Effectiveness of Vestibular Rehabilitation after Concussion

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ABSTRACT

Background: Concussion is defined as a condition that results in temporary alterations in brain function. The treatment is focused on those dysfunctions or diseases related to the vestibular system and/or the vestibular nuclei. The main objective of this study is to evaluate if vestibular rehabilitation is effective in the treatment of concussions. **Methods:** A systematic review of different biomedical databases was conducted, with the use of the keywords to form the final equation. According to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines, the following criteria for selection were included: randomized clinical trials, written in Spanish or English, which included patients of all ages, without differing in the severity of the concussion. Finally, the PEDro scale was used to assess the methodological quality and the Oxford Centre for Evidence-Based Medicine scale (OCEBM) was used to evaluate the level of scientific evidence. **Results:** After applying the inclusion and exclusion criteria, five articles were finally selected for this study. According to the PEDro scale, the following values were obtained: 1 article with an excellent score and 4 articles with a good score. The OCEBM scale shows a level of evidence 1b and a grade of recommendation A. **Conclusions:** The studies analyzed indicate improvements, reduction in recovery time and safe intervention in favor of the vestibular group. The limited scientific literature on this topic should be noted. Funding: This research did not receive any specific grant from funding agencies in the public, commercial or non-profit sectors.

Keywords: Brain concussion, traumatic brain injury, vestibular rehabilitation, vestibular system, disability related to dizziness

INTRODUCTION

Concussion or traumatic brain injury is defined as a condition that temporarily alters brain function, following a previous head injury [1]. This condition can be caused by a variety of factors, including direct blows, jolts or penetrating injuries [2]. They fall within the spectrum of less serious brain injuries [3]. However, depending on their clinical severity and duration of symptoms, they can be classified as mild, moderate or severe concussions, according to their score using the Glasgow scale during the first 24 hours, the duration of loss of consciousness or the alteration in consciousness- if there is no loss of consciousness-, and the duration of post-traumatic amnesia [4].

Concussions are complex in nature and are associated with multiple physical disabilities that may result from traumatic brain injury [5]. In this sense, signs and symptoms can be classified into five categories: somatic, vestibular and/or oculomotor, cognitive, emotional, and sleep-related [6]. These signs and symptoms will follow a sequential course. Therefore, they will evolve in a matter of minutes or hours. However, if they are acute signs and symptoms, they will reflect a functional alteration rather than a structural injury [5,6]. The most common clinical findings in patients who have suffered a traumatic brain injury include dizziness, confusion, blurred vision, headache, double vision, impaired balance and coordination, nausea, and incoherent speech [3].

Risk factors for concussion are related to history of migraines, younger age, initial learning disability, history of psychological disorders or mood disorders, female gender, and previous history of traumatic brain injury [2].

This pathology is directly related to the vestibular system. The vestibular apparatus plays a fundamental role in detecting acceleration produced by the head, transporting this information through the vestibular nerve and, therefore, directly influencing balance, spatial orientation, postural control, and stabilisation of the trunk and neck through the vestibulo-colic and vestibulo-spinal reflexes, as well as stabilisation of gaze through the vestibulo-ocular reflex [7]. All these factors will be affected after suffering a concussion, leading to dysfunction and/or alterations in the vestibular system and vestibular nuclei [8].

On the other hand, concussion is associated with clinical and social complications that will have a negative impact on both emotional development and general health [4]. Moreover, these complications imply an enormous social and economic cost [9]. The most common and significant clinical complications are depression, anxiety, psychosis, post-traumatic stress disorder, paranoia, pseudobulbar affect and aggression [4].

Measuring the severity of concussion presents certain difficulties since there are no clinical biomarkers or diagnostic tests which can confirm traumatic brain injury [10]. It will be based on the symptoms in the medical history and the signs found in the physical examination [3]. However, neuropsychological tests, vestibular tests, balance tests and oculomotor tracking to aid in clinical diagnosis can be used [10].

Anticoagulants, anticonvulsants, antidepressants, muscle relaxants and stimulants to increase alertness are used in order to treat symptoms and reduce some of the risks that may be associated with the use of medications to prevent anxiety. These are options aimed at effectively reducing symptoms [11]. The physiotherapeutic treatment of concussions varies depending on the symptoms, severity and time elapsed since the concussion. Moreover, it varies if there is cerebral haemorrhage, among other factors. Nevertheless, there are general recommendations to take advantage of neuroplasticity and early neural reorganization. These recommendations include therapeutic exercise, neuromuscular facilitation, manual therapies, electrotherapy, the use of physical agents and patient education to achieve the greatest effectiveness in treatment [12].

Vestibular rehabilitation is a rehabilitative or therapeutic intervention comprising a set of activities based on the treatment of dysfunctions or diseases in patients with alterations in the peripheral vestibular system and/or alterations in the vestibular nuclei with their respective afferents and efferents (8). The different techniques involved in vestibular rehabilitation are mostly complementary to each other and are not mutually exclusive, since vestibular deficits often present with multiple factors which need to be treated. Vestibular rehabilitation exercises will include habituation exercises, gaze stabilisation exercises and vestibulo-ocular reflex rehabilitation, postural control exercises and dynamic and static balance re-education, and conditioning and general fitness maintenance exercises [13].

Concussions are the leading cause of death in adults under 45 and in children. Furthermore, 40% of severe disabilities are the result of traumatic brain injury, which, due to its high rate of sequelae, has a negative and harmful impact on healthy adults with a long life expectancy [9]. An estimated four million injuries occur annually, making it a significant public health issue. There is growing awareness of the short- and long-term impact of these injuries, with particular emphasis on the high prevalence of post-traumatic dizziness that persists for several months following concussion [10]. Therefore, this research justifies the need to find evidence which supports and demonstrates greater benefits and more robust results, and which also validates effective treatments for its management.

In this sense, the main objective of this literature review is to determine the effectiveness of vestibular rehabilitation in the treatment of concussions, as well as to evaluate if vestibular rehabilitation accelerates the recovery process and its effect on dizziness-related disability.

MATERIAL AND METHODS

Search strategy

This study corresponds to a literature review that analysed the treatment of concussions through rehabilitation and vestibular treatment between October 2023 and December 2023. The biomedical databases PubMed, PEDro, The Cochrane Library, Web of Science, and Science Direct were consulted, using the medical search terms 'MESH' in English, which included *"Brain Concussions", "Traumatic Brain Injury", "Vestibular Rehabilitation" and "Vestibular System",* combined with the Boolean operators "AND" and "OR", which maximised the sensitivity and breadth of the search results by including documents which contained both terms. The following equation was finally obtained: *((Brain Concussions) OR (Traumatic Brain Injury)) AND ((Vestibular Rehabilitation) OR (Vestibular System)).*

Criteria for selection

The inclusion criteria were the following: articles published in the last five years, between 2018 and 2023, studies which included patients who had suffered a concussion of any severity, articles that evaluated vestibular rehabilitation or the recovery of the vestibular system, in which the evidence assessed as regards vestibular rehabilitation was effective in covering different aspects of concussion treatment, and articles which were written in Spanish or English. On the other hand, articles outside time range, written in other languages, addressing cervico-vestibular rehabilitation, and those with low methodological quality, i.e., with a PEDro scale score of 4 or less, were excluded.

Quality assessment

The methodological quality of the studies which were finally selected was assessed using the Physiotherapy Evidence Database (PEDro) scale. This scale is a 10 item rating scale which evaluates internal validity and statistical reporting [14]. All items were fulfilled, except item 1 (which addresses external validity). One point is awarded for each criterion met, with scores ranging from 0 to 10. Scores of 6 or above are generally regarded as high quality.

Finally, the strength of evidence was graded using the Oxford Centre for Evidence-Based Medicine hierarchy [15], which ranges from level 1 (systematic reviews of randomised trials) to level 5 (expert opinion). Therefore, these three tools offered complementary perspectives as regards the quality of the study, bias and evidential weight, ensuring, therefore, a coherent assessment framework.

RESULTS

Study Selection

The study selection process conformed to the PRISMA 2020 guidelines [16] and is presented in the flow diagram (Figure 1) and detailed in SI File (Supporting Information). As regards our summary of results, we started the study with 1,570 articles. After reading the titles, 23 articles were selected to continue to the next screening phase. Duplicate articles were eliminated using the Zotero bibliographic manager, leaving 11 abstracts to continue with the screening for eligibility and methodological quality. One article was ultimately excluded following the filtering of studies which lacked open access. Finally, the 10 remaining articles were read to determine whether they met the proposed criteria. Four articles that did not meet the criteria were discarded. One article was also excluded due to its low methodological quality on the PEDro scale, resulting, therefore, in five studies that met all the requirements for this review.

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Figure 1. Study selection process presented using the PRISMA 2020 flow diagram

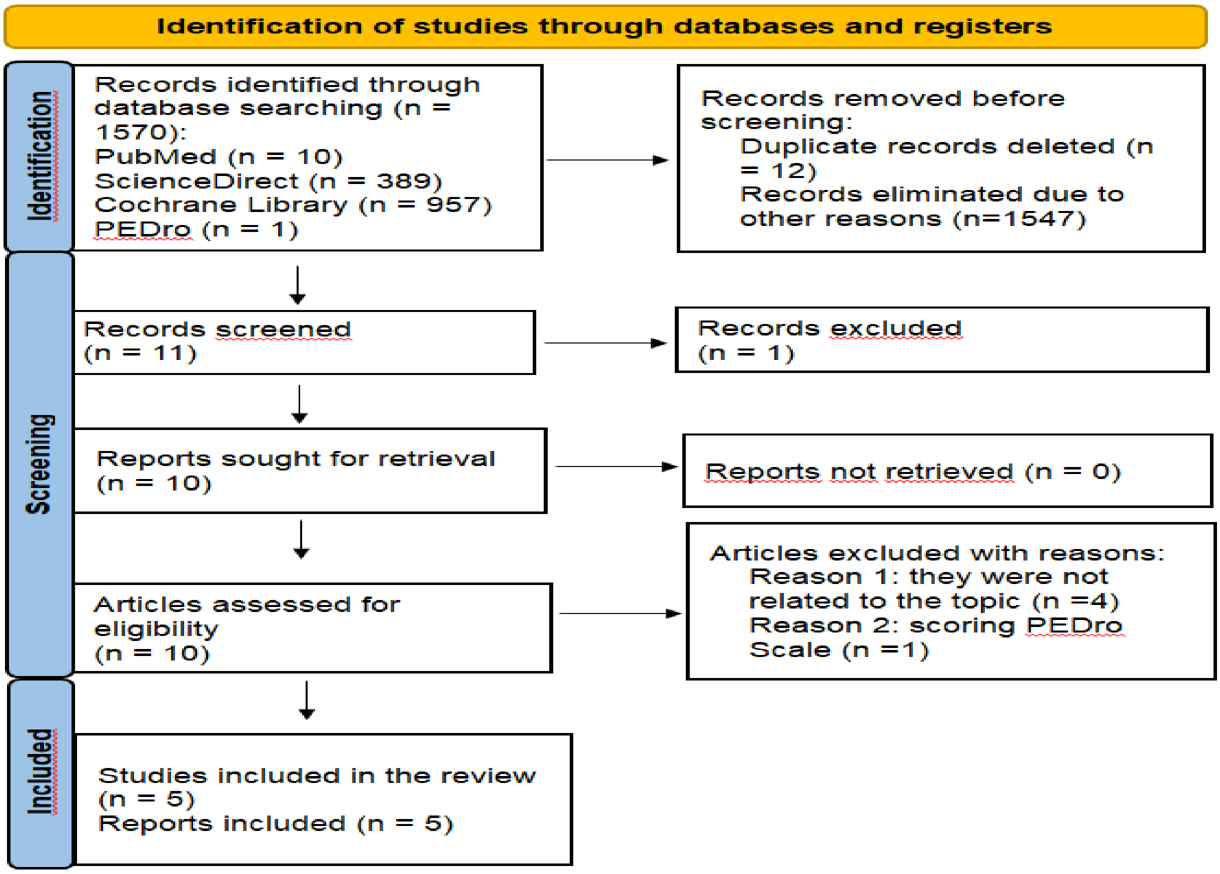

Figure 1. Flowchart which details the study selection. It summarises the phases of identification, pre-screening, eligibility and inclusion in the review. It was adapted from the PRISMA 2020 statement [16] and developed using the official template.

Methodological Quality Assessment

The PEDro scale [14] obtained results which revealed that the studies conducted by Kleffelgaard et al. (17), Tramontano et al. (19) and Kontos et al. (20) showed an excellent methodological quality. The studies by Søberg et al. (18) and Liao et al. (21) also showed excellent methodological quality whereas the study by Kontos (22) was eliminated since it obtained poor methodological quality according to the PEDro scale. On the other hand, the Oxford Centre for Evidence-Based Medicine (CEBM) scale [15] indicated that all studies showed a level of evidence 1b with a grade of recommendation A (Table 1), detailed in S2 File (Supporting Information).

Table 1. Assessment of methodological quality using the PEDro and Oxford scales

ARTICLE	PEDro Scale											Total	Oxford Scale
	I.1	I.2	I.3	I.4	I.5	I.6	I.7	I.8	I.9	I.10	I.11		
Kleffelgaard, et al. (2019)	YES	1	1	1	0	0	1	1	1	1	1	8/10	1b
Søberg, et al. (2021)	YES	1	1	1	0	0	1	1	1	0	1	7/10	1b
Tramontano, et al. (2022)	YES	1	1	1	0	0	1	1	1	1	1	8/10	1b

Kontos, et al. (2021)	YES	1	1	1	1	0	1	1	1	1	1	9/10	1b
Liao, et al. (2023)	YES	1	1	1	0	0	1	1	1	1	0	7/10	1b
Kontos (2024)	YES	1	1	1	1	0	0	0	0	0	0	4/10	1b

Table 1: Result Table. The PEDro scale is an 11-item questionnaire. One point will be awarded for each criterion met, whereas a negative response will result in zero points. The Oxford scale.

Description studies and synthesis of results

Once this step was completed, we proceeded with an in-depth reading and analysis of the different studies to obtain a description of their characteristics. In our analysis, we found that Kleffelgaard et al. [17] and Søberg et al. [18] used a sample of 65 patients aged 16 to 60, Tramontano et al. [19] conducted their research with 30 subjects between the ages of 15 and 65, Kontos, et al. [20] collected a sample of 55 participants aged 12 to 18, and finally, Liao, et al. [21] had a total of 70 participants with an average age of 54.40 ± 20.43.

Intervention Protocol

Kleffelgaard et al. [17] and Søberg et al. [18] conducted interventions for both groups over 8 weeks with two sessions per week, for a total of 16 sessions. Both groups received psychoeducational sessions and multidisciplinary outpatient rehabilitation, which consisted of clinical evaluations of the vestibular and the oculomotor systems, and vestibulo-ocular reflex tests. The difference was that the intervention group also performed exercises using a virtual reality programme based on the principles of vestibular rehabilitation: habituation, adaptation, substitution and relearning balance, together with general physical activity such as walking. Rehabilitation began 3.5 ± 2.1 months after the injury and consisted of 2 to 5 exercises.

In the study conducted by Tramontano et al. [19], the intervention lasted four weeks for both groups, with three sessions per week and a total of 12 sessions. The intervention group used virtual reality to perform vestibular exercises, two exercises focused on gaze stability, and two other exercises on postural and dynamic stability. In contrast, the control group performed three exercises aimed at stabilising the upper body. In addition, both groups were evaluated using sensors to check for improvements in gait quality during the neurorehabilitation programme.

The study by Kontos et al. [20] lasted four weeks for both groups. The control group received rehabilitation based on behaviour management strategies. The intervention group underwent vestibular rehabilitation with individually prescribed exercises, plus specific exercises performed at home for 30 minutes daily, in addition to the same behaviour management strategies, but without additional physical activity. Treatment began within 21 days after suffering the concussion.

The study by Liao et al. [21] conducted an 8-week intervention for both groups. The experimental group received vestibular rehabilitation with exercises, which lasted from 30 to 60 minutes, performed twice a week. These exercises included eye-head coordination exercises, sitting balance, static and dynamic standing balance and walking. However, the control group received standard care, which included monitoring of consciousness, muscle strength, medication administration, and education on the importance of getting up early. Therapy began 2.4 days after the injury.

The studies by Kleffelgaard et al. [17] and Søberg et al. [18] collected data on three occasions: the first assessment 3.5 ± 2.1 months after the injury, the second assessment 2.7 ± 0.8 months after the first, and the third 4.4 ± 1.0 months after the initial assessment. Tramontano et al. [19] carried out four measurements: at baseline, after 4 weeks of training, then at 4 and 8 weeks after completing the training programme. Kontos et al. [20]

carried out three data collections: at baseline, and after 2 and 4 weeks. Finally, Liao et al. [21] collected data five times: at baseline and at weeks 2, 4, 8, and 12 after the interventions.

Main Measurement Variables

As regards the results obtained in the articles, the study by Kleffelgaard et al. [17] showed significant improvements in the intervention group in both dizziness handicap index (DHI) (47.9 ± 16.6 vs. 32.1 ± 20.7 at the end of the intervention) and functional mobility tool (HiMAT) (40.9 ± 9.3 vs. 47.3 ± 8.2 at the end of the intervention). Although the vestibular rehabilitation group experienced a faster recovery, at the end of the treatment the control group reached the same level. After completing the 16 sessions, no changes were found in relation to vertigo, post-concussion symptoms, psychological distress or balance.

Søberg et al. [18] evaluated the integration of virtual reality into the rehabilitation programme following concussion, basing their primary analysis on quality of life after brain injury (QOLIBRI). Significant clinical improvements were observed from baseline to subsequent follow-ups, regardless of the assigned group, with a value of 53.2 at baseline compared to 61.4 at the last follow-up. This leads to clinical improvement from baseline to the first follow-up (95% CI: 2.2–8.3), from baseline to the second follow-up (95% CI: 3.7–11.6), and from the first to the second follow-up (95% CI 0.02–6.1). Symptoms on the physical RPQ3 and cognitive RPQ13 subscales were also reduced, contributing to an improvement in the quality of life. Patients with greater initial psychological distress, as measured by HADS, showed more significant improvements, regardless of the assignment group. No changes were observed in self-reported vertigo symptoms (VSS-SF).

Tramontano et al. [19] found significant improvements in both groups in the Berg Balance Scale (BBS) scores, Dynamic Gait Index (DGI) and Community Balance and Mobility (CB&M) scores. However, only the intervention group showed sustained improvement in the CB&M at the three assessment points (37.7±24.2 vs. 48.8±25.3 at the end of the intervention). Improvements in balance and specific activities measured by the ABC scale (74.1 (±11.8) vs. 84.2 (±15.1) 8 weeks later) and the CIQ community integration questionnaire (12.3, (±9.9) vs. 12.9 (±4.4) 8 weeks later) were exclusive to the vestibular rehabilitation group. In the instrumental assessments of the 10-minute walk test (10MWT), this group also showed better and greater effects as regards average stride frequency, mean square value of trunk and head control, smoothness of gait, and the figure-of-eight curvilinear walk test (F8WT) in the counterclockwise direction.

Kontos et al. [20] found significant results between the vestibular rehabilitation group and the control group as regards horizontal vestibulo-ocular reflexes (mean difference of -1.628) and vertical vestibulo-ocular reflexes (mean difference of -2.24). Nevertheless, there were no differences in visual motion sensitivity. In terms of secondary outcomes, no differences were found in the ocular elements of vestibular/ocular motor screening (VOMS), the total DHI score, the balance error scoring system (BESS), or the post-concussion symptom scale (PCSS), although both groups improved in dizziness symptoms (DHI) at a similar rate. There was a difference in recovery of 8 days in favour of the intervention group. Nevertheless, although this was not a significant difference, a reduction of 8 days could be considered relevant in a context of clinical importance.

Liao et al. [21] observed that, although there were no initial differences between groups in DHI dizziness and visual analogue scale for dizziness (DVAS), both improved over time ($p < 0.001$). However, the experimental group showed significant improvements at weeks 2, 4, and 8 ($p < 0.05$), indicating greater effectiveness in vestibular rehabilitation exercises. The same occurred with post-concussion symptoms, in which the experimental group showed a more favourable result as regards group interaction and time at week 4 ($p = 0.033$). On the other hand, with regard to physical balance, the vestibular rehabilitation group also had significant effects at weeks 4, 8, and 12 ($p < 0.01$). Finally, quality of life as measured by QOLIBRI and anxiety as measured by the Beck Anxiety Inventory (BAI) improved for both groups over time ($p < 0.001$), although in weeks 2, 4, 8 and 12 the effects were greater in the experimental group.

DISCUSSION

The discussion of all the results provides a comprehensive global view and a complete perspective of the different interventions used in the treatment of concussions, taking into account important factors such as the heterogeneity among the studies of the variables analysed, the measurement tools, which do not adhere to the same type of concussion, the difference in characteristics of the participants and the characteristics of the symptoms, and the duration of the interventions. Kleffelgaard et al. [17] and Søberg et al. [18] observed that, although both groups achieved similar results on the DHI and HiMAT scales, the experimental group showed improvements in a shorter time. Tramontano et al. [19] highlighted significant progress in the three CB&M measurements for the experimental group. Kontos et al. [20] found a favourable difference of 8 days for the intervention group. Finally, Liao et al. [21] reported early improvements in both anxiety and quality of life in favour of the experimental group from the start of the study.

Most of the studies reviewed show positive results in favour of the experimental group. In addition, the complementary and adjuvant use of virtual reality is highlighted as a promising technique in neurorehabilitation programmes. Researches such as those by Kleffelgaard et al. [17]; Søberg et al. [18] and Tramontano et al. [19] confirm that the integration of virtual reality had positive and significant effects on static and dynamic balance and motor function. Nevertheless, these interventions did not include exercises aimed at general strengthening or conditioning. Although this is an innovative approach, its implementation can be costly. Therefore, further research into the effects of vestibular rehabilitation applied in isolation and as a single therapy, without combining it with other techniques, is needed.

One of the most complex variables in the treatment of concussions is the presence of post-traumatic dizziness, which has led all the studies analysed to include the DHI (Disability Handicap Inventory) questionnaire related to dizziness. In the studies conducted by Kleffelgaard et al. [17] and Søberg et al. [18], the initial values indicated moderate disability, which was reduced to mild disability in the second follow-up, with significant improvements from the first follow-up only in favor of the experimental group, although the effects found for both groups reached equal levels. Tramontano et al. [19] also observed an improvement in DHI scores in both groups, from the first data collection to the last collection 8 weeks after treatment. On the other hand, Kontos et al. [20] concluded that there was gradual and positive progress for both groups. However, there were no significant differences between them. Finally, Liao et al. [21] reported significant improvements over time only in the experimental group, suggesting greater effectiveness of vestibular rehabilitation in reducing symptoms of dizziness.

It should also be noted that the secondary analysis conducted by Søberg et al. [18], which introduced the QOLIBRI questionnaire to assess health-related quality of life, concluded that there was a significantly higher mean score of 6.5 in the vestibular group.

Among the strengths of this study is the analysis of representative samples, which allows us to analyse the reliability and standardisation of vestibular rehabilitation in the treatment of concussions. This contributes to a deeper understanding of the subject. Furthermore, the inclusion of different studies with a range of ages, varying degrees of traumatic brain injury severity, types of vestibular exercises, etc., reflects the complexity and multifaceted nature of concussion recovery. On the other hand, the involvement and commitment of qualified teaching staff plays a crucial role. However, there are limitations such as the lack of long-term follow-up to verify whether the effects persist, with the exception of the study conducted by Soberg et al. [18], the relatively small sample size, and the difficulty of accessing technologies such as virtual reality, due to its costly innovative technology. This implies, therefore, that it cannot always be used as a method and/or complement. Furthermore, the scarcity of research papers with relevant results and the exclusion of the study conducted by Kontos et al. [22], due to low methodological quality, underscore the need for future studies to reinforce and expand the scientific evidence.

Future lines of research should be focused on addressing the multiple domains that exist nowadays and are a consequence of suffering a concussion, such as anxiety, migraines, sleep disturbances and mood swings, among others. This highlights the need to explore broader and more personalized therapeutic approaches and adjuncts tailored to the specific needs of the patient. It is also suggested that there is a need to develop a standardised guide that includes the frequency, intensity, duration and type of specific vestibular exercises, which allow for a more accurate perspective on the impact of the dose and the progression and duration of the intervention.

CONCLUSIONS

Although scientific evidence on the effectiveness of vestibular rehabilitation in concussions is still scarce and limited, the studies reviewed have shown that it is a safe and potentially beneficial intervention in a multidisciplinary approach. Moreover, it is also important to emphasize that it has accelerated recovery time in patients of different ages and levels of severity.

On the other hand, vestibular rehabilitation can also be effective as a method for combating dizziness-related disability, since it is capable of acclimatising and habituating vestibular responses, helping to progressively reduce the intensity of symptoms. Although some studies concluded that both groups improved their symptoms, it should be noted that in some of them the effects were more significant in the intervention group, and in others the reduction in dizziness was achieved in a shorter period of time.

In conclusion, although most studies reported more significant improvements in the vestibular rehabilitation group and/or a reduction in the recovery time, further research is needed in this field to support and demonstrate greater benefits, as well as more robust results to optimise its clinical application.

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Abbreviations

The following abbreviations are used in this manuscript:

MESH Medical Subject Headings

PEDro Physiotherapy Evidence Database

OCEBM The Oxford Centre for Evidence-Based Medicine

PRISMA Preferred Reporting Items for Systematic Review and Meta-Analyses

DHI Dizziness Handicap Inventory

HiMAT High-level Mobility Assessment Tool

QOLIBRI Quality of Life after Brain Injury

RPQ3 Rivermead Post Concussion Symptoms Questionnaire
RPQ13 Severity of Post-Concussive Symptoms

HADS Hospital Anxiety and Depression Scale

VSS-SF Vertigo Symptom Scale - Short form

BBS Berg Scale

DGI Dynamic Gait Index

CB&M Community Balance and Mobility Scale

ABC Activities-specific Balance Confidence Scale

CIQ Community Integration Questionnaire

10MWT 10 Meter Walk Test

F8WT Figure of 8 Walk Test

VOMS Vestibular Ocular Motor Screening

BESS Balance Error Scoring System

PCSS Post-concussion Symptom Scale Score

DVAS Visual Vertigo Analogue Scale

BAI Beck Anxiety Inventory

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