Cardiac pathophysiology: examining oxygen saturation in exercise-trained and untrained men before and after physical activity

Fisiopatología cardíaca: examen de la saturación de oxígeno en hombres entrenados y no entrenados antes y después de la actividad física

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Received: 08/20/2022 Accepted: 10/19/2023 Published: 12/12/2023 DOI: http://doi.org/10.5281/zenodo.10386507

Abstract

Normal oxygen saturation typically falls within the range of 95 to 100%, reflecting the blood's capacity to carry oxygen. During periods of physical exertion, the demand for oxygen increases, prompting enhanced respiration and blood circulation. This, in turn, facilitates the diffusion of more oxygen into the lungs and its binding with hemoglobin. In order to explore variations in oxygen saturation between individuals engaged in physical activity and those who are not, a comprehensive literature review was undertaken. PubMed and Google Scholar were utilized to source reference materials published from 2012 to 2021 for this study. After an exhaustive search and article selection process, a total of eight articles were incorporated into this literature review. Interestingly, the findings showed that both individuals engaged in sports and those leading a sedentary lifestyle exhibited an elevation in oxygen saturation following physical activity. Conversely, the remaining five articles demonstrated a reduction in oxygen saturation among both active and non-active individuals post-exercise. Regardless of one's physical activity level, a decline in oxygen saturation was observed after physical exertion. Significantly, those who remained at rest experienced a more substantial reduction in oxygen saturation compared to those who engaged in exercise.

Keywords: Oxygen Saturation, Physical Exercise, Hemoglobin Binding, Ventilation and Blood Flow, Blood Circulation

Resumen

La saturación normal de oxígeno suele estar dentro del rango del 95 al 100%, lo que refleja la capacidad de la sangre para transportar oxígeno. Durante los períodos de esfuerzo físico, la demanda de oxígeno aumenta, lo que provoca una mejor respiración y circulación sanguínea. Esto, a su vez, facilita la difusión de más oxígeno hacia los pulmones y su unión con la hemoglobina. Para explorar las variaciones en la saturación de oxígeno entre las personas que realizan actividad física y las que no, se

llevó a cabo una revisión exhaustiva de la literatura. PubMed y Google Scholar se utilizaron para obtener materiales de referencia publicados entre 2012 y 2021 para este estudio. Luego de un exhaustivo proceso de búsqueda y selección de artículos, se incorporaron a esta revisión bibliográfica un total de ocho artículos. Curiosamente, los hallazgos mostraron que tanto las personas que practicaban deportes como las que llevaban un estilo de vida sedentario exhibieron una elevación en la saturación de oxígeno después de la actividad física. Por el contrario, los cinco artículos restantes demostraron una reducción en la saturación de oxígeno entre individuos activos y no activos después del ejercicio. Independientemente del nivel de actividad física, se observó una disminución de la saturación de oxígeno después del esfuerzo físico. Significativamente, aquellos que permanecieron en reposo experimentaron una reducción más sustancial en la saturación de oxígeno en comparación con aquellos que hicieron ejercicio.

Palabras clave: Saturación de Oxígeno, Ejercicio Físico, Unión de Hemoglobina, Ventilación y Flujo Sanguíneo, Circulación Sanguínea

Introduction

Physical exercise, as a pivotal aspect of human health, encompasses a wide array of activities aimed at either enhancing or maintaining the body's physical fitness[1-3]. The significance of physical exercise lies in its multifaceted benefits, which extend far beyond just maintaining an attractive physique[4,5]. Regular physical activity is known to reduce the risk of various diseases and health issues, making the body more resilient to potential health challenges. Physical exercise can be broadly classified into two categories: chronic exercise, typically performed by athletes, and acute exercise, which is often pursued by non-athletes[6-8]. Chronic exercise, as commonly observed in athletes, is characterized by its regularity, programming, and competitive nature. Athletes rigorously train their bodies to achieve and maintain peak performance, thereby necessitating a different approach to exercise[9,10]. On the other hand, non-athletes often engage in sporadic and less structured physical activities, which can be collectively labeled as acute exercise. From an energy generation perspective, physical exercise can be categorized into two main types: aerobic and anaerobic exercise[11-14]. Aerobic exercise primarily relies on oxygen to produce energy, while anaerobic exercise, as the name suggests, can generate energy without oxygen. As the intensity of physical exercise increases, the heart's workload proportionally escalates. Muscles require more oxygen to fuel their increased demands during strenuous activity, prompting the body to optimize its cardiorespiratory system to meet these requirements effectively[15,16]. One notable outcome of regular physical exercise is an improvement in cardiorespiratory fitness. People who engage in consistent physical activity tend to exhibit a superior cardiorespiratory system, including enhanced lung diffusion capacity, compared to those who lead sedentary lives[17-19]. This increased fitness translates to better endurance and an improved ability to cope with the physical demands placed on the body. Athletes, particularly those with well-developed anaerobic exercise capabilities, can perform high-intensity exercises for shorter durations, showcasing the adaptability and efficiency of the human body[20-22]. Oxygen is a vital component during physical exercise, as it serves as an essential energy source. The assessment of oxygen levels in the blood is typically achieved through the measurement of oxygen saturation, a metric often determined using oximetry devices placed on the fingertips and toes[23,24]. It's crucial to maintain optimal blood oxygen levels during exercise, as oxygen deficiency can lead to severe consequences, including fainting and, in extreme cases, even death. Oxygen saturation is quantified as a percentage, reflecting the amount of oxygen present in the blood[25]. Hemoglobin plays a central role in transporting oxygen through the bloodstream, binding with oxygen molecules and releasing them as needed[26,27]. Various factors influence oxygen saturation levels, including the efficiency of oxygen intake in the lungs (ventilation), the rate at which oxygen diffuses from the lungs into the bloodstream, and hemoglobin's capacity to carry and release oxygen[28]. As physical exercise ensues, the body responds by increasing the amount of oxygen in the blood[29,30]. Excess oxygen readily diffuses into the capillaries and binds to hemoglobin, ultimately influencing oxygen saturation levels[31-33]. In light of these physiological principles, this literature review seeks to delve deeper into the effects of physical exercise on oxygen saturation levels. By exploring the impact of exercise on the body's ability to maintain optimal blood oxygen levels, we aim to gain a more comprehensive understanding of the role of oxygen saturation in athletic performance and overall health. This investigation may shed light on the benefits and potential risks associated with various forms of physical exercise and provide valuable insights into optimizing exercise routines for both athletes and non-athletes.

Methods

Study Design

The research conducted in this literature review focuses on the pathophysiology of the heart. We employ a systematic review method to examine existing studies that investigate the variations in oxygen saturation before and after physical activity among both trained and untrained individuals.

Literature Search Strategy

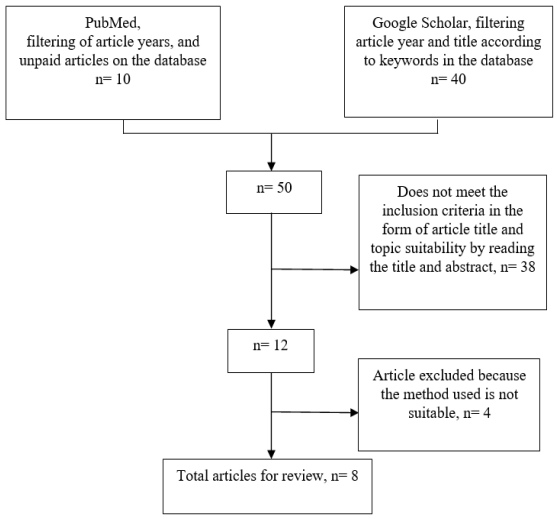
Our literature search criteria encompass articles published between 2012 and 2021, available in English. We extracted reference data from PubMed and Google Scholar by using specific keywords. These keywords include “acute physical exercise,” “basketball,” “SpO2,” “futsal,” “the effect of aerobic,” “sport athletes,” “training program,” “oxygen saturation,” “exercise,” “men,” “capillary blood volume,” “sprint running,” “hypoxia effects,” “oxygenation,” and “running.” We employed Boolean logical operators, such as OR and AND, in our search strategy to obtain the most precise information.

Analysis

The initial phase of our article selection process involved identifying articles with independent variables related to physical activity, dependent variables concerning oxygen saturation before and after physical activity, and research subjects categorized as either trained (athletes) or untrained men. Articles meeting these criteria were considered for inclusion in our literature review. The inclusion criteria restricted the search to articles published from 2012 to 2021, with free access to full-text PDFs. Exclusion criteria encompassed sources unrelated to the topic, publications predating 2012, and a preference for cohort studies or field experiments. Articles meeting these criteria underwent a descriptive analysis, where we compared and described research findings regarding variations in oxygen saturation before and after physical activity in both trained and untrained men.

Our initial electronic journal database search yielded 50 articles, distributed as follows: 10 from PubMed and 40 from Google Scholar. After a rigorous selection process involving title and abstract review, along with the application of inclusion and exclusion criteria, eight articles remained for inclusion in this literature review (Figure 1).

Figure 1. Literature Tracing Flowchart



Results and Discussion

The core elements of the literature employed in the study include the researcher’s name, research title, year of publication, research methodology, the quantity of subjects in both the intervention and control groups, as well as the study’s findings and conclusions. This summary will be incorporated into a table format to enhance the clarity and accessibility of the extracted information, as exemplified in the following table (Table 1).

Table 1. variations In Oxygen Saturation prior to And After Physical Activity

No	Research Title, (Authors; year)	Place	Participants	Methods	Result	Conclusions
1.	Comparison of oxygen saturation before and after performing acute physical exercise on students of the Faculty of Medicine, Unsrat Batch 2019, (Rompas et al., 2019)[1]	Manado	36 research subjects (10 men and 26 women aged 16-20 years)	Field experiment with pre-post one group test design	- The average value of oxygen saturation in male subjects before running was 98.10% and after running 98,20% - The average value of oxygen saturation in female subjects before running is 98.31% and after running 98,65% - The average value of oxygen saturation in all subjects before running was 98.25% and after running 98.53% with p value= 0.111 (p> 0.05) which showed that there was no significant difference between the pre-test and post-test oxygen saturation values. - The distribution of oximeter values measured in 36 subjects showed a decrease in oxygen saturation in 9 subjects, an increase in oxygen saturation in 16 subjects, and a steady oxygen saturation in 11 subjects.	- There is no significant difference in oxygen saturation before and after performing acute physical exercise on students of the Faculty of Medicine, Sam Ratulangi University
2.	The effect of short-term exercise on oxygen saturation in soccer players (Daglioglu et al., 2013)[7]	Gaziantep, Turkey	10 male soccer players and 8 healthy boys	Cross-sectional	- The average value of the pretest SpO_2 in the soccer player group was 97.20±1.26 while the average value of the posttest was 95.40±1.26 which had a significant decrease with p value = 0.016 (p<0, 05) - The mean value of pretest SpO_2 in the group that rarely exercised was 97.38 ± 1.30 while the mean value of posttest was 96.50 ± 1.07 which did not have a significant decrease with p value = 0.064 (p > 0 ,05) - When the two groups were compared, there was no significant result on SpO_2 because it had a p value of 0.249 (p> 0.05).	- Short-term exercise lowers oxygen saturation but regular exercise does not affect changes in oxygen saturation in short-term exercise.
3.	Are there hinder variations in the capillary blood Vil. and diffusing capacity response to exercise? (Bouwsema et al., 2017)[8]	Canada	16 women (mean age 26±6.4) and 16 men (mean age 22±2.7) were physically active	Cohort study	- At rest the average SpO_2 value for men is 98.9±1.1 but after exercise it becomes 97.1±1.9	- There was a decrease in the SpO_2 value of men after doing acute physical exercise.
4.	The effect of acute physical exercise on oxygen saturation in basketball players at the Faculty of Medicine, Unsrat (Simanjuntak et al., 2016)[6]	FK Unsrat Campus, Malalayang	32 students of FK Unsrat basketball players (26 males and 6 females).	Field experiment with pre-post one group test design	- The average value of oxygen saturation in men before physical activity is 97.42% while the average oxygen saturation after physical activity in men is 97.85% - The average value of oxygen saturation in women before physical activity is 97.50% while the average oxygen saturation after physical activity in men is 98.17% - The average value of oxygen saturation in all subjects before physical activity was 97.44% and after running 97.91% with p value = 0.041 (p < 0.05)	- There is a significant increase in oxygen saturation value with p value = 0.041 after doing acute physical exercise.
5.	The effect of wearing a mask while exercising on oxygen saturation in the blood (Salviano and Rochmania, 2021)[9]	Surabaya	20 male futsal players aged 16-20 years	Field experiment with pre-post one group test design	- The average value of the pretest SpO_2 in group B (not wearing a mask) was 97.6% while the average value of the posttest was 97.8% - In the results of the pretest group B p value = 0.177, it can be said that the data is normally distributed and the posttest group B has a sig value. is 0.025, it can be said that the data is not normally distributed.	- The use of masks during light exercise does not affect oxygen saturation levels in the blood.

6.	A clustered repeated-sprint running protocol for team-sport athletes per formed in normobaric hypoxia (Morrison et al., 2015)[10]	Australia	10 males who are amateur athletes of sports teams with an average age of 22.6±4.7 years.	Cohort study	- Oxygen saturation before RSR444 and after warm-up was 97.2±1.5%, after 8th sprint was 93.8±3.6 %, and after 16th sprint was 94.5±2.5%.	- This study revealed a decrease in oxygen saturation in male athletes after physical activity
7.	Sex differences in respiratory muscle activation patterns during high-intensity exercise in healthy humans (Mitchell et al., 2018)[11]	Canada	21 men and 19 women aged 19-37 years who had a habit were included in the active category.	Cohort study	- Oxygen saturation in men before physical activity is 97±2% and after physical activity, namely the exercise test cycling as hard as possible with a rhythm of 60 rotations per minute, oxygen saturation in men is 95±3%	- In the results of this study, the oxygen saturation before activity was higher than after physical activity in men, which means that the oxygen saturation value decreased after physical activity.
8.	Hypoxia afects tissue oxygenation diferently in the thigh and calf muscles during incremental running (Osawa et al., 2017)[12]	German	9 male runners participating in the triathon (mean age = 24±3 years)	Cohort study	- In this study, it was found that there was a decrease in oxygen saturation under normoxia, during the resting period (99.4±0.5) to the time when the VO_2 max value reached its peak value (1.3±2.4).	- This study states a decrease in male runner athletes after physical activity.

The study conducted by Rompas et al.[1], involving untrained subjects, demonstrated changes in oxygen saturation levels following physical activity, specifically a 100-meter sprint. The findings revealed a marginal increase of 0.1% in male subjects and a more pronounced increase of 0.34% in female subjects. The average oxygen saturation of all participants increased by 0.28%, although this change was deemed statistically insignificant. These observations are likely influenced by factors such as the nature, frequency, and duration of the physical exercises performed.

In contrast, research by Simanjuntak et al.[6] in 2016, which involved basketball-trained subjects, showed more substantial improvements in oxygen saturation. Male subjects exhibited an increase of 0.43%, while female subjects experienced a 0.67% increase after engaging in a 20-minute basketball session. The overall oxygen saturation of all participants significantly rose by 0.73%. This outcome underscores the cardiovascular benefits of training in physical activities, including enhanced cardiovascular ability, increased vital lung capacity, and improved oxygen uptake by the lungs. These adaptations facilitate the rapid replenishment of oxygen within the body, ensuring a sustained or increased oxygen saturation following physical exertion.

The study further suggests that different types of sports yield varying effects on oxygen saturation. Notably, basketball and futsal players experienced the most significant increases. Among these, Simanjuntak's research[6] with basketball athletes demonstrated the highest increase. This surge in oxygen uptake during physical activity can be attributed to the exponential increase in oxygen demand by the lungs and heightened blood flow during exercise. The increased ventilation and blood flow promote oxygen diffusion into pulmonary capillaries and its binding to hemoglobin. This ensures that oxygen levels in the blood remain stable or even increase post-activity, contributing to sustained and optimized physical performance.

Other studies, however, have reported decreases in oxygen saturation levels after physical activity, affecting both trained and untrained male subjects. Bouwsema et al.[8] study on untrained individuals observed a decline of approximately 1.7% in the average oxygen saturation levels following exercise, while Mitchell et al.[11] and Osawa et al.[12] documented more substantial drops of about 2% and 8.1%, respectively, after engaging in different forms of physical activity.

These variations in oxygen saturation can be linked to changes in the hemoglobin-oxygen dissociation curve. Physical activity can lead to increased carbon dioxide production, elevated lactic acid levels, and a rise in blood pH. These factors collectively shift the curve to the right, reducing hemoglobin's oxygen saturation even when the partial oxygen pressure remains constant during exercise. The decrease in oxygen saturation may also be attributed to factors such as increased body temperature, elevated 2,3-DPG concentration, and changes in pH and PCO2, all of which influence hemoglobin's affinity for oxygen and its ability to transport and release oxygen effectively.

Oxygen saturation fluctuations are not solely dictated by the hemoglobin-oxygen dissociation curve but are also closely associated with an individual's cardiorespiratory endurance. This endurance, defined as the capacity of the heart, lungs, blood vessels, and major muscle groups to deliver adequate oxygen to cells during prolonged, vigorous exercise, plays a pivotal role in maintaining oxygen levels during physical activity.

In conclusion, oxygen saturation levels are subject to changes in response to physical activity, with trained individuals generally exhibiting improved oxygen utilization and sustained or increased oxygen saturation. Cardiorespiratory endurance, exercise intensity, frequency, duration, heredity, age, and gender are key factors influencing these changes. Understanding these cardio-physiological adaptations is essential

for assessing the impact of physical exercise on the heart and the body's oxygen dynamics. Moreover, it emphasizes the importance of regular physical activity in maintaining optimal health and physical fitness.

Conclusions

In this study, we explored the variations in oxygen saturation levels among individuals engaged in physical activities, focusing on the pathophysiology of the heart. We conducted a comprehensive analysis of eight relevant research papers. Our investigation encompassed the impact of physical activity on oxygen saturation in individuals with a background in sports training and those without such training, both before and after the exercise. The results from these studies yielded interesting insights. Four of the eight reviewed articles revealed an increase in oxygen saturation following physical activity, irrespective of sports training. Conversely, the remaining four studies reported a decline in oxygen saturation after exercise, both in athletes and non-athletes. It's important to note that a reduction in oxygen saturation was observed in both trained and untrained individuals' post-physical activity. However, a noteworthy distinction emerged when comparing the two groups. Exercise-trained individuals exhibited a more significant reduction in oxygen saturation compared to their untrained counterparts. This discrepancy underscores the potential influence of sports training on the pathophysiology of the heart during physical activity.

Recommendations

Cardiorespiratory endurance can be increased with certain exercises, for example, sports athletes do better than untrained people. In this literature review, it can be seen that people who are trained will have better cardiorespiratory resistance than people who are not trained, therefore we can start getting used to exercising regularly to maintain body fitness.

Acknowledgments: Not applicable.

Conflict of interest: None.

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