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The Association Between Physical Activity and Chronic Symptoms After a Unilateral Vestibular Deafferentation: Narrative Review

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ABSTRACT

Objective: Most symptoms following acute unilateral vestibular deafferentation are expected to resolve spontaneously due to central vestibular compensation, yet 29%-66% of unilateral vestibular deafferentation patients develop chronic symptoms. This review investigates the influence of the level of therapeutic physical activity on the outcomes of chronic unilateral vestibular deafferentation patients.

Methods: PubMed, Web of Science, and Scopus were systematically searched on May 5, 2022, for studies investigating the association between physical activity and chronic symptoms in unilateral vestibular deafferentation patients.

Results: Eight studies met the eligibility criteria and were analyzed. Three cross-sectional studies objectified the level of physical activity and revealed a lower level of physical activity in unilateral vestibular deafferentation patients compared to healthy controls. Five interventional studies investigated the effect of a physical activity intervention on dizziness and balance performance. Interventions were categorized as: (1) movement sessions (Tai Chi, Lian Gong, and aquatic physiotherapy) and (2) technology-assisted physical activity using a balance platform. After the intervention, significant improvements were found in perceived health status, dizziness, or balance performance whereby 2 studies showed strong effect sizes. Furthermore, the effects of physical activity interventions were comparable to vestibular rehabilitation.

Conclusion: Unilateral vestibular deafferentation patients show a reduced physical activity level despite, and in contrast to, the advice to remain physically active. Additionally, an association was found between the lack of physical activity and chronic symptoms. Measuring physical activity might be useful to determine patient compliance concerning physical activity prescriptions and thus enable timely intervention and guidance when needed.

Keywords: Acute unilateral vestibular deafferentation, physical activity, chronic symptoms, dizziness, balance

Introduction

An acute unilateral vestibular deafferentation (UVD)—or sudden partial or complete loss of function of either labyrinth and/or vestibular nerve—can lead to dizziness, nausea, unsteadiness, oscillopsia, and cognitive problems.[1-4] Several diseases or medical procedures such as vestibular neuritis, labyrinthitis, a transtympanic gentamicin injection (as a treatment for Menière's disease), resection of a vestibular schwannoma, or a vestibular neurectomy can result in UVD.[2] In case of vestibular neuritis, an annual incidence of 15.5/100 000 individuals was found, with the highest incidence between 50 and 70 years.[5] In 29%-66% of UVD patients, symptoms of chronic dizziness will develop, implying an impaired central vestibular compensation

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in up to two-thirds of these patients.[6-11] This raises the question of which factors are responsible for this variety in the outcome. Unraveling predictive factors might lead to a more customized assessment and treatment and thus prevention of development into chronic symptoms.

Depending on the cause of UVD and accompanying symptoms, anti-inflammatory or anti-vertiginous medication can be prescribed.[12] Besides that, vestibular rehabilitation has been proven to be safe and effective and is therefore recommended after a UVD.[13,14] Physical activity in general is also advised to enhance the process of central vestibular compensation, as it is assumed that substitution, adaptation, and habituation strategies require repetition of movements.[15-17] However, many patients seem to struggle with the type, duration, frequency, and safety of the imposed physical activity. Since head movements may provoke symptoms, being physically active might be more challenging. Furthermore, anxiety, type of personality, and inappropriate sensory reweighting contribute to the development of chronic symptoms.[7,18-23] After a vestibular function loss, a mismatch between the afferent signals of the different sensory input systems (vestibular, visual, and proprioceptive) occurs in the brain leading to symptoms such as vertigo. The brain however is capable to reweigh the input of each system, favoring those sources that the brain considers most reliable, to achieve a new balanced sensory input free from mismatch, which is called sensory reweighting.[24] Nevertheless, an overweighing of visual input takes place in some patients, leading to visual dependency. It is likely that an anxious or visually dependent patient will avoid movements and thus show a decreased physical activity level.[25,26] Considering all the above, the level of physical activity might be related to the development of chronic symptoms. Data on physical activity and its consequence on chronic symptoms after UVD are lacking. Therefore, the purpose of this narrative review is 2-fold: (1) to describe the association between the level of physical activity and chronic symptoms and (2) to provide an overview of the effect of physical activity interventions, apart from vestibular rehabilitation, on chronic symptoms following UVD. This enables to guide further research on the importance and influence of physical activity after UVD.

Methods

A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[27]-compliant search (Supplementary Table 1 and 2) was performed on May 5, 2022, in PubMed, Web of Science, and Scopus based on the combination of free keywords referring to: "Unilateral Vestibular Deafferentation"(P), "Physical Activity," (I) and "Chronic Symptoms" (O). Both acute (<3 months after the onset of complaints) and chronic (≥3 months after the onset of complaints) UVD patients were included. Articles were manually screened (Supplementary Table 3) and were found eligible to include when reporting about the association between level of physical activity in UVD patients with chronic symptoms or the effect of physical activity or physical exercise intervention. Concerning the physical activity interventions, a definition of physical activity was formed and applied to enable a proper screening process. Caspersen et al (1985)[28] defined physical activity as follows:

"Any bodily movement produced by the skeletal muscles that result in energy expenditure."

However, as the scope of this review was physical activity and not vestibular rehabilitation—as safety and effectiveness of vestibular rehabilitation have already been proven before[14]—the definition of physical activity was adapted so that interventions consisting solely of head and eye—movements that are specific to vestibular rehabilitation exercises—[13,14] were excluded. As such, physical activity in this review was defined as:

"Whole body movements performed by the skeletal muscles that result in energy expenditure apart from vestibular rehabilitation."

Furthermore, in case a physical activity intervention was combined with vestibular rehabilitation, it was excluded to truly investigate the effect of physical activity itself. However, studies comparing vestibular rehabilitation with a physical activity intervention were included.

The search term delivered a total of 1234 unique citations. After a thorough and precise screening process according to the selection criteria, 8 studies were deemed eligible (Figure S1). After population (n = 736 during the first screening and n = 4 during the second screening), the most frequently applied reason to exclude was intervention (n = 331 during the first screening, n = 28 during the second screening) as (1) the majority of the clinical trials investigated the effect of vestibular rehabilitation and not a physical activity intervention and (2) little to no observational studies performed a measurement of the level of physical activity (Supplementary Table 3 and Figure S1). To evaluate the risk of bias and level of evidence, the Scottish Intercollegiate Guidelines Network (SIGN) and National Heart, Lung and Blood Institute (NHLBI) checklists corresponding to the study type were used and scored independently by LVL and NH (Supplementary Tables 4-6).[29-33] All available data on patient characteristics, interventions, means, and standard deviations of relevant outcome parameters and statistical tests were extracted (Supplementary Tables 7-11). Effect sizes (Cohen's *d*) and 95% CIs were calculated.[34,35] Effect sizes were considered to represent a strong difference between groups or a strong effect after intervention if the point estimate of Cohen's *d* exceeded 0.8 and if the 95% CI did not include 0.[34,35] Correlation coefficients between physical activity and outcome variables were categorized as negligible (r = 0-0.09), weak (0.1-0.39), moderate (0.4-0.69), strong (0.7-0.89), or very strong (>0.90).[36] Due to limited and heterogeneous outcomes (Supplementary Table 12), results are discussed in a narrative way.

Main Points

- Unilateral vestibular deafferentation (UVD) patients show reduced physical activity levels compared to healthy controls.
- Associations were found between the level of physical activity and chronic symptoms.
- More research is needed in which the level of physical activity is objectified in patients after UVD.
- Measuring physical activity is necessary to determine patient compliance with physical activity prescriptions and to intervene timely if necessary.

Results

Study Characteristics

Eight included studies report data on a total of 434 adults (167 men (38%) and 267 women (62%)) with sample sizes ranging between 21[37] and 106[38] and ages between 20[37] and 84 years[39]. Three studies objectified the level of physical activity in UVD patients[38,43,44] and 5 interventional studies investigated the effect of a physical activity intervention in UVD patients.[37,39,40-42] Different terminologies were used to describe UVD patients: (unilateral) peripheral dizziness,[40,41] unilateral/peripheral vestibular hypofunction,[37,38,42-44] and acute vestibular neuritis[39] (Supplementary Table 7). The 3 cross-sectional studies aimed at objectifying physical activity during everyday life through a wrist-worn device,[38] an accelerometer,[44] and a questionnaire.[43] The 5 interventional studies attempted to achieve an increase in physical activity through assigned interventions and compared outcome measures before and after the intervention.[37,39-42]

Level of Physical Activity in Unilateral Vestibular Deafferentation Patients

The included patients in the 3 cross-sectional studies were diagnosed with a (unilateral)[38,44] peripheral vestibular hypofunction[43] with an average duration of complaints of 16.3,[38] 18.1,[43] and 24 months[44] and were 42.4 (±12.6),[43] 51.7 (±9.3),[38] and 63.5 (±15.5)[44] years old, respectively. A lower amount of physical activity,[43,44] daily energy expenditure (both during rest and movement),[38] upright hours/day,[38] number of strides/day,[38] and covered distance/day[38] and a significantly higher amount of sedentary behavior[44] were found in UVD patients compared to healthy controls (Figure 1). All 3 studies investigated the correlation between physical activity and dizziness, balance, or vestibular function outcome measures (Figure 2).

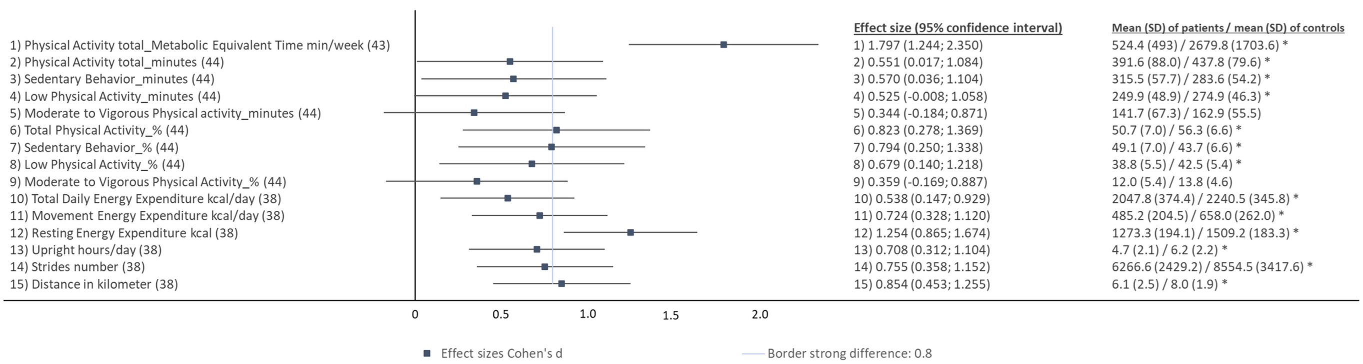

Figure 1. Comparison of the level of physical activity between UVD patients and healthy controls. Min = minutes, *Significant result. The exact values per group can be found on the right. Effect sizes were considered to represent a strong difference between groups if the point estimate of Cohen's *d* exceeded 0.8 and if the 95% CI did not include 0.[33,34] UVD, unilateral vestibular deafferentation.

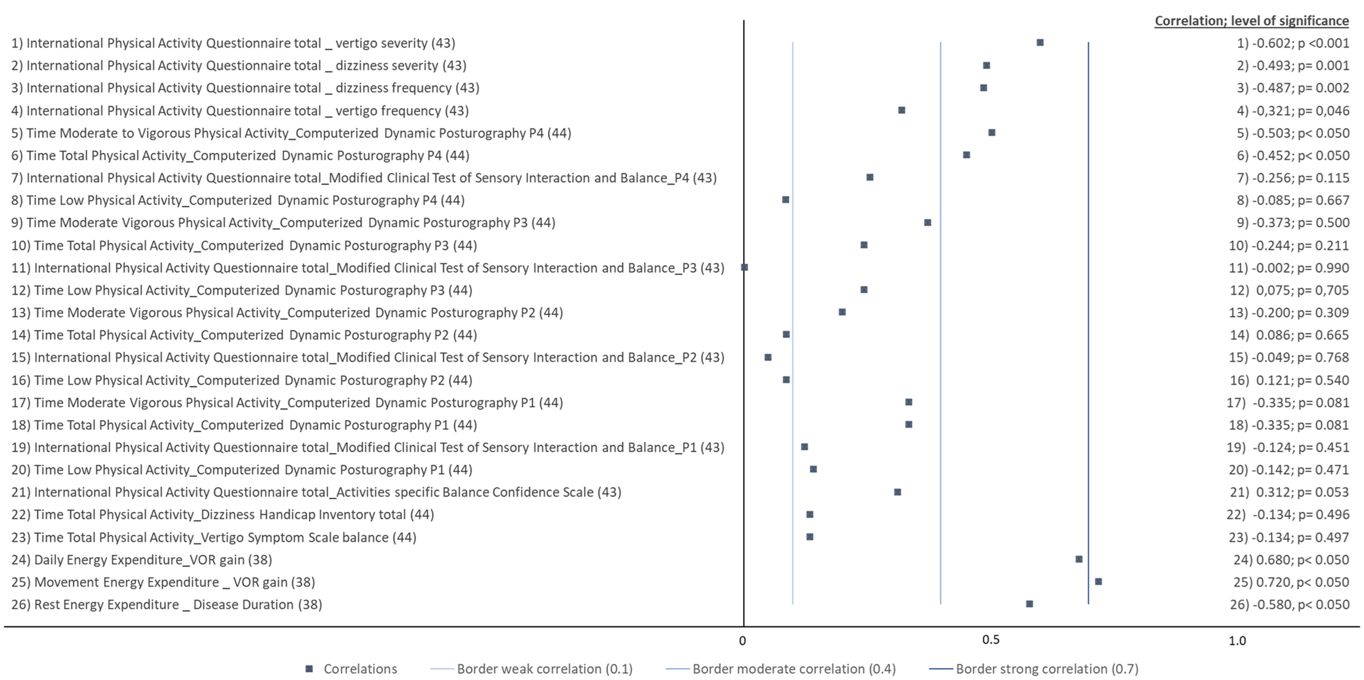

Figure 2. Correlation analysis between the level of physical activity and a dizziness, balance, or vestibular function outcome. P1/2/3/4 = Position 1/2/3/4. The exact correlation coefficient with level of significance can be found on the right. All correlations are presented as absolute values, but please note the right label to see whether the correlation is negative or positive. The coefficients were categorized as negligible (*r* = 0-0.09), weak (0.1-0.39), moderate (0.4-0.69), strong (0.7-0.89), or very strong (>0.90).[35]

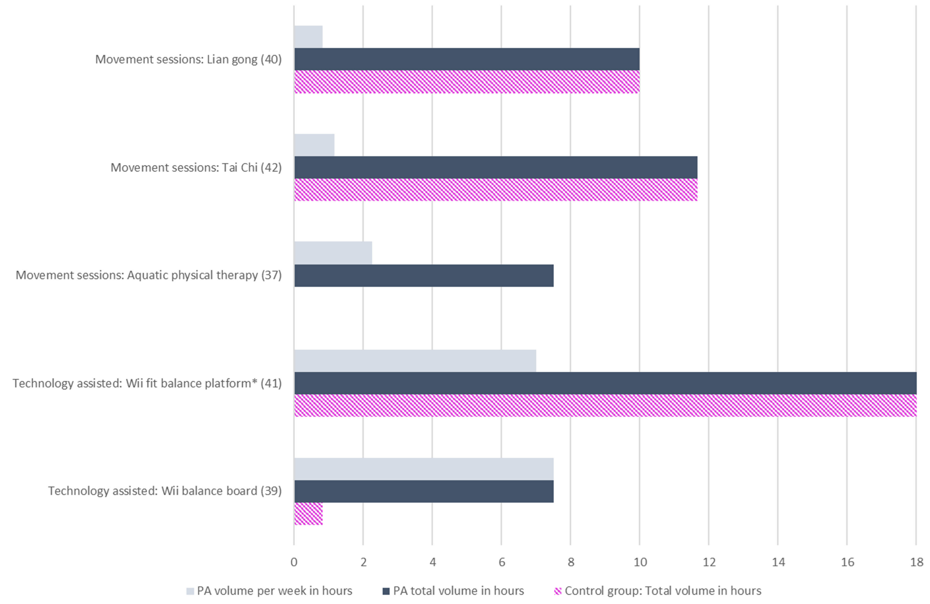

Figure 3. Movement volume of the physical activity interventions and control groups. PA = physical activity, *Total volume exceeds the figure: for both groups, the total volume equaled 112 hours.

The total level of physical activity correlated (1) moderately negative with vertigo severity,[43] dizziness severity,[43] dizziness frequency,[43] and postural sway when standing on foam with eyes closed[44] and (2) weakly negative with vertigo frequency,[43] Dizziness Handicap Inventory (DHI),[44] Vertigo Symptom Scale,[44] the Activities-Specific Balance Confidence Scale,[43] and following static balance tasks: standing on a firm surface with eyes open,[43,44] standing on foam with eyes open,[43] and standing on foam with eyes closed.[43] Moderate to strong correlations were found between total daily energy expenditure and vestibulo ocular reflex (VOR) gain (moderately positive), movement energy expenditure and VOR gain (strongly positive), and resting energy expenditure and disease duration (moderately negative).[38]

Effect of Physical Activity Interventions

Physical activity interventions were divided into 2 subtypes to present the results: movement sessions[37,40,42] and technology-assisted physical activity.[39,41] Four physical activity interventions were compared to a vestibular rehabilitation[40-42] or a control group with an intervention of lower movement volume[39] or no treatment at all[40] (Figure 3 and Supplementary Table 8).

Movement Sessions

Three studies examined the effect of movement sessions which included an aquatic physical therapy intervention[37] or a physical activity group session: Lian Gong therapy[40] and Tai Chi.[42] Aquatic physical therapy consisted of postural transfer exercises, going up and down the stairs, or performing knee flexions with maximum turbulence.[37] Tai Chi and Lian Gong mainly involve slow and continuous movements linked to breathing.[40,42] Sessions were organized 1[42,44] to 3[37] times a week and lasted for 45,[37] 50,[40] and 70[42] minutes per session. The population consisted of chronic patients with dizziness of peripheral origin (average age of 63 ± 5.17)[40] or vestibular hypofunction[37,42] (with age ranging between 20 and 63 years[37] and an average age of 61.7 ± 11.3 years[42]). Lian Gong and Tai Chi interventions were compared to vestibular rehabilitation which included ocular fixation, balance, and eye and head coordination exercises.[40,42] Only the study of Lopes et al (2019)[40] included a third group which did not receive any additional treatment.

Improvements in perceived health status (Short Form Health Survey-36, SF-36),[40] perceived disability (DHI),[37] dizziness (Visual Analogue Scale, VAS),[37] postural sway (mean stability index, antero/posterior stability index, and medio/lateral stability index), and gait (speed and step length)[42] were observed. However, effect sizes were only strong for VAS dizziness and DHI after the aquatic physical therapy intervention[37] (Figure 4). Lian Gong and Tai Chi did not result in strong effect sizes. When comparing Lian Gong to vestibular rehabilitation, significantly larger improvements favoring Liang Gong were found for 2 subdomains of the SF-36 (General Health Status, Pain).[40] No other significant differences were found between the physical activity interventions and vestibular rehabilitation (Figure 4 and Supplementary Table 10).[40,42] When compared to a control group, without intervention, Lian Gong revealed significantly higher improvements in favor of Lian Gong concerning 3 subdomains of the SF-36 (general health status, functional capacity, and limitation by physical aspects)[40] (Figure 4).

Technology Assisted

Two randomized controlled trials investigated the effect of physical activity using a Wii-fit-balance board. Therefore, the interventions were referred to as technology-assisted physical activity (Supplementary Table 8).[39,41] The interventions were compared to vestibular rehabilitation[41] or a control group with an intervention of a much lower movement volume.[39] Both acute[39] and chronic (average time since onset of 9 months)[41] patients were studied with acute vestibular neuritis[39] and unilateral peripheral dizziness.[41] The average age of the patients was 40 ± 3[39] and 48 ± 15[41] years old. The training consisted of either 9 balance games with total body movement[41] or 15 customized exercises (e.g., jogging, muscle workouts, and

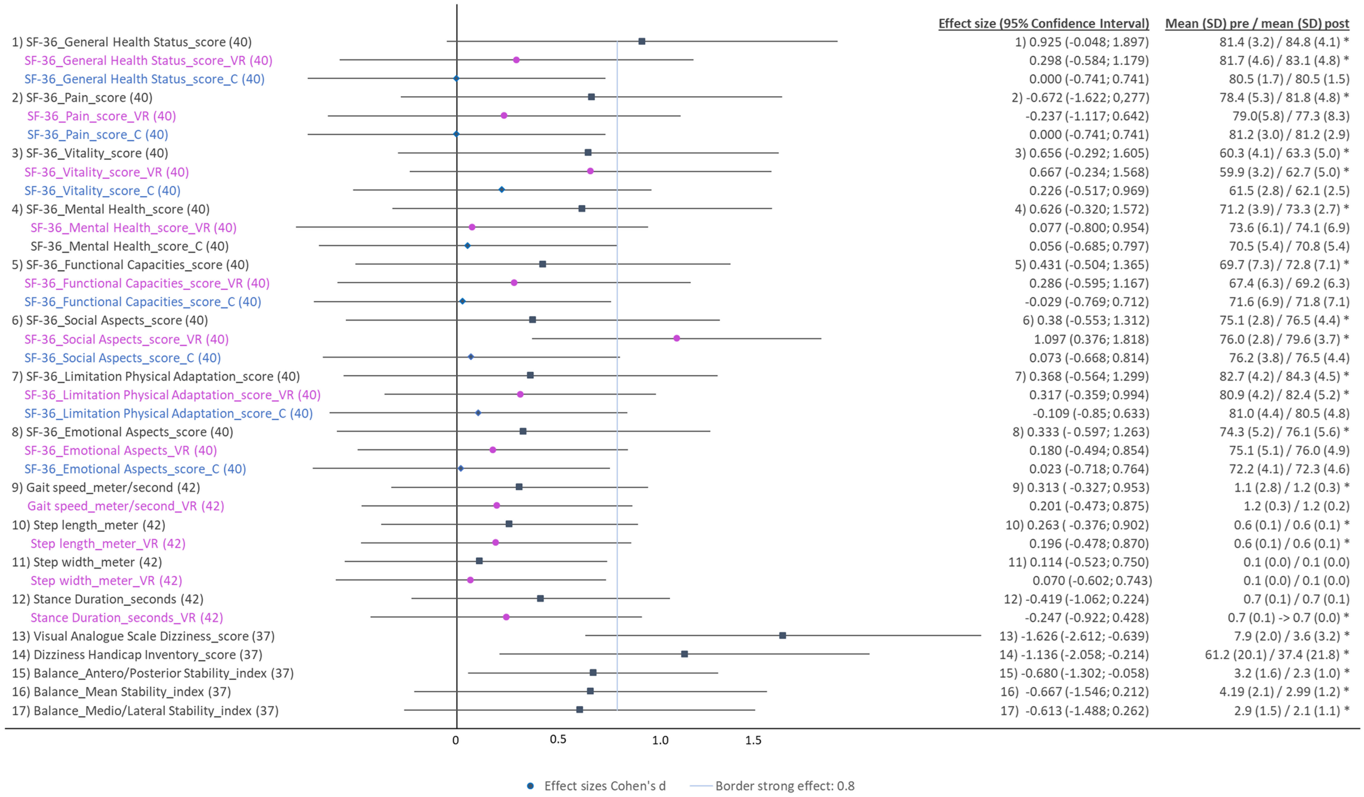

Figure 4. Effect sizes (Cohen's *d*) concerning outcomes related to movement session interventions. Square = physical activity, circle = vestibular rehabilitation, diamond = control, SF-36 = Short-Form Health Survey, VR = vestibular rehabilitation, C = control, *Significant result. In case an effect size was negative but equal to a favorable result, it was visualized as a positive effect size (e.g., lower score on the DHI means less-perceived handicap). The exact positive or negative effect size is presented as well. The exact pre- and post-values per outcome measure can be found on the right. Effect sizes were considered to represent a strong effect if the point estimate of Cohen's d exceeded 0.8 and if the 95% CI did not include 0.[33,34] DHI, Dizziness Handicap Inventory.

hula-hoop)[39] with a maximum total volume of respectively 112 hours (over a maximum of 16 weeks)[41] and 7.5 hours (over 1 week).[39] The vestibular rehabilitation consisted of an introductory session followed by home exercises, carried out twice a day for 30 minutes for a maximum of 16 weeks.[41] The control group of the customized exercise study performed only 2 out of 15 customized exercises and had a total movement volume of 50 minutes.[39]

Technology-assisted physical activity led to significant improvements on the DHI,[39,41] Fall Efficacy Scale,[39] Sensory Organization Test,[39] Vertigo Symptom Scale,[39] and Physical component of the SF-36.[42] Strong effect sizes were found after the 9 balance games[41] intervention concerning DHI and SF-36 physical component score (Figure 5). The exact pre- and post-values of the customized exercises-study[39] were not reported, and therefore, effect sizes could not be calculated.

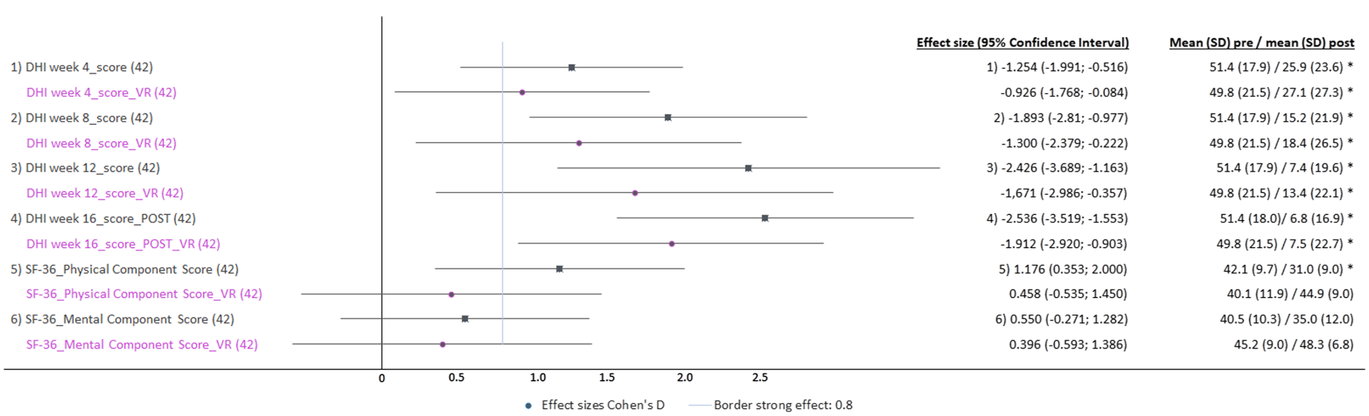

Figure 5. Effect sizes (Cohen's *d*) concerning outcomes related to technology-assisted physical activity interventions. Square = physical activity, circle = vestibular rehabilitation, VR = vestibular rehabilitation, DHI = Dizziness Handicap Inventory, POST = post-intervention (=16 weeks), *A negative effect size, +Significant result. In case an effect size was negative but equal to a favorable result (e.g., lower score on the DHI means less perceived handicap), it was visualized as a positive effect size. The exact positive or negative effect size is presented as well. The exact pre- and post-values per outcome measure can be found on the right. Effect sizes were considered to represent a strong effect if the point estimate of Cohen's *d* exceeded 0.8 and if the 95% CI did not include 0.[33,34] DHI, Dizziness Handicap Inventory.

Compared to a vestibular rehabilitation group, no significant differences were found in outcome after the balance games intervention.[41] Compared to a control group with lower movement volume, significantly higher improvements were found in both balance and dizziness outcomes after the customized exercises intervention.[39]

Discussion

Level of Physical Activity in Unilateral Vestibular Deafferentation Patients

After experiencing an acute UVD, central vestibular compensation will normally lead to resolution of most symptoms in both standing and moving conditions.[2,15,45] Static symptoms and signs resolve spontaneously within days to weeks after the acute event; however, dynamic deficits remain longer and require an active and long-term input stimulating brain plasticity.[15,46] Besides vestibular rehabilitation, general physical activity is necessary to encourage adaptation (e.g., return to initial function of VOR gain), habituation (lower response due to repeated exposure), and substitution (relying more on other sensory input sources) processes.[16,17] Current results revealed a lower level of physical activity in chronic UVD patients compared to healthy controls, implying that UVD patients might not have been sufficiently physically active since their UVD, leading to long-term dynamic deficits. Therefore, a vicious circle might originate: chronic symptoms provoked by (head) movements lead to increased avoidance of these movements, thus resulting in a lower physical activity level and as consequence, an inadequate input to instigate compensation for these dynamic symptoms. The negative moderate correlation ($r=-0.580$) found between disease duration and lower resting energy expenditure might even suggest that this process is worsening over time.[38] Moreover, dizziness, balance performance, and vestibular function showed a moderate negative correlation to physical activity, which emphasizes the importance of physical activity after UVD. However, these associations should be interpreted with caution as the correlation coefficients were moderate and not strong. Furthermore, 1 of the 3 cross-sectional studies did not mention a normality check in their description of the statistical analysis and reported Pearson correlation coefficients[40] whereas the other 2 did perform a normality check and reported Spearman correlation coefficients.[38,43] Nevertheless, the results of the 3 studies were similar and were confirmed by Kamo et al (2021)[47] reporting associations between higher perceived handicap due to dizziness and lower physical activity levels in patients with dizziness. Most of the included patients, however, consisted of other pathologies than UVD, and therefore, this study was not included in this review. In summary, further research in which the level of physical activity is objectified in a standardized way in UVD patients is needed, to confirm current results and to provide recommendations concerning the assessment of the level of physical activity and appropriate guidance in increasing the level of physical activity in UVD patients.

Physical Activity Interventions

Although physical activity interventions led to significant improvements in most outcome measures, only 2 (aquatic physical therapy and technology-assisted physical activity[37,41]) out of 5 interventions showed strong effect sizes concerning perceived disability (DHI),[37,41] perceived physical health status (SF-36 physical component score),[41] and dizziness (VAS).[37] In addition to strong effect sizes, the minimal detectable important difference was reached for DHI (decrease of >18 points)[48] and SF-36 physical component score (increase of >8 points)[49] after aquatic exercises or technology-assisted physical activity. However, it should be considered that for 1 study,[39] effect sizes were not calculated (due to absence of exact pre- and post-intervention values) and that the sample sizes of the Tai Chi[42] and Lian Gong[40] study were possibly too small to reach clinical significance. Furthermore, disease-related factors possibly influenced the results, for example the degree of vestibular function loss, origin, or type of UVD (sudden vs. progressive; inflammatory vs. medically induced) and time lag between onset and intervention (acute vs. chronic patients).[47] Although 2 interventional studies specify the inclusion criteria for the vestibular asymmetry of the UVD (>25%[37] and >30%[42]), none of them report data on the degree of function loss of the included patients. Hence, the amount of vestibular function loss was not taken into account in the analyses. The latter 2 factors—origin or type of UVD and time lag between onset and intervention—were heterogeneous in the included interventional studies. Concerning type of UVD, different terminologies were used to describe the included patients, revealing different types of origin of the UVD, for example peripheral dizziness (rather general, describing a symptom) versus vestibular schwannoma resection or vestibular neuritis (more specific, describing etiology). Time lag since onset and intervention differed as well, for example only 1 study[39] investigated an acute vestibular neuritis group in which the physical activity intervention (15 customized exercises) led to significantly better improvements on all outcome measures (DHI, Sensory Organization Test, Vertigo Symptom Scale, and Fall Efficacy Scale) compared to a control group only performing 2 out of 15 exercises. The importance of starting an intervention during the early stage has also been confirmed previously.[46,50,51] Therefore, physical activity interventions performed in patients already in the chronic stage possibly did not benefit from the most crucial period to optimize brain plasticity.[16]

Furthermore, in 2 studies, the population consisted of unilateral and bilateral vestibulopathies,[42,43] and in 1 study, it was not clearly mentioned whether only unilateral or both unilateral and bilateral vestibulopathies were included.[40] Including bilateral vestibulopathies in addition to UVD may adversely affect outcome. For example, the study of McGibbon et al (2005)[42] included both unilateral (58%) and bilateral vestibulopathies (42%) in the physical activity intervention group. A worse balance performance in bilateral compared to unilateral vestibulopathies was described before.[52] Therefore, inclusion of bilateral vestibulopathies possibly led to a less favorable outcome following physical activity interventions.

Additionally, only 1 intervention was compared to a control group without treatment,[40] raising the concern that not the intervention itself but rather the natural course following a UVD contributed to the improvements. Moreover, movement volume and intensity of the interventions largely differed between the studies and were possibly too limited to be considered as a higher level physical activity, which might explain the limited improvements. More research is needed to gain insight into the amount of movement volume necessary to result in clinically relevant changes concerning dizziness and balance outcomes. Considering the present limitations, it is difficult to draw a clear conclusion about the effect of physical activity interventions on chronic symptoms.

A general limitation present in all the included studies is the fact that the effect of age was not taken into account. Although a wide age range was present, the studies combined data from different age groups, probably due to the small sample sizes. However, it is known that with increasing age, levels of physical activity tend to reduce.[53] Therefore, in further research, we recommend larger sample sizes enabling stratification of the age groups to investigate whether the possible effect of levels of physical activity on the development of chronic symptoms differs between age groups.

When comparing physical activity interventions to vestibular rehabilitation in chronic UVD patients, only 1[40] out of 3 studies[40-42] found few significant differences favoring physical activity which were related to perceived health status and pain. Therefore, physical activity interventions and vestibular rehabilitation may have a similar impact on UVD patients. However, due to the paucity and heterogeneity of reported data within the included studies, results should be interpreted cautiously. Additionally, it remains difficult to distinguish physical activity interventions from vestibular rehabilitation as the latter can consist of numerous types of exercises. Although vestibular rehabilitation has already been thoroughly investigated and proven to be safe and effective,[13,14] a Cochrane review concerning the effect of vestibular rehabilitation in UVD patients concluded that no specific form of vestibular rehabilitation is superior to another and as consequence, no decisive advice could be formulated concerning specific content, duration, frequency, or intensity of vestibular rehabilitation.[14] Further research in which physical activity interventions are more clearly separated from vestibular rehabilitation or in which vestibular rehabilitation includes objective measurements of head and body movements might lead to the interesting debate questioning whether vestibular rehabilitation is superior to other sorts of physical activity interventions. If not, physical activity interventions might be of lower cost to society compared to vestibular rehabilitation. When holding this debate, several factors known to influence the effect of vestibular rehabilitation—such as age, presence of psychological factors, and amount of vestibular function loss[46]—should be considered. For example, older UVD patients (>50 years) seem to benefit more from vestibular rehabilitation compared to patients under 50.[51] Younger patients tend to pick up their daily activities, both work and leisure, more easily and are therefore in general more physically active. Furthermore, vestibular rehabilitation plays an important role in activating patients as was studied by Shiozaki et al (2021).[54] The authors related intensive and long-term physical therapy to a higher amount of light physical activity in chronic peripheral vestibular disorders. Additionally, vestibular rehabilitation allows a more individualized approach[13] and reduces the risk of the patient being overwhelmed by a general exercise program. Summarized, vestibular rehabilitation might therefore have a bigger impact on older patients, whereas younger patients might already benefit from alternative and less-expensive physical activity interventions. However, research in which physical activity interventions are clearly separated from vestibular rehabilitation is currently lacking and therefore recommended. Only after conducting such research, an appropriate comparison can be made between physical activity interventions and vestibular rehabilitation.

Conclusion

The level of physical activity is lower in chronic UVD patients compared to healthy controls. This reveals a long-term maladaptive strategy concerning physical activity and is in contrast with the fact that they are advised to remain physically active. This could imply that measuring physical activity is necessary to determine patient compliance with physical activity prescriptions, so that, if necessary, timely guidance or intervention is possible to ensure the required exercise volume.

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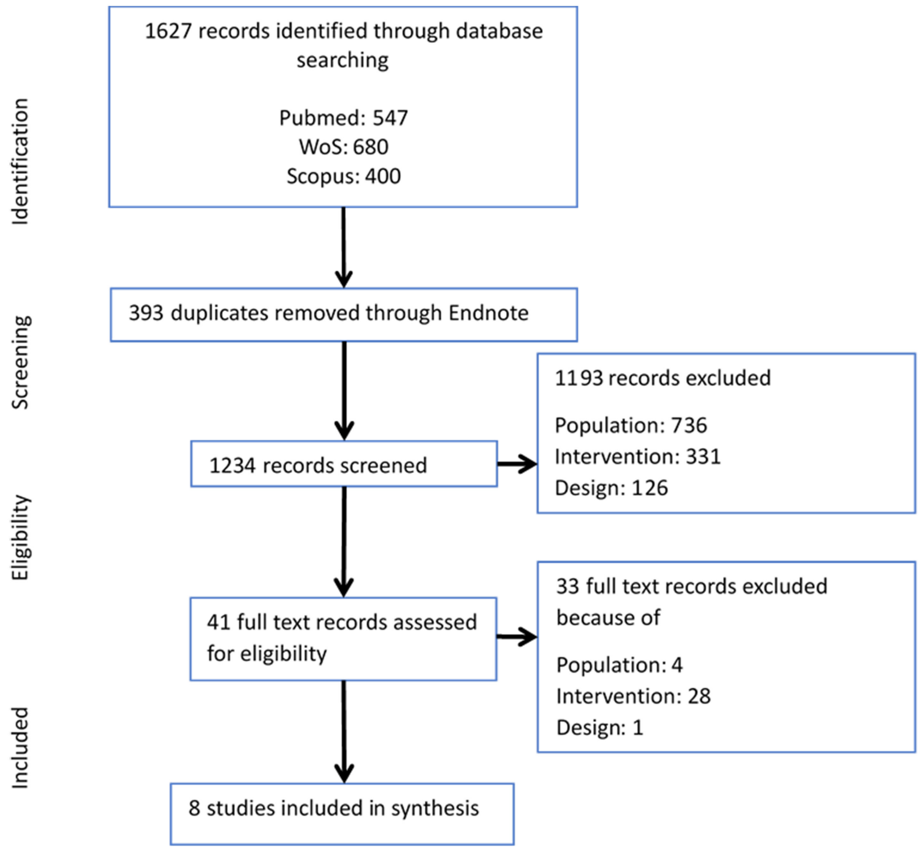

Figure S1. Flow chart study selection.

Supplementary Table 1. PIO-strategy

Population		Intervention		Outcome
OR Vestibular neuritis		**OR** Physical fitness		**OR** Chronic dizziness
Vestibulopathy		Exercise		Chronic vertigo
Vestibular neuropathy		Exercise Test		Chronic subjective dizziness
Vestibular hypofunction		Motor Activity		Persistent perceptual postural dizziness
Vestibular dysfunction		Fitness trackers		Phobic postural vertigo
Vestibular diseases		Accelerometry		Visual induced vertigo
Labyrinthitis	**AND**	Locomotion	**AND**	Dizziness
Labyrinthectomy		Physical Performance Functional		Vertigo
Vestibular neurectomy		Physical activity level		Terms referring to chronicity: • Chronic • Persistent • Enduring • Permanent • Compensation • Adaptation • Recurrent
Selective vestibular neurectomy		Physical Education and Training		
Neuroma, acoustic		Physical training		
Vestibular schwannoma		Activity level		
		Movement Analysis		
		Physical activity measurement/ questionnaire		

Building the search-term based on different keywords and MeSH-terms through the PI(C)O-strategy

Supplementary Table 2. Search Strings in Different Databases
Pubmed
("Vestibular neuronitis"[Mesh] OR Vestibular neur OR "Vestibular neuropathy" OR "Neurolabyrinthitis" OR "Vestibular hypofunction" OR "Vestibular dysfunction" OR "Vestibular schwannoma" OR "Neuroma, Acoustic"[Mesh] OR "Vestibulopathy" OR "Labyrinthitis"[Mesh] OR "Labyrinthectomy" OR "Vestibular neurectomy" OR "Selective vestibular neurectomy" OR "Vestibular diseases"[Mesh]) AND ("Physical fitness"[Mesh] OR "Exercise"[Mesh] OR "Exercise Test"[Mesh] OR "Motor Activity"[Mesh] OR "Fitness Trackers"[Mesh] OR "Accelerometry"[Mesh] OR "Locomotion"[Mesh] OR "Physical Functional Performance" OR "Physical activity level" OR "Physical Education and Training"[Mesh] OR "physical training" OR "activity level" OR "movement analysis" OR ("physical activity" AND ("measurement" OR "questionnaire"))) AND ("chronic dizziness" OR "chronic vertigo" OR "chronic subjective dizziness" OR "persistent postural perceptual dizziness" OR "phobic postural vertigo" OR "visual induced vertigo" OR "dizziness" OR "vertigo" OR "chronic" OR "persistent" OR "enduring" OR "permanent" OR "compensation" OR "adaptation" OR "recurrent")*
Web of Science
TS=((("Vestibular neuronitis" OR Vestibular neur OR "Vestibular neuropathy" OR "Neurolabyrinthitis" OR "Vestibular hypofunction" OR "Vestibular dysfunction" OR "Vestibular schwannoma" OR "Neuroma, Acoustic" OR "Vestibulopathy" OR "Labyrinthitis" OR "Labyrinthectomy" OR "Vestibular neurectomy" OR "Selective vestibular neurectomy" OR "Vestibular diseases") AND ("Physical fitness" OR "Exercise" OR "Exercise Test" OR "Motor Activity" OR "Fitness Trackers" OR "Accelerometry" OR "Locomotion" OR "Physical Functional Performance" OR "Physical activity level" OR "Physical Education and Training" OR "physical training" OR "activity level" OR "movement analysis" OR ("physical activity" AND ("measurement" OR "questionnaire"))) AND ("chronic dizziness" OR "chronic vertigo" OR "chronic subjective dizziness" OR "persistent postural perceptual dizziness" OR "phobic postural vertigo" OR "visual induced vertigo" OR "dizziness" OR "vertigo" OR "chronic" OR "persistent" OR "enduring" OR "permanent" OR "compensation" OR "adaptation" OR "recurrent")))*
Scopus
TITLE-ABS-KEY (("Vestibular neuritis" OR "Vestibular neuropathy" OR "Neurolabyrinthitis" OR "Vestibular hypofunction" OR "Vestibular dysfunction" OR "Vestibular schwannoma" OR "Neuroma Acoustic" OR "Vestibulopathy" OR "Labyrinthitis" OR "Labyrinthectomy" OR "Vestibular neurectomy" OR "Selective vestibular neurectomy" OR "Vestibular diseases") AND ("Physical fitness" OR "Exercise" OR "Exercise Test" OR "Motor Activity" OR "FitnessTrackers" OR "Accelerometry" OR "Locomotion" OR "Physical Functional Performance" OR "Physical activity level" OR "Physical Education and Training" OR "physical training" OR "activity level" OR "movement analysis" OR ("physical activity" AND ("measurement" OR "questionnaire"))) AND ("chronic dizziness" OR "chronic vertigo" OR "chronic subjective dizziness" OR "persistent postural perceptual dizziness" OR "phobic postural vertigo" OR "visual induced vertigo" OR "dizziness" OR "vertigo" OR "chronic" OR "persistent" OR "enduring" OR "permanent" OR "compensation" OR "adaptation" OR "recurrent")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT- TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "French") OR LIMIT-TO (LANGUAGE , "German"))
Search term in Pubmed, Web of Science and Scopus (05/05/2022)

Supplementary Table 3. In- and Exclusion Criteria

	Inclusion criteria	Exclusion criteria
Population	Acute (< three months) or chronic (≥ three months UVD • Neuronitis vestibularis • Labyrinthitis • Labyrinthectomy • Selective vestibular neurectomy • Gentamicin injection • Resection vestibular schwannoma • Majority (> 50%) of patient group consists of UVD with acute onset • Men and women • Age 18 + • Comorbid hearing loss	Other • Healthy subjects • Central vestibulopathies • Bilateral vestibulopathies • Specific episodic unilateral vestibular syndromes (BPPV / Menière)
Intervention	Physical activity level of intervention • Accelerometers • Pedometers • Smartphone technology • Watches • Heart rate monitors • Self-reported measurements • Questionnaires • Assigned tasks of PA	Other • Vestibular rehabilitation usual care such as gaze stability exercises or Cawthorne & Cooksey
Outcome	Chronic complaints (dizziness/balance/other) • Vestibular function measurements • Dizziness Handicap Inventory • Vertigo Handicap Questionnaire • Vertigo Symptom Scale • Visual vertigo Analog Scale Questionnaire concerning effects of dizziness • Vestibular Disorders Activities of Daily Living • Vestibular Activities and Participation Questionnaire • Posturographic and other balance measurements • Self-perceived health status	Other
Study design	• RCT • Cohort • Case control • Case report	• Systematic review • Meta-analysis
Language	• English • Dutch • French • German	Other

Supplementary Table 4. Risk of Bias and Level of Evidence, Scottish Intercollegiate Guidelines Network [30]

	Lopes (2019)[40]	McGibbon (2005)[42]	Philips (2018)[41]	Sparrer (2013)[39]	Morimoto (2019)[44]	Aypadin (2020)[43]	Alessandrini (2021)[38]
Study Design	RCT	RCT	RCT	RCT	CS	CS	CS
1.1 The study addresses an appropriate and clearly focused question.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1.2 The assignment of subjects to treatment groups is randomized.	Yes	Yes	Yes	Yes	/	/	/
1.3 An adequate concealment method is used.	Yes	?	Yes	?	/	/	/
1.4 The design keeps subjects and investigators 'blind' about treatment allocation.	No	?	No	No	/	/	/
1.5 The treatment and control groups are similar at the starts of the trial.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1.6 The only difference between groups is the treatment under investigation.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1.7 All relevant outcomes are measured in a standard, valid and reliable way.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1.8 What percentage of the individuals or clusters recruited into each treatment arm of the study dropped out before the study was completed?	<20%	>20%	>20%	>20%	<20%	<20%	<20%
1.9 All the subjects are analyzed in the groups to which they were randomly allocated.	Yes	Yes	Yes	Yes	/	/	/
1.10 Where the study is carried at more than one site, results are comparable for all sites.	NA	NA	NA	NA	NA	NA	NA
Score	9/10	7/10	8/10	7/10	6/10	6/10	6/10
2.1 Risk Of Bias	HQ	A	HQ	A	A	A	A
Level of Evidence	B	B	B	B	B	B	B

RCT= Randomized Controlled Trial, CS= Cross Sectional study, ?= answer unknown, NA= Not Applicable, HQ= High Quality, A= Acceptable Quality, B= Level of Evidence B

Supplementary Table 5. Risk of Bias and Level of Evidence, National Heart, Lung and Blood Institute [31]

	Gabilan (2008)37
Study Design	Uncontrolled clinical Trial
1. Was the study question or objective clearly stated?	Yes
2. Were eligibility/selection criteria for the study population prespecified and clearly described?	Yes
3. Were the participants in the study representative of those who would be eligible for the test/service/intervention in the general or clinical population of interest?	Yes
4. Were all eligible participants that met the prespecified entry criteria enrolled?	Yes
5. Was the sample size sufficiently large to provide confidence in the findings?	No
6. Was the test/service/intervention clearly described and delivered consistently across the study population?	Y
7. Were the outcome measures prespecified, clearly defined, valid, reliable, and assessed consistently across all study participants?	Yes
8. Were the people assessing the outcomes blinded to the participants' exposures/interventions?	Not Applicable
9. Was the loss to follow-up after baseline 20% or less? Were those lost to follow-up accounted for in the analysis?	Yes
10. Did the statistical methods examine changes in outcome measures from before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes?	Yes
11. Were outcome measures of interest taken multiple times before the intervention and multiple times after the intervention (i.e., did they use an interrupted time-series design)?	No
12. If the intervention was conducted at a group level (e.g., a whole hospital, a community, etc.) did the statistical analysis take into account the use of individual-level data to determine effects at the group level?	Not Applicable
Score	10/12
Risk of Bias	Good
Level of Evidence	B

Supplementary Table 6. Level of Evidence, Evidence Guideline Development Platform (EBRO platform) [32,33]

Level of evidence	Interventional studies	Diagnostic accuracy studies	Harm, side effects, etiology and prognosis
Level A1	Systematic review/meta-analysis of at least two independently conducted studies of A2 level		
Level A2	Randomized, double blind trial with good study quality and an adequate number of study participants	*Index test compared to reference test (reference standard); cut-offs were defined a priori; independent interpretation of test results; an adequate number of consecutive patients were enrolled; all patients received both tests*	*Prospective cohort study of sufficient magnitude and follow-up, adequately controlled for 'confounding' and no selective follow-up*
Level B	Clinical trial, but without all the features mentioned for level A2 (including case-control study, cohort study)	*Index test compared to reference test, but without all the features mentioned for level A2*	*Prospective cohort study, but without all the features mentioned for level A2 or retrospective cohort study or case-control study*
Level C	Non-comparative studies		
Level D	Expert opinion		

Supplementary Table 7. Data Extraction: Population Characteristics

Study	Population characteristics									
	Age (x ± SD))	Sex (M/F)	Diagnosis		TSO	Height	Weight	BMI	Number after DO	DO
Lopes et al, 2019 [40]	63 ± 5.17	4/29	Peripheral dizziness	Not further specified	Not specified		Not mentioned		33	3
McGibbon et al, 2005 [42]	59.5 ± 11.5 (I1)	16/20	Vestibular hypofunction	11 unilateral	3.05 y (range 0.58-12y)	1.71 ± 0.11 (m)	85.8 ± 13.6 (kg)	29.3423	36	17
				8 bilateral						
	61.7 ± 11.3 (I2)			12 unilateral		1.69 ± 0.11 (m)	81.1 ± 19.3 (kg)	28.3953		
				5 bilateral						
Phillips et al, 2018 [41]	48 ± 15 (I1)	7/14 (I1)	Unilateral peripheral dizziness	Not further specified	9 m, 7.36-30.34 (mean, IQR) (I1)		Not mentioned		40	19
	47 ± 16 (I2)	8/11 (I2)			10.15m, 5.19-25.23 (mean, IQR) (I2)					
Sparrer et al, 2012 [39]	40 ± 3 (I1)	16/21 (I1) (no	Acute vestibular neuritis	Not further specified	24h after hospital admission		Not mentioned		71	20
		information after DO)							(67	
	47 ± 4 (I2)	11/23(I2) (no							mentioned after DO)	
		information after drop- out)								
Gabilan et al, 2008 [37]	range 20-63 (mean and SD not specified)	3/18	Unilateral vestibular hypofunction	Vestibular neuritis (2)	<1y - >20y (range)		Not mentioned		21	/
				Labyrinthitis (4)						
				Schwannoma resection (2)						
				Menière (7)						
				Vascular inner ear disease (5)						
				Unknown cause (1)						
Alessandrini et al, 2021 [38]	51.7 ± 7.3	27/19	Unilateral vestibular hypofunction	Not further specified	16.3 ± 7m	169 ± 13 (cm)	71 ± 12.2 (kg)	24,6 ± 2	46	5
	53.1 ± 8.9	34/26	Healthy subjects	/	/	170 ± 11 (cm)	70.7 ± 11,5 (kg)	24.1 ± 2	60	/
Apaydin et al, 2020 [43]	42.36 ± 12.56 (PG)	10/29	Peripheral vestibular hypofunction	33 unilateral PVH (11	24m, 5-36m (mean, IQR)	163.69 ± 9.11 (cm)	72.05 ± 14.05 (kg)	26.99 ± 5.31	39	5
				BPPV), 6 bilateral PVH (3 BPPV)						
	38.96±10.29 (HG)	9/23	Healthy group	/	/	166.06 ± 7.92 (cm)	68.19 ± 15.15 (kg)	24.61 ± 4.54	32	0
Morimoto et al, 2019 [44]	63.5 ± 15.5 (PG)	12/16	Unilateral vestibular hypopfunction	Not futher specified	18.1m +/- 14.6m	157.9 ± 7.8 (cm)	54.9 ± 9.1 (kg)	22.1 ± 3.5	28	/
	65.0 ± 13.4 (HG)	10/18	Community dwelling Healthy group	/	/	158.6 ± 8.3 (cm)	55.5 ± 8.2 (kg)	22.0 ± 2.7	28	/

X= mean, SD= Standard Deviation, M= male, F= female, TSO= Time since onset, DO= Drop Out, y= year, m= meter, cm= centimeter, kg= kilogram, IQR= Inter Quartile Range, PVH= Peripheral Vestibular Hypofunction.

Supplementary Table 8. Data Extraction: Intervention Information About Content, Duration and Intensity of the Given Intervention(s)

Movement sessions	**Intervention (possibly combined with vestibular rehabilitation= VR)**	**Control group: vestibular rehabilitation (VR) of a less/no treatment group**
Lopes et al, 2019 [40]	9 patients received LG therapy consisting of 54 exercises coordinated with breathing, in a slow and continuous manner. Weekly collective sessions of 50 minutes during 12 weeks with a total volume of 10 hours.	10 patients received VR consisting of exercises for postural stabilization, ocular fixation and training to maintain balance. Weekly collective sessions of 50 minutes during 12 weeks with a total volume of 10 hours.
		Third group: 14 patients received no treatment.
McGibbon et al, 2005 [42]	19 (of which 11 unilateral) patients received TC consisting of a set of traditional TC warm-up exercises, five specific TC movements and a 5-minute seated breathing exercise. Once per week for 70 minutes during 10 weeks with a total volume of 11 hours and 40 minutes.	17 (of which 12 unilateral) patients received VR consisting of three groups of exercises: eye- head coordination, VOR training and balance. Weekly sessions of 70 minutes during 10 weeks with a total volume of 11 hours and 40 minutes.
Gabilan et al, 2008 [37]	21 patients received an aquatic physiotherapy protocol consisting of 12 phases with increasing difficulty. Phase 1: maintaining posture in the water, phase 12: up and down knee flexions during 5 minutes with maximum turbulence. 10 sessions of 45 minutes, three times a week for a period of 4 weeks with a total volume of 7.5 hours.	/
Technology assisted	Intervention	Control group
Philips et al, 2018 [41]	21 patients received Wii-fit therapy consisting of 9 different balance games with total body movement. Two 30-minute sessions per day during maximum 16 weeks with a total maximum volume of 112 hours.	19 patients received VR described as standard care. Two 30-minute sessions per day during maximum 16 weeks with a total maximum volume of 112 hours.
Sparrer et al, 2012 [39]	34 patients received an enhanced Wii balance board training consisting of 15 exercises with increased difficulty to challenge the stato-motor system and rise demand on the tri-modal system. 10 sessions (two daily units for five consecutive days) of 45 -60 minutes per session with a total volume of 7.5 - 10 hours. Each session containing 5-6 exercises.	33 patients received received only 2 exercises (one-leg figure and vendor specific training).

VR= Vestibular rehabilitation.

Supplementary Table 9. Data Extraction: Intragroup Differences

Movement sessions	Statistical analysis	Timing measurement	Outcome measures* and results	
Lopes et al, 2019 [40]	One-way ANOVA with Tuckey post hoc test (SF-36) Chi-square test (SPPB)	T0 T1: 12 weeks	T0 -> T1: SF-36 (CI 95%) ↑ General Health Status: + 3.44 (0.7-6.1) ↑ Functional Capacity: + 2.77 (1.2-4.3) ↑ Limitation by Physical Aspects: + 1.5 (0.3-2.7) ↑ Pain: + 3.4 (0.8-6.0)	↑ Vitality: + 3.0 (0.9-5.0) ↑ Social Aspects: + 1.8 (0.4-3.3) ↑ Emotional Aspects: + 1.7 (0.2-3.3) ↑ Mental Health: + 2.11 (0.2-3.9)
			T0 -> T1: SPBB Intragroup differences not reported	
McGibbon et al, 2005 [42]	Paired t-tests	T0 T1: 10 weeks	T0 -> T1 : Gait parameters ↑ Gait Speed: + (p=0.009) ↑ Step Length: + (p=0.010)	Stance Duration: + (p= 0.055) Step Width: + (p= 0.313)
Gabilan et al, 2008 [37]	Paired t-test	T0 T1 : 5 weeks	T0 -> T1 : DHI, VAS and posturography ↑ DHI (p = 0.001) ↑ Dizziness VAS (p= 0.001).	↑ Lower sway (MSI) (p=0.001) ↑ A/P SI (p = 0.001) ↑ M/L SI (p = 0.003)
Technology assisted				
Philips et al, 2018 [41]	Paired t-tests	T0 T1 : 4 weeks T2 : 8 weeks T3 : 12 weeks T4 : 16 weeks	T0 -> T1, 2, 3, 4 : DHI (T1, T2, T3, T4) and SF-36 (T1) ↑ DHI at T1, 2, 3, 4 : (p< 0.001) ↑ Physical Health score (SF-36) at T4 (p= 0.0122)	Mental Health score (SF-36) at T4: +, not significant
Sparrer et al, 2012 [39]	Paired-samples Wilcoxon test	T0 T1 : 5 days T2 : 10 weeks	T0 -> T2 : DHI, SOT, Tinetti and VSS ↑ DHI ($p < 0.05$) ↑ SOT ($p < 0.05$)	↑ Tinetti Questionnaire ($p < 0.05$) ↑ VSS ($p < 0.05$)

Differences of the relevant outcome measures before and after a physical activity intervention
↑= significant improvement; MS= Movement Sessions, TA= Technology Assisted, PT= Physical Therapy; T0, T1= pre and post intervention; LG= Lian Gong; TC= Tai Chi, SF-36= Short Form Health Survey; PA= Physical activity; DHI= Dizziness Handicap Inventory; SOT= Sensory organization Test, VSS= Vertigo Symptom Scale, DGI= Dynamic Gait index; VAS= Visual Analogue Scale; MSI= Mean Stability Index; A/P SI= Anterior/posterior Stability Index; M/L SI:= Medio/lateral Stability Index; LOC= Level of Conclusion.
*: relevant to research question

Supplementary Table 10. Data Extraction: Intergroup Differences

Movement sessions	Statistical analysis	Outcome measures*	Results
Lopes et al, 2019 [40]	One-way ANOVA with Tuckey post hoc test (SF-36)	Perceived Health status SF-36 SPPB	PA vs VR ↑ General Health Status ($p < 0.05$) ↑ Pain ($p < 0.05$) No other significant differences
McGibbon et al, 2005 [42]	One-way ANCOVA	Gait parameters	PA vs VR No significant differences
Technology assisted physical activity			
Phillips et al, 2018 [41]	Two-sample t-test	DHI SF-36	PA vs VR No significant differences
Sparrer et al, 2012 [39]	Paired-samples Wilcoxon test	DHI Tinetti Questionnaire VSS SOT	PA vs (less to none) PA ↑ Discharge from hospital (p-value not reported) ↑Absence of nystagmus Significant differences between groups compared to less PA : DHI, Tinetti, VSS and SOT ($p<0.05$)
Activities of daily living			
Apaydin et al, 2020 [43]	Student t-test	Level of physical activity IPAQ	Patient vs Controls ↓ IPAQ total score in patients compared to controls: ($p<0.05$)
Morimoto et al, 2019 [44]	Unpaired t-tests	Level of physical activity Accelerometry	Patients vs controls ↑ Sedentary Behavior time ($p< 0.05$) ↑ Low Physical Activity time ($p< 0.05$) ↓Total Physical Activity time ($p< 0.05$) No other significant differences were found
Alessandrini et al, 2021 [38]	Independent t-test	Level of physical activity Apple watch wrist-worn device	Patients vs controls ↓Total Daily Energy Expenditure ($p= 0.007$) ↓Movement Energy Expenditure ($p< 0.001$) ↓Rest Energy Expenditure ($p< 0.001$) ↓Upright hours/day ($p< 0.001$) ↓Strides number ($p< 0.001$) ↓Distance ($p< 0.001$)

Differences in relevant outcome measures between groups (physical activity compared to vestibular rehabilitation or a no-treatment control group
↑= significant improvement; SF-36: Short-Form Health Survey; PA= Physical Activity; CG= Control Group; VR=Vestibular Rehabilitation; IPAQ= International Physical Activity Questionnaire; LOC= Level of Conclusion. * relevant to research question

Supplementary Table 11. Data Extraction: Correlation Analysis

Activities of daily living	Statistical analysis	Results
Apaydin et al, 2020 [43]	Spearman's correlation	PA – Dizziness and vertigo outcome IPAQ total – Vertigo severity: R=0.602 (p< 0.001) IPAQ total – Vertigo frequency: R=-0.321 (p= 0.046) IPAQ total – Dizziness severity: R =-0.493 (p= 0.001) IPAQ total – Dizziness frequency: R=-0.487 (p= 0.002) IPAQ total – Condition 1 M-CTSIB : R= -0.124 (p= 0.451) IPAQ total – Condition 2 M-CTSIB : R= -0.049 (p= 0.768) IPAQ total – Condition 3 M-CTSIB : R= -0.002 (p= 0.990) IPAQ total – Condition 4 M-CTSIB : R= -0.256 (p= 0.115) IPAQ total – ABC : R= 0.312 (p= 0.053)
Morimoto et al, 2019 [44]	Pearson's correlation	PA – Dizziness and vertigo outcome Time of Total PA – DHI: R= -0.134 (p=0.496) Time of Total PA – VSS vestibular balance: R= -0.134 (p= 0.497) PA – Balance outcome Time of moderate to vigorous PA – CDP 4: R=-0.53 (p < 0.05) Percent of moderate to vigorous PA – CDP 4: R= -0.517 (p< 0.05) Time of total PA – CDP 4: R= -0.452 (p < 0.05) No other significant correlations were found
Alessandrini et al, 2021 [38]	Spearman's correlation	PA – vestibular function and disease duration Daily energy expenditure – VOR gain: R= 0.68 (p <0.05) Movement energy expenditure -VOR gain: R= 0.72 (p <0.05) Rest energy expenditure – Disease Duration= -0.58 (p< 0.05) No other relevant, significant correlations were found

Correlation PA – Dizziness, vertigo or balance outcome PA= Physical Activity; IPAQ= International Physical Activity Questionnaire; DHI=Dizziness Handicap Inventory; VSS= Vertigo Symptom Scale, CDP 4= Computerized Dynamic Posturography position 4.

Supplementary Table 12. Overview of the Relevant Outcome Measures

	Alessandrini et al [38]	Apaydin et al [43]	Gabilan et al [37]	Lopes et al [40]	McGibbon et al [42]	Morimoto et al [44]	Philips et al [41]	Sparrer et al [39]
Pre and post intervention outcome measures: Interventional studies								
Vestibular function								
Video Head Impulse Test	X							
Nystagmus evaluation								X
Balance performance								
Dynamic Gait Index (DGI)	X							
Gait analysis					X			
Static Posturography	X							
Computerized Dynamic Posturography (CDP)						X		
Modified-Clinical Test Sensory Interaction and Balance (M-CTSIB)		X						
Sensory Organization Test (SOT)			X					X
6 Minute Walking Test (6MWT)		X						
Dizziness, vertigo and perceived limitations on daily living								
Dizziness Handicap Inventory (DHI)	X	X	X			X	X	X
Vertigo Symptom Scale (VSS)						X	X	X
Vestibular Disorder Activities Daily Living Scale (VADL)		X						
Visual Analogue Scale: dizziness/vertigo severity (VAS)		X	X					
Fall Efficacy Scale (FES)								X
Activities Specific Balance Confidence Scale (ABC)	X	X						
Other								
Short Physical Performance Battery (SPPB)				X				
Short Form Health Survey-36 (SF-36)				X			X	
State Trait Anxiety Inventory (STAI)						X		
Physical activity level outcome measures: Cross-sectional studies								
Physical activity								
Apple Watch wrist-worn device	X							
Accelerometry: ActiGraphTM ActiSleep BT Monitor						X		
International Physical Activity Questionnaire (IPAQ)		X						

EO= Eyes Open, EC= Eyes closed, FW= Forward, BW= Backward