Infectious Disease in Athletes

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Abstract:
While orthopedic injuries most commonly are associated with sports, infectious diseases cause significant morbidity in athletes. Exercise improves immunity at moderate intensity but impairs immune function at extremes of duration and intensity. Respiratory infections are the most common, but skin, blood borne, sexually transmitted, and even cardiac infections occur. Infectious disease outbreaks are a constant concern. Treatment of such infections resembles those used in the general population. Return to play issues and prevention of infection are especially important in athletes.

INTRODUCTION
The National Sporting Goods Association (NSGA) reports that sports participation increased 7% in the United States from 1999 to 2009 (37). When most people think of sports medicine, orthopedic injuries such as sprained ankles or pulled muscles come to mind, but actually infectious diseases cause up to 50% of visits in high-school and college training rooms (31). Exercise has significant effects on the human immune system, and the effects of infection, such as fever and fatigue, can weaken muscles, impair exercise, and predispose to other injuries. Return-to-play is an important issue, both for the safety of the athlete and the well-being of others. Activities common to athletes can increase the likelihood of spreading infectious disease from one person to another. As a result, infectious disease outbreaks are a significant threat to the athletic population, especially in organized sports at the high-school, college, and Olympic levels.

EFFECTS OF EXERCISE ON THE IMMUNE SYSTEM
The human immune system is composed of two parts, the innate immune system and the adaptive or acquired immune system. The innate immune system includes infection-fighting cells, such as natural killer (NK) cells and phagocytes, and proteins such as tumor necrosis factor, cytokines, and complement factor (1,8). The innate immune system is always ready to meet invaders, regardless of whether the body has encountered them before.

The acquired immune system is composed of T and B lymphocytes, the immunoglobulins (Ig) that they produce, and cytokines that regulate the immune response (1). Through a complex pathway of intercellular interaction, IgM is produced about 7 d after exposure to a new pathogen and IgG about 7 d later. Secretory IgA is produced in mucous to provide front-line defense (24). The acquired immune system does not provide immediate protection against new pathogens but provides powerful and long-lasting protection against anything it has seen before. Combined, the innate and acquired immune systems comprise a remarkable defense against the millions of infectious threats that each person encounters over a lifetime.

Moderate exercise, commonly defined as exercise for 5 to 60 min within a range of 40% to 60% of maximum heart rate (MHR), improves many aspects of immunity (7,34,35). Neutrophil and NK counts and salivary IgA concentrations and secretion rates increase after moderate exercise (8,24). A 1989 Runner’s World survey revealed that 61% of runners reported fewer upper respiratory tract infections (URTIs) after starting running, whereas only 4% reported more (7). Some studies suggest that the incidence of URTIs drops 20% to 30% in moderate exercisers compared with sedentary people (9).

Intense exercise, defined as 5 to 60 min of exercise at 70% to 80% of MHR, and prolonged exercise, often defined as greater than 60 min, have detrimental effects on the immune system (7,34). Exercising harder increases the body’s requirement for oxygen, which forces the athlete to transition from nose breathing to mouth breathing, bypassing the nasal hairs and turbulent flow that protect the lungs from pathogens. Inhaling larger volumes of colder and usually drier air thickens the mucous and disrupts the mucociliary elevator. More foreign particles are deposited in the lower airways, the ability of airways to remove them is diminished, and airway inflammation results (5,8).

NK cell numbers and secretory IgA concentrations fall after intense, prolonged exercise (7,36). Lymphocyte and...
neutrophil counts and B cell function also decrease. The ratio of CD4 to CD8 T cells should be about 1.5:1 for optimal immune function, but intense, long-duration exercise decreases this ratio (8). Concentrations of cortisol, prolactin, adrenaline, and growth hormone increase, impairing cellular immunity (9). Salivary lactoferrin and lysozyme concentrations fall, affecting mucosal immunity (50). One study showed a decline in serum neutrophil levels with long-term, intense exercise (51). Serum IgG1, IgG2, and IgG concentrations fall (32). The immunosuppression associated with exercise could be considered an immunologic “open window” in which the risk of infection may be higher (34).

The relationship of URTI incidence to intensity and duration of exercise seems to be well described by a “J” shaped curve: sedentary individuals are at greater risk than those who exercise moderately. Extreme exercisers, however, are at the highest risk (35). Other infectious diseases may follow a similar pattern.

Effects of Infection on Exercise

Infections increase the risk of illness and injury in the exercising athlete. Fever impairs coordination, concentration, muscle strength, and aerobic power (31). It also hinders endurance and fluid and temperature regulation. Viral illnesses contribute to tissue wasting, muscle catabolism, and negative nitrogen balance (31). Pain, discomfort, or other symptoms of infection can be distracting during play and competition. Infections also have a small negative effect on performance (8). Drugs commonly used to treat the symptoms of infectious diseases have variable impacts on athletes. Acetaminophen seems to have few risks, but quinolones may be associated with tendon rupture, other antibiotics can cause diarrhea, antihistamines can cause sedation, and ephedrine-containing compounds are banned by many sports organizations (25,31). Usage of these compounds will lead to positive drug tests and disqualification of an athlete during the competitive season.

URTI

URTI affects almost every healthy adult one to six times a year, is probably the most common infection seen in the training room, and predominates among participants at the Olympic Games (19). URTI generally is viral and transmitted by direct contact, usually hand to nose, eyes or mouth, small particle aerosols, and large particle droplets. In closed communities such as locker rooms, 25% to 70% of teammates can be infected from one index patient (39). The peak incidence of IM is from ages 15 to 25 yr, and by age 35, the incidence drops dramatically (10 d) or equivalent helps reduce the risk of nonsuppurative tonsillar abscess, otitis media, and mastoiditis. Oral penicillin (10).

Infectious Mononucleosis

G wasn’t there until the 1940s and 1950s, so the infection was much less common. Infections increase the risk of illness and injury in the exercising athlete. Fever impairs coordination, concentration, muscle strength, and aerobic power (31). It also hinders endurance and fluid and temperature regulation. Viral illnesses contribute to tissue wasting, muscle catabolism, and negative nitrogen balance (31). Pain, discomfort, or other symptoms of infection can be distracting during play and competition. Infections also have a small negative effect on performance (8). Drugs commonly used to treat the symptoms of infectious diseases have variable impacts on athletes. Acetaminophen seems to have few risks, but quinolones may be associated with tendon rupture, other antibiotics can cause diarrhea, antihistamines can cause sedation, and ephedrine-containing compounds are banned by many sports organizations (25,31). Usage of these compounds will lead to positive drug tests and disqualification of an athlete during the competitive season.
than anterior), and fever present, and these classic symptoms typically last up to 4 wk (41). Of infected patients, 50% to 75% develop palpable splenomegaly, but physical exam can be unreliable, and 10% to 15% develop jaundice (18,31).

Heterophile antibody absorption tests (Monospot) have a false negative rate of 25% during the first week of infection and 5% by the third week, making it important to retest patients who were Monospot-negative (19). Complete blood count (CBC) may show mild lymphocytosis and atypical lymphocytes (41). Liver function tests may show a mild hepatitis. Computed tomography and ultrasound imaging reliably can measure the size of spleens and have been used to guide return-to-play decisions. However, normal spleens have significant variability in size, and athletes generally do not receive baseline measurements, so splenic imaging results in a patient with IM may not be a trustworthy guide to return-to-play (18).

Treatment for IM is symptomatic. Antibiotics and antivirals are not effective, and some antibiotics can precipitate a nonallergic rash (41). Corticosteroids should be reserved for patients with significant complications, such as impending airway compromise, hepatitis, myocarditis, or neurologic involvement (18). Aspirin can increase the risk of Reye's syndrome and should be avoided. The disease usually is self-limited, but complications can include splenic rupture, airway obstruction, thrombocytopenia, agranulocytosis, hepatic necrosis, myocarditis, pericarditis, orchitis, and hemolytic anemia (8,9,31). Neurologic complications include Guillain-Barre syndrome, encephalitis, myelitis, optic neuritis, and Bell's Palsy. Splenic rupture occurs in 0.1% to 0.2% of cases, most commonly in males in the first 21 d after infection (but sometimes later) and not precipitated by trauma or exertion (19).

According to the consensus statement of the American Medical Society for Sports Medicine, athletes should avoid all exercise for the first 21 d after the onset of illness (41). After that time, they can begin slowly to resume their activities, starting with walking and progressing not more than 10% per week in duration or intensity. Full recovery usually takes 2 to 3 months but can take longer in select cases.

**Sinusitis**

Defined as inflammation of the paranasal sinuses, especially maxillary and frontal, sinusitis is a common complication of URTI. Sinusitis affects 16% of the adult population in the United States annually (39) and usually is caused by the same viruses that cause URTI. As such, symptoms are very similar, including rhinorrhea, cough, fever, fatigue, and sore throat. Viral sinusitis usually is self-limiting, and 75% of cases of untreated bacterial sinusitis will resolve spontaneously within 1 month (39). Swimming, diving, water polo, and surfing athletes seem to be more likely to develop sinusitis (31).

Fever, purulent nasal discharge, maxillary toothache, sinus pain, and sinus tenderness to palpation suggest a bacterial cause (8,22). Patients who develop a URTI and improve for several days and then abruptly worsen are more likely to have a bacterial sinus infection (19). The Berg prediction rule, including such findings as purulent rhinorrhea and focal sinus tenderness, can assist in diagnosing bacterial sinusitis (43).

Antibiotics are indicated when the suspicion for bacterial sinusitis is high. A course of 10 to 14 d of amoxicillin, amoxicillin-clavulanate, cephalosporins, or macrolides will treat common bacterial sinusitis adequately, typically *pneumococcus* or *H. influenza* (22). Some studies imply that even 3-d courses of antibiotics are adequate (31). Symptomatic treatment is similar to that for URTI, including decongestants and analgesics. Saline nose drops can dilute thick mucus and provide short-term relief (42). Avoid sedating antihistamines as they thicken mucus and may impair clearance.

**Otitis Media (OM) and Externa (OE)**

Middle ear infections account for over 20 million provider visits per year in the United States, and almost 20% of affected patients are adults (31). Thirty percent of OM cases are viral, and the rest involved *pneumococcus*, *H. flu*, and *moraxella catarrhalis* (19). Patients typically present with ear pain and URTI symptoms. Most cases of OM are self-limited, and antibiotics generally do not affect the course of the disease in patients older than 2 yr (31). Therefore, symptomatic treatment with analgesics and decongestants is the most effective. In selected cases, such as when symptoms are severe or prolonged or if the patient is medically complicated (such as diabetics), antibiotics may be indicated. Patients involved in water sports should not return to play until the tympanic membrane is intact and has normal mobility (valsalva or tympanogram).

OE is an infection of the external ear canal and is seen frequently in water sports athletes. Repetitive water exposure, preexisting allergies, and inadequate cerumen have been implicated as risk factors (19). *Pseudomonas aeruginosa* is the most common identifiable cause, but fungi such as aspergillus have been implicated (19). Patients present with ear pain with tragal traction and purulent discharge. Preauricular, postauricular, or cervical lymphadenopathy may occur. Treatment involves cleaning the debris from the auditory canal and applying topical antibiotic/corticosteroid drops if the tympanic membrane is intact (19). Clinicians and coaches can teach swimmers to tilt the head, shake the water out of the ear canal, and dry it with a hair dryer after swimming (31). Athletes can decrease their risk of developing OE by avoiding sticking things into the ear canal and using isopropanol drops to dry and/or dilute acetic acid to acidify the external ear canal (19). Ear plugs are controversial. Return-to-water is based on symptom resolution and patient tolerance.

**Acute Bronchitis**

Acute bronchitis is inflammation of the bronchial tree with cough lasting about 3 wk, with or without sputum production, often associated with URTI (2). It accounts for more than 10 million office visits per year (28). Respiratory viral infections cause 90% of acute bronchitis cases, and the last 10% generally involve bacteria such as bordatella pertussis, mycoplasma pneumonia, and Chlamydia pneumoniae (28). Unlike URTI, with bronchitis cough is the dominant symptom. Fever can be present but more likely represents influenza or pneumonia (28). Treatment is symptomatic, and antibiotics rarely are indicated. Bronchodilators may be useful to improve respiratory flow dynamics, which
often are impaired (2,27). Antitussive medications often are
prescribed but lack proof of effectiveness (2).

Pneumonia
In healthy adults, community-acquired pneumonia is
caused 30% to 50% of the time by viruses and 50% to 70% of
the time by other organisms (31). Patients often have
fever, productive cough, malaise, anorexia, and myalgias. In
severe cases they may show signs of respiratory difficulty,
including tachypnea, nasal flaring, intercostal retraction,
necrosis, rales, abnormal pulsoximetry, and even cyanosis.
Liver-function tests, chest x-ray (CXR), or echocardiogram (ECHO)
may be normal in early stages, but CXR will show infiltrates and
patients may have leukocytosis with a left shift (28).

For stable patients, outpatient therapy with oral antibi-
otics such as macrolides for 10 d is appropriate. The patient
should be followed up in 72 h or less to ensure that they are
responding appropriately to the therapy. Patients with more
severe disease, especially with evidence of respiratory com-
promise, should receive in-patient care. Clinical prediction
score tools, such as the PSI/PORT score and the CURB-65/CRB-65,
can help clinicians decide on in-patient or out-patient ther-
apy (13). The PSI/PORT score predicts severity based on the
patient’s demographics, comorbidities, examination, and lab-
oratory or radiologic findings. The CURB-65/CRB-65 pre-
dicts severity based on the patient’s mental status, blood urea
nitrogen, respiratory rate, blood pressure, and age.

Conjunctivitis
Inflammation of the conjunctiva of the eye typically is
caused by allergens, irritant toxins (such as chlorine in a
pool), or infections. Viruses cause the majority of infectious
cases, and bacteria such as staphylococcus aureus, staph-
ylococcus epidermidis, streptococci, and hemophilus cause
most of the rest (15). Patients present with infected, eryth-
ematous conjunctiva, watering, and sometimes purulent
discharge. Purulent discharge more commonly is seen with
bacterial conjunctivitis (19). Trauma, loss of visual acuity,
visual field defect, or significant abnormality on exam
should prompt a more comprehensive evaluation, as these
findings are not usually present with simple conjunctivitis.
Treatment of allergic and viral conjunctivitis is sympto-
matic. Treatment of bacterial conjunctivitis can include
antibacterials ointments or drops such as ophthalmic eryth-
romycin. Conjunctivitis is highly transmissible, and so
infected athletes should be excluded from competition in
high-contact sports (such as wrestling) until the infection
has cleared completely. Because adenovirus can be trans-
mitted in chlorinated pool water, infected water sports
athletes should be kept out of the water (31).

Neisseria gonorrhoea and HSV are less common and more
dangerous causes of conjunctivitis. Neisseria must be con-
sidered in any sexually active adolescent presenting with
a prominent purulent discharge. Discharge should be gram
stained and cultured. Parenteral antibiotics are indicated.
Vesicular lesions on eyelids and prominent lymphadenopathy
suggest HSV conjunctivitis. Patients with this condition
should receive immediate ophthalmologic consultation (31).

Meningitis
Infectious inflammation of the meninges covering the
brain and spinal cord is a medical emergency. There are two
primary categories, septic meningitis, typically involving
niesseria meningitidis, pneumococcus, or hemophilus influ-
enza B, and aseptic meningitis (4). Septic or bacterial menin-
gitis is almost universally fatal if untreated and often has a
poor outcome even with treatment. After recovering from
bacterial meningitis in developed countries, 14% of people have
residual hearing loss and 4% have hemiparesis (4).

Aseptic meningitis, defined as “patients who have clinical
and laboratory evidence for meningeal inflammation with
negative routine bacterial cultures” is much more common
(19). Enteroviruses such as Coxsackie virus are responsible
for 55% to 70% of cases (19). Other viruses, fungi, protozoa,
other bacteria (tuberculosis), rickettsia, and even nonin-
fecious causes are seen. Aseptic meningitis is most common
during summer and fall, when enteroviridae, transmitted by
the fecal-oral route, are most likely to be passed (31).

Clinical manifestations of meningitis include the classic
triad of fever, stiff neck, and headache, but only 44% of
patients present with the triad (4). Other symptoms include
nausea, vomiting, pharyngitis, diarrhea, and photophobia.
Focal neurological signs and mental status changes are
especially worrisome. The patient should be taken imme-
diately to emergency care for treatment.

Prevention is a must for this life threatening disease.
Good hand washing and avoiding shared water bottles
helps decrease fecal-oral transmission. Immunization against
H. flu and N. meningitidis are important as well.

Myocarditis
Myocarditis, the inflammation of the heart muscle, is an
uncommon complication of otherwise benign viral infec-
tions. The most common cause is the coxsackie virus of the
enterovirus family (8). Other viruses, bacteria, and even
noninfectious agents such as cocaine, can cause myocardi-
tis (9). Males are more commonly affected than females,
and individuals between 20 and 40 yr are at the highest
risk (9).

Clinical presentation may include chest pain, shortness
of breath, and evidence of heart failure in the setting of
a preceding viral illness. Fatigue, fever, palpitations, and
tachycardia out of proportion to other symptoms may be
present (8). Examination may reveal muffled heart sounds,
mitral regurgitation, and if the pericardium also is involved,
a friction rub. Electrocardiogram (ECG) may be normal
or show nonspecific ST and T wave abnormalities. Echo-
cardiogram may demonstrate globally decreased ventricu-
lar function (28).

Myocarditis is self-limiting but can progress to dilated
cardiomyopathy and heart failure. Most patients recover
completely, but during recovery, they are at increased risk
for arrhythmias and sudden cardiac death (30). Athletes
with probable or confirmed myocarditis should be with-
drawn immediately from all competitive sports and avoid
all strenuous activity for 6 months after becoming symp-
tomatic (30). Patients may return to exercise once their
echocardiogram and ECG are completely normal, they
have no arrhythmias, and they have no serum evidence
of heart failure or inflammation (30). Strenuous exercise
while viremic has been associated with the development of
myocarditis in animals and may increase risk of myo-
carditis in humans (31).
**Gastroenteritis**

Gastroenteritis is the second most common infection, after URTI, in adolescents and young adults (33). A 2001 FoodNet report estimated that 76 million cases of foodborne illness occur each year (21). The most common causative organisms are viruses (rotavirus, Norwalk virus), but bacteria such as E. coli and salmonella, and protozoa such as cryptosporidium and giardia lamblia also can cause disease. Transmission usually is fecal-oral, and athletes, who commonly share food and water, travel and live in close quarters, and share personal care items, are at risk of large-scale outbreaks (21).

Symptoms include diarrhea, abdominal cramps, nausea, and vomiting. Myaligias and fevers are common (33). Dry mucous membranes, very dark urine, or low volume of urine and tenting of the skin suggests significant dehydration. Athletes should maintain good hydration, but patients who are more than 3% to 5% dehydrated should receive oral rehydration fluid if they can tolerate oral intake and intravenous fluids if they cannot (12). Isotonic sports drinks can be helpful, and cold water is fine in most cases. Those who are less than 3% to 5% dehydrated usually can take oral rehydration (12). Treatment is otherwise symptomatic, and these conditions usually resolve spontaneously in 3 to 4 days. Antimotility drugs such as loperamide can help patients who must maintain their activity. “Traveler’s diarrhea” can be prevented with antibiotics, but this is controversial. Bismuth subsalicylate is somewhat effective (8,20). Return-to-competition in athletes recovering from acute gastroenteritis is based on symptoms, especially hydrational status. A well-hydrated, asymptomatic athlete should be able to return to play.

**Bloodborne Infections**

Some infectious organisms, such as the human immunodeficiency virus (HIV), hepatitis B virus (HBV) and hepatitis C virus (HCV), are transmitted through blood and other body fluids. HIV has been transmitted during bloody street fights, and there was one case of HIV seroconversion where there was a question of a possible association with a bleeding injury during a football game in Italy (26). Still, the risk to athletes is extremely small. A 1982 case report revealed that half of a 10-member Japanese high-school sumo wrestling club contracted HBV in 1 yr (40). An outbreak of HBV in an American football team infected 11 of 65 players in 19 months (40). No known cases of HCV transmission have occurred from contact in sports, but one case did result from sharing a bloody rag during a fist fight (9). Three soccer players from an amateur club were infected with HCV from sharing needles to inject vitamin complexes (40). Tattooing and body piercing are high-risk activities for transmission of bloodborne infections.

HIV is most commonly transmitted from sexual contact, especially men having sex with men, and needle sharing, such as when athletes share needles to inject vitamins or steroids. Over one million Americans are infected with the HIV virus, and about 21% do not know that they are affected (49). Contact with saliva and sweat during sports does not seem to transmit infection.

Moderate exercise seems to benefit athletes who are infected with HIV. Moderate aerobic exercise (AE) and progressive resistance exercise (PRE) improve CD4 count, viral load, and VO2max (38). PRE improves body weight and limb girth, and AE enhances lipid profiles and decreases adiposity (16). It also seems to improve overall quality of life (11). There are neither accepted screening criteria for HIV in athletes nor any restriction to participation (25).

In 2007, the U.S. Centers for Disease Control and Prevention (CDC) estimates that nearly 43,000 people in the United States were newly infected with HBV (47). HBV is a hearty virus, able to survive outside the body for more than 7 d, and resistant to alcohol, drying, temperature changes, and many detergents (17). It is approximately 100 times more infectious than HIV and can be transmitted via fomites. Infected patients often will present with jaundice, fatigue, nausea and vomiting, abdominal pain, dark urine, and light stool. In severe infections, they many present with signs of liver failure, such as ascites, peripheral edema, and encephalopathy. Treatment is with interferon and some antivirals. The HBV vaccine is 95% effective and is strongly recommended. Many patients will clear HBV, but some go on to a chronic carrier state, which in 20% of cases results in death. HCV is the most common bloodborne disease in the United States, with 3.2 million people infected (48). Symptoms are very similar to HBV, and the treatments also are similar. Asymptomatic carriers with HBV or HCV should not be excluded from athletics (3).

**Sexually-Transmitted Infections**

The CDC estimates that 2.3 million people in the United States aged 14 to 39 yr are infected with chlamydia (45). Patients with chlamydia usually have no symptoms but may complain of discharge, increased urinary frequency, or pain with urination (9). Chlamydia is readily treatable with azithromycin or doxycycline, but failure to treat can result in pelvic inflammatory disease and permanent sterility in women. HIV infection also is more likely in people infected with chlamydia. All sexually active women under the age of 25 yr or those with new sexual partners should be tested (45).

Gonorrhea is another common sexually transmitted infection in the United States, with about 700,000 new cases every year (46). Symptoms are similar to those seen with chlamydia. Gonorrhea also is readily treatable with antibiotics such as ceftriaxone. There are no screening recommendations (9).

Human papilloma virus is a common sexually transmitted virus linked to cervical cancer. A vaccine is now available that dramatically decreases the risk of cancer and is recommended for nonpregnant women between ages 9 and 26 yr (9).

**EXERCISE IN UNUSUAL PLACES**

Extreme sports have gained in popularity over the past two decades. Participants often run, swim, climb, and do other strenuous activities in multiday events. These events are held in jungles, mountains, deserts, and other harsh areas that often have poor sanitation. Extreme sports athletes are at risk for infection with parasites, tick and waterborne diseases, and zoonoses, in addition to the typical traveler’s diarrhea noted previously. Because of the nature of the events, these athletes often carry little equipment and may not take time for important preventive
measures (52). Adequate information and preparation beforehand can minimize the dangers.

CONCLUSION

Infectious diseases are the most common illnesses that afflict athletes. Diagnosis and treatment is similar to that for nonathletes. High-level athletes often are at higher risk because of physiology, the realities of life on the road such as overcrowding, and personal hygiene and public health practices noted previously. Infection prevention and return-to-play issues are uniquely important among athletes.

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