REVISTA NEUROCIÊNCIAS

Revisão Sistemática

Early aerobic exercise following concussion: a systematic review and meta-analysis

Exercício aeróbico precoce após concussão: uma revisão sistemática e meta-análise

Ejercicio aeróbico temprano después de una contusión: una revisión sistemática y meta-análisis

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Resumo

Introdução. A concussão é um trauma craniano que pode causar alterações neurológicas transitórias ou até mesmo a morte. Tradicionalmente, o repouso completo era recomendado após uma concussão, mas evidências recentes incentivam o retorno ao exercício assim que for tolerável. **Objetivo.** Revisar o impacto do exercício aeróbico no tratamento precoce da concussão esportiva em relação aos sintomas e ao retorno às atividades. **Método.** Revisão sistemática com meta-análise utilizando as bases de dados PubMed, LILACS, Cochrane e SciELO. As palavras-chave utilizadas foram: (treinamento aeróbico OU exercício aeróbico) E (esporte OU atleta) E concussão. Foram selecionados artigos em inglês, espanhol e português, sem restrição quanto ao ano de publicação. **Resultados.** De 124 artigos, 8 atenderam aos critérios de elegibilidade. A maioria dos estudos relatou que a intervenção precoce com exercício aeróbico após concussão promove uma recuperação mais rápida da função cerebral, bem como a resolução de sintomas como alterações na visão, dor de cabeça, problemas de memória e desconforto com luz, quando comparado ao repouso e alongamento. O tempo de recuperação através da liberação médica foi mais curto nos pacientes que realizaram exercício (-0,25 dias; IC 95%, -0,50 a -0,01), quando comparado com o grupo controle. **Conclusão.** O exercício aeróbico demonstrou ser superior no tratamento precoce das concussões esportivas, proporcionando uma reabilitação mais rápida e eficaz.

Unitermos. Concussão cerebral; lesões esportivas; lesões em atletas; exercício aeróbico; resultados da reabilitação

Abstract

Introduction. Concussion is a head trauma that can cause transient neurological changes or even death. Traditionally, complete rest was recommended after concussion, but recent evidence encourages the return to exercise as soon as tolerable. **Objective.** To review the impact of aerobic exercise in the early treatment of sports concussion in relation to symptoms and return to activities. **Method.** Systematic review with meta-analysis using the PubMed, LILACS, Cochrane and SciELO databases. The keywords used were: (aerobic workout OR aerobic exercise) AND (sport OR athlete) AND concussion. Articles in English, Spanish and Portuguese were selected, with no restriction on the year of publication. **Results**. Of 124 articles, 8 met the eligibility criteria. Most studies have reported that early intervention with aerobic exercise after concussion promotes faster recovery of brain function, as well as resolution of symptoms such as vision changes, headache, memory problems, and discomfort with light, compared with rest and stretching. Recovery time through medical release was shorter in patients who performed exercise (-0.25 days; 95% CI, -0.50 to –0.01), when

compared with control. **Conclusion**. Aerobic exercise has been shown to be superior in the early treatment of sports concussions, providing faster and more effective rehabilitation.
Keywords. Brain Concussion; Sports Injuries; Athlete Injuries; Aerobic Exercise; Rehabilitation Outcome

Resumen

Introducción. La conmoción cerebral es un trauma craneal que puede causar cambios neurológicos transitorios o incluso la muerte. Tradicionalmente, se recomendaba un reposo completo después de una conmoción, pero la evidencia reciente fomenta el regreso al ejercicio tan pronto como sea tolerable. **Objetivo.** Revisar el impacto del ejercicio aeróbico en el tratamiento temprano de la conmoción cerebral deportiva en relación con los síntomas y el regreso a las actividades. **Método.** Revisión sistemática con meta-análisis utilizando las bases de datos PubMed, LILACS, Cochrane y SciELO. Las palabras clave utilizadas fueron: (entrenamiento aeróbico O ejercicio aeróbico) Y (deporte O atleta) Y conmoción. Se seleccionaron artículos en inglés, español y portugués, sin restricción en el año de publicación. **Resultados.** De 124 artículos, 8 cumplieron con los criterios de elegibilidad. La mayoría de los estudios reportaron que la intervención temprana con ejercicio aeróbico después de la conmoción promueve una recuperación más rápida de la función cerebral, así como la resolución de síntomas como cambios en la visión, dolor de cabeza, problemas de memoria y molestias con la luz, en comparación con el reposo y los estiramientos. El tiempo de recuperación mediante alta médica fue más corto en los pacientes que realizaron ejercicio (-0,25 días; IC del 95%, -0,50 a -0,01), en comparación con el control. **Conclusión.** El ejercicio aeróbico ha demostrado ser superior en el tratamiento temprano de las conmociones deportivas, proporcionando una rehabilitación más rápida y eficaz.
Palabras clave. Conmoción cerebral; lesiones deportivas; lesiones en atletas; ejercicio aeróbico; resultados de rehabilitación

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INTRODUCTION

Concussion is a head trauma caused by a direct blow that triggers a sequence of metabolic events and neurotransmitter release, which can cause anything from transient neurological changes to intracranial hemorrhage or death[1]. For a long time, complete rest was recommended after a concussion diagnosis, but several pieces of evidence now prove and encourage the return to exercise as soon as it is tolerable by the patient[2].

In the sports context, the American Medical Society for Sports Medicine published a position statement on concussion in 2013 and in 2019. In the 2019 report, a list of

data was made that estimated that between 1.0 and 1.8 million concussions occur annually in the 0 to 18 age group. In a subset, about 400,000, it occurs in high school athletes[3].

In addition to temporarily affecting brain function, some concussions cause structural damage to brain cells, reducing the ability to process information[4]. In the long term, or after repeated injuries, functions such as speech, thinking, memory, balance, coordination and mood can be compromised. Autopsies on boxers' brains revealed a pattern of changes, including destruction of the limbic system[5]. These findings justify initiatives to make sports safer and to validate effective assessment, measurement, and treatment measures.

At the 6th international consensus on concussion in sport, held in Amsterdam in October 2022, those involved once again reinforced the lack of evidence that makes rest an effective treatment measure. On the contrary, the significant influence of including exercise as a tool in early concussion rehabilitation (within 24-48 hours after injury) was emphasized[1].

The aforementioned consensus used as its scientific basis the study carried out by Leddy *et al*.[6], which demonstrated the importance of aerobic exercise in reducing the recovery period and decreasing the incidence of post-concussion syndrome. The data collected showed that the group that started practicing physical exercises early showed a 6-day faster recovery compared to the group that did not perform any physical activity.

This systematic review seeks to review the impact of aerobic exercise in the early treatment of sports concussion in relation to symptoms and return to activities.

METHODS

Type of Study

This systematic review was completed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[7]. The present study is registered in the International Prospective Register of Systematic Reviews with the code CRD420251001312.

Equity, diversity, and inclusion (EDI) statement

In the context of this systematic review, the Equity, Diversity, and Inclusion (EDI) statement was a central consideration. We assessed how the included studies addressed issues related to gender equity, cultural diversity, and the inclusion of minority groups, ensuring that the analysis reflected a broad and representative range of perspectives. EDI was incorporated as a key criterion for evaluating the quality and relevance of the studies, promoting a more comprehensive and equitable approach to data collection and interpretation. This focus ensured that the review not only reflected the effectiveness of the interventions studied but also acknowledged and valued the diversity of the populations involved.

Eligibility criteria

To carry out this systematic review, the PICOS[8] strategy was used, where the population studied were patients who suffered concussion, the intervention was physical exercise, in comparison with patients who did not perform exercise. Outcomes were related to symptoms and return to activities. Randomized clinical trials were used, with no restrictions on language or year.

Sources of information

We performed a computer search, consulting Ovid, Scopus, Web of Sciences, LILACS, CINAHL (Cumulative Index to Nursing and Allied Health), Pubmed, PEDro (Physiotherapy Evidence Database) and the Cochrane Central Register of Systematic Review. We also searched the reference lists of previous systematic reviews and clinical trials eligible for this review. The search for articles ended in July 2024.

Search

The search was based on the previously described PICOS[8] strategy and the Boolean operators AND and OR. The search strategy is represented in Table 1.

Study selection

Randomized controlled trials involving individuals who had suffered concussion were included in this systematic review. To be eligible, the clinical trial had to have assigned

these patients to perform physical exercise. Studies with adolescents and adults, regardless of gender, were also included. Exclusion criteria were studies that involved comparing the results of the intervention with aerobic exercises between a healthy group and a post-concussion group, not detailing the study and analyzing only the intervention group with aerobic exercises.

Table 1. Search strategy in PubMed.

("brain concussion"[MeSH Terms] OR ("brain"[All Fields] AND "concussion"[All Fields]) OR "brain concussion"[All Fields] OR "concussion"[All Fields] OR "concussions"[All Fields] OR "concussed"[All Fields] OR "concussive"[All Fields] OR (("head"[MeSH Terms] OR "head"[All Fields]) AND ("impact"[All Fields] OR "impactful"[All Fields] OR "impacting"[All Fields] OR "impacts"[All Fields] OR "tooth, impacted"[MeSH Terms] OR ("tooth"[All Fields] AND "impacted"[All Fields]) OR "impacted tooth"[All Fields] OR "impacted"[All Fields]))) AND ("exercise"[MeSH Terms] OR "exercise"[All Fields] OR "exercises"[All Fields] OR "exercise therapy"[MeSH Terms] OR ("exercise"[All Fields] AND "therapy"[All Fields]) OR "exercise therapy"[All Fields] OR "exercising"[All Fields] OR "exercise s"[All Fields] OR "exercised"[All Fields] OR "exerciser"[All Fields] OR "exercisers"[All Fields] OR ("physical therapy modalities"[MeSH Terms] OR ("physical"[All Fields] AND "therapy"[All Fields] AND "modalities"[All Fields]) OR "physical therapy modalities"[All Fields] OR ("physical"[All Fields] AND "therapy"[All Fields]) OR "physical therapy"[All Fields])) AND ("clinical trial"[Publication Type] OR "clinical trials as topic"[MeSH Terms] OR "clinical trial"[All Fields] OR ("randomized controlled trial"[Publication Type] OR "randomized controlled trials as topic"[MeSH Terms] OR "randomized clinical trial"[All Fields] OR "randomised clinical trial"[All Fields]))

Data collection process

To extract the selected articles, titles (first stage), abstracts (second stage) and complete reading (third stage) were checked. Next, an exploratory reading of the selected studies was carried out and, subsequently, a selective and analytical reading. The data extracted from the articles were

summarized in authors, journal, year, title and conclusions, to obtain important information for the research.

The methodological quality of the studies was assessed by two independent reviewers. When there was disagreement between them, the article was read in full for reassessment. If disagreement persisted, a third reviewer assessed and made the final decision.

Data items

Two authors independently (AC and CS) extracted data from published reports using standard data extraction considering: (1) aspects of the study population, such as mean age, sex, number of patients, diagnosis; (2) aspects of the intervention performed; (3) follow-up; (4) loss to follow-up; (5) outcome measures; and (6) results presented.

Quality of each study

The methodological quality was assessed according to the criteria of the PEDro[9] scale, which scores 11 items, namely: 1- Eligibility criteria, 2 - Random allocation, 3 - Concealed allocation, 4 - Baseline comparison, 5 - Blinded, 6 - Blinded therapists, 7 - Blinded evaluators, 8 - Adequate follow-up, 9 - Intention to treat analysis, 10 - Comparisons between groups, 11 - Point estimates and variability. Items are scored as present (1) or absent (0), generating a maximum sum of 10 points, not counting the first item.

Whenever possible, PEDro scores were extracted from the PEDro database itself. When articles were not found in

the PEDro database, two trained independent reviewers assessed the article using the PEDro scale. Studies were considered to be of high quality if they had a score of 7 or higher. Studies with a score of less than 6 were considered to be of low quality.

Synthesis of results

The presence of heterogeneity was evaluated using the Chi2 test and the I2 statistic. This statistic illustrates the percentage of variability in effect stimates from heterogeneity rather than sampling error.

Statistical assessment

The mean difference between groups and the respective 95% confidence intervals were calculated and used to quantify the effect of continuous outcomes. For the meta-analyzes in which the studies used the same scales, the results were presented as mean difference (MD) and 95% confidence intervals. Otherwise, the effects were calculated using standardized mean difference (SMD) and 95% confidence intervals. The effect size of the interventions was defined as small (MD<10% of the scale or SMD<0.4); moderate (MD=10% to 20% of the scale or SMD=0.41 to 0.7) or large (MD>20% of the scale or SMD>0.7).

RESULTS

Selection and characteristics of studies

According to the data presented in the article selection flowchart (Figure 1), the search in the databases yielded a total of 124 articles, 97 of which were initially excluded based on reading the title. Then, of the 27 evaluated based on reading the abstracts, 10 were considered not directly related to the theme of this study. Thus, 17 articles were chosen for full reading, of which 6 were excluded for being duplicates, 1 for comparing the results of the intervention with aerobic exercises between a healthy group and a post-concussion group, 1 for not detailing the study and 1 for analyzing only the intervention group with aerobic exercises. Therefore, this systematic review included 8 articles, which met the eligibility criteria for inclusion in this review.

Methodological quality results

According to the PEDro scale, five studies were classified as of moderate methodological quality, two as low quality and one as high quality. The criteria evaluated by the PEDro scale and the scores obtained by each of the studies are presented in detail below in Table 2.

Participants

A total of 547 patients participated in the studies included in this review. The age ranged from 26.7 to 48.5 years and the prevalence was male with 298 (55%). The other data are shown in Table 3.

Figure 1. Research strategy flowchart.

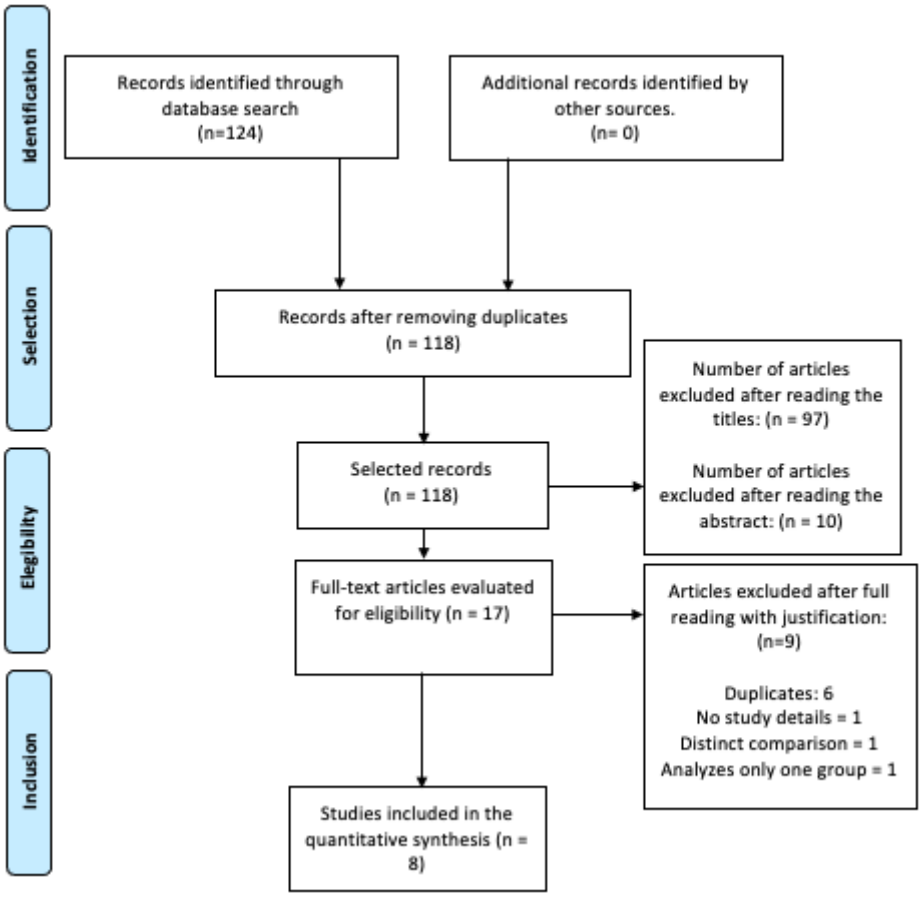


Table 2. Classification of articles on the PEDro scale.

Study	1*	2	3	4	5	6	7	8	9	10	11	Total
Leddy *et al*. (2018)[10]	-	1	1	1	0	0	0	0	0	1	1	5
Hutchison *et al*. (2022)[11]	-	1	0	1	0	0	0	1	0	0	1	4
Howell *et al*. (2021)[12]	-	1	0	1	0	0	0	1	0	1	1	5
Micay *et al*. (2018)[13]	-	1	0	1	0	0	1	1	0	1	1	6
Leddy *et al*. (2021)[14]	-	1	1	0	0	0	1	1	1	1	1	7
Leddy *et al*. (2019)[15]	-	1	0	1	0	0	0	1	0	1	1	5
Willier *et al*. (209)[16]	-	0	0	1	0	0	0	1	0	1	1	4
Kurowski *et al*. (2017)[17]	-	1	0	1	0	0	1	1	0	1	1	6

Items in the PEDro Scale: (1) Eligibility criteria were specified (* - this item is not used to calculate the PEDro score); (2) Subjects were randomly assigned to groups; (3) Subject allocation was concealed; (4) Groups were initially similar with respect to the most important prognostic indicators; (5) All subjects were blinded to the study; (6) All therapists who administered therapy did so blindly; (7) All assessors who measured at least one key outcome did so blindly; (8) Measurements of at least one key outcome were obtained in more than 85% of subjects initially assigned to groups; (9) All subjects from whom outcome measurements were available received the treatment or control condition as assigned or, when this was not the case, data for at least one outcome were analyzed by intention to treat"; (10) The results of statistical intergroup comparisons were reported for at least one key outcome; (11) The study presents both precision measures and variability measures for at least one key outcome.
1 = Item present; 0 = item not presente; a High methodological quality; b Moderate methodological quality; c Low methodological quality

Table 3. Summary of characteristics of the articles analyzed.

Study/ Country	Sample	Participants	Intervention		Measures	Results
			Intervention	Control		
Micay *et al*. (2018)[13] Canada	15	Athletes, aged 15 to 18 years, in the early post-acute phase of concussion and symptomatic on day 6 after injury.	Eight sessions (two consecutive days and one rest day) of aerobic exercise using a cycle ergometer. The first session lasted 10 minutes at 50% of maximum heart rate. The second session differed in duration: 20 minutes. The third session onwards differed in intensity: a 5% increase in heart rate at each session until reaching 70%.	They received usual care, rest and medical advice.	Medical clearance, resolution of symptoms.	No statistically significant difference was found between the mean times to medical discharge in the two groups. Mean time for the intervention group: 36.1 days. Mean time for the control group: 29.6 days. The results of a series of tests showed that the intervention group showed a significant improvement in symptoms between weeks 1 and 3 after injury, while the control group did not achieve a significant improvement until week 4 after injury.
Leddy *et al*. (2021)[14] USA	118	Adolescent athletes within 10 days of a sports-related concussion.	At least 20 minutes of aerobic exercise, at up to 90% of the maximum heart rate at the initial visit, for 4 weeks after the injury.	At least 20 minutes of gentle stretching and breathing exercises that do not significantly raise heart rate for 4 weeks after injury.	Clinical recovery and symptom resolution.	Aerobic exercise had a significant effect on clinical recovery in the first 4 weeks after injury, with a 34% reduction in the risk of persistent post-concussion symptoms. The intervention group recovered in a median of 12 days, while the control group took a median of 21 days.
Leddy *et al*. (2018)[10] USA	54	Adolescents with SRC (1–9 days from injury).	Buffalo Concussion Treadmill Test	Not Buffalo Concussion Treadmill Test	Days to recovery and typical (≤ 21 days) vs. prolonged recovery (> 21 days).	Days to recovery (p=0.7060) and typical vs. prolonged recovery (p=0.1195) were not significantly different between groups.
Howell *et al*. (2021)[12] USA	37	Participants (14–21 years old) from a primary care sports medicine clinic or emergency department within a tertiary care regional children's hospital	Were provided a specific exercise prescription that included an individualized target intensity (heart rate), frequency (5×/week), and duration (20 minutes at the target heart rate) prescription to perform over the subsequent four weeks.	Were told to comply with their physician recommended physical activity level.	Participants reported their exercise volume each week over the 8- week study period and reported symptoms at each study visit (initial, 1 month, 2 months).	There were no significant symptom severity differences between the intervention and standard-of-care groups at the initial (median Post-Concussion Symptom Inventory, 15 [interquartile range=10; 42] vs 20 [11; 35.5]; P=.26), 1-month (4 [0; 28] vs 5.5 [0.5; 21.5]; P=.96), or 2-month (6.5 [0; 27.5] vs 0 [0; 4]; P=.11) study visits.

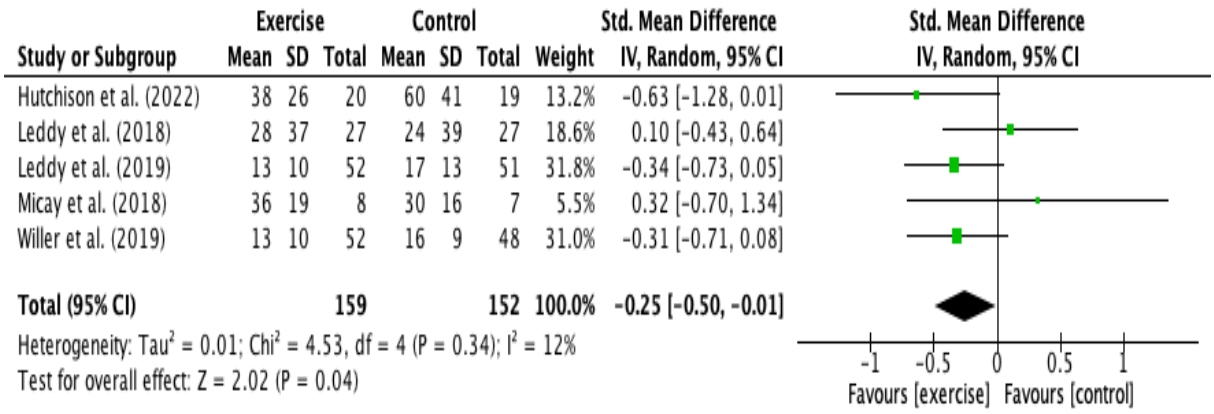
Table 3 (cont.). Summary of characteristics of the articles analyzed.

Study/ Country	Sample	Participants	Intervention		Measures	Results
			Intervention	Control		
Willer *et al*. (2019)[16] USA	151	Adolescents, aged 15 to 17, with sports-related concussion (10 days after injury).	Aerobic exercise (walking, running, cycling, treadmill or stationary bike) at an intensity of 80% of maximum heart rate, every day and for 20 minutes for 4 weeks or until recovery.	Progressive and gentle stretching and breathing exercises, which did not significantly raise the heart rate, every day for 20 minutes for 4 weeks or until recovery. There was also a group on complete rest.	Average recovery time	The average recovery time was significantly shorter in the intervention group, which took 13 days, while the group that did stretching and aerobic exercise took 16 days (similar to the group that rested – 17 days).
Hutchison *et al*. (2022)[11] Saudi Arabia	39	Men and women, aged 16–22 years, symptomatic after concussion injury in sports (3 days after injury).	Eight 20-minute aerobic exercise sessions over 11 days. The intensity of each session was quantified by a calculated target heart rate (60% to 75% of age-predicted maximum heart rate).	They followed the instructions, prescriptions and recommendations given by the sports doctor.	Recovery time.	Within the 28-day period, 74% of participants undergoing aerobic exercise were asymptomatic, while in the other group there were only 50% of participants. The average recovery time was 38 days for the intervention group and 60 days for the control group.
Leddy *et al*. (2019)[15] USA	103	Male and female adolescent athletes (age 13-18 years) presenting within 10 days of SRC	Participants in this group were instructed to perform aerobic exercise each day on a stationary bike or a treadmill, at home or in a gym under supervision,	were instructed to follow a prescribed stretching program and given the same instructions about resting as the aerobic group.	Days from injury to recovery;	Participants in the aerobic exercise group were seen a mean (SD) of 4.9 (2.2) days after the SRC, and those in the stretching group were seen a mean (SD) of 4.8 (2.4) days after the SRC.
Kurowski, *et al*. (2017)[17] USA	30	adolescents between the ages of 12 and 17 years who sustained a mTBI and had between four and 16 weeks of persistent symptoms.	were instructed on a full-body stretching program to be completed five to six days per week at home.	No exercise	The primary outcome was post injury symptom improvement assessed by the adolescent's self-reported Post Concussion Symptom Inventory (PCSI) repeated for at least six weeks of the intervention.	Repeated measures Analysis of Variance via mixed model analysis demonstrated a significant group by time interaction with self-reported PCSI ratings, indicating a greater rate of improvement in the sub-symptom exacerbation aerobic training compared to the full-body stretching group (F-value =4.11, p-value =.044).

Time to medical clearance

Five studies[10,11,13,15,16] analyzed the impact of exercise on time to medical clearance. For the meta-analysis of this comparison, a random model was used (I2=12%, df=4, p=0.04), in which there was a statistically significant difference between the groups in the comparison between the exercise and the control (difference between the means -0.25 days; 95% CI, -0.50 to –0.01; Figure 2).

Figure 2. Forest plot of the results of the meta-analysis.



DISCUSSION

This article reviewed clinical trials that compared the outcomes of early treatment of sports concussion with aerobic exercise versus interventions with stretching, rest, and usual care. Most of the selected studies showed a significant reduction in concussion symptoms and an improvement in return to activities when aerobic exercises were implemented, suggesting a faster and more efficient

recovery, compared to the outcome of other interventions (stretching, rest and usual care).

Leddy *et al*.[14] reported that the group that performed aerobic exercise had an average reduction in recovery time from concussion symptoms of approximately 43% compared to the control group. Similarly, it was observed an average reduction of approximately 23% in the time to symptom improvement for the aerobic exercise intervention group[18]. Willer *et al*.[16] also presented data demonstrating that the group that performed only stretching and light breathing exercises recovered their health status, on average, three days later than the group that practiced aerobic exercises, presenting a rehabilitation time similar to the group that remained on complete rest.

In the most recent study by Hutchison *et al*.[11], the outcome with the greatest difference between the groups was found, where the average time for symptoms to return was 38 days for the intervention group and 60 days for the control group. Within the 28-day period, 74% of participants undergoing aerobic exercise were asymptomatic, compared with only 50% of participants in the control group.

The results of Kurowski *et al*.[17] were based on data obtained from the self-reported Post-Concussion Symptom Inventory, which included 23 symptoms such as headache, nausea, difficulty falling asleep, and irritability. By week nine, 10/12 participants in the intervention group had already been discharged (returned to baseline and/or symptoms without exacerbation after training), while in the

control group 5/14 had been discharged. Regarding symptoms, in the final assessment the average self-report for the intervention group was 4.17 (7.36) and for the control group it was 15.93 (20.18).

Leddy *et al*.[15] were able to observe that the decrease in symptom scores occurs over time, as individuals recover and even without any intervention. Still, the intervention group had a greater reduction in symptoms immediately after the treadmill test when compared with the other group.

Howell *et al*.[12] worked with groups where both performed exercises, but the intervention group received a systematic program, while the control group did not, receiving only instructions to perform the activity. Over the two-month study period, no significant difference was found between groups in terms of reducing symptom severity, suggesting that simply exercising is enough to improve post-concussion outcomes.

It has already been proven that alterations in the autonomic nervous system (ANS), which regulates cardiovascular and pulmonary functions, and the control of cerebral blood flow are some of the dysfunctions resulting from concussions. This occurs especially due to rotational forces in the upper cervical spine that cause changes in the autonomic centers of the brain and the decoupling of connections between the ANS, arterial baroreceptors and the heart, in addition to the brain having its metabolic demand increased[14,15,19].

Aerobic exercise acts directly on the regulation of the ANS by promoting neuroplasticity (especially in the hippocampus), angiogenesis, neurogenesis (through the production of neurotrophic substances), gliogenesis, synaptogenesis, increased concentration of synapses, increased blood flow in the cortex and the production of chemical substances that trigger neural processes[19-22]. Another finding after this set of adaptations was the increase in gray and white matter in the brain[21].

Other acute and chronic biochemical responses that moderate exercise provides are the activation of the immune system and the anti-inflammatory state[22]. This occurs due to some processes, such as the production of myokines during muscle contraction (IL-6 and IL-5, for example) and the release of adrenaline and cortisol (modulates the immune response and reduces the production of pro-inflammatory cytokines)[23].

Still, one of the studies analyzed presented results that deviated from the pattern found in the articles cited above. Micay *et al*.[13] did not find a statistically significant difference between the mean medical release times of the two groups. The intervention group had an average time of 36.1 days for complete symptom retraction, while the control group took 29.6 days.

Possible reasons for the lack of significant difference in time to full recovery include the relatively small sample size (15 athletes) and variability in individual response to treatment. Another point to be considered is the

methodology used in prescribing intensity and duration. Initially, the treatment was carried out at 50% of the maximum heart rate and for a duration of 10 minutes in the first session. In the second session, the duration increased to 20 minutes, and from the third session onwards there was a gradual increase of 5% in heart rate with each new session until reaching 70%. In contrast, the other studies maintained the same intensity in all sessions, varying only between them (between 60-90% of maximum heart rate).

Although the overall recovery and medical clearance time did not differ significantly, aerobic exercise may have promoted a more rapid improvement in initial symptoms, as a series of trials in the Micay *et al*.[13] study showed that the intervention group showed significant improvement in symptoms between weeks 1 and 3 after injury, while the control group had their first signs of improvement at week 4 after injury.

Several factors may have affected the results of this review. The quality of the studies varied, with most being of moderate quality, with different sample sizes and intervention protocols. Furthermore, the small number of studies available is an important limitation to be considered.

These limitations highlight the need for further research with larger sample sizes and standardized methodologies to determine the specific effects of aerobic exercise on concussion recovery compared with other traditional interventions.

CONCLUSION

Given the evidence presented, it was possible to reaffirm the superiority of physical exercise in the early treatment of concussion in sports compared to rest, stretching and usual care. When it comes to offering a faster, more effective and lasting recovery, the results of the influence of exercise on the body, especially on the brain, and its biological and metabolic processes stand out significantly.

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