A COMPARISON OF VESTIBULAR REHABILITATION AND ACTIVE RECOVERY ON RETURN TO PLAY TIME IN SPORT-RELATED CONCUSSION ATHLETES OR PARTICIPANTS – LITERATURE REVIEW

LITERATURE REVIEW

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Date: February 2023

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Abstract

Introduction

Sport-related concussions (SRC) are extremely prevalent in athletes of all levels in our society today. Therefore, effective physiotherapy interventions are important to help with the recovery and the return to play (RTP) process, each athlete faces. This study investigates two modalities that have good effects on athletes' RTP or return to sport (RTS). These are vestibular rehabilitation (VRT) and active recovery (AR). However, there is a gap of knowledge in the current literature solely comparing these two interventions. This literature review's primary aim is to make an evidence-based recommendation on which modality has quicker RTP for athletes who have an SRC.

Methods

In this literature review, the databases used were Google Scholar, PubMed and PEDro. 'Sport-related concussions, athletes, vestibular rehabilitation, active recovery, injury or return to play time' were all elements of the search strategy. The number of participants, ages, initiation and type of rehabilitation, days out of the sport or time and duration of the injury were the data extracted for inclusion.

Results

Six studies met the inclusion criteria. Two studies were cohort studies and had a low to moderate level of bias on the Cochrane Risk of Bias Assessment tool. Out of the other four studies, one article scored 8/10, one scored 5/10 and two scored 4/10 on the PEDro scale. Both interventions have faster RTP/RTS times than their respective control groups, However, AR shows quicker RTP time in SRC athletes than VRT. Statistically significant evidence was found in both groups for quicker recovery and RTP time. A broad range of the timing of implementation from the injury of the two treatments resulted in a wide scope of RTP times.

Conclusion

SRC injury is ever-increasing in prevalence. The results indicated from this literature review that AR and VRT have a positive impact on faster recovery in athletes with SRC injuries. The modality with the faster recovery time was AR. At this current time, the literature is limited. However, physiotherapists should include these interventions in their treatment plans on an individual basis, especially AR, when faced with this population to permit faster RTS and recovery time.

Keywords: SRC, VRT, AR, athlete, RTP

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Introduction

Sport-related concussion (SRC) is a common injury for athletes of all age categories in all levels of sports (Harmon et al., 2019). SRC is a frequent injury in collision sports and full-contact sports (Gardner et al., 2019). It is estimated that 3.8 million concussions relating to sporting activities are diagnosed in the United States annually, with 50% going unreported (Hallock et al., 2023; Harmon et al., 2013). Professional sports have produced annual injury reports on the athletes participating in their leagues and sports codes for several years. The National Hockey League (NHL) incidence rate of SRC has increased to ten times more likely of receiving this injury, from the 1986-1987 season to the 2011-2012 season. The incidence rate of 0.42 concussions per 100 games, to 4.88 concussions per 100 games in the two seasons respectively in the NHL (L. Donaldson et al., 2013; Wennberg & Tator, 2003). The prevalence of SRC per 1000 player match hours is 3.9 in professional rugby and 4.3 respectively, in Australian Rules Football (Gardner et al., 2014). In the 2020-2021 season for professional men athletes in the English Rugby Football Union, the prevalence of a match SRC was 22.2 per 1000 hours (Premiership & Men, 2021). According to the latest consensus statement on concussion in sports, before starting the graded return to sport (RTS) progression strategy, a preliminary period of 24-48 hours of relative physical and cognitive rest is advised and should be adhered to by the athlete. All athletes of different skill levels, no matter their level of participation, or status as professional, elite, or recreational athletes, should be handled according to this RTS progression strategy (Hallock et al., 2023; McCrory et al., 2017).

An SRC originates from a direct jolt or blows to the head that causes several symptoms. Which might include headaches, loss of balance, dizziness, blurred vision, poor concentration, vomiting or nausea. (Kerr et al., 2018) The 2017 Concussion in Sport Group (CISG) consensus statement, clinically defines the course of an SRC: It is caused by a direct blow to the head, neck, or face or anywhere on the body which has been transmitted to the head by an instinctive force. This causes a quick onset in the disruption of neurological function, which can be resolved unprompted. These neuropathic changes are a disturbance of function rather than a structural injury, as seen in neuroimaging studies. This results in a variety of signs and symptoms that may or may not include loss of consciousness. Typically, symptoms follow a sequenced course, however, symptoms can be prolonged. (McCrory et al., 2017), (Gardner et al., 2019) Due to the nature of an SRC and the consequential vast symptoms experienced without an objective method of measuring the underlying metabolic injury, concussion management requires a broad skill set from physiotherapists. Many modalities like transcranial magnetic stimulation, heart rate, exercise, fluid biomarkers, functional MRI, magnetic resonance spectroscopy, diffusion tensor imaging, cerebral blood flow and electrophysiology can measure the physiological change that occurs after SRC (Feddermann-Demont et al., 2017; Kamins et al., 2017). However, there is no singular “physiological time window” for SRC recovery because variations in modalities, time course, outcomes and study design vary. (Kamins et al., 2017) Hence a range of different physiotherapeutic techniques and management are used in the treatment of SRC. (Howell et al., 2019), (Art et al., 2023)

Vestibular rehabilitation (VRT) and active recovery (AR) as the synonym term of aerobic exercise (AE) which will be referred to in this review also, are two treatment interventions that have both good effects on symptoms and return to playtime (RTP). They both are incorporated in a span of evidence-based interventions and guidelines that are available to assist physiotherapists and healthcare personnel in this field (A. Donaldson et al., 2016). VRT can be defined as an exercise-based

treatment to facilitate vestibular substitution and adaption. The aim of VRT can be spilt into main objectives, of increasing gaze stability, improving vertigo, optimizing everyday living activities and improve postural stability (Han et al., 2011). AR and AE are two forms of exercise intensity. AR means non-strenous light activity, exercises or activities like walking, mobility exercises and swimming, it helps to restore your muscles after intense exercise. AE is defined as any activity that relies on large muscle groups to do a structured and continuous physical activity. It needs the metabolic system to produce energy from the use of oxygen. It can be done at a low or high intensity (Patel et al., 2017; Schneider et al., 2017).

The wide-ranging and complex symptoms endured by the athlete mean the interventions for SRC must be individualised to the athlete experiencing the SRC (Baker et al., 2021; Gupta et al., 2019). In past research, the best recommendation for SRC treatment was complete rest in terms of cognitive and physical rest, from all activities or "cocoon therapy" even after the initial period of cognitive and physical rest advised for 24-48 hours after SRC (Haider et al., 2021; Leddy et al., 2018). Sustained rest, which is cognitive and physical rest after the initial 24-48 hours, is not effective in relieving post-concussion symptoms. Moreover, controlled AR treatment has higher efficacy in reducing symptoms than complete rest in this period (Hallock et al., 2023). Also, in turn, this reduces the time the athlete is out of the sport (Leddy et al., 2018), (Hallock et al., 2023). Balance and vestibular impairment from an SRC is contributed to a force sustained to the central and peripheral neural substrates that integrate sensory information. These symptoms of the patient must be addressed before RTS. Hence if not treated properly RTP time lengthened (Aligene & Lin, 2013). From the current literature VRT, has proven to be an instrumental factor in rehabilitating symptoms from a mild traumatic brain injury (mTBI) or SRC. Consequently, this has reduced time out of the sport (Aligene & Lin, 2013), (Gurley et al., 2013).

The RTP time for athletes diagnosed with SRC varies due to different treatments being administered and recommended (Covassin et al., 2021), (McLeod et al., 2017). These two interventions of VRT, and AR, as the umbrella term of aerobic exercise (AE), have both good effects on concussion symptoms and RTP/RTS time. The exact dates of RTP depend on the diagnosis and the commencement of SRC symptoms and treatment administered. There is a general structure for sports bodies to follow a graded RTS strategy. Furthermore, within individual sporting organisations, there are policies in place for SRC injuries in athletes on what parameters and markers need to be hit before a return from injury can happen (McCrory et al., 2017; McNamee et al., 2023). Nonetheless, there is a gap in the knowledge when we compare these interventions against one another by solely looking for the best RTP/RTS time for all athlete types young and old diagnosed with SRC. Reviewing the literature and seeing the most up-to-date trials and studies for these interventions of VRT and AR could be beneficial in understanding why one modality had a larger effect on quicker RTP time or the way the researchers conducted the study resulted in positive RTS time result for SRC in athletes. SRC's average RTP time is 29.4 days (D'Lauro et al., 2018). Additionally, looking at the results obtained by these interventions could help with better implementation of the interventions in the future for this patient population (Covassin et al., 2021), (McLeod et al., 2017). The main question of this literature review was to ask: When you compare VRT and AR what intervention has quicker RTP for an SRC athlete?

Methods

Study design

This literature review was undertaken to compare VRT and AR on SRC or mTBI in athletes' RTS/RTP time. This research question was conducted in adherence to the PICO concept, patient: sport-related concussion, intervention: VRT, comparison: AR, outcome: time out of sport from SRC.

Search strategy

From inception to April 2023, the execution of an electronic literature search was performed. Relevant and reliable literature was scrutinised in the scientific databases Google Scholar, PubMed, and Pedro for the review. The 3 databases were chosen due to the vast data available, which was used for its filtering of articles and citation tracking. This attained more in-depth physiotherapy-related articles.

Search Terms

In the PubMed and Google Scholar search the Boolean operators "AND" and "OR" were used to narrow the search. In Pedro, a wider search was conducted. The keywords identified for use in the 3 databases were: concussion in athletes or sports participants, "sport-related-concussion", "mild traumatic brain injury", balance recovery "vestibular rehabilitation", exercise recovery "active recovery", time out of sport "injury time" or "injury time loss". *(Table 1: Search Terms)*

Eligibility Criteria

Inclusion Criteria

Articles included had to undergo an eligibility criterion. The criteria used for data selection for the articles were only included if they specifically showed that the concussion received was an SRC, the participants had to be athletes, regardless of level. Therefore, amateurs or professionals either individual or team-orientated were included. Also, for a valid type of VRT or AR intervention, the study had to provide outcome measurement for the length of injury time or RTP/RTS time.

Inclusion Criteria

Studies were excluded if they were not accessible in full text or English. They had other serious injuries in conjunction with SRC. Finally, if the study was not a Randomised Control Trial, Non-Randomised Control trial or Cohort study it was excluded.

Data Process and data items

For this literature review, both abstracts and titles were assessed for credibility by two independent researchers (Shirley Bailey (SB) and Niamh Battles McGeoghan (NBM)). The same process was undertaken for the next step of judging full-text studies. The need for 2 researchers was to prevent bias, as both researchers undertook an independent search. If there was a discrepancy between the 2 researchers or an agreement could not be made, a third researcher made the final decision.

Data Extraction

The extracted data from the included studies in this literature review was the number of participants, the age of the participants, initiation and type of rehabilitation, days out of sport or time and duration of the injury. The extracted contents were contrasted with one another and analysed subsequently. *(Table 3: Study Characteristics) (Table 4: Interventions and Results)*

Data analysis

The data collected from every article was further analysed, using the guidelines for systematic reviews from PRISMA (Page et al., 2021). The effect size or p-value, CI 95% was used. The demographics of the study population, and the start time of either two modalities, recovery or RTP/RTS were expressed in averages and ranges.

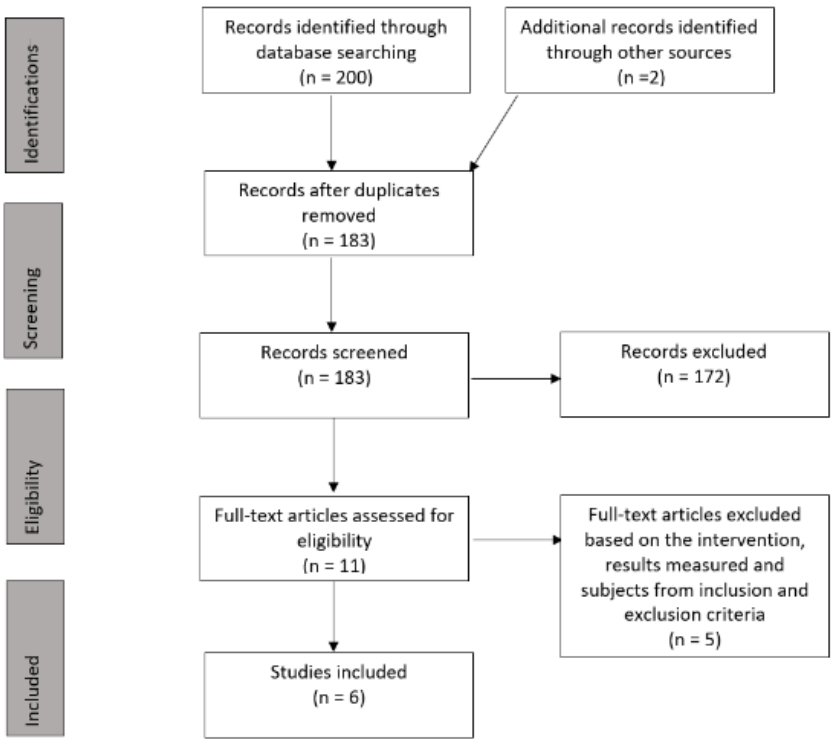
Methodological Quality Analysis

All studies included were screened for methodological quality and level of evidence (Arksey & O'Malley, 2005). The PRISMA guidelines were used in accordance with writing and selecting the studies. The studies included were of recent relevance being from the years 2014-2022.The PEDro scale was used to assess the validity of studies. The PEDro scale is an 11-point scoring system that recognizes the internal and external validity of the randomised control trial. A point is only given when the related criteria are present in the article. The scale can be divided into 3 subcategories, 3 points as "poor quality", 4-5 points as "fair quality "and 6-10 points as "high quality". This scale allows for the studies included to be assessed for the accuracy of their quality (Ma et al., 2020; Van Den Berg et al., 2013). For cohort studies, they were screened using the Cochrane Risk of Bias Assessment Tool. *(Table 2: Quality Analysis of Studies Included)*

Results

Study Selection

The search conducted from inception to April 2023, recorded 202 possibly relevant studies. 20 studies on Pedro, 44 studies on Google Scholar, 136 studies on PubMed and 2 through other sources. 183 was the total amount after duplicates were extracted. 183 studies were screened through 2 researchers (SB, NBM), and 172 were excluded. 11 full-text studies were chosen for eligibility and 5 texts were rejected for the current review of the literature because they failed to meet the qualifying requirements, the complete texts were not available, and the articles were not pertinent to the study and inclusion criteria. The method used to identify the 6 papers that were included in this literature review is shown in Figure 1: Flow Diagram. This process was conducted using PRISMA flow diagram guidelines (Page et al., 2021).



(Figure 1: Flow Diagram)

Study Characteristics

AR was used in 3 of the studies. The other 3 studies used VRT intervention out of the six studies included. The control groups of the studies included either involved a placebo, rest, or multimodal approach or different intervention commencement times, of the same intervention. The main outcome measure extracted was RTP/RTS or recovery time from the SRC. However, additional measures were applied in the studies, this included symptom resolution and severity. The total number of subjects across the six studies was 361. The population's age avergae over the six studies was 19.8 (10.2-30) years. Time elapsed from post-SRC injury to treatment inception for the three AR intervention groups from the three corresponding analysed studies was 4.9 days on average. The RTP/RTS or recovery time average was 18.83 days. In contrast, the 3 interventions for VRT from their respective three studies were on average 26.3 days. The RTP/RTS time on average was 45.7 days. The population characteristics, the intervention description and inception time, and the intervention and outcome measures are all described and can be viewed in the *Appendix. (Table 3: Study Characteristics) (Table 4: Interventions and Results)*

Risk of Bias / Evidence level

Of the three randomised control trials included one was of high evidence with a score of 8 out of 10 for risk of bias. When compared the other two randomised control trials had a low-quality score of 4 and 5 out of 10 and additionally the quasi-experimental study (non-randomised study) had 4 out of 10 for risk of bias. The PEDro scale was the measure used in these studies. The other two articles were retrospective cohort studies their risk of bias was low to a moderate level on the Cochrane Risk of Bias Assessment Tool. Four out of the six articles had substantial development when the outcomes of the treatment group and control group were set against one another (Kontos et al., 2021; Schneider et al., 2014; Willer et al., 2019; Worts et al., 2022). In the two articles comparing the intervention of

VRT and AR respectively, against the control being the different starting times of the intervention, there was also a significant improvement from the intervention to the control group (Ahluwalia et al., 2021; Popovich et al., 2021). Only one high-quality article demonstrated statistical significance in the results, comparing the intervention and control groups. However, no adverse effects and improved symptoms in the participants were seen with the intervention of VRT and AR was applied as the intervention.

Results of Individual Studies (Interventions)

Vestibular Rehabilitation Intervention

VRT intervention was included in three out of the six studies that analysed for the effect on RTP time (Ahluwalia et al., 2021; Kontos et al., 2021; Schneider et al., 2014). VRT intervention consisted specifically of seated vestibular-ocular reflex exercises with progression, which included the balance haul and exercises for visual motion sensitivity, and gaze stabilisation exercises. The exercises applied used adaption or substitution and habituation in different cases. VRT was personally administered to every subject from their symptoms produced and a physical examination was carried out. Regarding the RTP time the intervention in collation to the control (late initiation of VRT) was a median of (31 days ([IQR]22.5,74.5) vs 110 days ([IQR]61.3,150.8), P=0.03 (95%CI, -115.0 TO -8.0)). The intervention group had faster RTP. (Ahluwalia et al., 2021).

In the intervention, VRT exercises were performed. These home exercises were for 30 minutes/per day, for a duration of 4 weeks. 16% of the total study did not come for a medical clearance appointment. N=42 was the remaining sample for medical clearance. This ranged from 22-171 days, (mean 53.9±29.1, a median of 45 days). VRT group averaged 50.2±23.7 days (95% CI: 39.9-60.4 days) for medical clearance, whereas the control (multimodal treatment) averaged 58.4±34.7 days (95% CI: 41.7-75.3 days; p=0.37) (Kontos et al., 2021).

The intervention and the control treatment were distributed once a week for eight weeks, or until medical clearance by a physiotherapist that followed a standard concussion protocol, consisted of cognitive and physical rest until symptom-free, and then introduced a graded exertion plan. All participants kept a daily diary of activities to ensure compliance with the allocated home exercise plan. Participants in the intervention received VRT on an individualised basis. This included dynamic balance exercises, standing balance exercises, adaption exercises, gaze stabilization, canalith repositing manoeuvres, habitation, and joint mobilisation of the cervical and thoracic spine. 11/15 participants in the VRT group were medically cleared compared to the 1/16 participants in the control group (multimodal treatment) when RTP within the eight weeks (56 days) was the outcome and (95%CI 40-92.3 days, P=<0.001) (Schneider et al., 2014).

Active Recovery Intervention

For this literature review, three of the six studies used AR as the therapy for the intervention group. They defined AR as AE. (Popovich et al., 2021; Willer et al., 2019; Worts et al., 2022) AE treatment was performed at a sub-symptomatic level by participants involved in the study and with an assessor's supervision every time the treatment was carried out. The protocol followed was modified from the Buffalo Concussion Treadmill test. Athletes begin supervised AE at a low intensity on a stationary bike. Heart rate, perceived exertion, and self-reported symptom severity are recorded at 2-minute intervals, with the intensity of exercise increasing gradually as tolerated every 2 to 4 minutes unless symptoms do not surpass by 3 or more points on a 10-point symptom scale. If

symptoms do increase by 3 or more points, the intensity of the exercise is reduced. If symptoms continue to elevate when aerobic exercise intensity is reduced, the supervised AE was finished. If symptoms further worsen despite the decreased intensity of exercise, supervise aerobic exercise is then stopped. If stationary bike riding is tolerated, the inclusion of other cardiovascular exercises can occur, including elliptical or treadmill training; when these are also tolerated, agility drills and sport-specific exercises may also be performed. This was individualised per patient tolerance and capabilities of activity capacity, and recovery stage. The intervention (early supervised AE) was associated with earlier RTP time, Hazard Ratio was 2.35 and, 95%CI (1.09-5.07). When comparing the intervention to the control (non-early supervised AE) the RTS time mean was 26.5 ± 11.2 days vs 35.1 ± 26.5 days; P=0.020) (Popovich et al., 2021).

AE intervention was implemented as subthreshold AE when the participant was at 80% of heart rate as this achieved symptom exacerbation. The AE began with a 5-minute warm-up, and then 20 minutes of AE was conducted on a treadmill or stationary bike, or by walking or jogging outdoors if the equipment was not available to the subject. If the participant could not finish the AE in keeping within the parameters of the prescribed heart rate and if symptoms increased within 2 points or excess of this, from the pre-exercise symptom level (based on a 10-point Visual Analogue Scale) the intervention was stopped. This was concluded with a 5–10-minute cooldown. A new heart rate was determined each week on an individual basis for every participant from the assessors. AE group recovered in a median of 13 ([IQR]10-18.5) days, in contrast to the placebo-like stretching group and rest group who got better in 17 ([IQR] 13-23) days and 16 ([IQR]9.25-23.23) days respectively (p=0.020) (Willer et al., 2019).

The AE intervention was conducted once on a treadmill walking for 20 minutes at 40% age-predicted heart rate max. In comparison to the control groups (60% age-predicted heart rate max) and (seated rest) the intervention average recovery in days was shorter [Median=17.0 (IQR: 7) d vs. 22.5 (11) d vs. 19.0 (28) d] (p=0.358), respectively (Worts et al., 2022).

Discussion

Main points

This review's central objective was to examine the efficacy of VRT and AR modalities on RTP/RTS time after athletes were diagnosed with SRC after the 24-48 hours of cognitive and physical rest was adhered to before the interventions took place. The protocols and management of SRC are ever updating. (A. Donaldson et al., 2016; McCrory et al., 2017; Walshe et al., 2022). There is a gap of knowledge in the current literature regarding exclusively comparing these two effective interventions on RTP time in this specific population.

The results of this review answer the main question posed. What is the comparison of VRT and AR interventions on RTP time in SRC in athletes? This review showcases that decreased RTP time is evident for both interventions; VRT and AR when applied in post-SRC treatment against the control groups of the study. The controls either rest, placebo-like stretching, range of motion exercises, or later initiation time of the intervention. From the results and data collected AR intervention produces a faster recovery or RTP time for athletes, when compared to VRT intervention, 18.83 days vs 45.7 days. VRT was implemented later (26.3 days) after their SRC in contrast to their counterparts in the AR group (4.9 days). The two studies that looked at VRT and AR and their control group being the later initiation time of the intervention group, both had positive results compared to this control (Kontos et

al., 2021; Popovich et al., 2021). Therefore, there is an argument that implementation time could influence RTP time in SRC.

Summary of studies

Of the three VRT studies, the intervention of two of the studies results on RTP was statistically significant comparing the intervention group and the corresponding control group. The p-value was under 0.05 (Ahluwalia et al., 2021; Schneider et al., 2014). The third study in this category did not have a significant p-value, however, the control group's multimodal approach could have altered the effect size as the group had a lot of modalities (Kontos et al., 2021).

The three studies on AR intervention had one study with a significant p-value (Popovich et al., 2021). In the other two studies, they had two control groups compared to the first study which had one control group. This could have affected the statistical significance in the two studies. The first control group was a placebo-like stretching group and the other was a rest group (Willer et al., 2019). The other study's control groups were different rate of predicted heart rate max from the intervention and second control a seated rest group (Worts et al., 2022).

Future recommendations for Physiotherapy

A systematic review delved into the physiological time to recover after a concussion. This review could not delineate a precise 'physiological time window'. The author suggested through a multiform of studies researched that there should be a buffer period where gradual activity is increased before the instigation of full contact exercise, because physiological dysfunction may outlive present-day clinical assessments of recovery (Kamins et al., 2017).

AR and VRT should be implemented by physiotherapists as early as possible to improve RTP time duration in adolescent or adult athletes. According to the findings of the studies reviewed, there is evidence to support the use of VRT and AR respectively, in athletes of 19.8 (10.2-30) years in post-SRC. When weighed against conventional treatments like cognitive and physical rest, the data presented in this literature review indicates AR and VRT result in faster time to sport for this previously stated population cohort. To enable faster recuperation and RTS, physiotherapists and healthcare providers alike, ought to consider involving these therapies in their regimen of therapy for this group of patients. (Leddy et al., 2018; Park et al., 2018)

SRCs have become exceptionally frequent (Pfister et al., 2016; Walshe et al., 2022). The advantages of beginning training during the post-acute phase of SRCs have been highlighted in the up-to-date literature; however, the best mode or volume of physical therapy at this stage has not been unambiguously determined. Within the post-acute time frame, outcomes were demonstrated using a variety of exercise techniques, comprising of cycle ergometry, treadmill, swimming, biking, walking and even sports techniques and drills (Kamins et al., 2017).

As a result, while meticulously evaluating exercise intensity during this rehabilitation phase, clinicians should consider a personalised approach to exercise modality prescription. Though there is only a restricted quantity of evidence available, practitioners treating participants throughout this time frame of post-SRC might think about administering highly monitored, individually tailored exercise programs with increasing levels (Baker et al., 2021).

Limitations

Two papers per PEDro had a high probability of bias (Willer et al., 2019; Worts et al., 2022). A further limitation was there was a mix of RCTs and cohort studies in this literature review. Additionally, only one RCT had low high quality and low risk of bias, compared to the other three that had a high risk of bias but low quality. An additional disadvantage was that the studies were covering different time frames of recovery from SRC. This influenced the RTP/RTS time. This could impose applicability and validity of the results by the variation of the long timelines of SRC. Greater impact sizes, lower statistical power, and representation of the population could all be consequences of this. From the results, there was statistical significance in three out of the six studies when the intervention groups were compared to the control groups. However, if we interrupt clinical significance and talk about effect size, when we apply these interventions to clinical practice the small sample size and the variation of the interventions used will affect the implementation of these interventions into practice by physiotherapists.

Conclusion

This literature review aimed to look at the most recent research on the interventions of VRT and AR on athletes who obtained an SRC injury. Then to analyse and differentiate which intervention had a quicker RTP/RTS time for this specific population. SRC injury is ever-increasing in prevalence. The results indicated from this literature review that the modalities AR and VRT both have a positive impact on faster recovery in athletes with SRC injuries. The modality with the faster recovery time was AR. At this current time, the literature is limited. However, physiotherapists should include these interventions on an individual basis in their treatment plans, especially AR, when faced with this population to permit faster RTS and recovery time.

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Appendix

Electronic Data Base	Filters Applied	Search Terms
PubMed	No filters	((((Sport related concussion) AND (Active recovery)) AND ((Injury time) OR (Injury time loss))) AND ((injury time) OR (Injury time loss))) OR (((sport related concussion)) AND (Vestibular rehabilitation)) AND ((Injury time loss[Title/Abstract]) OR (Injury time)))
Google Scholar	No filters	("sport related concussion") AND ("active recovery") AND ("vestibular rehabilitation")
Pedro	No filters	"Sport related concussion"

(Table 1: Search Terms)

Study	Type of Study	PEDro Scale	Cochrane Risk of Bias Assessment Tool
(Ahluwalia et al., 2021)	Retrospective Cohort Study	N/A	6/8
(Kontos et al., 2021)	RCT	5/10	N/A
(Popovich et al., 2018)	Retrospective Cohort Study	N/A	6/8
(Schneider et al., 2014)	RCT	8/10	N/A
(Willer et al., 2019)	Quasi-experimental trial (non-RCT)	4/10	N/A
Worts et al., 2022)	RCT	4/10	N/A

RCT: Randomised Control Trial, N/A: Not applicable

(Table 2: Quality analysis of studies included)

Author and Year	Population	SRC Injury to Initiation of Intervention
(Ahluwalia et al., 2021)	Total Participants: N = 23, Median age (16.4 ± 2.98), age range (5-23y) 43.5% M (Intervention) Early VRT: N=10 Late VRT: N=13	Early VRT: treatment initiated within <30d 21.5d (17,28.25) Late VRT: treatment initiated over > 30d, 74 d (37.5,125)
(Kontos et al., 2021)	Total Participants: N=50 Adolescent athletes (62% F, N=31) age (12-18y) VRT Intervention: N=25 Control: N=25	1-17 d post-injury (mean: 6.1±4.0 d, median 5 d)
(Popovich et al., 2021)	Total Subjects: N=124 Intervention Group: N=26, Age 15.3 (10.2-19.4) 20M 6F, Control Group: N=98, Age 15.4(8.7-19.8) 68M 30F	Intervention (Early SE): Initiated under 16 d post-SRC. 5.4 (1-15) d Control Non-early SE): Initiated between 16-30 d post-SRC 10.5 (1-30) d
(Schneider et al., 2014)	Total Participants: N = 31 Intervention Group: N = 15 (age range 15 (12-27y), sex range 11M and 4F) Control Group: N = 16 (age range 15y (13-30), sex range 7M, 9F)	Intervention group: median of 53 days (range 8-276) Control Group: median of 47 days (range 31-142)
(Willer et al., 2019)	Total Subjects: N = 103 (age range 13-18y) Exercise Group: N = 52 (age range 15.3 ± 2y, sex range 46% F) Placebo-like Stretching: N = 51 (age range 15.4 ± 2y, sex range 47% F) Rest group: N = 48 (age range 15.4 ± 1y, sex range 25% F)	Starting within 10 days Exercise Group: 4.9 d (2.2) Placebo-like Stretching Group: 4.8 d (2.4) Rest Group: 4.4 d (2.0)
(Worts et al., 2022)	Total Participants: N=30, Age range (13-18y) SRC Participants: N=19 Healthy Participants: N=11 (Intervention)40HR Group: N=9 SRC, N=5 Healthy. 60HR Group: N=6 SRC, N=4 Healthy. NOEX Group: N=4 SRC, N=2 Healthy.	SRC group participants were treated on d 3-7 (4.5±1.3d) post-SRC, with either one of the three interventions: 40HR, 60HR, or NOEX.

Y: years, F: females, M: Males, RTP: Return to play time, VRT: Vestibular Rehabilitation, d: days, AE: Aerobic Exercise, HR: Heart Rate, 40HR: 40% of age-predicted Heart Rate Max, 60HR: 60% of age-predicted Heart Rate Max, NOEX Group: seated rest, min: minutes, SE: supervised exercise.
(Table 3: Study Characteristics)

Author and Year	Intervention	RTP/RTS Time (Days)
(Ahluwalia et al., 2021)	**(Early VRT) Intervention + (Late VRT) Control Group:** Seated vestibular-ocular reflex exercises with progression, which included the balance haul and exercises for visual motion sensitivity, and gaze stabilisation exercises, The exercises applied used adaption or substitution and habituation in different cases. VRT was personally administered to every subject from their symptoms produced and a physical examination was carried out.	**Early VRT:** 31 d ([IQR]22.5,74.5) **Late VRT:** 110 d ([IQR]61.3,150.8), P Value of RTP: **P= 0.03***(95% CI, -115.0 to -8.0) Early VRT RTP faster: SD (log-rank = 4.435, df = 1, P = 0.04).
(Kontos et al., 2021)	**VRT Group:** VRT exercises were performed. These home exercises were for 30 mins/per day, for a duration of 4 weeks. **Control Group:** behavioural management strategies applied, this included sleep, hydration nutrition, stress management and physical activity. Plus, physical activity and stretching (e.g., stationary bike, walking) for 30 mins/per d for the 4 weeks.	8/50 (16%) absent at MC. New MC (N=42). RTP time ranged from 22-171 d, (mean: 53.9±29.1 median of 45 d) **VRT Group:** averaged 50.2±23.7 days (95% CI: 39.9-60.4 days) for MC. **Control Group:** averaged 58.4±34.7 days (95% CI: 41.7-75.3 days; p=0.37).
(Popovich et al., 2021)	**(Early SE) Intervention and (Non-early SE) Control Group:** Start time difference in groups. The protocol for the supervised graded AE (SE) followed was modified from the Buffalo Concussion Treadmill test. SE begins at a low intensity on a stationary bike. Heart rate, perceived exertion, and self-reported symptom severity are recorded at 2-minute intervals, with the intensity of exercise gradually increasing as tolerated every 2 to 4 minutes. If symptoms are aggravated by 3 or more points, the intensity of the exercise is reduced. If further worsening of symptoms at decreased intensity, SE stopped. SE steps: stationary bike riding, other cardiovascular exercises, elliptical or treadmill training, agility drills and sport-specific exercises program is personalised based on the recovery stage and the athlete's individual activity capacity.	**Early SE** was associated with earlier RTS (Hazard Ratio 2.35, and 95%CI of (1.09-5.07). The early SE group had fewer d from SRC until clearance for RTP than the non-early SE group (mean 26.5 ± 11.2 d vs 35.1 ± 26.5 d, **P=0.020**) *. There was a trend toward fewer symptomatic days in the early SE group (P=0.054).
(Schneider et al., 2014)	**(VRT) Intervention + Control Group:** Seen once a week/over 8 weeks or until MC. Obeyed standard concussion protocol by PT (cognitive + physical rest until symptom-free) and logged daily activities of HE plans to ensure compliance. **VRT Group:** Individualised per athlete (dynamic balance exercises, standing balance exercises, adaption exercises, gaze stabilization, canalith repositing manoeuvres, habitation), cervical spine physiotherapy. **Control Group:** Range of motion exercises.	Medically cleared for RTP within 8 weeks (total participants) **Intervention Group:** 11/15 **Control Group:** 1/16 95% confidence interval (40-92.3) P Values and Effect Size **(p = < 0.001) ***
(Willer et al., 2019)	**(Exercise Group) Intervention:** Subthreshold AE was 80% of HR achieved at symptom exacerbation. The 5-minute warm-up and 20-minute exercise were conducted on a stationary bike or treadmill at the prescribed HR. Then 5–10-minute cooldown. The exercise was ceased if symptoms increased by 2 or more points. New HR was calculated each week. **Placebo-like**	**(Exercise Group) Intervention:** recovered in 13d ([IQR]10-18.5d) (P=0.20). 4% DR. **Placebo-like Stretching Group (Control):** recovered

	Stretching Group (Control): patients followed a progressive stretching program for the whole body, which included breathing exercises, and which did not elevate their HR dramatically. Did this for 20 minutes a day. Gradually increased in difficulty per week. **Rest Group (Control):** Complete physical rest and told this would help with their SRC. Rest was identified as abstaining from any sports or forms of exercise and limiting activities that could provoke symptoms.	in 17d ([IQR] 13-23d), 14% DR. **Rest Group (Control):** recovered in 16d ([IQR]9.25-23.23d), 13% of DR. No difference in recovery or DR between sexes.
(Worts et al., 2022)	**(40HR) Intervention, (60HR) Control:** The two-treatment interventions consisted of either a single session of treadmill walking for, 20-min at either 40% or 60% of age-predicted HRmax. **(NOEX) Group:** The control group consisted of seated rest for 20-min.	**40HR, 60HR, NOEX** recovery in d. [Median=17.0 (IQR: 7) d vs. 22.5 (11) d vs. 19.0 (28) d] (p=0.358), respectively

*RTP: Return to play time, VRT: Vestibular Rehabilitation, d: days, AE: Aerobic Exercise, MC: Medical Clearance, Heart Rate, IQR: Interquartile Range, DR: delayed recovery, 40HR: 40% of age-predicted Heart Rate Max, 60HR: 60% of age-predicted Heart Rate Max, NOEX Group: seated rest, min: minutes, PT – Physiotherapist, HE: Home Exercise, SE: supervised exercise, * - Significant Value.*

(Table 4: Interventions and Results)