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Abstract

Concussions are highly prevalent injuries in both youth and adult sports and can severely impact daily functions by impairing mental and physical health. Existing treatments, such as resting, have been found to be ineffective in promoting a faster recovery. They often lead to a decline in mental health, which can exacerbate ongoing symptoms. However, aerobic exercise is an emerging field that has the potential to make concussion recovery more effective. This literature review will explore the effectiveness of aerobic exercise on faster recovery rates, return to play, and its impact at the cellular level for concussion patients. In addition, it will address in detail why treatment plans vary from patient to patient and analyze commonly prescribed exercises. This review also introduces vestibular rehabilitation, an emerging type of exercise therapy that can improve common symptoms of concussions, such as balance and dizziness. Future studies in this upcoming field of treatment could investigate if a specific frequency, intensity, and duration unique to a patient's prescribed exercise treatment is more efficient for recovery. Additional research could focus on individual populations to examine if age and level of activity prior to injury influences post-concussion recovery.

Keywords: concussion, post-concussion treatment, aerobic exercise, prescriptions for concussion, vestibular rehabilitation

Introduction

A concussion is a broad term that is often used in sports medicine. It is defined as a mild traumatic brain injury (TBI) due to an external force altering brain function, which may involve loss of consciousness or lack of coordination and fatigue[1]. The relevance and awareness of concussions in sports medicine has expanded over the last decade, and is continuing to increase significantly. A study on 85% of NCAA schools reports that 82% of the schools had a concussion management system in place[2]. The average number of TBI's that occur in the United States each year is 1.6 to 3.8 million, and this includes emergency department visits, hospitalizations, and deaths[3]. However, this number is underestimated due to many reasons. These include data from people who are undiagnosed for TBI's, deny seeking care, diagnosed with TBI but do not seek care, or are treated in other settings like military facilities, outpatient, or physician's offices[3]. The number of occurrences is increasing when compared to previous years, and concussion management is extremely important for this reason. Concussion disclosure and accurate diagnosis are especially crucial, as there is a greater risk of acquiring a second concussion after obtaining the first. Symptom-free waiting period (SFWP) patients, or patients who wait for any symptoms to start appearing after acquiring a concussion, have a higher rate of repeat concussions than the non-SWFP

group, or patients who observe symptoms following a concussion[4]. Hence, immediate concussion disclosure and proper management are crucial to not only recovery, but also to decrease the risk of another concussion.

Resting is one of the current treatments for post-concussion patients. However, it often worsens one's condition as it prolongs concussion symptoms[5]. Because this method is ineffective for faster recovery rates, discovering new treatments has become a major focus of concussion research. Exercise to an athlete's maximum capacity without worsening concussion symptoms before they return to sports is crucial for efficient recovery[6]. Reasons like this drive researchers to investigate aerobic exercise, which is now a pioneering field demonstrated to benefit patient cognition, mood, recovery time, and symptom reduction following a concussion[7,8]. This review will primarily focus on the advantages of aerobic exercise for post-concussion patient recovery. More specifically, it will address the internal effects, both unique and common prescription patterns of aerobic exercise, and newly emerging vestibular rehabilitation under this broad category of exercise therapy. This review will also emphasize the importance of further exploration in this field, as there are few studies on aerobic exercise being conducted today. Additionally, some involve too small of a population size. Most importantly, additional variables like age, prior level of activity of the patient, and frequency or duration of the aerobic exercise treatment need further investigation. More awareness and research are required for its application in the clinical field to replace existing treatments.

Aerobic exercise for post-concussion

The Effectiveness of Aerobic Exercise

Although pre-existing treatments, like resting, are prescribed, the treatment is gradually transitioning to aerobic exercise. Post-concussion patients who withdraw from exercise undergo further negative mood scores and fewer activity peaks than patients who participate in some form of exercise[5]. Aerobic exercise is a revolutionizing treatment for concussion management that promotes both fast and effective recovery. The impact of aerobic exercise on concussion patients has been determined by splitting patients to undergo two different treatments—aerobic exercise and placebo-like stretching. Patients recovered with a median of 13 days with aerobic exercise, while a median of 17 days of recovery was necessary for the placebo-like stretching group[9]. From this study, it can be deduced that patient's recovery time in days was lower for the group that underwent aerobic exercise. Another study has investigated the effects of a structured exercise program with post-concussion patients using their symptoms to determine their capacity of exercise. Based on the patient's heart rate at which they experienced symptoms, a structured exercise plan helped more than two-thirds of patients return to full daily functions with diminished persistent symptoms[10]. These results demonstrated that aerobic exercise is indeed beneficial for recovery.

Full return to daily functions

Returning to full daily function is a key part of recovery. Since resting is ineffective and prolongs recovery time, studying the association between the time to begin aerobic exercise and the time to fully return to sports is crucial. As shown in Table 1, the proportion recovered was much higher in people who had the least time to initiate aerobic exercise[11]. Table 1 also shows that the probability for a full return to sports decreases gradually as the time to initiate aerobic exercise treatment increases (Table 1)[11]. This illustrates that earlier timing to implement aerobic exercise is associated with faster recovery rates following an acute sports concussion. The proportion of patients recovering and getting back to full functional ability increased gradually (Table 1)[12]. This was observed when players were investigated for concussion symptoms initially and along their recovery trajectory (Table 1)[12]. Another study found that 41 out of 57 (72%) who participated in the exercise rehabilitation returned to full daily functions, and only 1 out of 6 patients who declined exercise therapy returned to full function[10]. This supports how much aerobic exercise assists in faster, effective recovery and full return to daily functions.

Table 1: Comparison between the time to initiate aerobic exercise treatment to the time and reduced probability for full return to sports [11,12].

Time to start Aerobic Exercise post injury (Days)	Decreased probability for fully returning to sports	Average time to Full Return to Sport (Days) with aerobic exercise when proportion of patients who are not recovered yet = 0.4	Proportion of players recovering and reaching their full functional ability (n=100)
3	36.5%	15	0.03%
5	59.5%	22	0.05%
7	73.2%	31	24%
14	88.9%	42	83%

Impact of aerobic exercise at the cellular level

Biomarkers are another method to investigate the outcomes and effects of treatment. Tracking and examining these biomarkers can reveal details about the recovery process such as positive or negative impacts and length of recovery. Brain-derived neurotrophic factor (BDNF) is an example of a biomarker used to measure the effect of aerobic exercise on individuals[13]. It can affect the structural change of the brain by reorganizing synaptic connections in response to new information, development, or damage following an injury[13]. BDNSs can impact other brain functions, too, like the hippocampus, peripheral, and motor factors[13]. The hippocampus, located in the temporal lobe, is highly involved with learning and memory. The peripheral nervous system (PNS) connects the brain and spinal cord, which makes up the central nervous system (CNS), to the rest of the body. Lastly, motor factors are a set of central and peripheral structures that transmits information from the CNS to PNS. A study found

that BNDF levels are much higher for the exercising group and increases for distance exercised (km/night) when compared to the sedentary group[13]. It was concluded that exercise induces these BDNF coding genes, thus increasing neuroplasticity, neurogenesis (formation of new neurons), and other brain functions as mentioned above[13]. Taking this further, a study has applied this logic to post-concussion patients to see the difference between BDNF levels before and after implementing aerobic exercise. The levels of BDNF, on average, did not increase significantly between the two groups, which is inconsistent with the previous study[14]. However, they found that subjects who completed their exercise program in a shorter period had a higher increase in BDNF levels, while subjects who took a long time to complete the exercise program had minimal change in BDNF levels[14]. According to the first conclusion, there is no evidence to support the idea that the frequency of exercise impacted BDNF levels. However, the duration of the exercise program caused a change in its levels according to the second study, which is one way to test the effectiveness of aerobic exercise on these patients. There is some evidence that exists on the effects of frequency, intensity, and program duration on the recovery process for post-concussion patients. However, further research should be done as the evidence or the number of studies conducted is low[11].

Aerobic exercise prescriptions unique to each patient

There are various types of exercise within the broad category of aerobic exercise, and not everyone can benefit from the same type. Exercises should be implemented

carefully, as every prescription pattern is unique to the patient's condition and can have different effects on their post-concussion management. Thus, identifying the desired outcome for each patient is crucial. Patients with post-concussion syndrome, persistence of various symptoms after a heady injury, have cerebrovascular function impairments, which can impact functional responses. It may also cause hypo/hyper perfusion – decreased or increased blood flow respectively – during and after a high-intensity aerobic workout[15]. As exercise length and intensity increases, the mean arterial pressure during a single cardiac cycle increases. In addition, a big drop can be observed in the End-Tidal partial pressure of carbon dioxide, the maximum CO_2 concertation at the end of each exhalation, and the frontal cerebral oxygenation or oxygen delivered to the cerebrum's frontal lobe[15]. Thus, doctors prescribing programs to these patients have to carefully choose the progression of aerobic exercises, as implementing high-intensity workouts early on can be detrimental. The association between a patient's symptoms and the rigor of aerobic exercise implemented needs to be further explored to help physicians formulate a proper plan for individual patients. Another aspect of future research in this field should focus more on individual populations to see if their activeness before the injury affects how they react to post-concussion treatment[16]. Some may be highly active prior to injury or as part of their lifestyle, while others may be completely inactive. Likewise, if a high-intensity exercise plan is prescribed to a patient who has been inactive their entire lifetime, it can be overwhelming for them, thus, exacerbating concussion symptoms[17]. As everyone

experiences exercise differently, examining this association between prior physical activity and their response to exercise prescription can influence the treatment plan.

Common exercises prescribed

Although prescriptions vary from patient to patient, there are a few exercises that doctors tend to prescribe more commonly. In one study, researchers investigated the most common exercises doctors prescribed to their patients during their first therapy and throughout the rest of their therapy. They found that during the patients' first visit, eye-head coordination, vestibulo–ocular reflex x 1 (VOR), standing static and standing upright were the most common exercises prescribed with 89, 75, 69, and 65 percentages respectively[18]. In simpler terms, eye-head coordination deals with moving fingers side to side or up and down and following them with one's eye movements and moving eyes along with the head from side to side or forward and backward[19]. Vestibulo-ocular reflex deals with using the inner ear information and determining how much eye movement is necessary to allow one's eye to stay fixed on an object as it is moved around[20]. An example would be to hold a readable item in front of someone and test one's ability to read the words on the page while moving their head in all directions as fast as they can[20.]Lastly, standing tests include changing from a sitting to a standing position with eyes open and repeating the same with eyes closed, throwing a ball from hand to hand above eye level and under the knee, changing from a sitting to a standing position while turning around in between in addition to the eye and head coordination movements mentioned above[19]. Throughout their therapy, the most common exercises

were also eye-head coordination, VOR X 1, Standing static, and standing upright, however, with percentages of 99, 92, 92, and 87 respectively[18]. Also, vertigo, imbalance, and dizziness are common symptoms that prevail post-concussion[21]. Vestibular rehabilitation is an emerging field of therapy that focuses to improve balance and reduce dizziness related problems. When the severity of dizziness was measured pretreatment and posttreatment for 114 patients in a study, the severity drastically decreased—26 to 7 respectively[21]. This supports the claim that vestibular rehabilitation exercise therapy for post-concussion patients does help with recovery from dizziness and imbalance post-concussion.

Conclusion

Aerobic exercise is an emerging field for concussion recovery aimed at returning patients to their fully functional ability more efficiently. One of the main advantages of this treatment is that it targets areas of the brain to improve functions like cognition, mood, and neuroplasticity impacted by the concussion. Studies conducted also demonstrate that the earlier an aerobic exercise therapy is implemented, the faster the recovery rate and return to full functional ability. Additionally, there are many variations within this broad range of aerobic exercises, and each patient may react differently or need different plans based on their condition. Hence, the correct exercise program prescription selected by physicians also plays a huge role in the recovery process. Lastly, as dizziness and imbalance are prominent symptoms of a concussion, use of vestibular rehabilitation is increasing as it strives to specifically alleviate these

symptoms. Although aerobic exercise helps in faster recovery and diminishing prevailing symptoms, further research needs to be conducted to explore how recovery rates are influenced by additional variables, such as sleep and cognitive stimulation. Biomarkers are another source of potential, but in addition to BDNF, more types of biomarkers should be explored to determine the effects of aerobic exercise on individuals. In addition to investigating the effects of training duration, frequency, and age on the return to full daily functioning, the effect of a patient's activeness before the injury on recovery would also be a potential research topic[10]. Further research will strengthen the understanding of all the possible variables affecting recovery rates. Since general treatment does not satisfy everyone's condition, this research can aid in developing more efficient ways or specific prescription plans for everyone based on requirements at the individual level.

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