canal (Cakir et al. 2006; Britta et al. 2021). It is frequently reported among adults aged between 50-70 years old (Parnes et al. 2003; Perez et al. 2012). The estimated annual recurrence rate of BPPV is about 15–20% (Balatsouras.et al. 2014; Kim et al. 2021). Identified risk factors of recurrent BPPV are being female, having hypertension, diabetes mellitus, hyperlipidemia, osteoporosis and vitamin D deficiency (Chen et al. 2020). Adults with idiophatic posterior canal BPPV present with positional vertigo, nystagmus, dizziness, nausea and balance impairments (McDonell & Hiller 2015). As a consequence, restriction in activities of daily living and decreased level of balance confidence among adults with BPPV is common (Mira 2008).

In most cases, the Canalith repositioning maneuver (CRM) is effective in the management of positioning vertigo and nystagmus among adults with BPPV (Giommetti et al. 2017; Bhattacharya et al. 2008; Helminski et al. 2010; Hilton & Pinder 2014). However, problems related to balance impairments in persons with BPPV have been reported post CRM (Giommetti et al. 2017; Giacomini et al. 2002; Stambolieva & Angov 2006). This is probably due to the fact that CRM is a maneuver with a series of head position change that assist in the repositioning of otoconia from the posterior semicircular canal to the vestibule that relieves symptoms of vertigo such as spinning sensation and lightheadedness. Impairments in balance and gait requires therapeutic exercises as CRM cannot address these issues.

Two thirds of adults with BPPV still had postural instability after CRM (Maha et al. 2011). Static and dynamic balance was reported to be affected among adults with BPPV, examined using posturography (Chang et al. 2008). The specific type of therapeutic exercises that may be beneficial to address balance impairments in adults with BPPV after CRM is not known. Balance control includes several components such as stability during quiet stance, postural reactions to external disturbances, anticipatory postural adjustments, postural responses to perturbations and stability during gait (Sibley et al. 2011).

As for the treatment, combined CRM and vestibular rehabilitation reduced vertigo symptoms and improved balance in adults with BPPV (Angeli et al. 2003; Rajamani & Srinivasan 2013: Se To et al. 2021). Vestibular rehabilitation is a specific type of balance retraining to improve vestibular dysfunction by stimulating the vestibular ocular reflexes (VOR), vestibular spinal reflexes (VSR) and other postural control mechanisms (Whitney & Rossi 2000). Vestibular dysfunction is symptoms of motion-provoked dizziness and balance dysfunction (Murray et al. 2010). Vestibular rehabilitation is effective in persons with vestibular hypofunction (McDonell & Hiller 2015) in promoting central compensation which implies three main mechanisms: habituation, adaptation, and substitution (Deveze et al. 2014; Writer & Arora 2012).

Customized vestibular rehabilitation (CVR) may be beneficial in providing best long term treatment results of balance impairments among adults with idiopathic unilateral posterior canal (IUPC) BPPV. CVR are personalized exercises tailored specifically by physiotherapists to address individual symptoms and functional disability. Comprehensive assessment to identify individual impairments is essential when using CVR. CVR has been found to relieve vertigo symptoms and postural imbalance problems in adults with unilateral vestibular dysfunction (Giray et al. 2009; Tee et al. 2010). Improvements in both gait speed and balance were demonstrated in adults with chronic bilateral and unilateral vestibular dysfunction using CVR (Kreb et al. 2003). However, there is no information regarding the effectiveness of CVR for adults with BPPV. The purpose of the present study was to evaluate the effectiveness of CVR in addition to CRM in improving static balance among adults with idiopathic unilateral posterior canal BPPV.

METHOD

STUDY DESIGN AND PARTICIPANTS

This experimental study was a double blind randomized controlled trial (parallel design) with a four and six week follow up period. It was carried out at Physiotherapy Department, Serdang Hospital, Selangor, Malaysia. Ethical approval was obtained from two Ethics Committees; Research and Ethics Committee of Universiti Kebangsaan Malaysia (UKM 1.5.3.5/244/NN-068-2014), and Ministry of Health, Medical Research and Ethics Committee (NMRR 14-168-19645 IIR). The study was conducted in compliance with the declaration of Australia New Zealand Clinical trials Registry (ACTRN12614000945628). Written informed consent was obtained from participants.

Sample size was calculated based on the G-power 3.0 analysis (ANOVA). Power analysis showed that 30 participants should be sufficient to reveal any significant differences between two different groups within effect size (0.3), α is the significance level ($p < 0.05$) and power of

0.80 and allowing for a 20% drop out rate. Hence, 15 participants per group was required.

The diagnosis of IUPC BPPV was confirmed through records from the Otolaryngology specialist clinic. The inclusion criteria includes adults age between 30-65 years old, diagnosed as having IUPC BPPV and independent in mobility (walking with no more support than a single walking stick). Participants were excluded if they have bilateral BPPV, horizontal or anterior canal BPPV, have had previous vestibular rehabilitation, central nervous system (CNS) involvement, BPPV due to head trauma, Meniere's disease, Labyrinthitis, vestibular neuritis, any unstable medical condition (e.g. severe hypertension or unstable heart problem), Orthopedic and neurological conditions or sensory loss (e.g Diabetes) that may affect postural control and have an impact on functional mobility.

After baseline assessment, participants were randomly allocated into the experimental or control group. Randomization was performed by a research assistant who was not involved in the clinical trial. Block randomization with concealed allocation were employed to minimize observation bias and to prevent time related influences from disturbing the homogeneity of between groups over the data collection period (1.5 years). A research assistant independent of the assessor identified group allocation, communicate with the participants as to which group they were in, and made arrangements for the next visit. Baseline and repeated measurements were performed by a trained physiotherapist who was blinded to group allocation.

OUTCOME MEASURES

The mobility lab (APDM / Ambulatory Parkinson's disease monitoring, Portland, USA) was used to measure balance (Figure 2). This portable device has a computerized system and wireless wearable inertial sensors with a docking station, an access point for wireless data transmission and automatically analyzing and reporting of the recorded data. It is reported to be a fast, sensitive, reliable and low cost measure of postural sway and functional movement during task performance (Mancini & Horak 2012). The inbuilt software that includes the instrumented clinical test sensory of interaction balance (iCTSIB).

The iCTSIB protocol helps to determine which sensory system (visual, somatosensory or vestibular) the participant relies on to maintain balance and it measures postural sways. This test is an accepted test protocol for balance assessment on a static surface (Cohen et al. 1993). As a safety measure the therapist stood beside and monitored the participant throughout the test. The measure of smoothness of sway (jerk) and time domain have been shown to have high test re-test reliability in persons with Parkinson disease (PD) compared with healthy older people (Jerk, Intraclass correlation coefficient/ ICC was 0.86 in PD, 0.87 in Controls, Time domain ICC, range from 0.55-0.84 in PD and 0.60-0.89 in controls) (Mancini et al. 2009). A thirteen centimetre foam pad was used. Static balance (postural sways) was measured under four sensory conditions: 1) eyes open with feet together on firm surface, 2) eyes closed with feet together on firm surface, 3) eyes open with feet together on foam surface, and 4) eyes closed with feet together on foam surface.

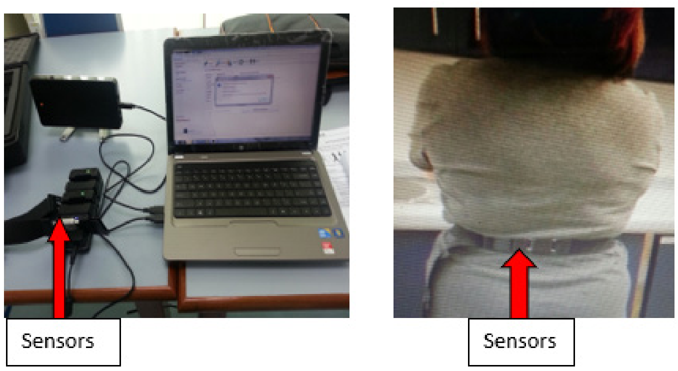

Figure 2 Kinematic sensors used and attachment of sensors at waist level

INTERVENTION

The control group received the CRM maneuver treatment described by Epley (1992), once weekly for two consecutive weeks performed by a CRM trained physiotherapist with five years experience of treating clients for vestibular rehabilitation and was not part of the research team. Prior to the CRM treatment, all participants were informed the possible provoked symptoms such as vertigo, nausea and vomiting that may arise during the CRM. The participants were also instructed to keep their eyes open during the whole procedure to enable the researcher to observe the participant's eyes for the direction of the nystagmus. The therapist move the participant's head position in a few positions. First, the participant was positioned in a positive dix hallpike position with the head rotated in 45 degrees and 20 degree extention. After which, the head was passively turned to the opposite dix hallpike position. This was followed by positioning the participant in side lying with the nose pointing to the floor. The final step was participant sitting up with head tilted down 20 degrees. To enable otoconia to settle, each position is maintained at least 30 seconds or until there is no more nystagmus or vertigo. The CRM treatment was repeated until no positional nystagmus was elicited during any of the position changes or until a total of 2 cycles had been performed for each session.

The experimental group received the CRM maneuver treatment once a week for two weeks. In addition, participants in this group participated in an hours tailored/ customized/ (individualized) vestibular rehabilitation (CVR) program provided by a trained physiotherapist weekly for six weeks to progress their exercises (one visit after the baseline assessment and subsequent visit weekly for six weeks). The CVR exercise program was adapted from Herdman (1998). (Table 1). The exercises includes substituation and balance exercises that were repeated for ten times and the program was customized to address balance and mobility problems. The exercise was progressed and customized based on individual's response to the training. CVR exercise prescription and implementation took participants' safety into account. Participants were monitored closely by the physiotherapist throughout the process of the assessment and treatment. Participants were advised to inform the physiotherapist if they experience any discomfort during the examination and intervention. Any adverse events were reported to the participant's consultant physician and were followed up and assessed by their treating physiotherapist and specialist. The CVR programme that was used in this study is as depicted in table 1. Figure 1 illustrates the participants' flow throughout the study

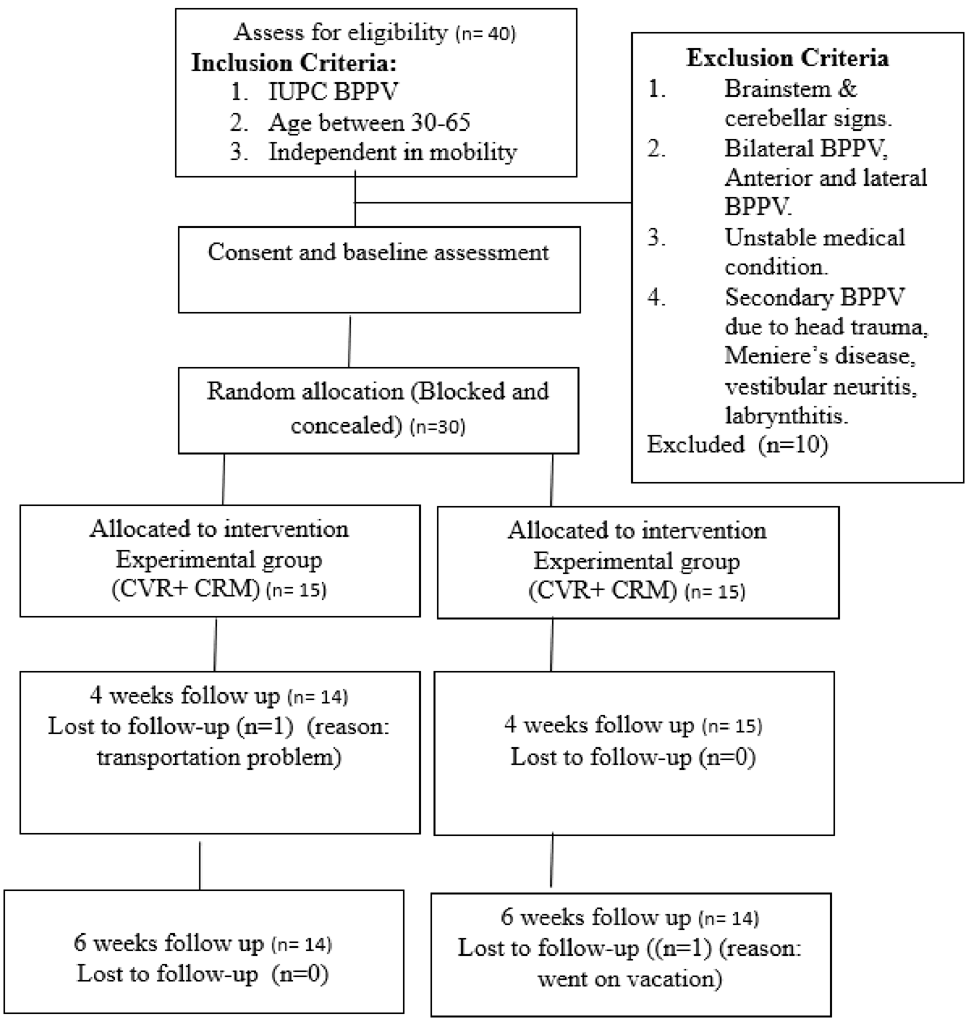

Figure 1. Flow chart of the study

Table 1.Customised Vestibular rehabilitation exercises

Type of Exercise	Aims
Substitution exercises	Synthesizing the use of all sensory input from visual, vestibular and somatosensory system. The aims is to promote the use of the vestibular system by removing visual cues and / or altering somatosensory input (Herdman. 1998). e.g. Standing on foam with eyes closed is an example of maximizing use of the vestibular system.
Balance exercises	Using alternative strategies and sensory information to compensate for the defective vestibular input Balance exercises were designed to intergrade a variety of sensory environments such as vision, vestibular and somatosensory input The aims is to improve co-ordination of muscle responses and postural balance. e.g. moving from sitting to standing, turning around or reaching for an object.
Gait exercises	The aim is to improve functional activities or dynamic balance related to vestibular function. e.g. walking and pivoting and walking and turning around

Table 2. The characteristics of the participants at baseline

Variables		Experimental group n=4	Control group n=4	p-value baseline
Age (years) / mean (SD)		50.71±9.88	54.36±8.55	0.30 +
Gender n(%)	Females	9 (40%)	13 (59%)	0.16#
	Males	5 (83%)	1 (16%)	
Race n (%)	Malay	9 (50%)	9 (50%)	0.78#
	Chinese	3 (42%)	4 (57%)	
	Indian	2 (66%)	1 (33%)	
BPPV lesion site n(%)	Right	8 (42%)	11 (57%)	0.42 #
	Left	6 (66%)	3 (33%)	
Duration of onset on BPPV (days) Mean (SD)		62.14 ± 24.86	35.36±20.10	0.53 +
Nystagmus latency (sec) Mean (SD)		9.79 ± 1.31	9.29 ± 1.59	0.37+
Duration of nystagmus (sec) Mean (SD)		25.00 ±4.38	17.86± 3.23	0.99+
Static Balance				
St firm EO(m2/s4)		0.09±0.12	0.09±0.07	0.35#
St firm EC (m2/s4)		0.16±0.22	0.20±0.11	0.15#
St foam EO (m2/s4)		0.29±0.48	0.28±0.13	0.04#
St foam EC (m2/s4)		2.06±2.21	1.86±1.67	0.48#

* $p<0.05$, **$p<0.001$
+ p-value for independent samples T-Test
# p-value for Chi-Square Test
Abbreviations:
GLM:General linear measures
ηp2 – partial eta- square+
m2/s4:root mean-square of centre of body mass acceleration in the mediolateral & anteroposterior directions
St firm EO:Standing on firm surface with EO (eyes open)
St firm EC:Standing on firm surface with EC (eyes close)
St foam EO:Standing on foam surface with EO (eyes open)
St foam EC:Standing on foam surface with EC (eyes close)

DATA ANALYSIS

Statistical analysis was performed using the SPSS version 20.0 (IBM SPSS Stastistics version 20). A Mixed model ANOVA was used to estimate the main effects of within and between group on static balance (postural sway) (at baseline, 4th and 6th week) and interaction effect was calculated between groups (experimental and control group) and post-hoc analyses was performed where indicated. A significance level of $p < 0.05$ was set.

RESULTS

The demographic, clinical characteristics and baseline measurements are as shown in Table 2. A total of 30 participants were recruited in this study but only 28 participants successfully completed the post intervention assessment (14 participants each in the experimental and control group). The experimental and control group were equal in age and clinical characteristics of conditions at baseline measurements ($p>0.05$) as depicted in Table 2.

Postural sways during stance on solid floor and a foams with eyes opened (EO) and closed (EC) were quantified using the acceleration-based opal system. The results are as outlined in Table 3. A significant group effect was demonstrated on static balance measurement only for standing on firm surface with EC, $F (1, 26) = 5.92$, $p<0.05$ and standing on foam surface with EC; $F (1, 26) =5.09$, $p<0.05$. There was a significant time effect in standing on foam surface with EO, $F (2, 52) = 4.40$, $p< 0.05$ and EC, $F (2, 52) = 5.79$, $p<0.001$. However, only standing on foam surface with EC was observed to have a significant interaction effect, $F (2, 52) =5.28$, $p<0.05$.

The post hoc test results for each group at different time level showed that the experimental group (CVR in addition to CRM) demonstrated a significant improvement (decreased) in postural sway, between baseline and 4th week ($p<0.05$) and also between baseline and 6th week after intervention ($p<0.05$). While, control group (only CRM) demonstrated significant difference between baseline and 4th week ($p<0.05$), with increased in postural sways from baseline to 4th week of re-evaluation. Only one comparison between baseline and 6th week after intervention demonstrated significant differences ($p<0.05$) in postural sways between groups when standing on foam surface with EC. The results indicate that CVR in addition to CRM significantly improved static balance in adults with UPC BPPV at 6th week after intervention with greater improvements at the 6th week.

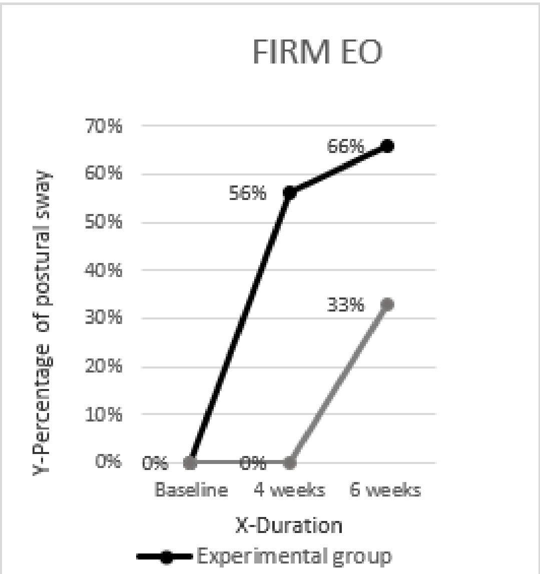

Figure 2a Percentage change in static balance parameters after intervention in standing on firm surface with eyes opened (EO)

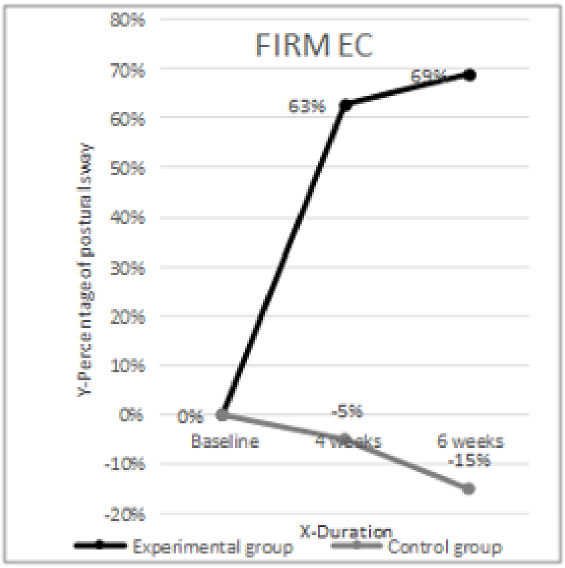

Figure 2b Percentage change in static balance parameters after intervention in standing on firm surface with eyes closed (EC)

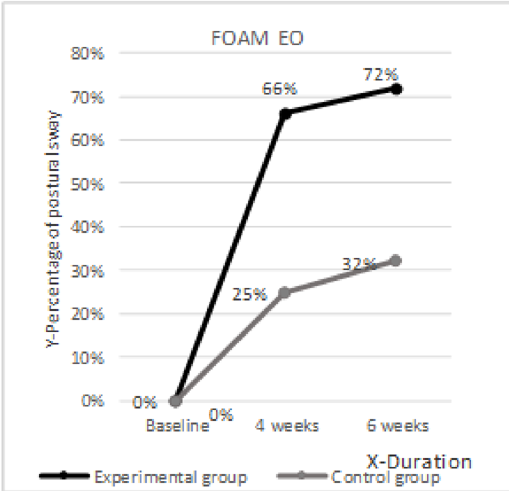

Figure 2c Percentage change in static balance parameters after intervention in standing on foam surface with eyes opened (EO)

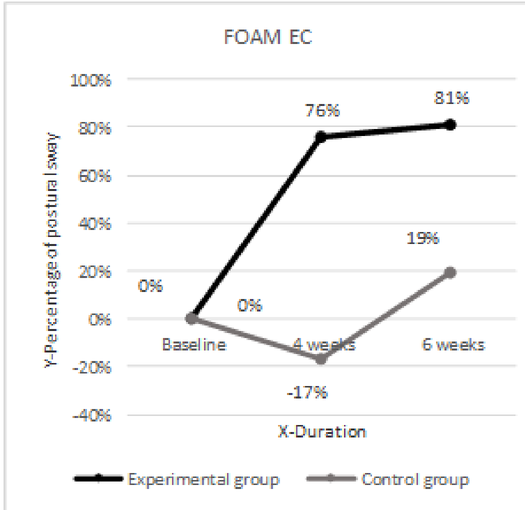

Figure 2d Percentage change in static balance parameters after intervention in standing on foam surface with eyes closed

Table 3 Static Balance Measurements in the Groups at Baseline, Fourth and Sixth Week of Intervention (presented as means ± SD)

Study group			GLM Repeated Measures		
Parameter	Experimental(n=14)	Control (n=14)	p-value Time effect (ηp2)	p-value Group effect (ηp2)	p-value Interaction effect (ηp2)
Static balance (m2/s4) St firm EO					
0 week	0.09±0.12	0.09±0.07	0.058	0.171	0.282
4 week	0.04±0.01	0.09±0.07	(0.121)	(0.071)	(0.046)
6 week	0.03±0.02	0.06±0.03			
St firm EC					
0 week	0.16±0.22	0.20±0.11	0.472	<0.05*	0.200
4 week	0.06±0.02	0.21±0.17	(0.026)	(0.186)	(0.061)
6 week	0.05±0.03	0.23±0.31			
St foam EO					
0 week	0.29±0.48	0.28±0.13	<0.05*	(0.174)	0.399
4 week	0.10±0.03	0.21±0.13	(0.145)	(0.070)	(0.029)
6 week	0.08±0.02	0.19±0.06			
St foam EC					
0 week	2.06±2.21	1.86±1.67	<0.05*	<0.05*	<0.05*
4 week	0.49±0.23	2.18±1.64	(0.182)	(0.164)	(0.169)
6 week	0.39±0.18	1.51±0.86			

* p <0.05, **p<0.001, using mixed ANOVA (repeated measure)

Abbreviations:
GLM:General linear measures
ηp2 – partial eta- square+
m2/s4:root mean-square of centre of body mass acceleration in the mediolateral & anteroposterior directions
St firm EO:Standing on firm surface with EO (eyes open)
St firm EC:Standing on firm surface with EC (eyes close)
St foam EO:Standing on foam surface with EO (eyes open)
St foam EC:Standing on foam surface with EC (eyes close)

Figures 2a, b, c and d show the percentage change for postural sways between the groups in static balance in four conditions; standing on firm and foam surface with EO and EC. The calculations were derived from the differences of mean in percentage between baseline and 4th week and between baseline and 6th week. Generally, these figures demonstrate that the experimental group (EG) that received CVR in addition to CRM had higher percentage of improvements in static balance on both firm and foam surface, on eyes open (EO) and closed (EC) at 4th and 6th week after intervention compared to the control group (CG) that only received CRM.

DISCUSSION

In this study, we examined the effects of customized vestibular rehabilitation (CVR) in addition to canalith repositioning maneuver (CRM) intervention in improving static balance control at four and six weeks among adults with UPC BPPV. The results of our study showed that CVR in addition to CRM significantly improved static balance in adults with UPC BPPV at 6th week after intervention.

In our study, the participants with BPPV age range was between 30 to 65 years with a mean age of 50 and 54 years for experimental and control group respectively. In a study by Chang et al. (2008), patients with BPPV had a mean age of 53 to 56 years for both the experimental and control groups. In addition, another study by Seok et al. (2008) on residual dizziness and imbalance after successful CRM in BPPV patients consisted of participants with a mean age of 59 to 61 for both the experimental and control groups.

It has also been suggested that age does not significantly influence the beneficial effects of vestibular rehabilitation for persons with vestibular dysfunction (Whitney et al. 2002). No statistical differences ($p>0.05$) were demonstrated between a younger (aged 20 to 40 years) and older (aged 60 to 80 years) group on DHI (dizziness handicap inventory), DGI (dynamic gait index), ABC (activities balance confidence) scale, reported symptoms at discharge and number of falls (Whitney et al. 2002). This result is in contrast to the understanding that the balance systems' function that includes visual, somatosensory and vestibular input (Barin & Dodson 2011) and number of hair cells and neurons in the vestibular system (Rauch et al. 2001) deteriorates with age (Barin & Dodson 2011; Rauch et al. 2001).

As for the lesion side, there were more participants with right BPPV (right/left side: 19/9) in our study. Our results were in accordance with the study by Von Brevern et al. (2007), which documented that BPPV is more likely to involve the right labyrinth in the general population (right 1.41 times more than left), probably due to the preference of sleeping on the right side. On the contrary, it was found in a recent study that the left labyrinth was more frequently affected (Silva et al. 2015).

Females accounted for 78.6% (n =22) of the participants in the present study. Similar results were reported in previous studies (Chang et al. 2008; Silva et al. 2015; Von Brevern et al. 2007). In a current review, 72.3% of the cases with BPPV were reported to be females (Silva et al. 2015). In addition, lifetime prevalence of BPPV is estimated to be 2.4%: 3.2% of females and 1.6% of males in the general population.

The results of our study showed that combined CVR and CRM intervention received by the experimental group demonstrated significant improvement within-group in standing on foam surface with EO and EC at 4th and 6th week after intervention. The significant effects may be due not only to successful repositioning of the particles back to the utricle during CRM (Blatt et al. 2000), but also as a result of further enhancement of postural stability from the effect of CVR. The substitution strategy that includes utilisation of visual, somatosensory and vestibular cues (Se To et al. 2022 ; Tee & Chee 2005) during vestibular rehabilitation may have further boosted postural stability in the experimental group.

The control group in our present study showed an increased postural sway velocity, no improvement was observed in standing on firm surface with EC at 4-week and 6-week and standing on foam surface with EC at 4-week after intervention. There was a significant increase in postural sway in standing on foam surface with EC, at 4-week after intervention. Similarly, the control group with CRM showed an increase in sway velocity at the fourth week of intervention in the earlier study by Chang et al. (2008). However, there was a slight postural sway reduction in standing on foam surface with EC at 6-week but the results was not significant. Only slight increased in postural sway in standing on firm surface with EC at 4th and 6th week after intervention and the results were not significant.

Participants with UPV BPPV in combined treatment group who received CVR in addition to CRM demonstrated significant reduction in postural sway in standing on foam surface with EC at 6-week after intervention, as compared to the control group only received CRM. This indicates that the groups were affected differently by the intervention and greater improvement were demonstrated in the experimental group. There was also a significant difference of average mean between groups.

On this condition, participants with UPV BPPV need to rely more on the vestibular system to maintain their postural balance as visual and proprioceptive inputs were eliminated. Therefore, balance retraining in the group receiving CVR assisted in enhancing vestibular input during sensory reorganisation. These results are similar with an earlier study where both CRM and VR (vestibular rehabilitation) were performed as a single intervention (Chang et al. 2008). Static balance control improvement in the stance on the foam surface with eyes closed was demonstrated with combined CRM and VR intervention(Chang et al. 2008). It is noteworthy that the combined intervention in the study by Chang et al. (2008) comprised of CRM and VR, whereas our study emphasised CRM and customized VR (CVR). Although the VR principles where the same; it was customised to individual needs and problems. Both study results showed positive outcomes.

In another previous study (Celebisoy et al. 2009), participants with UPC BPPV improved significantly in static balance control with a decrease in sway velocity when visual and proprioceptive inputs were eliminated after 1 to 2 weeks of CRM treatment. These results are contradictory to our present study results, as our findings showed no significant improvements in the group that received only CRM at 4 weeks after intervention. The difference in the results may be due to the fact that successful CRM may restore the function of the posterior semicircular canal after repositioning of the floating debris. However, the function of the otoliths that detect linear accelerations, body movements and maintenance of posture may not have been restored (Seok et al. 2008). Also, although CRM dramatically improves vertigo, some participants may still experience residual dizziness after CRM. Evidence has shown that two-thirds of adults with BPPV demonstrated residual dizziness after successful CRM (Maha et al. 2011; Seok et al. 2008).

When comparing the groups in a static balance test, no statistically significant difference was found between group in standing on firm and foam surface with eyes open. However, there was a 66% and 72% (Figure 2a) relative gain in the experimental group, compared with 33% and 32% (Figure 2c) in the control group, indicating a clinically important improvement in static balance reflected as decreased sway velocity. In addition, the experimental group demonstrated superior results in all four conditions of static balance at the sixth week after intervention.

In our present study, BPPV participants with only CRM intervention demonstrated a slight increase in postural sway at fourth week after intervention. In addition, this delay in the recovery may be due to the longer time needed for central adaptation after CRM. CVR in addition to CRM may be beneficial in helping integrate and gain complete compensation or adaptation to improve balance ability in adults with BPPV. In the study by Celebisoy et al. (2009), it was found that static balance control improved two weeks post CRM. The differences in the results could be due to the differences in the severity of the BPPV in the participants of these studies.

In summary, Post-hoc analysis confirmed that CVR in addition to CRM significantly improved static balance in UPC BPPV at 6-week after intervention. Control group demonstrated no improvement in postural sway reduction at 4-week after intervention. Although control group revealed a small reduction in postural sway at 6 weeks after intervention, but the results was not significant.

One of our study limitations is that our study results are confined to adults within the age group of 30-65 and with idiopathic UPC BPPV. Thus the results may not be applicable to other age group and types of BPPV. It is also noteworthy, CRM and CVR in this study was provided by therapists trained in performing this intervention. Replication of CRM and CVR intervention in future studies will require specially trained therapists with clinical experience in vestibular rehabilitation. The effects of CVR in addition to CRM may be examined among adults with other types of BPPV in future studies.

CONCLUSION

It can be concluded that six weeks of CVR performed in addition to CRM is more effective than CRM alone for improving static balance in adults with BPPV. Our study demonstrated that adults with UPC BPPV who received CVR in addition to CRM showed significant improvement in static balance ability, especially when visual and proprioceptive inputs were eliminated or deprived. The results of this study justify the use of CVR in addition to CRM in the rehabilitation of adults with BPPV.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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