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REVIEW ARTICLE

Effect of Exercise on Immune System

Ishak Gocer[1*] | Muhammed Oniz[2]

[1]Ministry of National Education, Kirikkale, Turkey, Türkiye
[2]Faculty of Sport Sciences, Mardin Artuklu University, Mardin, Türkiye

ABSTRACT

This study investigated the response of the immune system to different exercise intensities in healthy, unhealthy, athletic, and sedentary individuals. To better understand the effects of exercise on the immune system and develop more effective training programs, a review of the existing literature investigating the impact of exercise on the immune system was conducted. In this review, ten academic studies examining the effects of exercise on the immune system were analyzed. The research was conducted using literature searches from scientific databases, including "Google Scholar," "Web of Science," and "PubMed." Both Turkish and English literature searches were conducted using "effect of exercise on the immune system," "immune system," "immunology," "athletic performance" and "exercise and immune system" as keywords. The findings of the selected studies were analyzed in detail, and common points regarding the effects of exercise on the immune system were identified. Regular moderate-intensity exercise has been found to positively affect the immune system, reduce inflammation, reduce the incidence of diseases, and increase resistance to certain diseases. However, it has been observed that high-intensity exercise may temporarily suppress the immune system, potentially increasing the risk of infection. This study revealed that both sedentary individuals and athletes should prioritize adequate rest, sleep, and balanced nutrition, especially during intense training, and consider the health of their immune systems when designing training programs.

Keywords: Exercise, health, immune system, physical activity

*Corresponding: Ishak Gocer; ishakgocer71@gmail.com
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INTRODUCTION

In the simplest definition, physical activity can be defined as the expenditure of energy as a result of the movement of the muscles in the body. exercise can be defined as planned and regular physical activity performed for a specific purpose (ACSM,2025). Regular exercise within a specific program has been proven to have many benefits for general health. These include the formation of a healthy sleep pattern, healthy weight loss, maintaining physical fitness levels, reducing signs of aging, stress management, and contrib-uting to cardiovascular system development (Romeo et al., 2010;Baltacı G.,2008). In addition, exercise is known to be beneficial in preventing non-communicable diseases, protecting and developing the cardiovascular system, protecting health, and reducing the incidence of diseases such as hypertension, diabetes, and cancer (Pinckard et al., 2019; Mann et al., 2014; Colberg et al., 2016). Exercise has the greatest effect on disease prevention by positively activating the immune system, thus contributing to the fight against disease-causing microbes or pathogens and facilitating the fight against harmful substances such as tumors (Jee, 2020). As it is known, the immune system is the body's defense mechanism. This system, also known as the immune system, contributes to maintaining a healthy body by enabling it to fight bacteria, viruses, pathogens, or other pests that can cause disease (Songu & Katılmış, 2012). In other words, it can be said that a healthy body requires a healthy immune system. A brief overview of the immune system is necessary for a more comprehensive understanding of the subject. In humans, the immune system is typically divided into three main components, and the first of these is the innate (natural) immune system, which constitutes the body's initial line of defense and is present from birth. This system acts as a non-specific barrier against pathogens and responds uniformly to a wide variety of microbes and viruses (Buck et al., 2017). The innate immune response begins with physical and chemical barriers such as the skin, mucous membranes, and antimicrobial peptides that prevent pathogen entry. Once pathogens breach these barriers, components such as phagocytes (e.g., neutrophils and macrophages), natural killer (NK) cells, and dendritic cells are activa-ted. NK cells play a crucial role by recognizing and inducing apoptosis in infected or abnormal cells wit-hout the need for prior sensitization. Furthermore, plasma proteins like complement proteins (particularly C3b) mark pathogens for destruction, while pro-inflammatory cytokines such as interleukin-1 (IL-1), tumor necrosis factor-alpha (TNF-α), and interferons coordinate the immune response by recruiting immune cells to the site of infection. These innate immune mechanisms work rapidly and broadly to contain infections during the early stages before the adaptive immune system is engaged (Medzhitov & Janeway, 2000; Ab-bas et al., 2015).

Another immune system, the adaptive immune system, develops later and becomes more specific. Our bodies develop immunological memory by recognizing the bacteria or viruses that we are exposed to through illness or vaccination. When they initially fight a pathogen, their immune systems memorize it, allowing them to respond more effectively when encountering the

same pathogen. The adaptive immune system consists mostly of T cells, B cells, and antigens, with a specific response. The innate immune sys-tem primarily comprises leukocytes (Kurosaki et al., 2015). Another type of immune system is a passive system. The immune system is formed by the administration of pre-prepared antibodies to the body. For example, when the body cannot produce antibodies for any reason, or the antibodies it produces are insufficient, antibodies are given from the outside to help the body fight the disease. Thus, the body fights microbes or viruses by using an artificial immune system (Cabral, 2014).

Exercise plays an important role in maintaining a healthy immune system (Brolinson & Elliott, 2007). Exercise is a valuable intervention that reduces the incidence of chronic diseases and has anti-inflammatory effects that reduce mortality (Duran, 2023). In this context, it is possible to contribute to the development of the immune system by exercising regularly. To understand this in greater detail, it is neces-sary to investigate the effects of exercise on the immune system. When examining studies on this subject, it is essential to evaluate the acute and chronic effects of exercise on the immune system in two ways. Addi-tionally, factors such as the scope of exercise, intensity, age, and sex of the exerciser differ in their effects on the immune system (Jee, 2020).

The importance of exercise in maintaining a healthy immune system and knowing how the body's immune system will react to different exercise intensities, regardless of age group, healthy or unhealthy, athlete, or sedentary, is necessary to create a more appropriate exercise prescription. Although exercise is not a direct treatment method, it can be considered a complementary treatment. In this context, a review study, in which studies investigating the effects of different exercise intensities on the immune system were collected and synthesized, is intended to help athletes or sedentary people when preparing a training program.

Effects of Exercise on the Immune System

Acute Exercise

Acute exercise refers to physical activity performed during a single exercise session. The effects of acute exercise on the immune system vary significantly depending on the intensity and duration of the session. For instance, mild to moderate acute exercise can positively stimulate immune responses, whereas short-term but high-intensity acute exercise may transiently suppress certain immune functions. Mild or moderate acute exercise increases natural killer (NK) cell activation, enhances cytokine production, elevates white blood cell count, and thereby supports the innate immune system (Nieman, 2020). Specifically, such exercise induces a transient increase in anti-inflammatory cytokines such as IL-10 and IL-1ra, which help regulate inflammation without causing tissue damage (Pedersen & Febbraio, 2008). This acute immune modulation provides short-term protection against pathogens and may last for several hours post-exercise, although the magnitude and duration vary between individuals (da Luz Scheffer & Latini, 2020).

In contrast, high-intensity acute exercise, particularly when prolonged, can result in transient immunosuppression. This phenomenon is often referred to as the “open window” period, which typically lasts from 3 to 72 hours post-exercise depending on the severity and duration (Eroğlu, 2024). During this period, the number of circulating immune cells, such as lymphocytes and NK cells, may decrease, rendering the body more susceptible to infections (Wang et al., 2020). This immunosuppressive effect is also associated with increased production of pro-inflammatory cytokines such as IL-6 and TNF-α, which may temporarily impair mucosal immunity and barrier defense (Walsh et al., 2011).

However, this suppression is reversible, and immune parameters generally return to baseline after a sufficient recovery period (Nieman, 2012). Nonetheless, repeated high-intensity sessions without adequate rest may lead to chronic immune disturbances and heightened vulnerability to infections, particularly of the upper respiratory tract (Simpson et al., 2020). Therefore, elite athletes must carefully manage training loads and ensure adequate recovery, including balanced nutrition, sufficient sleep, and infection precautions during the open window phase.

In summary, acute exercise elicits a complex interplay of pro- and anti-inflammatory signals. While moderate-intensity acute sessions induce beneficial immune activation, vigorous and prolonged acute sessions may evoke a transient pro-inflammatory and immunosuppressive state. Understanding these differential effects is critical in optimizing training and health in both recreational and elite athletes (Peake et al., 2017; Krüger et al., 2016).

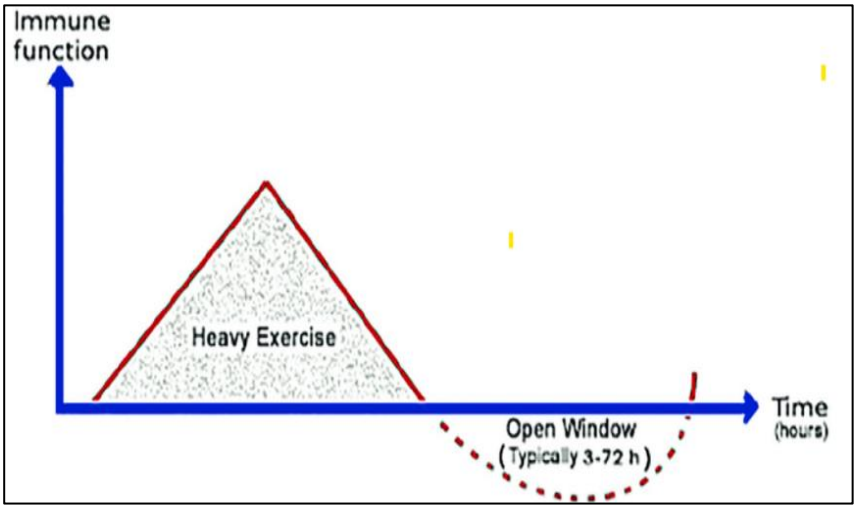

Figure 1. The open window hypothesis states that the immune system is compromised 3 to 72 h after strenuous exercise, leading to an increased risk of opportunistic infections the following day (Shirvani, 2020).

Chronic Exercise (Regular Exercise)

According to ACSM, high-intensity exercise is a physical activity performed at 77-95 percent of the individual's maximum heart rate. At this intensity, a person has difficulty speaking and generally has a short fatigue period (Table 1) (ACSM, 2025; WHO, 2020). Studies have shown that regular exercise at moderate intensity increases natural killer cell activity, improves antigen presentation, reduces cancer incidence, reduces inflammation, and has positive effects on the immune system, such as preventing cellular aging (Nieman & Wentz, 2019; Wang & Zhou, 2021; Suzuki & Hayashida, 2021).

Table 1. Training Intensity According to ACSM and WHO

Intensity Level	Heart Rate (% Max HR)	Perceived Exertion (RPE 1-10)	Talk Test	Example Activities
Moderate	50% - 70%	5 - 6	Can talk, cannot sing	Brisk walking, light cycling, light swimming, gardening
Vigorous	70% - 85%	7 - 9	Out of breath, speaking is difficult	Running, HIIT, spinning, vigorous swimming, fast cycling

According to ACSM, regular moderate-intensity physical activity is an exercise performed between 64-76% of the maximum heart rate, performed 3-5 days a week at an intensity where the person could talk without straining himself, but could not sing (Table 2) (ACSM, 2025; WHO, 2020). Owing to moderate and regular physical activity, the skeletal muscle system develops, and the body's resistance to diseases increases by regulating the natural immune system. The level of inflammation that increases with age can be reduced through regular exercise (Forte et al., 2022; Duran, 2023). In addition, regular exercise at a moderate intensity reduces the incidence of diseases that negatively affect immunity, such as obesity and diabetes, and increases the rate of factors that contribute to immunity, such as regular sleep, stress management, and oxygen intake (Özen & Civil, 2020, Simpson et al., 2020).

Table 2. Regular Training Recommendations According to ACSM and WHO (Adults: 18-64 Years)

Component	ACSM and WHO Recommendation
Aerobic Exercise	150–300 minutes of moderate-intensity or 75–150 minutes of vigorous-intensity activity per week
Muscle Strengthening	At least 2 days per week, exercises involving major muscle groups
Movement Frequency	Prolonged sitting should be reduced; standing up at regular intervals is recommended

Mechanism

Exercise induces a series of physiological reactions in humans. Reactions to exercise vary according to several factors, including the duration and intensity of the exercise as well as the condition of the individual exercising. During periods of strenuous physical exertion, the human body secretes hormones, such as adrenaline, noradrenaline, and cortisol (Gleeson, 2007). Mobilization of immune cells is accelerated by adrenaline and noradrenaline, resulting in a temporary increase in immunity. Conversely, cortisol, a stress hormone, suppresses immune cell function and temporarily compromises the immune system function (Jones et al., 2022). At the start of intense exercise, there is a rapid increase in the number of neutrophils, which form the body's first line of defense, and a temporary increase in the number of T and B lymphocytes. After exercise, there was a significant decrease in the number of lymphocytes to below the initial level. Some studies have reported that this decrease lasts between three and six hours. During this period, the IgA levels and NK cell activity decreased. Additionally, the levels of cytokines IL-1, IL-6, and TNF-α increase after exercise, causing inflammation and potentially overwhelming the immune system (Sitlinger et al. 2020; Kurowski et al. 2022).

Since there is no or very little cortisol release during mild and moderate exercise, the immunosuppressive role of this hormone is less, so mild and moderate exercise affects the immune system more positively. During moderate-intensity acute exercise, the mobilization and activation of immune cells increase as a result of increased adrenaline and noradrenaline secretion. The number of neutrophils increases and natural killer (NK) cells and T and B lymphocytes become active in producing antibodies. After exercise, the number and activity of NK cells and macrophages increase, similar to that of neutrophils. Host immune resistance increases after exercise because of the release of pro-inflammatory and anti-inflammatory cytokines (Campbell & Turner, 2018; Duran, 2023).

Material and Method

This review included a systematic analysis of scientific studies related to research data with the research topic obtained through a literature review. In this context, ten academic studies were conducted. This study reviewed the current literature on the effects of exercise on the immune system. The study included meta-analyses and studies from various scientific databases such as Google Scholar, Web of Science, and PubMed. Literature searches using keywords such as 'effect of exercise on the immune system, immune system, immunology, athletic performance,' and 'exercise and immune system' were performed using these databases in both Turkish and English. The conclusions of the present study were based on the results of these studies. The findings and results of the ten selected articles were analyzed in detail, and common points were identified, with solution suggestions presented. The included studies and their characteristics are presented in Table 3.

The inclusion criteria for this review were as follows: (1) publication date of 2000 or later, (2) direct examination of the relationship between exercise and the immune system, (3) publication in peer-reviewed journals, and (4) accessibility to the full text.

The exclusion criteria were as follows: (1) studies presented only as abstracts; (2) studies based on animal experiments; and (3) exercise studies that were not directly related to the immune system.

Table 3. Summary of literature

Reference	Participant (n)	Title	Type of exercise	The effect of exercise on the immune system
Born et al., 2017	28 male recreational runners	The mucosal immune function is not compromised during a period of high-intensity interval training. Is it time to reconsider an old assumption,	Hit exercise	no effect
Kurowski et al., 2022	Rewiew	Physical exercise, immune response, and susceptibility to infections - current knowledge and growing research areas	Acute and regular exercise	modarate exercise ↑ high intensy exercise ↓
Chastin, 2021	systematic review and meta analysis	Effects of regular physical activity on the immune system, vaccination and risk of community-acquired infectious disease in the general population: systematic review and meta-analysis.	Acute and regular exercise	↑
Chakravarty et al., 2008	284 experimental group 156 control group	Reduced Disability and Mortality Among Aging Runners A 21-Year Longitudinal Study	Acute and regula modarate exercise	↑
Duran, 2023	Review	Overview of the Effect of Exercise on Immunity	Acute and regula modarate exercise	↑
İşleğen, 2015	Review	Physical activity in elderly and its effect on diseases	Modarete reguler exercise	↑
Forte et al., 2022	Review	The Relationships between Physical Activity, Exercise, and Sport on the Immune System	Acute and regular modarate and intense exercise	modarate exercise ↑ high intensy exercise ↓
Tanner et al., 2017	Experimental group 10 elite female synchronised swimmers	The Effects of a 4-Week, Intensified Training, and Competition Period on Salivary Hormones, Immunoglobulin A, Illness Symptoms, and Mood State in Elite Synchronised Swimmers	High intense	no effect
Wang et al., 2020	Review	Exercise Regulates the Immune System	High intense	↓
Monje et al., 2020	Experimental group :10 women and 10 men	Effects of a high intensity interval session on mucosal immune function and salivary hormones in male and female endurance athletes.	High intense	no effect

↓ reducing effect ↑ improving effect.

Discussion

Studies examining the effect of exercise on the immune system are generally limited and the results of existing studies are often contradictory (Agustiningsih et al., 2024). An examination of the relevant literature reveals that regular mild- and moderate-intensity acute and chronic exercise positively affects the immune system (Gibb et al., 2017). These exercises are known to improve immunity in the long term, increase the body's resistance to many pathogens, reduce the incidence of cancer and metabolic syndrome, and delay the signs of aging (Chakravarty et al., 2008; İşleğen, 2015; Duran, 2023). On the other hand, it is stated that long-term acute or chronic severe exercise suppresses the immune system. In particular, consecutive severe exercise without recovery time negatively affects the immune system, rendering the organism vulnerable to infection (Forte et al., 2022; Simpson et al., 2015; Şenışık, 2015). However, they also stated that high-intensity exercise may temporarily suppress the immune system owing to oxidative stress. In a study conducted by Tanner et al. in 2017, ten elite synchronized swimmers' saliva samples were analyzed during a competitive season. It has been asserted that during intensive training, cortisol levels do not increase significantly, and there is no suppression of the immune system. However, cortisol levels increased during competition. It has been asserted that rigorous training in such circumstances does not engender a heightened immune response. In another study, Kurowski et al. (2022) reported that regular moderate-intensity exercise has positive effects on immune health, reduces inflammation intensity, and provides benefits by reducing susceptibility to respiratory infections. In contrast, in the same study, it was reported that both acute and chronic high intensity exercise may weaken both cellular and antibody-producing humoral immunity by negatively affecting immune mechanisms. In another study, it was reported that the immune system was not significantly suppressed as a result of the evaluation of 28 male recreational runners during and after the HIIT training period lasting three weeks (nine sessions) (Born et al., 2017). Similarly, another study reported that the immune system was not suppressed after HIIT in a study conducted with 20 participating athletes, 10 women, and 10 men (Monje et al., 2020). Regular exercise at moderate intensity may increase immunity, while high-intensity exercise may suppress immunity (Wang et al., 2020). In another study examining the effect of exercise on the immune system, it was stated that regular physical exercise can regulate the immune system increase its effectiveness, and reduce the incidence of some diseases (Chastin, 2021).The reason why the results of these studies differ may be that the training intensities applied are different or the sports branches of the participants differ. In addition, it is thought that there may be factors such as sedentary individuals among the participants, environmental conditions, age differences of the participants.

Conclusions

According to the results obtained from the analysis of the results of the studies compiled within the scope of the current research, sedentary life is very harmful to immunity. Regular moderate physical activity is important to strengthen the immune system and reduce the risk of infection. Regular moderate physical activity is recommended for a healthy life and immune system in the medium and long term. High intensity, prolonged acute or chronic exercise may temporarily suppress immunity, which may increase the risk of infection. Athletes or sedentary people who perform high-intensity training should avoid consecutive intense training tempo and pay attention to the recovery period. Especially during the recovery period, they should get enough sleep by eating adequate and balanced nutrition, as well as resting. It is recommended that athletes or sedentary people who perform high-intensity training be informed about this issue and adjust their training programs accordingly.

Author Contributions

Conceptualization, I.G. methodology, I.G., M.O; formal analysis, I.G., M.O; investigation, I.G.,M.O; data curation, I.G., M.O; writing–original draft preparation, I.G., M.O; writing–review and editing, I.G., M.O.

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The research was conducted in line with the Declaration of Helsinki.

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The authors declare that no conflicts interest.

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