Respiratory Physiology & Neurobiology 209 (2015) 76–80

Contents lists available at ScienceDirect

Respiratory Physiology & Neurobiology

journal homepage: www.elsevier.com/locate/resphysiol

Respiratory tract infections in the military environment

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ARTICLE INFO

Article history:
Accepted 24 September 2014
Available online 30 September 2014

Keywords:
Military environment
Respiratory tract infections
Soldiers

ABSTRACT

Military personnel fighting in contemporary battlefields as well as those participating in combat training are at risk of contracting respiratory infections. Epidemiological studies have demonstrated that soldiers deployed to the harsh environment have higher rates of newly reported respiratory symptoms than non-deployers. Acute respiratory diseases are the principle reason for outpatient treatment and hospitalization among military personnel, with an incidence exceeding that of the adult civilian population by up to three-fold. Adenoviruses, influenza A and B viruses, *Streptococcus pneumoniae*, *Streptococcus pyogenes*, coronaviruses and rhinoviruses have been identified as the main causes of acute respiratory infections among the military population. Although infective pathogens have been extensively studied, a significant proportion of illnesses (over 40%) have been due to unknown causative agents. Other health hazards, which can lead to respiratory illnesses among troops, are extreme air temperatures, desert dust, emissions from burn pits, industrial pollutants, and airborne contaminants originating from degraded soil. Limited diagnostic capabilities, especially inside the area of operations, make it difficult to accurately estimate the exact number of respiratory diseases in the military environment. The aim of the study was to discuss the occurrence of respiratory tract infections in army personnel, existing risk factors and preventive measures.

1. Introduction

Respiratory infections are the leading cause of outpatient treatment and are responsible for 25–30% of infectious disease hospitalizations in army personnel (Armed Forces Health Surveillance Center, 2010). Because of crowded living conditions, harsh environment, over-exertion, psychological stress, mixing of people from diverse geographic locations, and exposure to respiratory pathogens in disease-endemic areas, soldiers and newly mobilized troops are at particularly high risk for respiratory disease morbidity (Korzeniewski et al., 2013a). Before vaccines were used, even 80% of military trainees suffered from respiratory infections, and as many as 20% were hospitalized during the 2 months of recruit training (Gray et al., 1999). Most of respiratory illnesses, including pneumonia, are treated empirically. Without accurate laboratory diagnoses and an early warning system to detect changes in acute respiratory infections rates and antibiotic resistance, more air-borne epidemics are likely to occur in the military environment. Acute respiratory infections (ARI) have significant impact on military operations. High ARI morbidity may reduce the operational readiness of deployed military personnel by causing loss of person-days and increase in medical visits and medical evacuations. During the military operations in Iraq and Afghanistan respiratory tract infections have been reported in 39.5% to even 69% of deployed personnel (Korzeniewski et al., 2013b; Soltis et al., 2009; Sanders et al., 2005). ARI are the most common cause of missed service days in army personnel among young adults. Almost 90% of all recruits report symptoms of respiratory illness at some point in their first months of military service (Ryan et al., 2001). The unique susceptibility of military recruits to respiratory infections, including pneumonia, bronchitis, pharyngitis, tonsillitis, sinusitis, and common cold, has long been recognized. Adenoviruses, influenza A and B viruses, *Streptococcus pneumoniae* and group A *Streptococcus pyogenes* have been recognized as the primary causative agents of ARI in army personnel, while the etiology of over 40% cases is unclear (Wang et al., 2010; Gray et al., 1999).

The aim of the study was to discuss the occurrence of respiratory tract infections in army personnel, existing risk factors and preventive measures.

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http://dx.doi.org/10.1016/j.resp.2014.09.016
1569-9048/

2. Past and present of respiratory infections in army personnel

Respiratory tract infections have plagued military personnel throughout history. Records from the World War I in the years 1914–1918 document their devastating power and the inability of public health sector to control them. In total, it was estimated that more than 1.4 million U.S. Army personnel suffered from respiratory diseases during World War I, accounting for more than 41% of all health problems and causing more than 77% or 45,000 of disease deaths. Before antimicrobials were widely available, strategies to prevent military epidemics of respiratory disease were not successful (Gray, 1997).

Nowadays, the best example of complex health prevention against respiratory tract diseases are procedures implemented in the U.S. Forces, where military personnel receive benzathine penicillin G or oral erythromycin, adenovirus vaccines, tuberculosis screening, vaccines against pneumococcal and meningococcal infections and against influenza during their initial military training. This is followed by annual influenza vaccines and periodic tuberculosis screening throughout their military careers (Eick-Cost et al., 2012; Mancuso et al., 2010). The pathogens recognized to cause respiratory diseases among soldiers are similar to those causing community-acquired diseases among the general population. Most frequently, they include adenoviruses, influenza A and B viruses, *S. pneumoniae*, *S. pyogenes*, coronaviruses and rhinoviruses. Less frequently, military personnel also suffer infections from *Mycoplasma pneumoniae*, *Chlamydia pneumoniae*, *Haemophilus influenzae*, *Haemophilus parainfluenzae*, *Legionella pneumophila*, *Bordetella pertussis*, respiratory syncytial virus, and parainfluenza viruses (Dawood et al., 2011; Eick et al., 2011). Moreover, military health service need to focus their attention on the causative agent of tuberculosis (TB). The risk of active TB under operational conditions in endemic areas is unknown. It has typically been assumed that the risk of TB is approximately the same as among nationals in a given country (Mancuso et al., 2010). Despite a potential increase in exposure to TB resulting from deployment to endemic areas, the current rate of active TB in the active component U.S. military based on surveillance data, remains low – with a rate of 0.7 verified cases per 100,000 person-years from 1998 to 2006, compared to an age-adjusted U.S. rate of 4.3 per 100,000 person-years (Centers for Disease Control and Prevention, 2008). The actual contact of U.S. military service members with potentially infectious TB cases in deployed settings may be very limited, as many U.S. service members have limited or no contact with local nationals outside U.S. military installations. Thus, their resultant risk of TB infection may be much lower than that of most civilian long-term travelers. Nevertheless, there is a concern that deployments to endemic and hyperendemic areas such as Iraq and Afghanistan could result in large numbers of potentially infected military service members (Mancuso et al., 2010). Until late 2008 the U.S. Army tested each soldier within 1 year prior to deployment, then twice on return from deployment, resulting in more than 500,000 tests performed each year in the Army alone. Although some units have noted unusually high proportions of tuberculin skin test (TST) converters after returning from deployment, subsequent investigation of these units has suggested that the excess cases are attributable to false-positive skin tests rather than TB transmission (Mancuso et al., 2008).

Other health hazards, which can lead to the development of respiratory illnesses among troops deployed to operations and participating in combat training, are also extreme air temperatures, desert dust, emissions from burn pits, industrial pollutants, and airborne contaminants originating from degraded soil. Barth et al. (2014) investigated the population prevalence of asthma, bronchitis, and sinusitis among veterans deployed to Afghanistan and Iraq compared to nondeployed soldiers. 20,563 participants of the study completed the survey (64% deployed and 36% nondeployed). Deployed veterans were 29% more likely to have been diagnosed with sinusitis during and after 2001 compared to non-deployers. The authors suggested that environmental exposures such as dust, sand, burning trash or human waste, petrochemical fumes, oil fire smoke, and other ambient air pollution are widespread in the deployment setting and are presumed to contribute to respiratory morbidity among deployed service members. Studies carried out by U.S. Armed Forces Health Surveillance Center focusing on service members deployed to Iraq and Afghanistan have reported increased prevalence of respiratory illnesses. A report looking at out-patient and hospital visits among all individuals deployed on operations between October 2001 and December 2010 demonstrated the "excessive" numbers of respiratory conditions in males and females with repeated deployments (Armed Forces Health Surveillance Center, 2011). Abraham et al. (2012) linked administrative records with medical records of deployed service members and found an increase in the rate of respiratory symptoms and medical encounters for obstructive pulmonary disease, primarily asthma and bronchitis, from before (20.4 encounters/10,000 person-years) to after deployment (30.1 encounters/10,000 person-years). In a population of active duty U.S. military personnel, the authors observed an increase in post-deployment respiratory symptoms and medical encounters for obstructive pulmonary diseases, relative to pre-deployment rates, in the absence of an association with cumulative deployment duration or total number of deployments. The authors did note that the rate of respiratory symptoms and encounters for obstructive pulmonary diseases, predominantly asthma and bronchitis, increased from before to after deployment. Smith et al. (2009) reported that among members of the Millennium Cohort Study, a population-based cohort of active duty service members, those who had deployed to Iraq and Afghanistan, had a higher prevalence of newly reported respiratory symptoms (including cough and shortness breath) than those who had not been deployed (14% vs. 10%). No differences were observed for chronic bronchitis, emphysema, and asthma.

Military personnel are at a high risk for respiratory tract infections because of their exposure to contagious pathogens and harsh environmental conditions, mainly in disease-endemic areas during deployments. Sanders et al. (2005) conducted a survey of 15,000 redeploying military personnel from Iraq and Afghanistan and estimated that 69% had reported experiencing respiratory illnesses, of which 17% required medical care. A further survey, conducted by the Naval Health Research Center personnel on respiratory symptoms, found that deployed personnel had a higher rate of newly reported respiratory diseases than non-deployed soldiers (14% vs. 10%) (Smith et al., 2009). Korzeniewski et al. (2013b) studied the prevalence of acute respiratory diseases among troops of Polish Military Contingent deployed to Iraq and Afghanistan. The prevalent health problems reported among 871 Polish soldiers treated in the sick call of the field hospital (level 2) in Iraq in years 2003–2004 were respiratory tract diseases (45.6 cases per 100 persons), with a predominance of common cold (26.9/100 persons), pharyngitis and/or tonsillitis (13.3/100 persons), sinusitis (3.1/100 persons), and bronchitis (2.3/100 persons). The increased prevalence of respiratory illnesses was observed every 6 months, when the Polish contingent rotated its troops and when the newly arriving soldiers were undergoing an acclimatization to different environmental conditions prevailing in the theater of operations. Respiratory diseases were the most common health problem in 400 soldiers treated in the outpatient medical treatment facility supporting the Polish Military Contingent in Afghanistan (level 1) in years 2003–2005 (61.8 cases/100 persons), with the predominance of common cold (37.8/100 persons), pharyngitis and/or tonsillitis (17.0/100 persons), sinusitis (4.3/100 persons), bronchitis

(1.0/100 persons), and pneumonia (0.5/100 persons). The increased prevalence of respiratory illnesses was observed, when the Polish contingent rotated its troops. The prevalent health problems reported among 2500 Polish military personnel treated in the sick call of the field hospital in Afghanistan (level 2) in 2010 were respiratory diseases (54.8 cases per 100 persons), including common cold (33.9/100 persons), pharyngitis and/or tonsillitis (15.8/100 persons), sinusitis (3.7/100 persons), bronchitis (1.3/100 persons), and pneumonia (0.1/100 persons). Medical personnel supporting Polish Military Contingents in Iraq (2003–2004) and Afghanistan (2003–2005, 2010) at levels 1 and 2 had limited diagnostic capabilities as far as the treatment of acute respiratory diseases was concerned. Neither bacteriological nor virological diagnostic procedures were available under operational conditions. Therefore, patients exhibiting acute respiratory symptoms routinely received antibiotics to treat the infection. As a rule, a course of antibiotics was administered following a physical examination and additional tests such as erythrocyte sedimentation rate, complete blood count, chest X-ray and sinus X-ray (Korzeniewski et al., 2013b).

3. Risk factors of respiratory diseases in the military environment

Respiratory illnesses can cause substantial morbidity in soldiers undergoing military training and in deployers. Service members are placed in the settings that can favor transmission of respiratory infections and therefore can have higher incidence rates than the comparable civilian populations. In these settings, service members can be exposed to overcrowding, mixing, and inadequate hand-washing facilities (Harris and Johnson, 2006). In military installations, bacteria and viruses are transmitted person-to-person via respiratory droplets, and typically result in acute self-limiting infections (Lee et al., 2008). However, highly virulent and transmissible strains of pathogens can emerge and lead to high morbidity and mortality (Brundage, 2006). Acute respiratory infections are the leading cause of missed service days among military personnel. The majority of these infections are common colds. However, viral infections may be accompanied by bacterial complications or exacerbations of asthma, and therefore lead to a more serious illness. Training during the winter months, when most of viral epidemics occur, further predisposes soldiers to respiratory infections (Juvonen et al., 2008). Mäkinen et al. (2009) examined whether the development of acute respiratory tract infections (RTI) is potentiated by cold exposure and lowered humidity. In their study, cold temperature and low humidity were associated with increased occurrence of RTI, and a decrease in temperature and humidity preceded the onset of the infections. A common phenomenon is seasonal variation in the outbreaks of viral respiratory infections, with peaks often being observed during the winter months. The reasons for the higher incidence of RTI in winter remain controversial, and several causal factors, such as changes in host physiological susceptibility, immune function, overcrowding, and climatic factors have been suggested. There are some pathophysiological mechanisms to explain how cold exposure could increase the occurrence of RTI. The available laboratory and clinical evidence suggests that either inhalation of cold air, cooling of the body surface, or cold stress causes pathophysiological responses that may contribute to increased susceptibility to respiratory infections. Mäkinen et al. (2009) observed that low humidity was associated with the increased occurrence of pharyngitis. One plausible explanation for the association between humidity and RTIs is that some viruses, e.g. the influenza virus, seem to be more stable in cool and dry air (Lowen et al., 2007).

Another essential risk factor contributing to increased prevalence of respiratory symptoms in soldiers is the higher rate of tobacco use in the military and its increased use during deployment. The 2006 National Health Interview Survey estimated that 23.5% of males and 18.1% of females in the United States were smokers. A recent survey of soldiers deployed to Iraq reported that 51.9% of males and 41.7% of females were using tobacco products before deployment; 58.3% of males and 52.1% of females were using tobacco during deployment, and 25.4% of males and 48% of females increased the use of tobacco during deployment (DiNicola and Seltzer, 2009). Cigarette smoke is known to cause several respiratory ailments, including chronic bronchitis, emphysema and lung cancer, and is associated with an increase in respiratory infections. In addition, cigarette smoking is considered a principal etiological factor responsible for the development of certain diffuse interstitial and bronchiolar lung diseases, namely respiratory bronchiolitis-interstitial lung disease, desquamative interstitial pneumonia and adult pulmonary Langerhans' cell histiocytosis (Rajesh et al., 2008). Smoking is also an important risk factor in the development of community acquired pneumonia. Infection incidence increases in smokers due to impaired mucociliary clearance, increased inflammation and adherence of pathogens, epithelial destruction and changes in the host defense mechanisms (Tas et al., 2008).

The current guidelines for accession of new military personnel are service specific, but in general, the established diagnosis of asthma after the age of 12 has been an exclusion criterion. Despite these restrictions, asthma remains a significant problem in active duty military members that may mirror the incidence in the general population (Morris et al., 2011). Nish and Schwietz (1992) evaluated 192 Air Force recruits for symptoms of exertional dyspnea and found that 45% of these patients had a previous diagnosis of asthma. The majority of the patients suffered mild or exercise-induced disease but exhibited clinically significant symptoms to be referred for a formal evaluation. Morris et al. (2002) concluded that nearly half of their active duty patients with exertional dyspnea had either asthma or exercise-induced bronchospasm. Roop et al. (2007) surveyed deploying Army personnel and found that 5% of troops deployed to South-West Asia reported a previous diagnosis of asthma.

During military deployment, personnel are exposed to inhalation hazards originating from local and regional sources, including the desert environment, unregulated regional industry, vehicles, diesel-powered generators and other machinery, and waste fires (Abraham et al., 2014; Helmer et al., 2007). Also burn pit emissions exposures have been implicated as a cause of chronic respiratory illnesses (Rose, 2012), but no study has identified an association between burn pit emissions exposure and post-deployment chronic lung conditions. Among a case series of 38 soldiers diagnosed with constrictive bronchiolitis, 63% reported exposure to burn pits, although a larger proportion of these patients (86%) reported dust storm exposure (King et al., 2011). The increased frequency of respiratory symptoms and illness during and after deployment, relative to those experienced before deployment, has been reported among Iraq and Afghanistan-deployed military personnel (Abraham et al., 2012).

Diagnosis of infections as the cause of respiratory tract diseases (RTD) has come under scrutiny (Cox et al., 2008). There are individuals who, under over-exertion, suffer recurrent episodes of upper respiratory illnesses, but who require a more exhaustive medical assessment in order to exclude non-infectious causes of the respiratory symptoms, such as allergy, autoimmune disorders, vocal cord dysfunction and unresolved non-respiratory infections. These studies identified that approximately one-third of RTD are caused by infection (bacterial, viral pathogens), one-third are due to a non-infectious cause, while the remaining third are of unknown etiology. The speculative causes of the 'unknown-etiology' group could include physical and mechanical damage such as drying of the airways (Bermon, 2007), asthma and allergic airway inflammation

(Helenius et al., 2005), or psychological impacts of exertion on the immunity (Bjermer and Anderson, 2005). Lange et al. (2003) examined the health status of over 21,000 U.S. soldiers taking part in military training conducted in the desert. Researchers noticed that healthy, young adults exposed to high levels of soil-derived dust may have increased susceptibility to respiratory infectious illnesses after prolonged exposures to desert environments. The increased risk was largely attributable to excess hospitalizations for pneumonia and influenza. Whitham et al. (2006) studied paratroopers for 19 weeks, training at sea level. Their main findings were an increase in respiratory infections in weeks 2 and 3, and a progressive decrease in the salivary flow rate during the study, which might have led to hypohydration. In military settings, strain is put on the participants' immune system in many ways, including strenuous physical activity, sleep deprivation, caloric deficit, and environmental and mental stress. All these factors lead to immunological changes, resulting in a high rate of dropouts due to infections during military training and combat operations (Ekblom et al., 2011).

Historically, preventive medicine professionals have explored many strategies to combat respiratory infections among soldiers. Attempts to use dust suppression, ultraviolet radiation, disinfectant vapors, and mass prophylaxis have had variable success. One of the easy ways to decrease the number of respiratory infections is personal hygiene. Ryan et al. (2001) observed in their study a 45% reduction in total outpatient visits for respiratory illness after implementation of the hand-washing program. Promoting hand hygiene and reducing overcrowding through the provision of adequate living space and cohorting of training units may offer benefits in respiratory disease control (Lee et al., 2005). Acute respiratory diseases (ARD) are a frequent problem in the military environment. Vaccines are available for only a few pathogens, and may have limited efficacy. Influenza vaccines, for example, must target circulating viral strains to be efficacious, as demonstrated when nearly half the crew of a U.S. Navy ship was affected despite 95% of the sailors being vaccinated (virus isolated from ill crew members was antigenically distinct from the vaccination strain; with an attack rate of 42%, this outbreak demonstrated the potential for rapid spread of influenza in a confined population) (Earhart et al., 2001). Other vaccines, such as those against adenovirus (ADV) types 4 and 7, were very effective in reducing ADV-associated ARD morbidity in military populations for two decades, until production ceased in 1996. Subsequently, pre-vaccine era morbidity (15–20% hospitalization rates) returned (Gray et al., 2000). After a 12-year hiatus, military recruit training centers resumed administration of adenovirus type 4 and type 7 vaccine, live, oral (adenovirus vaccine) to trainees beginning in October of 2011. Subsequently, rates of febrile respiratory illnesses and adenovirus isolations markedly declined (Hoke et al., 2012). Nowadays, ARD vaccine arsenals in the U.S. Armed Forces consist of measles–mumps–rubella, diphtheria, meningococcal disease, pneumococcal disease, and influenza doses. Except for the vaccination schedule implemented among the military members, an important element of effective respiratory infections prevention are non-vaccine ARD interventions (NOVARDIs). NOVARDIs used and considered for ARD control include antimicrobials and other medications; management of work and rest; hand hygiene (handwashing and antiseptics); administrative and engineering measures to limit contact between people; decrease the concentration of potentially harmful agents in the environment (by increased indoor air dilution ventilation, air sterilization, ventilation filter efficiency, dust suppression) (Lee et al., 2005).

4. Summary

Military personnel are at a particularly high risk of developing respiratory tract infections because of exposure to contagious pathogens and harsh environmental conditions, mainly in disease-endemic areas during deployments. In a population of active duty service members as well as in participants in contemporary combat operations, researchers have observed an increase of post-deployment respiratory tract infections, compared with pre-deployment rates. Military medical services put special emphasis on preventing air-borne diseases before deploying troops to areas of operations. Prophylactic actions are primarily based on vaccinations against influenza and adenoviruses, pneumococcal and meningococcal infections as well as treatment by means of targeted pharmacotherapy.

Soldiers often experience respiratory diseases, including febrile upper respiratory infections, pneumonia, pharyngitis, and bronchitis, leading to significant morbidity and missed service days. Adenoviruses, influenza A and B viruses, *S. pneumoniae* and *S. pyogenes* are implicated in over half of the febrile respiratory illness cases reported at medical treatment facilities, while the etiology of the remaining cases is unclear. Numerous studies and reports covering the last 20 years suggest a high incidence of respiratory tract diseases during combat training and on military operations carried out in difficult environmental conditions. The factors contributing to an increase in respiratory infections susceptibility include the combined effects of heavy work in relation to the individual's physical condition, overexertion, food restriction, and psychological stress on the immune function.

Approximately 40–70% of all soldiers participating in recent military operations in Iraq and Afghanistan report to medical treatment facilities due to upper respiratory tract infections. Medical personnel have no capabilities to perform bacteriological or virological diagnostic procedures, therefore they typically administer a course of antibiotics although in some cases antibiotic treatment has no clinical justification and may facilitate the emergence of pharmacotherapy resistant microorganisms. If medical services implemented appropriate disease prevention measures (sanitation, hygiene, and anti-epidemic support), the risk of developing infectious diseases including respiratory tract infections would be greatly reduced.

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