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Systematic Review/Meta-Analysis

Vestibular Rehabilitation as an Early Intervention in Athletes Who are Post-concussion: A Systematic Review

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Background

Sports-related concussions (SRC) are a common injury sustained by many athletes of all different age groups and sports. The current standard treatment is rest followed by aerobic activity. Minimal research has been done on the effects of vestibular rehabilitation for concussion treatment, especially in physical therapy practice.

Objective

The purpose of this study was to examine the effects of early intervention of vestibular rehabilitation (VRT) on an athlete's time to return to play compared to rest alone.

Study Design

Systematic Review

Methods

Two searches were conducted (August 2021 and January 2022) using databases: CINAHL complete, MEDLINE, PubMed, and Wiley online database. One hand search was performed to find relevant articles. Search terms included "vestibular rehabilitation" or "vestibular therapy" and "concussion" or "mild traumatic brain injury" or "mTBI" and "athletes" or "sports" or "athletics" or "performance", and "early interventions" or "therapy" or "treatment". Inclusion criteria were athletes with a SRC, incorporation of vestibular rehabilitation in athletes' recovery, and early vestibular intervention tools. Tools used to assess quality and risk of bias were the PEDro scale and the *Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence*. The PRISMA method for determining inclusion and exclusion criteria.

Results

Eleven articles were included, six randomized control trials and five retrospective cohort studies. Various balance interventions, visual interventions utilizing vestibulo-ocular reflex (VOR), and cervical manual therapy were used during VRT for athletes' post-concussion. Incorporating visual interventions and cervical manual therapy into early rehabilitation significantly reduced symptoms and time to return to sport. However, balance interventions did not have a significant effect on reducing time to return to sport when used as a sole intervention.

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Conclusion

Addressing VRT deficits in the acute stages of a concussion may contribute to a quicker resolution of symptoms and a quicker return to sport. More research needs to be performed to determine the effectiveness of early intervention of VRT in concussion recovery.

Level of Evidence

1

INTRODUCTION

Sport-related concussions (SRC) are a common injury across all age groups. SRC was defined by McCrory[1] in 2017 and adopted by athletic leagues including the National Collegiate Athletic Association and National Football League as a traumatic brain injury induced by biomechanical forces through either direct or indirect forces to the head causing neurological and cognitive dysfunction.[2,3] Concussions involving loss of consciousness, and later symptoms of dizziness and confusion and is correlated with a prolonged recovery time. Dizziness during the acute stage of concussion is reported in up to 81% of cases.[4,5]

Due to concerns that early activity such as quick return to contact sports and school related functions may disrupt healing and prolong return to sport post-concussion, the gold standard in concussion treatment is rest followed by various levels of aerobic activity.[6] However, further research has shown that an extended period of rest after a concussion may result in prolonged recovery time.[7] Recent literature has examined the efficacy of vestibular rehabilitation (VRT) in concussion treatment for the management of post-concussion symptoms. Using VRT as an early treatment for concussions in athletes has been shown to reduce severity of symptoms and duration, therefore decreasing recovery time to less than 21 days.[8,9] This suggests that vestibular rehabilitation can be an effective early intervention for SRCs.[10,11]

Despite the strong evidence found to support the use of VRT, results are conflicting regarding when to initiate this intervention and little is known about what is considered to be the best initial treatment for athletes who have experienced a concussion. Therefore, the purpose of this study was to examine the effects of early intervention of VRT on an athlete's time to return to play compared to rest alone.

METHODS

Prior to beginning research, a PICO question was developed to determine eligibility criteria and objective of the study. The PICO question asked, "does vestibular rehabilitation decrease return to sports time in athletes who experienced a concussion?" This addressed:

- *Population*: Athletes of all ages ranging from 5-30 years old.
- *Interventions*: Vestibular rehabilitation tools involving the vestibular, somatosensory, and visual systems performed by physical therapists to athletes after sustaining a concussion.
- *Comparison*: Alternative treatments such as rest and aerobic activity.
- *Outcomes*: Time for resolution of symptoms and an athlete's time to return to play.

A computerized electronic search was performed to identify relevant articles from the following databases: CINAHL complete, MEDLINE, PubMed, and Wiley online database. Two searches were conducted: one in August 2021 and one in January 2022 as these were the available times the four researchers collectively searched and reviewed the literature. Articles were screened for randomized control trials and retrospective studies as these are primary studies that provide the best evidence for conducting a systematic review. The search terms included "vestibular rehabilitation" or "vestibular therapy" and "concussion" or "mild traumatic brain injury" or "mTBI" and "athletes" or "sports" or "athletics" or "performance", and "early interventions" or "therapy" or "treatment". One hand search from the included studies was performed to find additional relevant studies to the research question. The four primary researchers were responsible for article collection, screening, and selection and they established 100% consensus regarding inclusion. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methods were used throughout the search process to determine inclusion and exclusion criteria for the articles reviewed and to evaluate the effects of each research article (Figure 1).[12]

Articles were included by author consensus after reviewing titles and abstracts of all relevant items that discussed SRC in athletes, vestibular interventions, and tools for early intervention and recovery and were in accordance with the systematic review protocol based on PRISMA. Exclusion criteria included articles published earlier than 2008, systematic reviews, and no discussion or mention of athletes or use of vestibular rehabilitation in the study. Other systematic reviews were not included as these are secondary sources and would not provide adequate information.

Risk of bias assessment was based on the PEDro scale which was determined as a consensus by each researcher. PEDro scores of 0-3 are considered 'poor', between 4-5 are 'fair', 6-8 is considered 'good', and a score of 9-10 is 'excellent.[13] All articles included in the review were analyzed using the *Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence*, a hierarchy of evidence scale.[14] This scale was used to assess whether the evidence in the articles were relevant to the PICO criteria and question. Data were extracted regarding subject numbers and groups, interventions used in each article, assessment tools, outcomes, limitations, and conclusions.

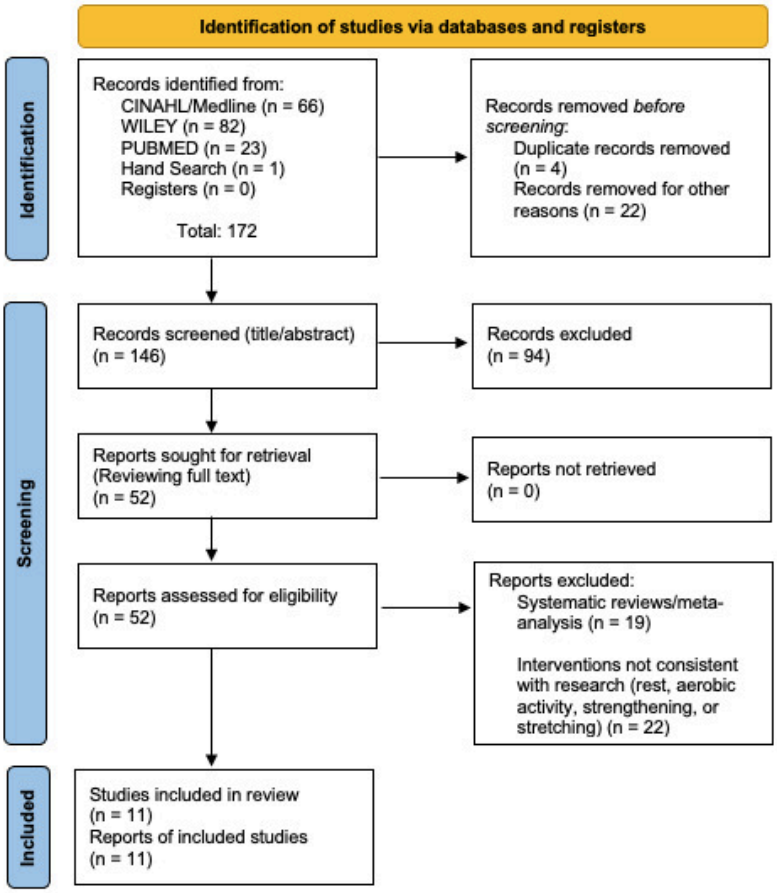

Figure 1. Flow diagram of article identification following PRISMA guidelines

RESULTS

Eleven studies met the inclusion criteria with nine articles utilizing VRT as a treatment to reduce post-concussion symptoms and two utilizing VRT to measure the severity of vestibular symptoms after sustaining a concussion. This review contains six RCTs and five retrospective cohort studies. The quality of the included studies, assessed using the PEDro scale, can be found in supporting file (Appendix 1). The scores of the included studies range from 4-8, indicating fair to good quality evidence.

The included RCTs utilized cervical manipulation, postural exercises, cervical ROM, rest, and vestibulo-ocular exercises as interventions for post-concussion symptoms in athletes and recovery time back to sports. Athletes from various contact sports such as soccer, football, field hockey, lacrosse, and snowboarding were observed in the research.

VRT: BALANCE INTERVENTIONS AND OUTCOME MEASURES USED TO EVALUATE BALANCE

Five studies utilized static and dynamic balance activities as concussion treatment in an athlete's return to play. Balance deficits are caused by abnormal sensory processing following a concussion and these deficits are commonly used to treat athletes in their recovery. In the retrospective cohort study performed by Ahluwalia et al.,[15] dynamic balance training was observed in 23 patients with SRC. Researchers divided patients into two groups, early therapeutic intervention, and late therapeutic intervention. The Post-Concussion Symptom Scale (PCSS) was one of the outcome measures used by Ahluwalia et al. The PCSS is commonly used by clinicians to obtain objective data regarding patients' perceptions of the severity of their symptoms. It is a 22-item questionnaire that ranks symptoms from none (0) to severe (6), with a maximum score of 132. A second outcome measure used was the number of days to initiate VRT. The PCSS was used to determine the resolution date of symptoms, return to play date, and return to learn date. Early therapy was defined as less than 30 days after injury and late therapy as more than 30 days after injury.[15] Ahluwalia et al. found that the early therapy group achieved a 0 on the Post-Concussion Symptom Scale (PCSS) for balance deficits, meaning that symptoms were resolved by the time the athlete returned to play.[15] The late therapy group achieved a 0.5 in balance deficits suggesting that the early rehabilitation group had a quicker return to play than those who participated in the late rehabilitation.[15]

Schneider et al[16] recorded patient reports of improvements in standing balance exercises and dynamic balance

exercises through the Activities-specific Balance Confidence Scale (ABC scale) at baseline and at time the athlete was cleared to return to sport. Athletes were separated into two groups, with the control group receiving conservative physical therapy interventions and the intervention group receiving VRT with additional balance interventions. Athletes who were not cleared to return to sport were re-evaluated at eight weeks after their initial measurement. Both groups received cervical range of motion, stretching, and postural exercises. The intervention group included balance exercises. After eight weeks of intervention, 30% of athletes in the control group were cleared to return to play, compared to 8% in the treatment group based on the ABC scale.[16]

Along with the ABC scale, the Balance error scoring system (BESS) was used throughout various studies observing concussion symptoms in athletes. The BESS is a common outcome measure used to assess postural stability. The test measures three different positions: double-leg stance with hands on hips and feet together, single-leg stance on non-dominant leg with hands on hips, and tandem stance with non-dominant foot behind the dominant foot. Each stance is measured on a firm surface, then a foam surface with eyes closed. The evaluator gives one point for every error made on each position. All six stances are allotted up to 10 points. The lower the score, the better the balance.[17] Using these outcome measures to create balance interventions has shown to be more effective at improving balance related symptoms compared to the standard concussion treatment of rest.[18] Storey at el[19] reported athletes who completed the BESS at initial evaluation had an average score of 33.8, which decreased to 21.7 at final evaluation.[19] After completing a tandem gait task and other balance exercises, 14.1% of athletes reported balance deficits at final evaluation compared to 63% at initial evaluation.[19]

The Modified Balance Error Scoring System (mBESS) is a balance measure used by researchers Kontos et al[8] in their randomized control trial to assess postural stability during static balance stances in subjects' post-concussion. The three balance stances used were: double leg stance, tandem stance, and single leg stance on the non-dominant leg. These assessments were also used to determine time to return to play. Upon initial clinical assessment, participants in the vestibular group received an mBESS score of 5.4 (+/- 3.6) and those in the control group received a score of 4.6(+/-m 2.8). Post-intervention, those in the vestibular group received an mBESS score of -1.36 (+/- 0.61) and the control group received a score of -0.80 (+/- 0.64).[8] No significant differences were found between groups, suggesting that the use of vestibular rehabilitation alone as an early intervention is not successful in reducing balance deficits related to concussion injuries. There was no significant difference in postural stability during balance between the vestibular and control group.

VRT: VISUAL INTERVENTIONS AND TOOLS TO MEASURE VISUAL OCULAR PERFORMANCE

Ten studies utilized visual interventions and testing for visual ocular function. These interventions consisted of near point convergence (NPC), horizontal saccades, vertical saccades, smooth pursuits, adaptation, habituation, hand-eye coordination, and gaze stabilization exercises often called the vestibulo-ocular reflex (VOR). Descriptions of each VOR test and normal findings are outlined in Table 1. These tests can be used as interventions to treat vestibular deficits.

To screen for visual impairments related to vestibular dysfunction, the Vestibular Ocular Motor Screening (VOMS) is used. The VOMS includes five domains: smooth pursuit, horizontal and vertical saccades, near point of convergence (NPC) difference, horizontal VOR, and visual motion sensitivity (VMS).[10] The VOMS is scored using a 10-point Likert scale with 0 being no symptoms and 10 being severe symptoms. Mucha et al[10] reported that athletes who receive a score of $\geqslant 2$ indicates a concussion. Current research has identified the VOR and VMS components as being the most predictive of a concussion.[10,11]

Ellis et al[24] studied smooth pursuits, near point convergence, horizontal and vertical saccades, and VOR in their retrospective review. Abnormalities of smooth pursuits were indicated by saccadic eye movements while abnormalities of near point convergence were defined as diplopia or inability to maintain fixation greater than 6 cm from the bridge of the patient's nose.[24] Overshooting or more than two saccadic corrections during testing was deemed abnormal when testing horizontal and vertical saccades. A report of worsening of vestibular and oculomotor symptoms during VOR testing were deemed abnormal. These results suggested that those who presented with vestibular-ocular dysfunction (VOD) had a longer recovery of 40 days compared to 20 days in those presenting without VOD.[24] Similarly, Whitney et al.[11] reported that in NCAA athletes scoring $\geqslant 2$ on the VOMS, specifically in the smooth pursuits, saccades, and convergence components was correlated with a significantly longer recovery time. Those authors concluded that it is important to assess for vestibular eye dysfunction within three days of sustaining a concussion. However, Glendon et al[20] reported that the VOMS should be incorporated within the initial two weeks following a SRC. In their data collection, the authors found that the average time to RTP was 22 days. The athletes that presented with VOM impairment were able to return to play within 30-51 days which was a 14-day difference compared to those without a VOM impairment.[20]

Ahluwalia et al[15] also utilized gaze stabilization exercises and focused on convergence insufficiency, saccadic eye movements, and accommodative dysfunction. Their study discussed utilizing seated VOR exercises with progressions to standing balance exercises as part of the athlete's treatment plan. Habituation and adaptation exercises were also used. This study found that patients who started late therapy (after 30 days) took longer to return to play and achieve visual symptom resolution. The early therapy group had a mean score of 1 (IQR: 0, 5.5) in the ocular score and

Table 1. VRT Tests[10,11,15,16,20–23]

Tests	Description	Normal result	Abnormal results
Near point convergence	Ability to focus on an object as it moves closer to the bridge of the nose	Focusing on specified object at 6cm or closer	Diplopia or inability to maintain Fixation greater than 6 cm from the bridge of the patient's nose
Horizontal and vertical saccades	Ability to quickly shift gaze right to left (horizontally) or up and down (vertically) while maintaining a stationary head position	Quickly changing focus between two objects without having to correct eye position	Overshooting or more than two saccadic corrections during testing
Smooth pursuits	Ability to coordinate smooth eye movements right and left (horizontally) and up and down (vertically) while maintaining a stationary head position.	Slowly following an object through all visual fields with consistent normal eye movements	Saccadic eye movements present
Adaptation	Ability to focus gaze on a stationary object while moving head right and left (horizontally) and up and down (vertically).	Maintaining focus on an object while moving heading	Patient experiences dizziness or inability to keep eyes focused with head movement
Habituation	Use of repeated exposure to symptom-provoking positions or movements to reduce dizziness overtime.	Symptoms will lessen as practice with stimuli continues	No change in stimulus effect over time
Hand-eye coordination	Activities incorporating simultaneous use of hands and eyes, such as throwing darts, juggling, or catching a ball.	Good communication between visual cues and voluntary muscles allowing task completion.	Inability to perform various tasks that require precision
Gaze stabilizations / Vestibulo Ocular Reflex (VOR)	Patient fixates on an object 0.5–1 meter from the bridge of the nose and shakes their head back and forth 30° from midline for 5–10 seconds. An attempt to "recalibrate" connection between eyes and ears	No change in symptoms	A report of worsening of vestibular and oculomotor symptoms indicates an abnormal result

blurred vision on the PCSS whereas the late therapy group also had a mean score of 1 (IQR: 0, 2) on the PCSS.[15]

Reneker et al.[21] utilized vestibular rehabilitation techniques that included habituation, adaptation, oculomotor control, neuromotor control (including proprioceptive and kinesthetic awareness), as well as balance exercises as indicated by the six therapists in charge of rehabilitation. These interventions were used to promote symptomatic recovery and medical clearance for return to play. These authors found that the vestibular treatment group recovered 1.99 times faster when compared to the control group. These results indicate those in the experimental group were medically cleared to return to sport at a faster rate than those in the control group, and that the experimental intervention is safe and feasible to perform. It also found that those with a prior history of concussion recovered faster than those who have no history.[21]

The intervention in the Schneider et al[16] study included an individualized program consisting of habituation, gaze stabilization, adaptation exercises, and canalith repositioning maneuvers as needed. Dizziness or balance deficits are caused by abnormal sensory input, so the study focused on maintaining proper orientation. This is done by having equal and consistent visual, vestibular, and proprioceptive input through interactions with the environment.[16] These authors also addressed cervical spine dysfunction with either manual techniques or a combination of neurological and sensory motor aspects. Their findings suggest that individuals with persistent post-concussion symptoms are more likely to be medically cleared to return to sport within eight weeks of concussion when using a multimodal approach to treatment.[16]

Storey et al.[19] utilized a standard visuo-vestibular examination including smooth pursuits, horizontal and vertical saccades, horizontal and vertical gaze stability, tandem gait, near point of convergence (NPC), and accommodation. Interventions were created based on the findings of these examinations. Interventions included VOR and balance techniques to improve deficits found during initial examination. Their results indicated that 74% of participants no longer had deficits at final evaluation.

Integrated cervical, vestibular, and visual treatment were utilized by Wong et al.[22] Visual interventions included smooth pursuits, saccades, complex motor tasks including divided attention and laterality, and vergences. Results indicated significant improvement for convergence however, no significant changes in divergence and abnormal saccades were found between baseline and final evaluation.[20] Additionally, 55.6% people who had cervical dysfunction at initial evaluation were cleared with normal cervical ROM, and 100% diagnosed with BPPV symptoms were cleared with full resolution of symptoms.[22]

Majerske et al observed concussion symptom resolution with repeated measures of neurocognitive performance in athletes.[23] The authors found that younger athletes had more difficulty with visual memory, visual motor speed, and reaction time compared to the older athletes. However, the study did not examine whether these symptoms resulted in a longer RTP. Rather, the authors concluded that a well-rounded treatment plan of vestibular, cognitive, and behavioral management should be included in an athlete's recovery, but more research needs to be conducted on how soon after injury these interventions should be incorporated.[23]

VRT AND CERVICAL MANUAL THERAPY

Three studies used cervical manual therapy in combination with VRT to treat vestibular symptoms.[16,21,22] Cervical manual therapy (CMT) treatments included soft tissue release, joint mobilization, and manipulation techniques, cervical neuromotor retraining exercises, and cervical stretching. CMT is used in conjunction with VRT to treat headaches that may occur from whiplash or force trauma that can occur at the time of a concussion.[16] Due to whiplash and/or biomechanical forces cervicogenic headaches are a common symptom.[16,22]

The use of CMT in conjunction with VRT has been shown to increase cervical ROM, decrease average time until medical release,[21] decrease average days until symptom resolution when using the Post-Concussion Scale (PCS).[21] Acute concussion was defined as up to 14 days post-concussion in a study by Reneker et al.[21] Subjects were eligible for examination and to begin therapy treatment at 10 days post-concussion. The average time of treatment until medical release for those in the experimental group was 15.5 days, and 26 days for those in the control group. The average number of days to recover when using the Post-Concussion Scale (PCS) was 13.5 days for the experimental group and 17 days for the control group. Additionally, participants who received treatment for cervical dysfunction and vestibular dysfunction demonstrated significant improvements in cervical ROM (55.6%) and post-concussion symptoms.[22]

In the study by Schneider et al.[16] the intervention group received both cervical and thoracic manual therapy as well as vestibular rehabilitation whereas the control group underwent conventional physical therapy interventions, not including CMT or VRT. Cervical spine interventions were performed prior to providing vestibular rehabilitation during each session. Objective outcome measures used included the Sport Concussion Assessment Tool (SCAT) and the Dizziness Handicap Inventory (DHI). The SCAT is a standardized tool used for evaluating suspected concussions that was first published in 2004 by the Concussion in Sport Group.[25] Since then, it has been continuously updated leading to the development of the SCAT 5 in 2017. Although the SCAT employs a baseline neurological screen, it does not utilize adequate vestibular or oculomotor testing.[25] The DHI is a 25 item self-assessment designed to evaluate the self-perceived handicapping effects imposed by dizziness.[26] Of the participants that completed the study, one of fourteen participants (7.1%) in the control group was cleared to return to sports within the eight weeks of treatment while eleven of fifteen participants (73.3%) in the intervention group were cleared,[16] and 64% of participants that were medically cleared reported no cervical pain. Participants who did not complete the study were included in final data analysis and these results suggest that 55% more of the participants in the treatment group would be cleared to return to sport within 8 weeks. These statistics suggest that utilizing vestibular rehabilitation and cervical manual therapy to treat concussions makes athletes 10.27 times more likely to be medically cleared to return to sport within 8 weeks of initial concussion onset.[16] Additionally, participants in the intervention group who were medically cleared to return to sport showed greater improvements in Sport Concussion Assessment Tool-2 total score and the Dizziness Handicap Inventory (DHI) score as compared to those participants that were not medically cleared to return to sport.

DISCUSSION

The aim of this systematic review was to evaluate the benefit of early vestibular rehabilitation therapy in reducing symptoms of post-concussion syndrome and return to sports time compared to rest. The randomized control trials and retrospective cohort studies mentioned in this review provide evidence that monitoring these symptoms is effective at revealing concussions and assisting with the development of a recovery timeframe. However, not all results showed beneficial outcomes between vestibular exercises and an early return to sport.

VRT: BALANCE INTERVENTIONS

Ahluwalia et al[15] utilized various progression of balance loads with the addition of gaze stability and VOR exercises, however, specifics were not mentioned in the study. Delaying VTR initiation more than 30 days post-injury appears associated with prolonged times to RTP and achievement of symptom resolution.[15] However, more research should be conducted to determine effects of early initiation of VRT on return to learn rather than just return to play. Return to learn indicates when an athlete is allowed back to normal school functions such as sitting in a classroom with bright lights, using tablets/screens/computers, and focusing on the usual schoolwork/studying. This is important to note as it can dictate an athlete's post-concussion symptoms and whether they are ready to also return to their specified sport. Schneider et al[16] concluded that a combination of cervical and vestibular physiotherapy decreased time to medical clearance to return to sport in youth and young adults with persistent symptoms of dizziness, neck pain and/or headaches following a sport-related concussion.[16] Although this particular study discussed the residual effects of post-concussion symptoms, little is known as to when it is safe to begin VOR and balance exercises immediately after a concussion. Story et al. indicated that

even young children with persistent dizziness and balance deficits after concussion can tolerate and potentially benefit from a course of vestibular rehabilitation.[19] Yet again, the time frame to include these types of exercises is not outlined in a 'return to play' protocol for athletes. Kontos et al. demonstrated that adolescents who receive early (<21 days from injury) vestibular rehabilitation intervention following concussion experience more pronounced clinical improvement in vestibular items (as measured by the VOMS) than a behavioral management control group.[8] Based on the results from these studies, there is no clear timeline as when to begin balance activities to treat vestibular symptoms during concussion recovery.

VRT: VISUAL INTERVENTIONS AND CERVICAL MANUAL THERAPY

Ellis et al. discussed that patients with VOD take twice as long to recover following acute SRC compared to those without VOD. The identification of the presence of VOD at initial consultation is important to prevent prolonged recovery and development of PCS.[24] Based on the results interpreted from Wong et al.[22] visual and vestibular rehabilitation improved clinical and patient-reported outcomes for all systems. Therefore, it is important to assess for vestibular symptoms within the first three weeks following injury to improve recovery time. Patients with physical symptoms at 10 days post-concussion may benefit from PT interventions consisting of individually prescribed manual techniques, vestibular rehabilitation, oculomotor, and neuromotor retraining.[21] These should be performed much earlier than one week into an athlete's recovery from a concussion to prevent chronic physical symptoms from developing.

Based on the results from different studies, balance interventions alone were not proven to be an effective treatment at significantly reducing early concussion symptoms if used without other vestibular interventions. Solely using balance interventions does not address the other systems (visual and vestibular) that are highly affected during a concussion. However, there were no positive or negative significant differences between groups, indicating they did not hinder an athlete's performance. Visual interventions along with cervical manual therapy showed significant improvements in concussion symptoms when performed early (10-30 days after onset of injury) as compared to performing these interventions at a late onset of injury (after 30 days). This is due to the idea that multiple systems need to be addressed when treating for concussion symptoms as multiple systems are injured when a concussion is sustained. While some appear to recover from concussions in a relatively short time frame it appears that those who display vestibular symptoms require the most time to reach full recovery secondary to the thought that several systems must work together to achieve equilibrium in a person's body. Patients with vestibular signs on initial evaluation, along with those who experienced prior concussions take a significantly longer time to return to sport.[27] These patients also achieved worse scores on computerized neurocognitive testing and require longer recovery times. Although more research and data collection studies need to be done to determine the effectiveness of early intervention of VRT for SRC; using VRT in conjunction with a standard protocol can reduce post-concussion symptoms and reduce an athlete's time to return to play.

LIMITATIONS

This systematic review had several limitations related to the amount of available data on the topic of VRT and SRC, including a limited number of randomized controlled, and differences in the age groups and genders of the athletes represented in each study. The age of participants ranged from five to thirty years. This is a large age range and represents vast differences in brain development which may affect recovery from a concussion or a mild traumatic brain injury. Additionally, there was an absence of consistency within the included articles with the type of sport (contact vs non-contact) played when the athlete sustained the concussion, the severity of the concussion and related symptoms, and a lack of a consistent definition for defining medical release for the athlete to return to sport.

CONCLUSION

Beginning vestibular rehabilitation therapy as early as 10 to 14 days post-concussion does not appear to be detrimental to an athlete's healing and may help to reduce recovery time and time to return to sports. However, more data collection is needed to further determine the effectiveness of VRT as an early intervention in reducing post-concussion symptoms and decreasing recovery time before return to sport. Leaving vestibular symptoms untreated is shown to have long term effects and a prolonged return to play interval. Therefore, incorporating vestibular rehabilitation therapy into concussion recovery protocols is beneficial for the athlete's long-term health.

COI STATEMENT

All authors of this manuscript declare that they have no financial or non-financial conflicts of interest to disclose.

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SUPPLEMENTARY MATERIALS

Appendix 1

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