Respiratory Infections and Mucosal Immunity in Athletes

Maree Gleeson, PhD;1 David B. Pyne, PhD;2 Hunter Immunology Unit, Hunter Area Pathology Service, Royal Newcastle Hospital, Newcastle, NSW,1 Sports Science and Sports Medicine Centre, Australian Institute of Sport, Canberra ACT,2 Australia

Habitual, intense exercise undertaken by highly trained athletes can cause suppression of mucosal immune parameters, leaving some individuals prone to respiratory illness. Salivary IgA and IgM concentrations decline immediately after a bout of intense exercise, but usually recover to baseline levels within 24 hours. However, intense physical training over a period of months to years can result in a chronic suppression of mucosal immunoglobulin levels. The degree of mucosal immune suppression is associated with the intensity of the exercise and the duration or volume of the training program. Low levels of secretory immunoglobulins are associated with an increased risk of respiratory illness in both athletic and general populations. Monitoring mucosal immune parameters and establishing personal profiles may provide an assessment of the risk status of an athlete for respiratory illness and allow effective management by the athlete and coach. Intervention strategies are centered on ensuring well balanced training programs, educating athletes in self-management and coping skills, applying appropriate clinical management, and limiting exposure to infectious agents. (Am J Med Sports. 2001;3:159–165)

Address for correspondence/reprint requests: Maree Gleeson, PhD; Hunter Immunology Unit, Royal Newcastle Hospital, PO Box 664J, Newcastle NSW 2300, Australia
Manuscript received September 20, 1999; accepted October 13, 1999

Respiratory Infections in Athletes

Upper respiratory tract infections (URTI) are the most common infections observed in highly trained athletes, representing 30%–40% of presentations to sports medicine clinics, and the majority of URTI are of viral origin.1,2 Reports of URTI in exercising populations tend to favor a higher incidence in endurance athletes (33%–40%) compared to sedentary or moderately exercising subjects (12%–15%).3,4 The frequency of URTI in a study of endurance athletes ranged from zero to seven episodes in 1 year.5 The timing of an URTI is critical for competitive athletes and does not follow the usual increased winter prevalence for the general population. An increase in the incidence of URTI usually occurs at the end of high intensity training periods, usually in the taper period prior to competition, when volumes are decreasing.6,7 Most URTI in both the athletic and general populations will be self-limiting or respond to treatment. However, intense exercise during the acute phase of a viral illness may increase the severity of the illness1 and can have serious complications for an athlete, such as muscle weakness and even sudden death from myocarditis due to infections, such as Coxsackie virus.2,8 Studies examining the relationships among exercise, infection, and immunosuppression have not been conclusive as a consequence of conflicting, uncontrolled, and nonstandardized data. However, it is universally accepted that exercise alters various immune parameters, but that this is usually of a transient nature,9,10 with baseline levels restored in 6–24 hours. Prolonged, intense exercise may induce immunosuppression, but this is reversible with rest.11 Low levels of secretory antibodies in saliva are associated with an increased risk of respiratory illness in elite swimmers undertaking high-intensity training.5,12
Impact of URTI on Athletic Performance

Recurrent URTI can result in decrements in performance, and two recent case studies have identified an association with suppression of mucosal immune parameters. The incidence of URTI was monitored in the 1998 Commonwealth Games Australian Swim Team by the team doctor prior to and during the Games. The international performance ranking of the swimmers who suffered an URTI was lower after the competition, while those who were free of illness prior to the competition performed above or at their personal best and the international performance rankings increased after the competition.

Mucosal Immunity and Infection

Secretory antibodies play an important role in defense against respiratory illness. Secretory immunoglobulin α (SIgA) antibodies predominate at mucosal surfaces and play the major role in effective specific mucosal immunity. Secretory immunoglobulin μ (SIgM) antibodies contribute to a lesser extent in the normal adult but play a significant role in mucosal defense in IgA-deficient states. It is well known that individuals with selective IgA deficiency suffer a high incidence of infections, particularly URTI; however, in individuals in whom the immune defect is compensated by an increase in IgD, IgM, and IgG-producing cells at mucosal surfaces, the incidence of infection is lower and they may remain asymptomatic. In normal individuals, reduced SIgA levels have been shown to be related to an increase in the incidence of URTI. A cause and effect between low levels of SIgA and illness has not been shown, and SIgA levels should be viewed as a risk factor for developing infection. In the absence of other factors, such as exposure to pathogens or host susceptibility, low levels of SIgA may be of little clinical consequence. Habitual, intense exercise is associated with mucosal immunosuppression and a low level of SIgA is a risk factor for URTI in elite athletes (Table I).

Acute Effects of Exercise on Mucosal Immunity

The changes in mucosal immunity after a bout of exercise vary among sports and appear to depend on the level of fitness of the subjects. The consensus on elite or highly trained athletes studied during their normal training or competition is that intense endurance exercise results in lower levels of IgA, IgA1, and IgM in saliva after each exercise session. However, in an elite squad of squash players the response of salivary IgA to exercise was an increase in healthy athletes and a decrease in those who developed an URTI. The concentration of salivary IgA is usually unaffected or slightly increased in moderately exercising groups. Under laboratory controlled conditions, using the treadmill or cycle ergometer to test competitive or recreational athletes and normally sedentary subjects, it would appear that no changes in salivary IgA concentrations are evident immediately after moderate exercise loads, but variable changes are seen with maximal exercise.

Cumulative Effects of Training on Mucosal Immunity

Investigations of the long-term effects of habitual, intense exercise confirm that suppression of mucosal immune parameters is cumulative in endurance sports. Declining concentrations of
salivary IgA can be seen within a few days of intense training but are more apparent when followed longitudinally over several months of high-performance training. The long-term responses of salivary IgM parallel those of salivary IgA, indicating that these measurable parameters of mucosal immunity are under the same immune control mechanisms in response to intense training. The influence of long-term exercise on salivary IgG levels appears to be minimal. Fortunately, recent studies suggest that the suppression of mucosal immunity is reversible with rest and does not interfere with the ability of elite athletes to respond to oral vaccines. The long term effects of regular low- to moderate-intensity exercise on mucosal immune parameters are still emerging.

Longitudinal studies of elite athletes show that the concentrations of salivary IgA decrease with increasing duration of training. In a cohort of elite swimmers followed over a 7-month training season, the pretraining levels of salivary IgA fell, on average, by 4% for each additional month of training (duration) and the post-training levels fell by an average of 7%. The post-training IgA levels were, on average, 8.5% lower for each additional kilometer swum during a training session (session volume). The interaction of duration of training and intensity has also been examined in groups of Olympic athletes. The levels of salivary immunoglobulins are usually lower in the Olympic athletes at rest compared to nonexercising controls when tested at the end of a high intensity training phase (usually precompetition), reflecting the cumulative effect of habitual training on suppression of mucosal immunity. The levels of SIgA in Olympic athletes also show sudden decreases during the periods of maximum-intensity training. Specific antibody titers to systemic vaccinations of Olympic athletes have also shown the same negative trend during competition periods.

Other influences on mucosal immunity and susceptibility to URTI that must be considered in elite athletes are psychological stressors and environmental changes caused by adaptation to extremes of ambient temperature, altitude exposure, and long-distance travel. Anxiety and psychological stress are known to significantly decrease salivary IgA concentrations, and there are positive associations of salivary IgA concentrations with positive mood states. The influence of psychological stress or anxiety on elite athletes has been comprehensively studied, but to date no correlations have been found between salivary immunoglobulins and any measure of stress or anxiety in exercising populations. In a cohort of elite swimmers there was a positive relationship between stress and the number of URTIs, and this was accompanied by inverse relationships with the physical intensity and volume of exercise. The higher stress/anxiety scores associated with URTI may reflect the concern of elite athletes that they are unable to train to full capacity.

There are no published data on the effect of long-distance travel, altitude training, or sleep deprivation on salivary IgA levels. However, sleep deprivation can cause a decrease in specific antibody responses in saliva to oral immunization. Ambient temperatures ranging from 6°C–34°C have no effect on the concentration of salivary IgA, either pre- or post- submaximal exercise. Studies assessing the impact of nutritional supplements on mucosal immunity have failed to show any significant alterations or effects on the incidence of URTI.

**Management of URTI in Athletes**

The risk of illness is the product of two factors: the ability of the immune system to respond to infectious challenge and the degree of exposure to infectious agents. The recommendations for managing the health of athletes fall into three areas of responsibility: 1) training—responsibility of the athlete and coach; 2) lifestyle and behavioral management—responsibility of the athlete; and 3) clinical considerations—responsibility of the physician.

**TRAINING MANAGEMENT.** It is important to remember that moderate exercise in both trained athletes and sedentary or moderately active
individuals\textsuperscript{38,39} can boost immune function. Experience has shown that athletes in endurance sports generally require high training volumes to develop the background necessary for success in competition.\textsuperscript{40} Developing aerobic fitness may have an important role in maintaining immunocompetence in highly trained athletes and may serve as a protective buffer during more intensive training and competitive phases. Sudden increases in either training volume or intensity, or in both, place additional pressure on immune function. The risk of overtraining is increased by monotonous training without alternating hard and easy training days. A lack of a complete rest day once per week, increasing loads when the total load is already high, and too many competitions.\textsuperscript{41} Athletes, coaches, and medical personnel should be alert to periods of increased risk of URTI and pay particular attention to recovery and other intervention strategies (Table II).

**LIFESTYLE AND BEHAVIORAL MANAGEMENT.** Limiting exposure to pathogenic agents is an important part of reducing the risk of URTI. Athletes are continually and unwittingly exposed to infectious agents. The three main causes of transmission of infectious agents between individuals are airborne droplets, physical contact, and common source exposure. Isolating infected individuals will limit cross-infection in a team situation. Athletes should be encouraged to avoid infected individuals and crowded environments where possible. Potential situations where the risk of transmission may be increased include travel, public transport, shared accommodation, crowded community facilities, and sporting venues. Recirculated air and air conditioning also increase the risk of pathogen transmission. Attention to personal hygiene is important and athletes should be reminded to wash hands prior to eating, avoid sharing towels, beverage bottles, and eating utensils, and avoid cross-contamination with sporting equipment and appliances.

Do athletes’ diets place them at risk of immunosuppression? Most diets have sufficient calories and range of macro- and micronutrients to maintain immune function, and resistance to infection is unlikely to be compromised in most circumstances.\textsuperscript{42} There are two major groups of athletes who may be at increased risk of nutritional imbalance and associated adverse effects on immunity: athletes who voluntarily restrict caloric and nutrient intake to make weight limits or for aesthetic reasons, and athletes who consume excessive calories and/or nutritional supplements in the expectation of improved performance. Athletes should be clearly advised that immune responses can be jeopardized by both inadequate and excessive intake of certain nutrients.\textsuperscript{43} This advice is pertinent, as many athletes incorrectly assume that a greater intake of nutritional supplements increases the beneficial effects of athletic practice on health, immunity, and performance.

The impact of micronutrient supplementation on immune function has been studied in both athletic and general populations. Zinc, iron, and magnesium levels are decreased by exercise and training and this may have consequences for effective immunity.\textsuperscript{44} Vitamins C and E act as antioxidants in protecting cellular membranes from the effects of exercise-induced oxidative damage. Vitamin C supplementation has been effective in reducing the incidence of illness in marathon runners.\textsuperscript{45} Apart from prophylactic supplementation of vitamins and minerals, there is also evidence that therapeutic ingestion of selected nutrients at the onset of URTI symptoms may be beneficial. Combination throat lozenges containing vitamin C and zinc may decrease the duration of cold symptoms and should be considered as a first-line treatment for athletes and active individuals with URTI.\textsuperscript{46}

**CLINICAL MANAGEMENT.** The sports medicine physician plays a central role in coordinating the

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**TABLE II. CONSIDERATIONS FOR REDUCING THE RISK OF URTI IN ATHLETES**

- Avoid excessive training volume and intensity, and include adequate rest and recovery.
- Reinforce personal hygiene practices, such as hand washing and avoiding the sharing of eating utensils, towels, and sporting equipment.
- Limit exposure to pathogenic agents by isolating infected individuals, and avoid overly crowded public places.
- Consider influenza vaccinations as a prophylactic measure in the winter season or when traveling to winter climates.
- Assess nutritional status and avoid voluntary restriction or excessive macronutrient and micronutrient supplements.
- Use prophylactic and therapeutic vitamin C and zinc supplements.
provision of medical care with the athlete, coach, and other members of a team (Table III). The physician is required to differentiate between localized and systemic symptoms of respiratory illnesses and assess whether the illness is viral, bacterial, or inflammatory in origin. Guidelines for the administration of medications for the treatment of the common cold (e.g., antihistamines and decongestants) in athletes have been described. Systemic signs and symptoms, such as fever, elevated heart rate, fatigue, myalgia, arthralgia, and lymphadenopathy indicate a more significant illness and a greater need for rest from competition and training. The amount of time off training varies according to the individual and rate of recovery from illness. The prophylactic use of influenza vaccines prior to the winter season or when an athlete is traveling to a winter climate should be considered, along with other vaccinations recommended for athletes. Physicians should also ensure that athletes are appropriately medicated for any known acute and chronic conditions, such as URTI, sinusitis, asthma, or allergy, which may lead to fatigue or poor performance. URTI have also been implicated in the development of bronchial hyper-responsiveness and asthma in endurance athletes who continued to train during the symptomatic period.

Should athletes exercise when suffering an illness? Caution is required for athletes suffering or possibly suffering from myocarditis, infectious mononucleosis, or related viral syndromes. Athletes are advised to refrain from exercise during the early course of a febrile illness. Viral myocarditis is a particular concern and current recommendations are for athletes with this condition to avoid exercise until a medical clearance is obtained. Myocarditis can be caused by a variety of microorganisms and may or may not be associated with fever, malaise, and upper respiratory tract illness.

Monitoring mucosal immune parameters during critical training periods and establishing personal profiles for individual athletes may provide an assessment of the risk status for respiratory illness and allow effective management by the athlete and coach to avoid illness. Lower levels of salivary IgA are associated with an increased risk of URTI. When levels fall below an individually determined threshold level, alteration in the training program, particularly reduced exercise intensity or rest, allows recovery of salivary IgA to protective levels. Salivary IgA may also play a predictive role in monitoring overtraining in elite athletes; Mackinnon and Hooper have reported lower salivary IgA levels in "stale" (defined as decreased performance and persistent fatigue) compared to well-trained swimmers.

**Summary and Conclusions**

The mucosal immune system plays an important role in defense against respiratory illness. The network of mucosal immune structures, lymphocytes, antigen-presenting cells, mucosal epithelium, and communicating cytokines requires an exquisite balance to ensure effective immunity without promoting inflammatory damage at mucosal surfaces. Disruption of any component of the network can result in decreased immunity or damage of the mucosal structures. Exercise, particularly habitual, high intensity exercise undertaken by competitive athletes or highly trained individuals, has the potential to disrupt this balance.

Exercise at moderate- and high-intensities causes an immediate decrease in SlgA and SlgM in mucosal secretions. Recovery to pre-exercise levels usually occurs within 24 hours of high-intensity exercise but may remain suppressed for longer periods. Several consecutive days of high-intensity training will cause a decrease in SlgA and SlgM over the days of training. Habitual training at an
intense level results in a cumulative decline in SgA levels over a training season. Psychological stress/anxiety has been shown to cause a decrease in SgA, but this association has not been observed in high-performance athletes. Low levels of SgA and SgM are associated with an increased risk of URTI in the general population as well as moderate- and high-intensity exercising groups of athletes. URTI in the precompetition period are associated with performance decrements. Low levels of SgA have also been associated with excessive training (overtraining), resulting in poor performance.

The low levels of secretory immunoglobulins resulting from intense exercise and associated with an increased risk of respiratory illness must still be interpreted within a clinical and training context. One measurement of mucosal immune parameters is unlikely to be informative, unless mucosal immune suppression is extreme. Monitoring of mucosal immune parameters, such as SgA, SgA1 and SgM, will provide an assessment of the risk status of an athlete for URTI and allow effective management by the athlete and coach during critical training periods. A personal profile should be established for individual athletes of their salivary IgA response to exercise and the association with URTI. Management strategies for the prevention of URTI are centered on three areas: training interventions, lifestyle and behavioral education, and clinical interventions, when necessary, by the physician. All three strategies are aimed at prevention of URTI and the associated decrements in performance.

REFERENCES

24. Mackinnon LT, Hooper S. Mucosal (secretory)


