THORAX

Editorials

Upper respiratory tract infections and exercise

There is a common belief among fitness enthusiasts that regular exercise confers resistance against infection. For example, a 1989 survey of subscribers to *Runner's World* revealed that 61% of 700 runners reported fewer colds since beginning to run, while only 4% felt they had experienced more.[1] In a survey of 170 non-elite marathon runners (average personal best time of 3 hours 25 minutes) who had been training for and participating in marathons for an average of 12 years, 90% reported that they definitely or mostly agreed with the statement that they "rarely get sick".[1] On the other hand, among elite athletes and their coaches a recurrent concern is that heavy exertion lowers resistance, impairs immunity, and is a predisposing factor to upper respiratory tract infections. During the winter and summer Olympic Games it has regularly been reported by clinicians that "upper respiratory infections abound" and that "the most irksome troubles with the athletes were infections".[2]

Exercise and upper respiratory tract infection

Understanding the relationship between exercise and upper respiratory tract infection has potential significance for public health and, for the athlete, may mean the difference between being able to compete, performing at a subpar level, or missing the event altogether because of illness.

The relationship between exercise and upper urinary tract infection may be modelled in the form of a "J" curve[2 3] (fig 1). This model suggests that, although the risk of upper respiratory tract infection may decrease below that of a sedentary individual when engaging in moderate exercise training, the risk may rise above average during periods of excessive amounts of high intensity exercise. Nearly 20 different investigations have been published on the link between exercise and upper respiratory tract infection in humans.[2] At present there is considerable evidence on the relationship between heavy exertion and upper respiratory tract infection, with more research needed in the area of the potential protective effect of moderate physical activity.

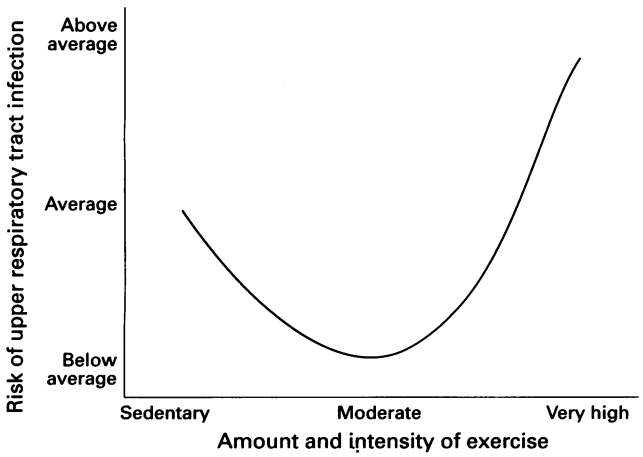

Figure 1 "J"-shaped model of the relationship between varying amounts of exercise and risk of upper respiratory tract infection. This model suggests that moderate exercise may lower the risk of upper respiratory tract infection while excessive amounts may increase the risk.

HEAVY EXERTION AND UPPER RESPIRATORY TRACT INFECTION: EPIDEMIOLOGICAL EVIDENCE

Several epidemiological reports suggest that athletes engaging in marathon type events and/or very heavy training are at increased risk of upper respiratory tract infection.[2–6] Nieman *et al*[4] assessed the incidence of upper respiratory tract infection in a group of 2311 marathon runners who varied widely in running ability and training habits. Runners retrospectively reported demographic data, training, and upper respiratory tract infection and symptom data for the two month period before and the one week period immediately after the 1987 Los Angeles marathon. During the week after the race 12·9% of the runners reported an upper respiratory tract infection compared with only 2·2% of control runners who did not participate (odds ratio 5·9), and 40% of the runners reported at least one upper respiratory tract infection during the two month winter period before the marathon. Controlling for various confounders, it was determined that runners training more than 96 km/week doubled their odds for sickness compared with those training less than 32 km/week.

Other epidemiological data support these findings. Studies on South African ultramarathon runners, Danish orienteers, and South Carolina runners all support the viewpoint that heavy acute or chronic exercise is associated with an increased risk of upper respiratory tract infection.[2 3 5 6] The risk appears to be especially high during the one or two week period after the race.

MODERATE EXERTION AND UPPER RESPIRATORY TRACT INFECTION

What about the common belief that moderate physical activity is beneficial in decreasing the risk of upper respiratory tract infection? Two randomised experimental trials using small numbers of subjects have provided important preliminary data to support the view that moderate physical activity may reduce the symptoms of upper respiratory tract infection. In one randomised controlled study of 36 women (mean age 35 years) exercise subjects walked briskly for 45 minutes, five days a week, and experienced symptoms of upper respiratory tract infection during the

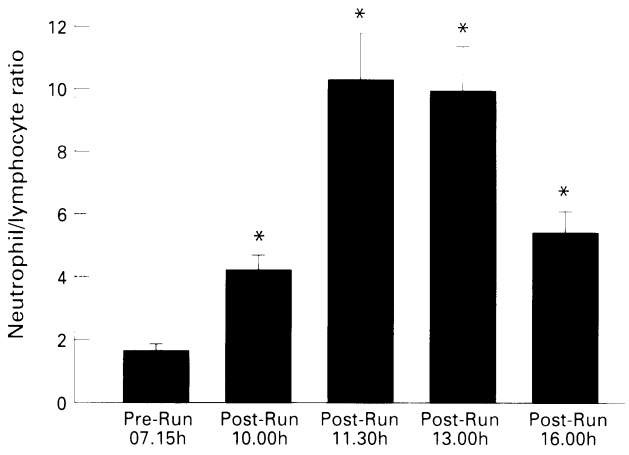

*Figure 2 Response of the neutrophil/lymphocyte ratio in 22 marathon runners following 2·5 hours of running at 76% of the maximal oxygen uptake. Data from Nieman et al.[11] * p<0·01 difference from baseline.*

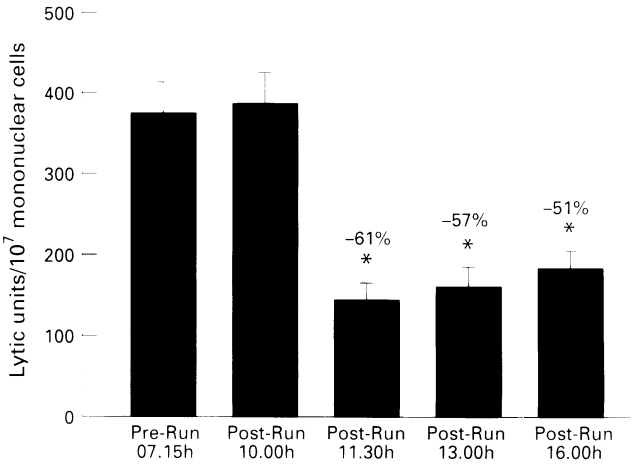

*Figure 3 Change in natural killer cell activity (NKCA, expressed in total lytic units) in 22 marathon runners following 2·5 hours of running at 76% of the maximal oxygen uptake. Data from Nieman et al.[12] * p<0·01 difference from baseline.*

15 week period on half as many days as a sedentary control group (5·1 (1·2) versus 10·8 (2·3) days, p<0·05).[7]

In a study of elderly women[8] the incidence of the common cold during a 12 week period in the autumn was found to be lowest in highly conditioned, lean subjects who exercised moderately each day for about 1·5 hours. Elderly subjects who walked 40 minutes five times a week had an incidence of upper respiratory tract infection of 21% compared with 50% for a sedentary control group. ($\chi = 6{\cdot}36$, p<0·05). These data suggest that elderly women not engaging in cardiorespiratory exercise are more likely to experience an upper respiratory tract infection during the autumn than those who do exercise regularly.

Effects of exercise on the immune system

It naturally follows that, if heavy and fatiguing exertion leads to an increased risk of upper repiratory tract infections, various measures of immune function should be negatively affected and, conversely, if moderate exercise decreases the risk of upper respiratory tract infection there should be some aspect of immune function that is chronically or at least transiently improved. There is a growing consensus that the transient changes in immunity that occur following heavy exertion (the acute immune response) better explain the upper respiratory tract infection epidemiological data than do the exercise training-induced alterations (the chronic immune response).

IMMUNE RESPONSE TO ACUTE EXERCISE

A growing number of published reports on exercise immunology provide evidence that the immune system is profoundly affected by acute exercise.[9,10] Following prolonged intensive running, for example, concentrations of blood neutrophils are raised for more than six hours while the lymphocyte count is depressed.[11,12] As a result the neutrophil/lymphocyte ratio, which has been used as an index of stress to the immune system, is increased for most of the day following heavy exertion such as marathon running (fig 2). Moderate intensity exercise has been shown to induce much smaller changes in leucocyte subsets.[9,10] This is because the extent and duration of the alterations in leucocyte subset counts are very much dependent on the exercise-induced changes in levels of adrenaline and cortisol which begin to increase rapidly when the exercise intensity rises above 60% of the maximal oxygen uptake.

T cell function – defined in the laboratory as the ability of T cells to proliferate (or clone themselves) after coming into contact with specific viruses, bacteria, or mitogens (for example, plant lectins) – is an important component of the antigen-specific immune system. Several investigators have now reported that T cell function is decreased by 35–50% for more than three hours after prolonged and intensive exercise.[11,13,14] The decrement in T cell function is caused by inhibition by plasma cortisol and adrenaline, and exercise-induced alterations in blood concentrations of lymphocyte subsets.

Natural killer (NK) cells account for 10–15% of lymphocytes and usually react rapidly to viruses and bacteria, initially controlling them until the antigen-specific immune system begins to respond. Thus, the cytotoxic activity of NK cells (NKCA) represents a major first line defence system against infection. Investigators have consistently reported that, following prolonged exertion, NKCA is decreased by 35–60% for several hours[12] (fig 3). The decrease is most likely to be caused by the transfer of NK cells from the circulation to other tissue compartments including the muscles.

In addition to mitogen-induced lymphocyte proliferation and NKCA, neutrophil phagocytic function and salivary IgA concentration have also been reported to be suppressed for several hours during recovery from prolonged intense endurance exercise.[15–18] During this "window of decreased host protection," viruses and bacteria may gain a foothold, increasing the risk of subclinical and clinical infection.[19,20] This may be especially apparent when the athlete goes through repeated cycles of heavy exertion.

IMMUNE RESPONSE TO CHRONIC EXERCISE

Numerous studies have made cross sectional comparisons of the immune systems of athletes and non-athletes or have followed sedentary individuals as they initiate exercise programmes, comparing immune measures before and after exercise training relative to control groups.[2,3,7,8,21,22] Several of these studies have shown significant improvements in NKCA with exercise training. In cross sectional comparisons, for example, NKCA has been reported to be significantly higher in highly conditioned compared with sedentary elderly women,[8] and in elite cyclists compared with untrained subjects.[22] The function of other cells of the immune system, including T and B lymphocytes, neutrophils, and monocytes, appears to be relatively unaffected by chronic exercise training.[2,20–22]

Management of the athlete during an episode of infection

Endurance athletes are often uncertain whether they should exercise or rest during an episode of infection, and there are few data available to provide definitive answers. Most clinical authorities in this area recommend that, if the athlete has symptoms of a common cold with no constitutional involvement, then regular training may be safely resumed a few days after the resolution of symptoms.[5 20] However, if there are symptoms or signs of systemic involvement – for example, fever, extreme tiredness, muscle aches, swollen lymph glands – intensive training should not be resumed for 2–4 weeks. There is no method available to predict in advance which individual with an upper respiratory tract infection will develop viral myocarditis, cardiomyopathy, pericarditis, or valvulitis.

Depending on the pathogen (with some more affected by exercise than others), animal studies generally support the finding that one or two periods of exhaustive exercise following inoculation of the animal leads to a more frequent appearance of infection and a higher fatality rate.[21] For example, there are many reports that the virulence of the coxsackie virus B3 is significantly augmented by intense exercise in mice, including increased replication of the virus in heart muscle cells leading to necrosis and death.

If an athlete experiences sudden and unexplained deterioration in performance during training or competition a viral infection should be suspected. In some athletes a viral infection may lead to a severely debilitating state known as "post-viral fatigue syndrome (PVFS)" which can persist for months with lethargy, easy fatiguability, and myalgia. It is well established that various measures of physical performance capability are reduced during an infectious episode.

For elite athletes who may be undergoing heavy exercise stress in preparation for competition, several precautions may help them to reduce their risk of upper respiratory tract infection. Considerable evidence indicates that improper nutrition[23] and psychological stress[24] can compound the negative influence that heavy exertion has on the immune system. Based on current understanding, the athlete is urged to eat a well balanced diet, keep other life stresses to a minimum, avoid overtraining and chronic fatigue, obtain adequate sleep, and space out vigorous workouts and race events as far apart as possible.[3] The function of the immune system appears to be suppressed during periods of low calorie intake and weight reduction so, when necessary, the athlete is advised to lose weight slowly during non-competitive training phases. If possible, athletes should avoid being in contact with ill people before and after important events to reduce the risk of becoming infected with the cold virus. If the athlete is competing during the winter months vaccination against infleunza is recommended.

Summary

The epidemiological data suggest that endurance athletes are at increased risk for upper repiratory tract infections during periods of heavy training and the 1–2 week period following a marathon or similar event. At present there is no clear indication that chronic alterations in immune function explain this increased risk. Following acute bouts of prolonged heavy endurance exercise, several components of the immune system are suppressed for several hours. This has led to the concept of the "open window" theory described as the 1–9 hour period following prolonged endurance exercise when host defence is decreased and the risk of upper respiratory tract infection is increased.

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