Immunity in Athletes

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Abstract

Objective: To analyze the current research to determine the effects of exercise on immune system function.

Data Collection: A manual search of available reference texts and a search of PUBMED were collected with an emphasis on immunity in exercise and athletes.

Results: The reviewed material indicated that exercise has affects on the functioning of the immune system. The immune system responds to increased physical activity and may be given the credit for the exercise-related reduction of illness. In contrast, it is repeatedly shown that intense exercise causes immunosuppression. Essentially, the immune system is enhanced by moderate exercise while intense long duration exercise is followed by immunodepression. The depressed immune system populations include neutrophils, natural killer cells, and IgA mucosal levels. Depression of these populations leads to increased susceptibility for infection in athletic populations that engage in activities which require long intense training sessions and/or competition.

Conclusion: Because the immune system is essential in the suppression of disease and infection, it is vital to maintain its function at the highest level. Through exercise, immune function can be positively or negatively altered depending on the intensity and/or duration. To fully appreciate the effects of exercise, immune responses must be considered to gain the optimum benefits from an exercise regimen.

Key Indexing Terms: Immune system; exercise; athletes

Introduction

During exercise the body can be exposed to extreme stresses. With stress often comes a reduction or increase of function of the various systems of the body. The immune system is no different. Its response and function are correlated with the amount of exercise.

There has been growing interest in this correlation between exercise and the immune system. It is generally believed that exercise increases the immune systems function, however, there have been reports of intense training associated with increased incidence of infections, particularly respiratory infections (12). It is supported that the immune system is affected by increased physical activity (14). The question is: when is exercise responsible for the reduction of illness versus exercise becoming too intense and causing immunosuppression? This review will discus how the volume and the types of exercise affect immune system function, specifically leukocyte populations such as neutrophils, natural killer cells, and anti-body function. These populations were chosen because of their role as primary agents in fighting infection. Also, the 'open window' theory will be considered.

Discussion

Types of exercise

Because there are wide variations in types of physical activity and training, it is essential to attempt to standardize the levels of activity. Key variables include the type of exercise, intensity, and duration of individual exercise sessions. The intensity of aerobic exercise is usually standardized by expressing it as a percentage of an individual's aerobic power. Low intensity exercise is between 30-45 percent aerobic power, duration between 10 and 45 minutes, and is associated with walking or very low-level types of exercise. Moderate intensity exercise is between 45 and 65 percent aerobic power, a duration of 30 to 60 minutes and is associated with exercises such as jogging or low level running, most aerobic classes and recreational biking. High intensity exercise is between 65 and 100 percent aerobic power, duration's of 30 minutes to over 3 hours, and is associated with events such as marathons, triathalons, or any competition level endurance event.

Neutrophils

Physical activity affects neutrophil function. Since neutrophils represent 50 to 60% of total circulating leukocytes, they are considered essential for host defense (14). However, they are also involved in the pathology of various inflammatory conditions. As part of inflammatory responses, neutrophils may begin attacking normal cells and cause tissue damage, therefore, neutrophil activation can be considered a double-edged sword in the effectiveness of the immune system. Intense prolonged physical activity results in neutrocytosis (1). Short bouts of vigorous exercise lasting from approximately 10 seconds to 30 minutes (sprinting or gymnastics), sustained strenuous exercise lasting a few hours (marathon races), or intermittent vigorous exercise (American football or soccer) can induce participants into immediate neutrocytosis (1). At the end of short-term exercise lasting up to 30 minutes (sprinting), the neutrocyte count was increased 20 to 100% but the levels fell quickly, approaching normal levels within 30 minutes of the termination of exercise. After sustained exercise lasting 2.5 to 3.5 hours (marathon races) neutrophil counts ranged from 100% to 310% above normal levels with elevation lasting for 1 to 3 days. After intermittent exercise over 1.5 hours or sustained exercise of 1 hour (football or soccer), neutrophil levels raised 10 to 60% and continued for 1 to 4 hours, before falling slowly to normal levels (14). These elevations along with the duration of the elevation could indeed cause inflammatory responses, especially in the respiratory system (10), and have ill effects on the overall effectiveness of the immune system.

In regards to neutrophil function and response to infection, including chemotaxis, phagocytes, oxidative burst, degranulation and microbial killing, moderate exercise boosts its function. In contrast, extreme exercise suppresses these functions except with chemotaxis and degranulation, which were unaffected (2). In a study by Smith et al (14) neutrophil killing capacity was enhanced for at least 6 hours following 1 hour of moderate ergometer cycle exercise. In another study, immediately following a marathon, neutrophils from runners were less able to ingest bacteria and this effect lasted for 3 days (2). The microbial killing activity was depressed in short (10 to 20 minutes), intense exercise (14). The magnitude of the neutrophilic function seems to be affected by both the intensity and the duration of the activity. If the exercise is too intense (80% maximum aerobic power) or too long (over 1.5 hours) the neutrophil function is suppressed for a period of days. More moderate exercise with limited duration (less than 1 hour) increases the neutrophil function most effectively.

Open window

Neutrophils have the ability to attack normal cells and cause tissue damage, therefore, too many could be harmful to the body. Also, neutrophils are considered the first line of defense against infection. Several authors have suggested that prolonged cardiorespiratory endurance exercise leads to transient but clinically significant changes in immune function (1,2,5,9). During this 'open window,' hypothesized by David Nieman, of altered immunity which lasts anywhere from 3 to 72 hours, viruses and bacteria may have the ability to induce clinical infection or sickness in a much more effective manner (13). His hypothesis is based on changes in immune system components after prolonged exertion such as increases in blood granulocyte and monocyte phagocytosis and interleukin-6 levels. These components suggest a strong pro-inflammatory response to heavy, intense exercise. This pro-inflammatory state, coupled with negative changes of the immune system after heavy exertion suggests the immune system could be suppressed and stressed (13). Data from a study of triathletes also supports the hypothesis. Skin test response to recall antigens of pneumococcal, tetanus and diphtheria showed immunosuppression in the athletes compared to the control group 48 hours after the event was completed. This example further demonstrates the possibility of the 'open window' after prolonged intense exercise. Although this is an attractive hypothesis, no serious attempt has been made by investigators to demonstrate that athletes showing the most extreme immunosuppression following heavy exertion are those that contract an infection during the following 1 to 2 weeks. This is a link that must be established before the 'open window' theory can be wholly accepted.

Natural Killer Cells

Natural killer cells (NK) play an important immune role in the first line of defense against acute and chronic viral infections and tumor spread. Human and animal stress model studies show that high concentrations of NK cells are recruited to the circulation within a few minutes after the onset of a stressful stimulus. With exercise being a source of stress, concentration changes of NK cells in the blood would be evident. Exercise of various types, intensity and duration can play a role in the response of NK cells to circulation and their lytic capacity. NK cells are recruited rapidly from peripheral lymphoid tissues to the circulation in large numbers in response to high-intensity cardiorespiratory exercise. Investigators have consistently reported that immediately following high-intensity exercise, NK cell cytotoxic activity (NKCA) is increased by 40 to 100% above pre-exercise levels in 1 to 2 hours of recovery (6). Another study comparing 45 minutes of high verses moderate intensity exercise (8) demonstrated a 61% and 25% increase in NKCA 2 hours post-exercise, respectively. A 40-45% increase in NKCA was measured during several hours of recovery from 2 to 3 hours of endurance cycling or running (4). Together, these results suggest that the NKCA is elevated during both moderate and high exercise intensities, but the NKCA is higher in the more intense exercise.

Natural killer cell population and cytotoxic function has also been studied in populations of athletes versus non-athletes. The populations of NK cells were found not to be of significant difference, while the NKCA was increased in the conditioned individuals. In a study of marathon runners and sedentary individuals, the population of NK cells was the same while the NKCA was much higher in the marathoners than the sedentary individuals (4). Another study of highly trained cyclists verses healthy, untrained individuals, demonstrated a higher NKCA in the trained group with only a slight increase in the NK cell population in the trained group (3). In a study of highly conditioned versus sedentary elderly females, NK cell populations were higher in the athletically conditioned group (8). These studies demonstrate that NK cells in the conditioned athletes had a higher cytolytic capacity per cell than the sedentary individuals. The number of NK cells that enter the circulation can be dependent on the intensity of the stimulus.

Data from these studies suggest that more intense exercise with increased duration, increases the NK cell function. Athletes also had higher NKCA levels than their sedentary counterparts. Although NK populations were not significantly affected by the exercise, the cytotoxic ability of the cells present increased substantially. With the findings of chronic elevations in NK function in long duration events, athletes and individuals who exercise may experience host protection (3).

Upper respiratory infections

The secretory immune system of mucosal tissues such as the upper respiratory tract is considered to be the first barrier to pathogenic microorganisms that might cause upper respiratory tract infections (URTI)(5). An important question is to what degree are the immunological changes through exercise of clinical significance for the breakthrough of these microorganisms to cause a URTI. A series of studies by the Pyne and Gleeson research team profiled the immune responses of elite swimmers during training.

Collectively their studies indicated that prolonged training by athletes could suppress aspects of systemic and mucosal immunity. The most notable changes were in salivary IgA levels and incidence of URTI. As the athletes trained over a 7-month period, the athletes with the lowest IgA levels at the end of the training session had a higher rate of reported URTI. Also, the swimmers demonstrated an average of a 4.1% decrease in the IgA levels per month of training per athlete. Collectively these results indicate that IgA levels are decreased in prolonged training with an increase of URTI incidence with the decreased IgA levels (9).

Studies in running have indicated an increase incidence of URTI in long distant events such as marathons. A study indicated that 12.9% of Los Angeles Marathon (LAM) participants reported an infectious episode during the week following the race in comparison to only 2.2% of similarly experienced runners who applied but did not participate (12). Forty percent of the runners also reported at least one URTI during the 2-month winter training period prior to the marathon. It was determined that runners training more than 96 km/week doubled their chances for sickness verses those who trained less than 32 km/wk (10).

Peters and Bateman carried out a prospective study of the incidence of symptoms of URTI in 150 randomly selected runners who took part in the 1982 Two Oceans Marathon and compared this with the incidence in individually matched controls who did not run. Symptoms of URTI occurred in 33.3% of runners compared to 15.3% of controls and symptoms were most common in those who achieved faster times (7). Based on the above epidemiological studies, Nieman proposed a model (figure1) that demonstrates the relationship between an acute period of exercise and susceptibility to URTI. The model depicts a "J"-shaped relation between the intensity of exercise and the risk of URTI (7). More moderate exercise reduces the risk of URTI compared to the sedentary lifestyle (11). In contrast, a person whose exercise intensity is very high, as in a marathon, may experience increased odds for URTI (1). Clinical data supports the concept that heavy exertion exercises such as marathons and high level swimming increases an individuals risk of contracting an URTI because of the negative changes that occur in the immune system and at the mucosal barriers in the lungs.

Figure 1:

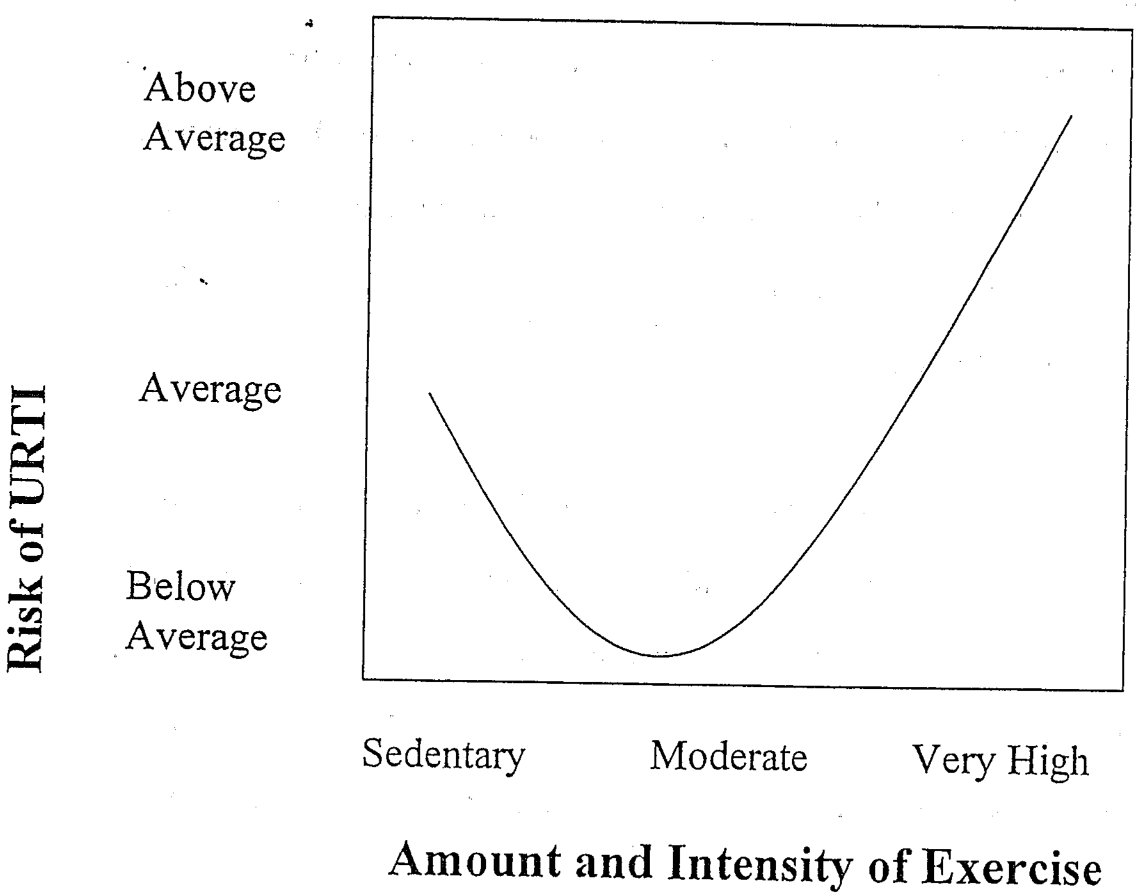

Figure 1. Adapted from Nieman, DC. Exercise, upper respiratory tract infection, and the immune system. *Med Sci Sports Exerc.* Vol. 26, No. 2, p.129.

Conclusion

As reviewed in this article, the clinical data supports the concept that heavy exertion and intense exercise increase` one's risk of contracting an infection while moderate exercise increases one's ability to suppress infection. Participants in events such as marathons show an increased susceptibility to upper respiratory tract infections. Through exercise, neutrophil populations and function can be altered. Excessive and intense exercise can induce neutrocytosis to a point of potential tissue damage and suppress the function of neutrophils. While the neutrophils are suppressed, the likelihood of infection is increased. The is termed the 'open window.' In contrast, moderate exercise creates increased populations of neutrophils that are non-damaging to normal tissue, and have improved overall function. Natural killer cell function is increased with intense exercise. The cytotoxic function of the NK cells is enhanced in athletes while the control populations remain unchanged. The data clearly shows, even with increased NK cell function, that the incidence of infection following intense exercise is increased. Moderate exercise enhances immune function and host protection. Individuals who partake in moderate exercise show slightly elevated immunity with no 'open window.' The athlete and the doctor should be aware of the benefits that one may derive from engaging in regular, moderate forms of exercise. Through this study, the evidence suggests improved host protection with moderate exercise.

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