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COCHRANE CORNER

Is vestibular rehabilitation effective in improving dizziness and function after unilateral peripheral vestibular hypofunction? An abridged version of a Cochrane Review

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ABSTRACT

INTRODUCTION: Unilateral peripheral vestibular dysfunction (UPVD) is characterized by complaints of dizziness, gaze disturbances and balance impairment. Current management includes medication, physical man oeuvres and exercise regimes, the latter known collectively as vestibular rehabilitation. The aim was to assess the effectiveness of vestibular rehabilitation in people with symptomatic UVPD.

EVIDENCE ACQUISITION: A systematic review was conducted for the population of adults diagnosed with symptomatic UPVD, living in the community. We searched all relevant databases and trials registers to identify randomized controlled trials comparing vestibular rehabilitation *versus* control (*e.g.* placebo), other treatment (non-vestibular rehabilitation, *e.g.* pharmacological) or another form of vestibular rehabilitation. We considered possible effectiveness in the domains of symptoms (dizziness) or function (activities, quality of life) and where possible combined results in meta-analyses to provide overall estimates of effect.

EVIDENCE SYNTHESIS: We included 39 studies involving 2441 participants with UPVD in the review. Individual and pooled analyses of the primary outcome (frequency of dizziness) showed a statistically significant effect in favor of vestibular rehabilitation over control or no intervention (odds ratio (OR) 2.67, 95% confidence interval (CI) 1.85 to 3.86). Secondary outcomes measures related to levels of activity or participation showed a strong trend towards significant differences between the groups (standardized mean difference -0.83, 95% CI -1.02 to -0.64). However when movement-based vestibular rehabilitation was compared to physical maneuvers for benign paroxysmal positional vertigo (BPPV), where the latter was shown to be superior in cure rate in the short term (OR 0.19, 95% CI 0.07 to 0.49). There were no reported adverse effects and risk of bias was generally low across the studies.

CONCLUSIONS: There is moderate to strong evidence that vestibular rehabilitation is a safe, effective management for UPVD. For the specific diagnostic group of BPPV, physical (repositioning) maneuvers are more effective in the short term than exercise-based vestibular rehabilitation; although a combination of the two is effective for longer-term functional recovery. There is insufficient evidence to discriminate between differing forms of vestibular rehabilitation.

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Key words: Vestibular diseases - Rehabilitation - Clinical trials as topic - Review.

Introduction

People with dysfunction within the vestibular system (vestibulopathy) often complain of dizziness, visual or gaze disturbances, and balance disorders. Dizziness alone accounts for nearly seven million doctor visits per annum in the US.[1] These impairments lead to significant activity and participation restrictions for the person affected.[2] The cause of the dysfunction can be a disease-related pathology or trauma and can be sited

in the central (brain) or peripheral (inner ear) portions of the vestibular system. More specifically, because the vestibular system is replicated symmetrically in the periphery, many commonly presenting vestibulopathies involve unilateral (asymmetrical) peripheral vestibular dysfunction (UPVD). Examples of these disorders include benign paroxysmal positional vertigo (BPPV), vestibular neuritis, Ménière's Disease (and endolymphatic hydrops) and perilymphatic fistula. Unilateral peripheral vestibular dysfunction can also occur after surgical interventions such as unilateral labyrinthectomy or neurectomy (acoustic or vestibular).[3, 4]

Medication is often directed at vestibular suppression and/or control of symptoms, such as nausea, or for specific disease processes, such as control of infection. Surgery may have a role in the management of patients with vestibular dysfunction, such as the repair of a perilymphatic fistula or removal of an acoustic neuroma.

Vestibular rehabilitation is an exercise-based group of approaches that began with the aim of maximising central nervous system compensation for vestibular pathology.[5] The original protocols by Cooksey and Cawthorne used group activities in a hierarchy of difficulty to challenge the central nervous system.[6] Currently protocols differentiate across several key features with differing physiological mechanisms proposed. These include: compensatory responses (for positional or motion-provoked symptoms), based on the inherent plasticity of the central nervous system and using motion to habituate or reduce responsiveness to repetitive stimuli and to re-balance tonic activity within the vestibular nuclei.[1] Whilst this process is often termed habituation it is more likely to be a compensatory or neuroplastic process,[7] rather than a physiological synaptic habituation response; adaptation for visual-vestibular interaction (gaze stabilization) and possibly eye/hand co-ordination, using repetitive and provocative movements of the head and/or eyes to reduce error and restore vestibulo-ocular reflex (VOR) gain;[8, 9] substitution promotes the use of individual or combinations of sensory inputs (such as visual or somatosensory) to bias use away from the dysfunctional vestibular input or conversely to strengthen use and drive compensation; and Postural control exercises, falls prevention, relaxation training, (re)conditioning activities and functional/occupational retraining are based on motor learning principles to change movement behavior and/or to promote movement fitness.

In addition, there are specific repositioning maneuvers that may be incorporated into the overall vestibular rehabilitation package for particular diagnostic groups of vestibular dysfunction (for example, BPPV).[10, 11] These maneuvers (*e.g.* canalith repositioning maneuvers (CRM) or Epley, Semont and Liberatory) are performed on the patient (rather than the patient performing exercises) and are based on a mechanical rationale to shift vestibular debris. Such techniques are not the focus of this review.

The objective of this review was to assess the effectiveness of vestibular rehabilitation for people with symptomatic unilateral peripheral vestibular dysfunction.

Evidence acquisition

This review was conducted according to the Cochrane Collaboration guidelines. The types of studies considered for this review were randomized controlled trials. We only considered those trials investigating community-dwelling adults with vestibular dysfunction of unilateral peripheral origin, experiencing a combination of symptoms that may include one or all of the following: dizziness, vertigo, balance deficits (dysequilibrium), visual or gaze disturbances. Participants with a diagnosis of a symptomatic UPVD, named as: peripheral vestibular hypofunction, vestibular neuritis, acoustic neuroma/schwannoma, perilymphatic fistula, Ménière's Disease, BPPV or a combination of these. We contacted authors to obtain results separately for those with UPVD if mixed with bilateral or central vestibulopathies, and if this was not possible we included studies provided those with central and/or peripheral disorders numbered less than 10% of the sample size.

We included interventions described as "vestibular rehabilitation" that were predominantly exercise and movement-based, excluding specific (passive) repositioning maneuvers or medical, electrophysiological or pharmacological management. Trials comparing vestibular rehabilitation to no intervention, sham/placebo or other interventions were included.

We considered measure(s) of change in the specified symptomatology as our primary outcome of interest, for example, proportion with dizziness resolved, frequency or severity of dizziness. Measure of function and quality of life were considered as secondary outcomes, as were adverse effects.

We conducted systematic searches for randomized controlled trials. There were no language, publication year or publication status restrictions. The date of the last search was 18 January 2014, following previous searches in July 2010 and March 2007. We searched the following databases from their inception for published, unpublished and ongoing trials: the Cochrane Ear, Nose and Throat Disorders Group Trials Register; the Cochrane Central Register of Controlled Trials (CENTRAL 2013, Issue 12); PubMed; EMBASE; AMED; CINAHL; LILACS; KoreaMed; IndMed; PakMediNet; CAB Abstracts; Web of Science; ISRCTN; ClinicalTrials.gov; ICTRP; Google Scholar and Google. In searches prior to 2013, we also searched BIOSIS Previews 1926 to 2012 and CNKI.

We scanned the reference lists of identified publications for additional trials and contacted trial authors where necessary.

Data analysis

One of the authors retrieved papers from the identified lists on the basis of the title and abstract. The two authors then reviewed these in full against the established criteria and confirmed them as eligible for consideration. Where there was disagreement between the authors about the inclusion/exclusion criteria, we consulted a third expert and reached a consensus decision.

The two authors extracted data from the included studies independently such as participant characteristics (number, age, gender), eligibility and exclusion criteria, setting, description of intervention/s and outcomes. The two authors undertook assessment of the risk of bias of the included trials independently, with the following taken into consideration, as guided by the *Cochrane Handbook for Systematic Reviews of Interventions* [12] and ascribing a judgment of low, high or unclear risk of bias against each criterion.

We extracted and analyzed data to calculate odds ratios (OR) (fixed-effect), 95% confidence intervals (CI) and individual and total effect sizes. This required the identification of the number of participants in each group in each trial and total number (for dichotomous data) and number of participants plus mean and standard deviations for each group (for continuous outcome data). We used the standardized mean difference (SMD) for continuous data, and the mean difference (MD) for outcomes from single studies.

We assessed heterogeneity between trials with the I^2 statistic. Where significant heterogeneity was present, we attempted to explain the differences based on the patient clinical characteristics and interventions of the included studies.

Evidence synthesis

We retrieved a total of 2218 titles papers and reviewed them against the inclusion criteria, with 289 being retrieved for full text review. We excluded a further 250 for reasons such as inclusion of mixed etiology, lack of clear intervention or lack of randomization (a list of excluded studies/reasons is available from the authors), leaving a total of 39 included studies. The characteristics of the included studies are summarized in Table I.[13-51]

All studies were of parallel design and while they all reported randomization the majority were unclear in their description of the method of allocation or generation. A total of 2441 participants participated in the 39 studies, with a mean sample size of 64.7 and a range of 14 to 360. The comparisons varied, with 16 investigating vestibular rehabilitation *versus* placebo or sham interventions. Seven studies compared vestibular rehabilitation with a non-vestibular rehabilitation intervention. Eighteen studies compared a form of vestibular rehabilitation with one or more other forms of vestibular rehabilitation. Some studies involved multiple comparisons, for example vestibular rehabilitation *versus* control (sham) *versus* non-vestibular rehabilitation (medication).

Five studies investigated vestibular rehabilitation in an acute hospital setting, with the remainder being conducted in community or outpatient environments. Some studies required the vestibular rehabilitation intervention to be performed in the outpatient clinic, others established programs to be performed in the home or more frequently a combination of the two was administered.

Eight studies investigated BPPV, six investigated acute unilateral vestibular loss, five investigated postoperative patients (either acoustic neuroma resection, removal of vestibular schwannoma or ablative vestibular surgery), three specifically investigated Ménière's (non-acute phase) and the rest reported their sample

TABLE I.—*Included studies.*

Study ID	Inclusion criteria	Intervention/comparator	Result
Barozzi 2006 [23]	Unilateral peripheral vestibular deficit, 1 to 6 months after the acute phase, diagnosed by clinical examination, CDP, videonystagmography, rotatory chair and caloric tests demonstrating a canal paresis of at least 25%	Intervention groups (n not stated): oculomotor rehabilitation (adaptation) Comparator group (n not stated): vestibular electrical stimulation	No significant differences between groups
Basta 2011 [31]	Experienced balance disorder for more than 12 months due to the following conditions: canal paresis, otolith disorder, removal of an acoustic neuroma, microvascular compression syndrome, Parkinson's disease, presbyvertigo	Intervention group (N.=59): vibrotactile neurofeedback training and vestibular rehabilitation exercises performed daily (15 minutes) over 2 weeks with the Vertiguard system Comparator group (N.=9): sham Vertiguard device and vestibular rehabilitation exercises	Significant reduction in trunk and ankle sway and improved VSS scores on the Vertiguard group. No changes observed in the sham Vertiguard group
Cakrt 2010 [41]	Participants undergoing retrosigmoid microsurgical removal of vestibular schwannoma	Intervention group (N.=9): received visual feedback while performing VR using the BalanceMaster Comparator group (N.=8): control group received VR without feedback	2-week intervention post acoustic neuroma removal, significant improvement in 5 out of 7 centre of pressure parameters in quiet stance on foam in the visual feedback group only
Chang 2008 [18]	First ever attack of unilateral posterior canal BPPV, diagnosed by neurologist and clinical examination	Intervention group (N.=13): canalith repositioning technique (CRT) and vestibular exercises Comparator group (N.=13): CRT only	Intervention group demonstrated a significant improvement in single leg stance with eyes closed at the 2-week assessment, and static balance and DGI at the 4-week assessment
Cohen 2002 [29]	Acoustic neuroma resection - postoperative (1 week - acute) diagnosed by history, audiometry, MRI	Intervention group (N.=16): VR (head exercises) Comparator group (N.=15): control (attention only)	No significant difference between groups
Cohen 2003 [14]	Chronic vestibulopathy (labyrinthitis or neuronitis of more than 2 months) diagnosed by physician using posturography, calorics and oculomotor test battery	Intervention group (N.=13): VR (slow head exercises - habituation) Comparator group 1 (N.=22): VR (rapid head exercises) Comparator group 2 (N.=18): VR (rapid plus attention)	All groups significantly improved for VI, VF, DHI, VSS VHQ no change
Cohen 2005 [19]	Unilateral BPPV (post SC) diagnosed by physician (D-H test), with dizziness for at least 1 week	Intervention group (N.=25): B-D exercises Comparator group 1 (N.=25): habituation exercises Comparator group 2 (N.=24): CRM Comparator group 3 (N.=25): LM Comparator group 4 (N.=25): sham manoeuvre	Manoeuvres (CRM and LM) better results than exercises (B-D, habituation), both better than sham
Foster 2012 [42]	Adults with a history suggestive of BPPV and Dix-Hallpike manoeuvre consistent with unilateral posterior canal BPPV	Intervention group: (N.=33) half-somersault manoeuvre was performed twice in the clinic and also given as a home exercise Comparator group: (N.=35) Epley manoeuvre was performed twice in the clinic and also given as a home exercise	Significantly less nystagmus observed after the initial half-somersault manoeuvre, but no difference in recurrence over the 6-month follow-up period
Garcia 2013 [51]	Participants were included if they had Ménière's disease diagnosed by an ENT specialist, and had complaints of dizziness between exacerbations of their disease	Intervention group (N.=23): 12 rehabilitation sessions (twice weekly for 45 minutes) with virtual reality stimuli in a Balance Rehabilitation Unit, plus diet and lifestyle advice and betahistine Intervention group (N.=21): 12 stimulus enriched exercise sessions (twice weekly) on the Balance Rehabilitation Unit, plus diet and lifestyle advice and betahistine	Intervention participants improved significantly on the DHI, dizziness analogue scale and had greater stability on posturography compared to control participants

(to be continued)

TABLE I.—*Included studies (continues).*

Study ID	Inclusion criteria	Intervention/comparator	Result
Giray 2009[44]	Participants were diagnosed by a neuro-otologist or neurologist with chronic decompensated unilateral peripheral vestibular deficit, secondary to peripheral vestibular dysfunction. Diagnosed by ENG, bithermal caloric test, ocular motor testing and positional testing	Intervention group (N.=20): VR incorporating adaptation, substitution, visual desensitisation and balance exercises Comparator group (N.=21): control, no input	Significant improvements were seen in all parameters for the intervention group while there were no changes in the control group
Herdman 1995[47]	Participants post removal of acoustic neuroma. Diagnosed by MRI and surgically resected - study performed in acute post period	Intervention group (N.=11): VR (adaptation to increase gain) plus ambulation exercises Comparator group (N.=8): smooth pursuit exercises (no head movement) plus ambulation exercises	Intervention group significant improvements for dysequilibrium VAS, VOR to slow head movements, gait and posturography on day 6 compared to control group
Herdman 2003[48]	Unilateral vestibular hypofunction with abnormal DVA, diagnosed by caloric, rotary chair, positive head thrust	Intervention group (N.=13): VR (adaptation to enhance VOR) Comparator group (N.=8): placebo exercises designed to be "vestibular neutral"	12/13 improved DVA in intervention group 1/8 improved DVA in comparator group Both improved VAS
Horak 1992[22]	Peripheral vestibular dysfunction diagnosed by neuro-otologist for BPPV, inner ear concussion syndrome, reduced unilateral vestibular function, 18 to 60 years of age	Intervention group (N.=14): VR Comparator group 1 (N.=4): general conditioning exercises Comparator group 2 (N.=8): medication (meclizine or Valium)	VR - superior reduction in sway and increased SOOL DI decreased for both VR and medication 92% improvement rate with VR (75% with comparator group 1, 75% with comparator group 2)
Kammerlind 2005[32]	Acute unilateral vestibular loss confirmed by ENG with calorics	Intervention group (N.=28): VR (home exercises plus extra PT (habituation, adaptation, balance and gait) (extra PT included individualised instruction and further exercises) Comparator group (N.=26): VR (home exercises only)	No significant difference between groups - intensity not supported
Karanjai 2010[30]	Diagnosed with posterior canal BPPV through history and clinical examination (Dix-Hallpike manoeuvre)	Intervention group: Brandt-Daroff exercises 3 times a day for 2 weeks, N.=16 Comparator group 1: single Epley manoeuvre followed by post-treatment instructions, N.=16 Comparator group 2: single Semont manoeuvre followed by post-treatment instructions (sleep upright for 2 nights, then on the unaffected side for the next 5 nights), N.=16	Statistical analysis of the differences between groups not performed; 73% of participants overall reported resolution of symptoms with no recurrence at 3 months follow-up
Krebs 2003[24]	Mixed diagnoses - unilateral and bilateral peripheral vestibular dysfunction. Diagnosed by VOR gain, calorics etc.	Intervention group (N.=42): VR (adaptation, balance) Comparator group (N.=44): control (strength exercises)	VR group significantly improved for gait speed and base of support measures UPVD and BVD groups improved equally though BVD were less functional at baseline
Kulcu 2008[21]	Diagnosed with BPPV and has undergone repositioning techniques by their otorhinolaryngologists but were still complaining of vertigo and dysequilibrium	Intervention group (N.=19): VR (Cawthorne-Cooksey exercises) Comparator group (N.=19): medication (betahistine)	The intervention group demonstrated significant improvements in the VSS and VDI at the end of the study (8 weeks)
Marioni 2013[25]	Adults aged 18 to 65 with acute unilateral peripheral vestibular disorder occurring within 2 weeks of entry into the study, with at least 50% weakness on videonystagmography with caloric testing	Intervention group (N.=15): posturography-assisted VR Comparator group 1 (N.=15): group awaiting spontaneous compensation, no VR Comparator group 2 (controls, N.=10): healthy adults without a vestibular disorder	Both groups of participants with vestibular dysfunction improved over the 6-week intervention but only the posturography-assisted VR improved postural control, which approximated the healthy controls

(to be continued)

TABLE I.—*Included studies (continues).*

Study ID	Inclusion criteria	Intervention/comparator	Result
Morozetti 2011[33]	Adults with a chronic vestibular disorder diagnosed by otorhinolaryngologists	Intervention group (N.=10): home exercises based on vertical and horizontal vestibulo-ocular reflex stimulation (VRS) Comparator group (N.=10): personalised VR home exercise programme	Both groups improved over time but the personalised VR group reported less dizziness on VAS and greater gains on the DHI
Mruzek 1995[43]	Participants had been reviewed by a physician for acoustic neuroma or Ménière's disease and were referred for ablative surgery	Intervention group (N.=8): VR plus social reinforcement, 15 minutes, 2 x day plus a daily walk Comparator group 1 (N.=8): VR no social reinforcement Comparator group 2 (N.=8): general range of motion exercises plus social reinforcement	All the same at 4 weeks Intervention group and comparator group 1 significant improvement for MSQ at 7 weeks Intervention group significant improvement for DHI at 8 weeks CDP no difference between groups
Pavlou 2004[34]	Peripheral vestibular disorder diagnosed by full vestibular examination	Intervention group (N.=20): VR (customised exercises, including gaze control and stability, balance training) Comparator group (N.=20): simulator (optokinetic disc to produce visual-vestibular conflict plus above)	Both groups improved significantly on posturography: intervention group more than comparator group Subjective symptom reports reduced for both (? any difference) Visual-vertigo symptoms improved for intervention comparator group Depression reduced significantly for both groups: intervention group more than comparator group Anxiety reduced for both BBS not sensitive
Pavlou 2012[35]	Participants with a history of acute onset of vertigo and had a confirmed peripheral vestibular deficit on the basis of the caloric tests and/or rotational tests on ENG	Intervention group (N.=5): dynamic virtual reality, performed for 45 minutes twice weekly for 4 weeks plus home exercises and general conditioning programme (walking) Comparator group 1 (N.=11): static virtual reality image rehabilitation, performed for 45 minutes twice weekly for 4 weeks plus home exercises and general conditioning programme (walking) Comparator group 1 (N.=5): cross-over of 5 group 1 participants who then received dynamic virtual reality (not included in our analysis)	After 4 weeks the dynamic groups reported significantly less visual vertigo, but depression improved in the static virtual reality VR group only
Resende 2003[49]	Participants with BPPV diagnosed by ENT using history, ENT examination, ENG	Intervention group: VR (compensation, adaptation, sensory substitution, balance: C-C) Comparator group: control (nil)	Intervention group significantly improved Comparator group no change
Rossi-Izquierdo 2011[36]	Participants with instability due to chronic unilateral peripheral vestibular disorders, which had not spontaneously resolved after a month. Hypofunction was defined with caloric tests, at least 25% labyrinthic preponderance according to defined criteria	Intervention group (N.=12): computerised dynamic posturography (CDP), 5 sessions of approximately 15 to 20 minutes on consecutive days Comparator group (N.=12): optokinetic stimulation (OKN), 5 sessions lasting 5 to 15 minutes on consecutive days	Outcomes assessed 3 weeks after treatment. Both groups improved, with the CDP group showing greater gains in the visual and vestibular input and limits of stability, while the OKN group showed greater improvement in visual preference
Rossi-Izquierdo 2013[37]	Participants with instability due to chronic unilateral peripheral vestibular disorders, which had not spontaneously resolved after a month	Intervention group (N.=13): 5 sessions of posturography-assisted VR over a 2-week period Comparator group (N.=13): 10 sessions of posturography-assisted VR over a 2-week period	Outcomes assessed 3 weeks after the intervention and both groups improved over time, with the 5-session group reporting greater gains on the DHI, but some items of posturography improved to a greater extent in the 10-session group

(to be continued)

TABLE I.—*Included studies (continues).*

Study ID	Inclusion criteria	Intervention/comparator	Result
Scott 1994[15]	Ménière's disease diagnosed by medical and audiological examination (5 were bilateral but had one "worse" ear)	Intervention group (N.=10): applied relaxation Comparator group (N.=10): transcutaneous nerve stimulation to the hand	No change in either group for relevant measures (dizziness etc.) Intervention group improved on hearing ability more than comparator group Comparator group improved on psychoacoustic tests more than intervention group
Strupp 1998[50]	Vestibular neuritis (acute/sub-acute). Diagnosed by history, examination - nystagmus, postural imbalance, ENG, calorics, ocular tilt reaction	Intervention group (N.=19): VR (home exercises, based on Cooksey-Cawthorne, Norre - habituation, gaze exercises, sensory substitution, functional retraining) Comparator group (N.=20): control (nil exercise but encouragement to move)	For OT and SVV tests, intervention group equal to comparator group For SP, intervention group improved significantly more than comparator group, i.e. balance improved
Szturm 1994[16]	Clinical diagnosis of peripheral vestibular dysfunction, persistent dizziness, disorientation or imbalance for at least 1 year, and abnormal balance performance during CDP at baseline	Intervention group (N.=11): VR Comparator group (N.=12): VR (home, C-C)	Intervention group had reduced falls, improved CDP values and reduced VOR asymmetry compared with comparator group
Teggi 2009[28]	Participants were recently hospitalised for an acute episode of rotational vertigo which lasted several days and were diagnosed with vestibular neuritis	Intervention group (N.=20): VR Comparator group (N.=20): control ("perform usual daily activities")	Significant improvement in DHI between groups and reduction in anxiety. For both groups, there was a significant correlation between change in anxiety and change in DHI/DGI
Toledo 2000[20]	BPPV diagnosed with clinical assessment and electronystagmography	Intervention group (N.=10): VR (PC, head-eye and habituation) Comparator group 1 (N.=10): Semont manoeuvre Comparator group 2 (N.=20): Semont + VR	Intervention group 80% cure rate at day 15 versus comparator group 1 45% Intervention group 66% cure rate at 3 months versus comparator group 2 100%
Varela 2001[13]	BPPV, diagnosed by history and D-H test (nystagmus)	Intervention group (N.=29): VR (B-D habituation exercises) Comparator group 1 (N.=35): Semont manoeuvre Comparator group 2 (N.=42): Epley manoeuvre	Comparator groups 1 and 2 had a similar cure rate at 1 week; by 3 months comparator group 2 were superior but comparator group 1 more stable CRM superior to habituation (B-D) for BPPV
Venosa 2007[26]	Acute episode of rotational vertigo within the last 5 days	Intervention group (N.=45): VOR adaptation exercises (X1 and X2 viewing exercises) Comparator group (N.=42): placebo exercises (sham visual fixation task)	Intervention group recovered more quickly in all parameters measured and required significantly less medication by the end of the follow-up period (21 days)
Vereeck 2008[45]	Consecutive patients post removal of an acoustic neuroma	Intervention group (N.=31): customised VR (exercises for balance, head motion, mobility, gaze and treadmill walking) Comparator group (N.=22): general instructions	Participants were stratified according to age (above and below 50 years). Older participants performed significantly better than the control group for balance, TUG and tandem gait compared to the control group. There was no group effect for the younger participants
Winkler 2011[38]	Participants with chronic dizziness (greater than 6 months duration) who had completed a VR programme, functional range of motion and strength in the lower limbs and trunk, intact sensation in the lower limbs, ability to stand unassisted for 1 minute	Intervention group (N.=10): platform tilt perturbations only Comparator group 1 (N.=7): platform tilt perturbations and VR exercise programme Comparator group 2 (N.=12): VR only	Outcomes were assessed after the 3-week intervention and a follow-up at 2 months later. The VR group only demonstrated significant improvement on the DHI but the platform tilt groups improved activity and participation domain outcomes

(*to be continued*)

TABLE I.—*Included studies (continues).*

Study ID	Inclusion criteria	Intervention/comparator	Result
Yardley 1998[46]	Dizziness of vestibular origin. Mixed aetiology - diagnosed where possible by medical records (1/3) Possibility of central pathology	Intervention group (N.=67): VR (education, head and body movements, relaxation, breathing, encouragement to function) Comparator group (N.=76): control	Intervention group improved significantly on all measures more than comparator group, except VHQ (no difference) Overall intervention group 4 times more likely to report subjective improvement than comparator group
Yardley 2004[27]	Dizziness of vestibular origin diagnosed by case history and MPD	Intervention group (N.=83): VR (primary care: demonstration, booklet and follow-up) Comparator group (N.=87): control, usual medical care	All measures improved significantly in VR group compared with control group Clinical improvement 67% VR; 38% control
Yardley 2006[39]	Participants with Ménière's disease (non-acute phase) who had experienced dizziness of imbalance in the last 12 months, had consulted their GP regarding involvement in the study	Intervention group (N.=120): VR (booklet of exercises) Comparator group 1 (N.=120): SC (booklet for self management) Comparator group 2 (N.=120): waiting list control	At 3 months intervention group had greater improvement on 5 measures compared with comparator group 1 (2 measures) compared with comparator group 2 (0 measures) At 6 months intervention group and comparator group 1 both reported significant improvement, more than comparator group 2 Correlation between adherence and outcome
Yardley 2012[40]	Chronic dizziness, as diagnosed by their GP	Intervention group (N.=112): VR (self-management booklet with phone support from a vestibular therapist) Comparator group 1 (N.=113): SC (self-management booklet only) Comparator group 2 (N.=112): routine medical care	At 12 weeks all groups showed some improvement in the VSS, and at 1 year both intervention groups improved significantly compared to usual care
Zimbelman 1999[17]	Unilateral peripheral vestibular dysfunction diagnosed by neuro-otological tests	Intervention group (N.=6): VR (individual with adaptation and postural control) Comparator group (N.=8): VR (general C-C)	Intervention group improved dizziness over time, comparator group did not No change for either on the BBS (insensitive) No between-group differences - but 100% of intervention group reported improvement compared with 62.5% of comparator group Intervention group had more Ménière's disease

variously as having chronic unilateral vestibular weakness, hypofunction, dysfunction or dizziness of vestibular origin (including labyrinthitis, neuronitis and other mixed or idiopathic unilateral peripheral vestibular dysfunction pathologies).

Interventions

Most studies included a mixture of the various components of vestibular rehabilitation, the most common combination being habituation (movement-provoking) with gaze stabilizing (adaptation), balance and gait/activity training. Other additions to this type of package included education (three), booklet-based (three), sensory substitution (three) and relaxation (two). Five studies described single component vestibular rehabilitation: these included Soto-Varela [13] that investigated Brandt-Daroff exercises (a form of habituation), Cohen [14] that investigated rapid *versus* slow head movements (habituation) and Scott [15] that investigated relaxation. Two studies compared individualized vestibular rehabilitation with a generic vestibular rehabilitation programme.[16, 17]

Control or placebo interventions involved either usual care or some form of sham exercise that did not target

compensatory or adaptation processes (*e.g.* sham maneuvers, range of motion, general conditioning, general instructions or strength training).

Studies that compared vestibular rehabilitation with non-vestibular rehabilitation interventions were also varied. Chang,[18] Cohen,[19] Toledo,[20] and Soto-Varela[13] compared exercise-based vestibular rehabilitation with repositioning maneuvers; Kulcu [21] and Horak [22] compared vestibular rehabilitation with medication; Scott [15] compared vestibular rehabilitation (relaxation) with electrical stimulation; and Barozzi [23]compared oculomotor exercises (adaptation vestibular rehabilitation) with electrical stimulation.

Outcomes

There was considerable variation in the outcome measures used. Subjective measures of change in symptoms (impairments) included:

— dizziness cure rate: "cure" defined as the disappearance of the sensation of dizziness;

— subjective improvement in dizziness: subjects asked to nominate improvement (better) or no change/worsening in subjective experience of dizziness;

— Vertigo Symptom Scale (VSS): shortened version (14-item), measuring frequency of dizziness/vertigo, imbalance and related autonomic symptoms during the past month, with a higher score indicating greater symptoms (score range 0 to 60) (Component related to vertigo reported [VSS-V], second component related to autonomic/somatic anxiety [VSS-A]);

— vertigo Visual Analogue Scale (VAS): subjective rating of vertigo on a closed VAS ranging from 0 mm (no symptoms) to 100 mm (worst possible symptoms);

— vertigo intensity: subjective rating of intensity of vertigo on a five-point qualitative scale from 1 (no vertigo) to 5 (severe);

— vertigo frequency: subjective rating of frequency of vertigo experiences on a four-point scale from 0 (no episodes per day) to 3 (more than 10 episodes per day or constantly).

Objective measures of change in impairment, activity or participation included:

— repetitive head movement task: measure of standard head movements and resultant provocation (or not) of symptoms, scored as time to perform and intensity of elicited vertigo;

— dynamic visual acuity: tests for visual acuity during head movements either under predictable conditions (patient moved own head) or unpredictable (head moved by tester), related to oscillopsia and scored as number of errors during tests;

— Romberg Test: a measure of standing balance, as dichotomous data, scored as number of pass or fail scores;

— Sway path: measure of standing balance, recording the length of the path of the center of force (in two planes) during a given time and potentially under differing stance conditions, giving a total sway path measured in meters per minute where the smaller path indicates greater balance proficiency;

— posturography: (computerized dynamic posturography) a battery of standing balance tests under prescribed variable conditions (Sensory Organization Test), which can be scored as composite scores and sensory ratios (compared to normative data, other variables available);

— Dynamic Gait Index (DGI): scores eight mobility tasks (ranging from straight walking through to stair ascent/descent) to give a total score of 24 points;

— gait ataxia: the presence or absence of abnormal coordination during walking;

— tandem walk: test of dynamic balance and gait proficiency where the patient walks 15 steps forward then backward along a line, scored as the number of correct steps (performed heel to toe and on line), with a higher score indicating greater proficiency;

— vestibular dysfunction in activities of daily living (VD-ADL): questionnaire to rate the impact of dizziness or vestibular dysfunction on primary activities of daily life, with a higher score indicating greater functional loss;

— Vertigo Handicap Questionnaire (VHQ): shortened version (14-item), which measures restriction of activity caused by dizziness and the social effects of this activity restriction (score range 0 to 56);

— Dizziness Handicap Inventory (DHI): measures patient perception of handicap related to dizziness (an indication of the effect of the symptom on participation or quality of life), where a higher score indicates greater dysfunction;

— Beck Anxiety Inventory: a self-report measure of anxiety state;

— Situational Vertigo Questionnaire: a self-report

measure of visually induced vertigo; Subjective health - self report of current health status with respect to dizziness.

Follow-up was variable, from none (12 studies) to between two, three, six and 12 months for the remaining studies.

The risk of bias for each of the six domains is reported for the review overall and for each trial in Figures 1, 2. These figures most significantly demonstrate a marked deficiency in the reporting of the methods used to generate and conceal the randomization process across the majority of studies. The other domains were more clearly reported and we generally evaluated them as low risk of bias.

Effects of the intervention

Twenty nine studies were able to be incorporated in meta-analyses to identify effect estimates. First we analyzed 13 trials which compared vestibular rehabilitation *versus* control (placebo, sham, usual care or no intervention) and supplied sufficient data. We found statistically significant differences between vestibular rehabilitation and control/placebo interventions in favor of vestibular rehabilitation for the following outcomes:

— subjective improvement in dizziness (odds ratio (OR) fixed-effect 2.67, 95% confidence interval (CI) 1.85 to 3.86, P-value<0.0001; four studies, 565 participants);

— VSS (standardized mean difference (SMD) fixed-effect -0.68, 95% CI -0.87 to -0.49, P-value<0.00001; three studies, 553 participants);

— Gait ataxia (OR fixed-effect 0.04, 95% CI 0.00 to 0.77, P-value=0.03; one study, 19 participants);

— VD-ADL (mean difference (MD) fixed-effect -10.50, 95% CI -14.09 to -6.91, P-value<0.0001; one study, 16 participants);

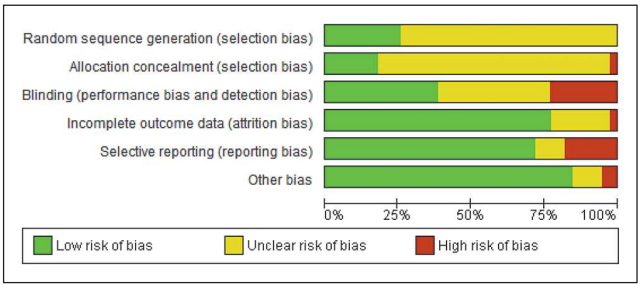

Figure 1.—Overall risk of bias.

Figure 2.—Individual study risk of bias.[13-51]

— Sway path (posturography data) (MD fixed-effect -13.70, 95% CI -16.51 to -10.89, P-value<0.00001; one study, 39 participants);

— dynamic visual acuity (OR fixed 84.00, 95% CI 4.51 to 1564.26, P-value=0.003; one study, 21 participants);

— VHQ (MD fixed-effect -3.40, 95% CI -6.76 to -0.04, P-value=0.05; one study, 143 participants);

— Sharpened Romberg Test scores (balance) (MD fixed-effect 9.90, 95% CI 0.80 to 19.00, P-value=0.03; one study, 143 participants);

— DHI (SMD fixed-effect -0.83, 95% CI -1.02 to -0.64, P-value<0.00001; five studies, 535 participants);

— DGI (SMD fixed-effect -0.92, 95% CI -1.38 to -0.46, P-value<0.0001; two studies, 93 participants) under 50 and over 50 years old).

Differences were non-significant for the other four measures: Romberg test, vertigo intensity (two separate comparisons) and posturography.

The three studies that could not be included in the meta-analysis, due to inadequate reporting of data, supported the positive findings of vestibular rehabilitation improving gait and reducing the duration of dizziness symptoms compared to a control group.[24-26]

We calculated heterogeneity as being high in three analyses in this comparison. On visual inspection of data from the VSS and DHI, we noted the same study to have markedly larger effects than the other pooled studies.[27] Comparison of methods and clinical parameters did not reveal any clear reasons for the difference. Furthermore, removal of the study from each analysis still retained the statistically significant effects. In the analysis for Dynamic Gait Index, the Teggi [28] Study provided a higher effect size than the other pooled study results; again there were no obvious clinical or methodological differences to explain this, as all studies had acceptably low risk of bias and usual care control groups. However, in this instance removal of the study also removed the significant effect.

Seven studies were able to be analyzed comparing vestibular rehabilitation with other kinds of treatment,[13, 18,19, 22, 23, 29, 30] with a further three studies with inadequate data.[15, 20, 21] Statistically significant differences between vestibular rehabilitation and other interventions (maneuvers) in favor of "other" (where "other" were physical maneuvers for BPPV) were found for: Dizziness cure rate (OR fixed 0.19, 95% CI 0.07 to 0.49, P-value=0.006; two studies, 119 participants) and for DGI (MD fixed-effect -1.00, 95% CI -1.85 to -0.15, P-value=0.02; one study, 26 participants).

Differences were non-significant for all other measures (four): subjective improvement in dizziness, vertigo intensity (two) and DHI.

One study not included in the meta-analysis compared a home-based exercise programme with betahistine medication and found that the exercise programme improved dizziness symptoms and health-related quality of life to a greater extent.[21] The second study compared relaxation with electrical stimulation and found no significant differences.[15] The third study not included in the meta-analysis compared only the Semont maneuver with combined maneuver and vestibular rehabilitation for people with BPPV.[20] The maneuver was found to be superior in cure rate in the short term (15 days), but the combination approach was superior in the longer term (three months).

We included 12 studies in the analyses comparing vestibular rehabilitation with other kinds of vestibular rehabiliation.[14, 17, 31-40] Another four studies also performed this comparison but did not provide appropriate data.[16, 41-43]

We found statistically significant differences between one form of vestibular rehabilitation and another form of vestibular rehabilitation for the following: VSS-V (SMD fixed-effect -1.12, 95% CI -1.80 to -0.45, P-value=0.001; one study, 40 participants) in favor of the inclusion of simulator activities, however the overall Vertigo Symptom Score was non-significant (P-value=0.18); and for DHI (SMD fixed-effect -0.96, 95% CI -1.78 to -0.14, P-value=0.02; one study, 26 participants) in favor of five sessions of balance training compared to 10.

Differences were non-significant for all other measures in these comparisons between different forms of vestibular rehabilitation: repetitive head movement task, VAS tandem walk, posturography (five), VSS (four), DHI (seven), subjective improvement in dizziness, vertigo intensity, vertigo frequency, VHQ, ataxia, VD-ADL and subjective health.

Four studies were not included in the meta-analysis. One reported that after surgical removal of a schwannoma patients' recovered balance (as measured by posturography) was greater with visual feedback on training than without feedback.[41] Another found varying

results when comparing a half-somersault *versus* the Epley maneuver for BPPV, with the former superior in improving exercise-induced dizziness.[42] One study reported similar results whether vestibular rehabilitation was performed with or without social support.[43] A final single study reported that a formal vestibular rehabilitation programme was more effective in improving balance/reducing falls than a home-based Cooksey-Cawthorne programme.[16]

We evaluated heterogeneity as high, as indicated by the I^2 statistic for two analyses. Visual inspection of the forest plot for VSS revealed that Pavlou [34] had reported a larger effect size using the VSS vertigo component. This is to be expected clinically given that vertigo reduction is the primary goal and outcome of vestibular rehabilitation. The second analysis revealed that a larger effect size was produced by the Rossi-Izquierdo [36] Study than other studies in the meta-analysis. The overall effect was not significant and there was no obvious clinical or methodological explanation for the effect, other than that computerised dynamic posturography or posturography measures have multiple interpretations and parameters, which may not be appropriate for pooling.

Discussion

Given the number of moderate to high quality studies reporting outcomes in favor of the vestibular rehabilitation intervention there appears to be strong evidence that vestibular rehabilitation is effective in improving dizziness and function in people with UPVD. The heterogeneity of the 39 studies still acts as a qualifier to this strong conclusion. The study variability lies in three domains: the varied comparators and the nature of the vestibular rehabilitation intervention, the sample characteristics (for example sub-categories of UPVD, or acute versus chronic) and the outcome measures.

Vestibular rehabilitation is better than no or other interventions

Taken at the strictest level of evidence provided by meta-analysis, the low risk of bias studies [22, 27, 28, 44-46] offer support for the use of vestibular rehabilitation to improve subjective measures of dizziness (including the VSS), level of participation (DHI) and gait performance (DGI) in people with chronic peripheral vestibulopathy, as compared to sham exercises or no vestibular rehabilitation/usual care. Individually the studies of Herdman,[47] Herdman,[48] Resende,[49] and Strupp [50] also offer evidence of effectiveness in terms of improvement in measures of balance, activities of daily living and vision compared to no or sham interventions. These studies, as a body of evidence, therefore offer strong support for the effectiveness of vestibular rehabilitation across a broad range of outcomes in unilateral peripheral vestibular dysfunction as compared to placebo, sham or no intervention.

Studies that compared vestibular rehabilitation to other forms of unilateral peripheral vestibular dysfunction management (non-vestibular rehabilitation) include Barozzi [23] (electrical stimulation), Horak [22] and Kulcu [21] (medication), Chang [18] (physical maneuvers for BPPV (CRM) plus vestibular rehabilitation *versus* CRM alone), Toledo [20] (Semont maneuver), and Soto-Varela [13] and Karanjai [30] (Semont and Epley manoeuvres). Horak [22] and Kulcu [21] found that vestibular rehabilitation was superior to medication in improving subjective reports of dizziness in people with UPVD. In contrast, Toledo [20], Soto-Varela [13] and Karanjai [30] found in favor of maneuvers over vestibular rehabilitation as defined for this review. The difference in findings can be explained by considering the different subject groups – Horak[22] recruited a pool of people with general peripheral vestibular dysfunction, whereas Soto-Varela[13] and Karanjai [30] investigated confirmed BPPV diagnoses only. This specific issue of BPPV will be discussed later. The studies by Cohen [29] and Cohen[19] failed to reach a sufficient effect size despite statistical significance in the original 2005 paper. Barozzi [23] reported no difference in effect size between the vestibular rehabilitation and electrical stimulation groups.

What form of vestibular rehabilitation is most effective?

Considering the comparative or relative effectiveness of different forms of vestibular rehabilitation, three studies reached statistical significance in our review. Pavlou [34] compared customized home-based vestibular rehabilitation exercises with the same programme plus simulator-based visual and self-motion stimulation, finding in favor of the supplemented programme. There-

fore there is some evidence to support the addition of simulator-based activities in a vestibular rehabilitation approach. A later study by Pavlou [35] found that dynamic *versus* static virtual reality vestibular rehabilitation was superior in reducing visually induced dizziness. Rossi-Izquierdo [37] found that only five sessions of balance training (*versus* ten) were needed to improve dizziness experiences on the DHI, but that 10 were superior to five in improving balance. The lack of homogeneity means that it is not possible to draw strong conclusions about the other studies that compared different versions of vestibular rehabilitation. Further studies with a larger sample size are needed to clarify the questions of which exercises should be used, in what environment, administered by whom and for how long or how intensively (dosage).

Do different categories of unilateral peripheral vestibular dysfunction respond differently and what signs/symptoms are affected?

Five studies considered vestibular rehabilitation in the acute stage immediately postsurgery for acoustic neuroma resection, removal of schwannoma or vestibular ablation. Vereeck [45] reported that older participants in particular (over 50 years old) regained postural control more quickly with vestibular rehabilitation compared to general instructions, and that the greater benefits for postural control were maintained 12 months postoperatively. Herdman [47] found a variable picture comparing vestibular rehabilitation that targeted vestibular gain *versus* eye movements that did not influence gain, reporting that balance and gait tests were superior in the vestibular rehabilitation group at day six postoperatively. Cohen [29] found no difference between vestibular rehabilitation and sham interventions at day six; Cakrt [41] found that patients post schwannoma removal, who received visual feedback as part of their vestibular rehabilitation, had greater improvement in balance parameters than those who did not receive feedback; and finally Mruzek [43] found that vestibular rehabilitation (with or without social reinforcement) had better effects than a sham exercise for several dizziness and sensitivity quotients in the longer term (seven weeks post operation). Neither of the two latter studies could be included in a meta-analysis.

Kammerlind [32] investigated acute unilateral vestibular loss, comparing two forms of vestibular rehabilitation and finding them equally effective. Teggi [28] (vestibular rehabilitation *versus* control) and Venosa [26] (adaptation vestibular rehabilitation *versus* placebo) both reported greater benefits for people with acute vestibular presentations receiving vestibular rehabilitation, in terms of reduced symptom duration and medication use. Marioni [25] found that posturography-assisted vestibular rehabilitation compared to no vestibular rehabilitation had similar results but only the vestibular rehabilitation group improved to a level similar to healthy controls.

Eight studies investigated BPPV specifically. Resende [49] investigated elderly patients with BPPV and compared vestibular rehabilitation (Cooksey-Cawthorne type exercises) with no intervention — both groups had received prior Ginkgo biloba. The vestibular rehabilitation group performed significantly better on measures of activities of daily living postintervention. In contrast, the study Soto-Varela [13] also investigated participants with confirmed BPPV and found that maneuvers (either Epley or Semont) were more effective in producing resolution than habituation exercises.[52] They concluded that a hierarchy of interventions should be offered to people with BPPV, starting with a canalith repositioning maneuver. This suggestion has found favor in current clinical practice and is supported by the similar study of Cohen[19] (though not in the meta-analysis), who also found in favor of maneuvers (canalith repositioning maneuver and modified Liberatory) compared to two versions of vestibular rehabilitation habituation exercise, noting that the exercises were also superior to a sham maneuver. Further, more recent support is provided by Foster [42] and Karanjai,[30] who both found in favor of the Epley maneuver compared to the Semont or Brandt-Daroff maneuvers. Similarly, Toledo [20] found the Semont maneuver to be superior to vestibular rehabilitation alone at 15 days, however by three months a combination of Semont and vestibular rehabilitation was superior to either of the sole interventions. The Semont only group had a >30% recurrence rate by this time leading these authors to suggest that vestibular rehabilitation has a preventative role. This result was confirmed more recently by Chang,[18] who compared CRM with vestibular rehabilitation *versus* CRM alone. They reported that the combination promoted greater mobility skills (improved DGI) than the CRM alone. This body of evidence suggests that for people with BPPV

the primary intervention should include maneuvers to actually treat the condition and that this should be supported by vestibular rehabilitation to aid in longer-term functional recovery. The evidence for the effectiveness of maneuvers for BPPV is the subject of other Cochrane reviews.[10, 11]

The majority of studies investigated chronic dizziness of broad UPVD origin and hence attract the general recommendations of this review. More specifically vestibular neuritis was investigated firstly by Strupp,[50] who found postural control measures improved more in a group of patients with vestibular neuritis who performed vestibular rehabilitation (physical therapy and home-based) compared to no specific intervention (other than encouragement to move). More recently Teggi [28] also reported that vestibular rehabilitation significantly reduced anxiety in people with acute neuritis compared to the control group. Scott [15] investigated people with Ménière's Disease but found no difference between applied relaxation training *versus* transcutaneous nerve stimulation on dizziness scores (could not be included in meta-analysis). Yardley [39] also investigated people in a non-acute phase of Ménière's Disease using booklet-based forms of vestibular rehabilitation or symptom management and reported significant effects for subjective improvement in dizziness compared to control.

Follow-up was performed in the majority of studies and confirmed that any positive effects gained lasted for the three, six or 12-month period. This lends further support to the conclusions in favor of the use of vestibular rehabilitation for UPVD, as does the lack of reported adverse events. Studies also reported nil or low to moderate drop-out rates and loss to follow-up, although there was some suggestion that compliance may be an issue in some groups. Yardley [39] reported a strong correlation between adherence and positive outcomes using booklet-based vestibular rehabilitation, and again in 2012 confirmed superior outcomes for this intervention along with findings in favor of cost-effectiveness.[40] These issues warrant further investigation both within future randomized controlled trials and with qualitative methodology to establish individual experiences regarding patient acceptability of vestibular rehabilitation interventions.

Risk of bias was variable and not necessarily related to the age of the study. Randomization was poorly reported; blinding of personnel and participants was also more likely to be a potential source of bias not unexpectedly given the physical nature of the interventions. Selective reporting and incomplete data were unlikely to be a consistent source of bias. Overall the potential for bias was considered low to moderate and therefore tempers the evidence moderately.

Conclusions

There is moderate to strong evidence that vestibular rehabilitation (movement, exercise-based) is a safe and effective approach for unilateral peripheral vestibular disorders. Improvements are reported across a range of outcomes including symptom reduction (dizziness), improved gait and activities of daily living. There is also moderate evidence that there is maintenance of improvements over the following months postintervention.

For the specific diagnosis of BPPV, there is more evidence for the use of repositioning maneuvers in the first instance, with evidence that vestibular rehabilitation should be incorporated in the long term as a preventative measure or to promote functional recovery, or both.

Further research in this field should consider diagnostic groups, sufficient participant numbers, strong randomized controlled trial design and reporting, use of the most common outcome measures and comparative effectiveness of differing techniques and dosages.

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