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# **DEFINING ANTIMICROBIAL TEXTILE REQUIREMENTS FOR MILITARY APPLICATIONS – A GAP ANALYSIS**

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<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b> Warfighters are at high risk for incidence of hygiene and medical conditions related to bacterial and fungal outgrowth while in training and deployment operations. This report summarizes a literature search, conducted between April 2014 and August 2015, of skin physiology, incident rates and costs of common medical and health conditions among military personnel, and the benefits and risks of incorporating antimicrobial technology in Warfighter Clothing and Individual Equipment (CIE). The purpose was to collect data as basis for future efforts to define specific requirements for incorporating antimicrobial textiles (AMTs) in CIE components to reduce the incidence of these conditions, which are costing the military up to \$1 billion in treatment costs per year and are compromising mission accomplishment. Four groups of health and medical issues relevant to Warfighters are discussed: odor, bacterial infections, fungal skin conditions, and bacterial female health issues. Data were found on incident rates of the bacterial and fungal infections because many required medical treatment. Modeling studies were conducted using these rates to approximate treatment costs. However, it is believed that other bacterial and fungal irritations occurred and went unreported because individuals felt treatment was unnecessary, and there were little data on odor issues due to lack of a reporting mechanism. There were also very little conclusive laboratory and field test data on the effectiveness, risks, and potential for bacterial resistance of use of AMTs. For an antimicrobial performance standard to be established, more research is needed regarding the short- and long-term effects and safety of AMT on human skin and the risk versus benefit of deploying a uniform ensemble with AMTs incorporated. Recommendations are offered in several categories for bridging the current knowledge gaps.					
<b>15. SUBJECT TERMS</b> ODORS      EFFICACY      DEPLOYMENT      FUNGUS DISEASES      MILITARY EQUIPMENT ILLNESS      BACTERIA      SKIN DISEASES      CAPABILITY GAPS      WOUNDS AND INJURIES HEALTH      UNIFORMS      RISK ANALYSIS      LABORATORY TESTS      TEST AND EVALUATION FABRICS      BODY ODOR      REQUIREMENTS      FUNGAL INFECTIONS      ANTIMICROBIAL AGENTS HYGIENE      INFECTIONS      SKIN(ANATOMY)      PERFORMANCE GAPS      MILITARY APPLICATIONS TEXTILES      FIELD TESTS      SKIN INFECTIONS      DIAGNOSIS(MEDICINE) ANTIMICROBIALY-TREATED FABRICS      BACTERIAL SKIN INFECTIONS					
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## EXECUTIVE SUMMARY

Warfighters are at high risk for the development of hygiene and medical conditions related to odor and bacterial and fungal outgrowth during training and deployment operations. This increased risk is due to close-quarter living, high physical and psychological stress, working in hot and humid environments, and poor hygienic behaviors. Bacterial skin and soft tissue infections (SSTI), fungal infections, and bacterial or fungal female urogenital conditions account for a significant amount of lost duty time and can also cost the military up to \$1 billion in medical costs in a given 5-year time period. To provide information on how to reduce the incident rates and associated adverse mission effects and costs, the Natick Soldier Research, Development and Engineering Center (NSRDEC) conducted a comprehensive literature search of odor, bacterial, and fungal conditions experienced by military personnel during training exercises and when deployed. Also researched was the use of antimicrobial textiles (AMT) to mitigate odor and bacterial and fungal growth. Incidence data found during the search were then used as input for model analysis of the prevention and/or treatment costs. NSRDEC performed this search and cost analysis between April 2014 and August 2015 as part of a transition agreement with the Training and Doctrine Command (TRADOC) and the Maneuver Center of Excellence (MCoE) under TeCD1b.

Recent widespread use of antimicrobial products and textiles within the civilian population has led to the idea of incorporating such products into materiel for distribution to military personnel. Despite several previous collaborations between NSRDEC and Microban® Products Company (MPC) starting in 2005 after the initial request that AMT be included in Soldier Clothing and Individual Equipment (SCIE), there is no specific requirement for AMT in any SCIE component.

The initial focus of the literature search was to gather information regarding the relevant aspects of human skin physiology and immune system to enable understanding of the environment in which an antimicrobial technology would attempt to kill or inhibit growth of pathogenic organisms while maintaining the integrity of the normal skin flora. Focus then shifted to the particular health and medical issues that may potentially be mitigated through use of AMTs and finally to information on potential antimicrobial treatments found in terms of their use in or on AMTs and their potential benefits and risks.

Four groups of health and medical issues relevant to Warfighters in training and deployment were identified and researched: odor, bacterial infections, fungal skin conditions, and bacterial and fungal female urogenital issues. Hygiene and medical issues related to bacterial and fungal outgrowth fall into reportable (i.e., reported to medical personnel for treatment, yielding known incidence rates and enabling cost modeling) and non-reportable (no treatment required, no statistics) categories. Medical surveillance data associated with bacterial and fungi infections contracted by military personnel were obtained from the Armed Forces Health Surveillance Center (AFHSC), the largest repository for military medical data from the Military Health System, as well as the US Army Research Institute of Environmental Medicine's (USARIEM's) Total Army Health and Injury Outcome Database (TAIHOD). This information provides incident rates among Soldiers for the three groups (all but odor) of reportable conditions and, in turn, justification for the need for AMTs. It was also used in this project as input for the Medical Cost Avoidance Model (MCAM), developed by the Army's Public Health Command

(PHC), to assess costs and explore the monetary implications of the conditions identified.

Army clothing items treated during the NSRDEC/MPC studies included the Army Combat Uniform (ACU), tan t-shirt, and green boot socks. MPC determined these items could be effectively treated with antimicrobials, specifically using triclosan and polyhexamethylene biguanide (PHMB) because of their broad spectrum of efficacy.<sup>1</sup> Each component passed a safety analysis by outside laboratories and the Army's PHC. It was found that antimicrobial technologies can be incorporated into textiles by either encapsulation or by woven fiber.<sup>2</sup> Most of the antimicrobials used for textile treatments are effective against a broad spectrum of bacteria and fungi. Those found in the literature, in addition to triclosan and PHMB, included silver, copper, chlorhexidine gluconate, quaternary ammonium compounds, and N-halamine. However, very little information was found on the effects of AMTs on healthy skin microflora and development of resistance in bacteria to the antimicrobials over time.

It is apparent from the literature sources researched during this study that conditions such as SSTI, fungal infections, and female health are problematic, costing a significant amount of money and negatively impacting operations. It is also apparent there is a large gap between what is known and the knowledge that is needed regarding the direct effects of AMTs and their efficacy in treating the health and medical conditions most commonly experienced by military personnel in order to generate and update requirements and standards for incorporating anti-odor, antibacterial, and antifungal properties into CIE. Gaps appear in four general areas:

- The magnitude and operational impact of the non-reportable (odor) conditions within the military population
- Correlation between the use of AMTs and the immediate and long-term reduction of conditions related to bacteria and fungi growth during Warfighter training and deployments
- Effects of various AMTs on skin flora over time: safety and potential resistance
- Price and number of AMTs that are currently fielded or expected to be fielded in the near future

Recommendations are offered in the following areas to address these gaps:

*Non-Reportable Hygiene Issues:*

- Conduct new and refined surveys that include on-site data collection to increase the number of responses.
- Conduct field studies correlating detailed survey results with laboratory analysis to provide additional data on quality of life issues.

*Reportable Hygiene Issues:*

- Collect data related to demographics (e.g., age, occupation) and geographic location to help identify the potential need for AMTs and generate of treatment requirements.

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<sup>1</sup> Swofford et al. "Antimicrobial Treated Products for Military Use." Microban® Products Company. Final Report. ADA479083. Prepared for NSRDEC. 2007.

<sup>2</sup> Johnson, AL. "Analysis of Alternative Antimicrobial." US Army NSRDEC Final Report. 2009.

- Determine which Soldiers, (e.g., initial entry training or deployed), are having the highest number of medical encounters and where most of these issues occur (i.e., training sites, field, garrison, down range, etc.).
- Determine operational impact and lost time, including data from forward operating areas in theater.

*AMT Performance and Effectiveness:*

- Conduct laboratory analysis, using artificial skin models, etc., under controlled conditions.
- Conduct environmentally controlled chamber tests and/or field tests using volunteer subjects in typical Soldier tasks and drills while being exposed to varied environmental conditions (heat, cold, altitude).
- Conduct field evaluations to validate results from laboratory analyses.

*Safety Testing:*

- Evaluate health hazards such as skin irritation due to the AMT as another factor in safety related to use and/or wearing of the product.
- Test for potential resistance and changes in microbiota of the skin in particular regions of the body.

*Return on Investment*

- Compare cost of hygiene issues with cost of medical treatment to make informed decisions regarding return on investment for inclusion of antimicrobials in CIE.

*Non-Antimicrobial Solutions*

- Explore incorporation of non-antimicrobial functionalities, such as moisture wicking technologies, in ACU textiles.
- Increase education and training in areas of personal hygiene, especially before Warfighters deploy to austere environments where they will not have access to shower and laundry facilities they typically have in garrison.

# DEFINING ANTIMICROBIAL TEXTILE REQUIREMENTS FOR MILITARY APPLICATIONS—A GAP ANALYSIS

## CHAPTER 1: INTRODUCTION

This technical report summarizes a literature search of skin physiology, incident rates and costs of common medical and health conditions among members of the military, and the benefits and risks of potential antimicrobial textile (AMT) treatments. The information was collected by the Natick Soldier Research, Development and Engineering Center (NSRDEC) between April 2014 and July 2015. NSRDEC work included modeling efforts to analyze treatment costs of the medical and health conditions reported in literature and documented in military epidemiological databases. The purpose was to collect data in these areas as basis for future efforts to define specific requirements and standards for incorporation of AMTs in Soldier Clothing and Individual Equipment (SCIE) because there are many clothing-related skin and hygiene problems in the military, AMTs have been used successfully outside the military, and there are currently no requirements for AMT use in military. Requirements generation will require analysis of cost and risk vs. benefits. This report is being published as part of a transition agreement under TeCD1B with the Training and Doctrine Command (TRADOC) and will serve as guidance for the Maneuver Center of Excellence and the Maneuver, Aviation and Soldier Division under the Army Capabilities Integration Center for generation of requirements.

### *1.1 Background*

There is a long history of skin-related medical problems within the military population, dating back to World War I and evolving through Operations Iraqi and Enduring Freedom (OIF and OEF). According to a recent review, about 27% of dermatological diagnoses recorded in theater correlated with a bacterial or fungal infection [1]. Most infections were exacerbated in hot and humid climates such as in Vietnam, while other conditions, e.g., eczema, were worsened in dry climates such as in Iraq and Bosnia. There is a high morbidity of dermatological problems in theater, as illustrated by the 883 evacuations of military personnel over a 3-year period during OIF/OEF, accounting for a significant decrease in operational readiness [1]. Better prophylaxis for skin conditions needs to be explored and implemented for Warfighters who serve in a variety of regions around the world.

Recent widespread use of anti-odor, antifungal, and antimicrobial products within the civilian population led to the idea of incorporating such products into materiel for distribution to military personnel. Currently, there is no official specific requirement for an AMT in any component of Warfighter CIE. However, within the last decade, particular fielded items such as (e.g., the green boot socks) have been made with antimicrobial properties, reflecting interest in microbial protection has been of interest, primarily for fabric preservation. Items such as the Army Combat Uniform (ACU), Temperate Weather Boot, and Protective Undergarment (PUG) have been considered for integration of AMT.

Previously, NSRDEC and Microban Products Company® (MPC) collaborated on several field studies starting in 2005 after the initial request that antimicrobial properties be included in SCIE. Treated products included the ACU, tan t-shirt, and green boot socks. To ensure safety

and to avoid potential toxicity issues, each antimicrobial component was subjected to a health hazard analysis (HHA) completed by outside laboratories and the Army's Public Health Command (PHC) [2, 3]. Each component passed the HHAs, and NSRDEC completed human user evaluations, as well as laboratory analyses for efficacy of antimicrobial capabilities. Following these tests, no further evaluation was completed. While subjects indicated a desire to include antimicrobial functionality, no clear benefit of the technology was demonstrated.

Medical surveillance data of relevant health and hygiene conditions associated with bacteria and fungi have been collected and compiled for epidemiological analyses. The largest repository of military medical data is the Armed Forces Health Surveillance Center (AFHSC). Other sources include the US Army Research Institute of Environmental Medicine's (USARIEM) Total Army Health and Injury Outcome Database (TAIHOD). The Army PHC has developed a tool to assess costs based on information in these databases called the Medical Cost Avoidance Model (MCAM), a full explanation of which can be found in a paper by Smith et al [4].

## *1.2 Organization of Documents*

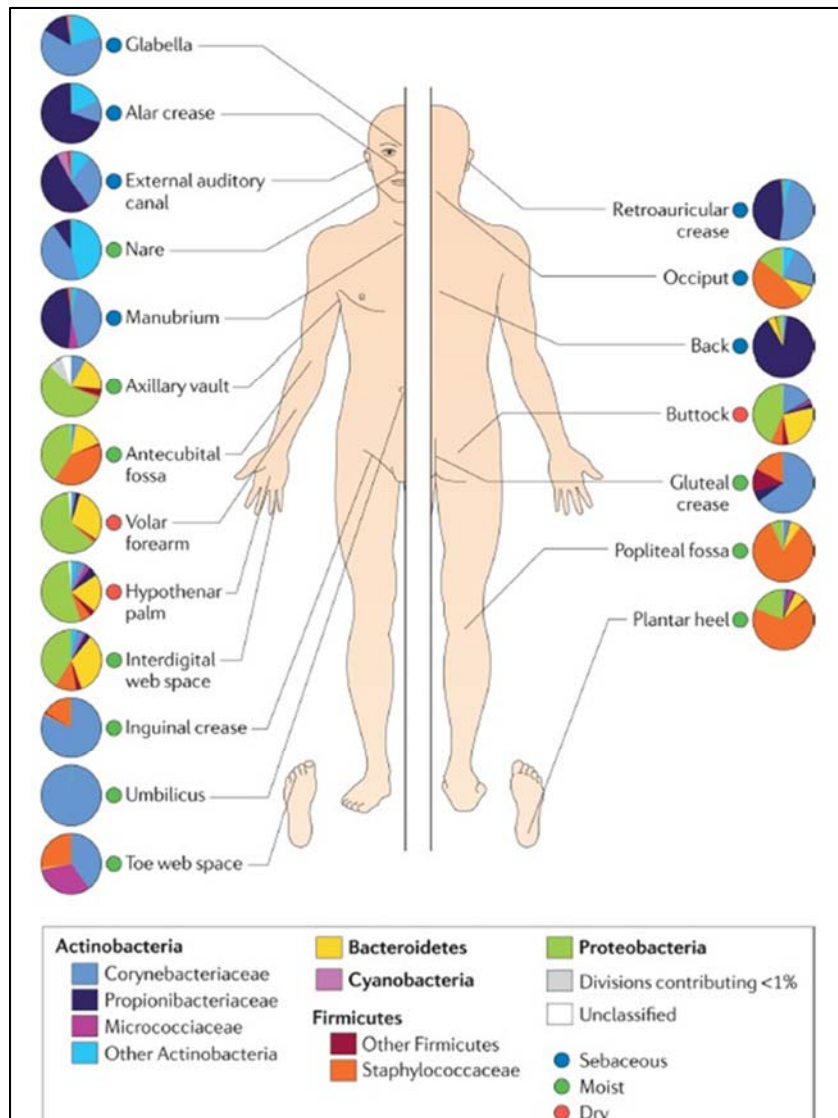
Chapter 2 discusses literature findings regarding the relevant aspects of human skin physiology and immune system to enable understanding of the environment in which the antimicrobial technology would attempt to kill or inhibit growth of pathogenic organisms while maintaining the integrity of the normal skin flora. Chapter 3 discusses the particular health and medical issues found in the literature that may potentially be mitigated through use of AMTs and presents results of analyses of medical costs of treating these conditions performed by NSRDEC using PHC's MCAM. Chapter 4 discusses information found on various potential antimicrobial treatments in terms of their use in AMTs and their potential benefits and potential risks. Chapter 5 draws conclusions from the findings presented in Chapters 3 and 4 and summarizes the gaps between what is known and the knowledge that is needed regarding the effects of AMTs and their efficacy in treating the conditions commonly experienced by military personnel in order to generate and update requirements and standards for incorporating AMTs into CIE. Chapter 6 presents recommendations for future testing and evaluation in five areas for bridging these gaps, as well as recommendations for use of non-antimicrobial approaches to reducing occurrence and severity of the medical and health conditions.

## CHAPTER 2: SKIN PHYSIOLOGY

### 2.1 Skin Microbiome

In the assessment of potential AMT use, it is important to understand typical skin structure and physiology, specifically its normal surface bacteria, which is commonly referred to as the skin microbiome. While there is interpersonal variation of the composition of surface bacteria, the majority of normal skin flora has been identified and is understood. This bacterial layer plays a significant role in the skin's protective barrier against pathogens and other stressors. Shifts or changes in the flora can play a part in disrupting skin barrier homeostasis and can make a person more susceptible to disease or infection [5, 6]. This function is discussed in Section 2.2.

Over the past decade, the National Institutes of Health (NIH) have done extensive work to explore the skin microbiome. According to the work done by Grice and Segre [7], *Staphylococcus* and *Propionibacterium spp.* are the dominant organisms making up a large proportion of the skin microbiota. These organisms, and numerous other species, inhabit regions of the body in different proportions and also vary depending on the innate microenvironment (i.e., moisture of skin) (see **Figure 1**). These bacteria are normal and assist in defense mechanisms for the epidermal barrier. Work has also been done to explore and identify the fungal diversity of the skin, and it is shown that *Malassezia spp.* dominate the body. Mapping and understanding the skin microbiome is important for considering the type of AMT to be used and into what component of clothing it is incorporated.



**Figure 1.** Distribution of bacteria on skin sites throughout human body [7]

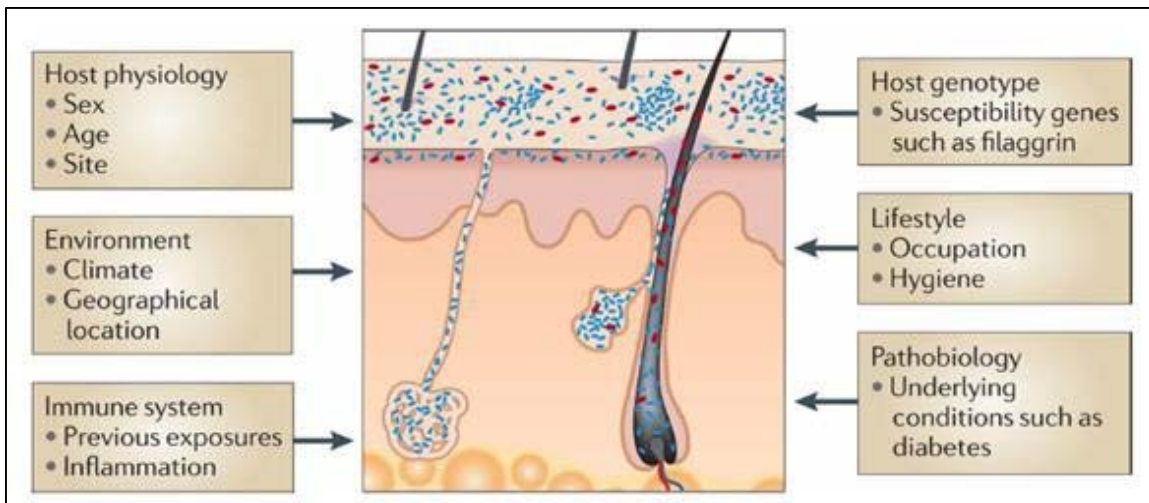
## 2.2 Skin as a Function of Immune System

The skin has innate defensive barriers and physical permeability attributes that maintain homeostasis and protect against pathogens. Most of the superficial epidermal cells are keratinocytes that express molecular components that contribute to antimicrobial properties of the skin. Other protective properties include continual shedding of skin cells, lower pH (acidic), and resident skin microflora (production of antimicrobial peptides, competition of nutrients), all of which create an environment unfavorable to non-native organisms, some of which are pathogenic [8].

There are numerous factors that contribute to variation and shifts in the skin's bacterial population (**Figure 2**). External factors include ambient temperature, humidity, and light exposure, while internal or host factors include gender, use of medications, changes in immune system, occupational stress (psychological and physical), and poor hygiene [7, 9]. These factors



become important for Warfighters, as they are exposed to these elements such as during field training or a deployment. The changes in skin microbiome may disrupt normal immune defense mechanisms and may lead to an inability to protect the deeper tissue layers from abnormal and pathogenic organisms.



**Figure 2.** Internal and external factors contributing to shifts in skin microbiome [7]

One important external variable potentially affecting skin barrier homeostasis is psychological stress (PS). It is well documented that PS has particular effects on susceptibility to skin infection and disease, primarily due to alterations in tissue integrity as well as antimicrobial peptide expression [10, 11]. A result of acute PS is increased production of hormones called glucocorticoids (mainly cortisol), which tend to have a negative impact on the body when systemic levels are chronically elevated [12]. Increased PS and the subsequent increase in glucocorticoids have been shown to delay wound healing, impair stratum corneum cohesion, disrupt permeability barrier homeostasis, and compromise epidermal immunity [5, 13]. Impaired wound healing is due in part to immune system suppression as well as decreased synthesis of epidermal lipids, affecting membranes that mediate barrier function of the stratum corneum [14]. Another adverse effect occurs in the down-regulation of the antimicrobial peptide cathelicidin, which is expressed in epidermal tissue and has been shown to be altered by PS and by increased glucocorticoids [12]. With the psychological and physical stress that Warfighters endure during training and combat, it can be assumed that suppressed immune function and chronic elevation of glucocorticoids are harmful to skin tissue integrity which increases susceptibility to infections and other skin related conditions [6].

### 2.3 Consideration for AMT Design

Knowledge of the skin microbiome and its physiology is important in relation to use and design of AMTs because an ideal requirement for an antimicrobial technology would be the capability to kill or inhibit growth of pathogenic organisms while maintaining the integrity of the normal skin flora. The impact of internal and external variables on skin barrier homeostasis should also be considered. Specific types of AMTs are discussed in Chapter 4, along with their degree of safety. The effects of long-term AMT wear on the normal skin microbiome and potential resistance have not been well studied, and this is discussed in Chapter 4.

### CHAPTER 3: RELEVANT HEALTH AND MEDICAL ISSUES

Four groups of health and medical issues relevant to Warfighters in training and when deployed were identified and researched: odor, bacterial infections, fungal skin conditions, and female urogenital health issues. These are discussed in Sections 3.1, 3.2, 3.3, and 3.4, respectively, in terms of their relevance to the military, bacteriology, available research data, and cost analysis, where available. Hygiene and medical issues related to bacterial and fungal outgrowth fall into reportable (i.e., reported to medical personnel for treatment, known incidence rates) and non-reportable (no treatment/rates) categories. All of the odor issues addressed in Section 3.1 are non-reportable. Most of the conditions discussed in Sections 3.2, 3.3, and 3.4 are reportable, though some are non-trackable because they are not actually reported to medical personnel.

The magnitude of the problem for reportable issues can be somewhat determined by creating a ranking system based on incident rates and medical cost savings. PHC’s MCAM (Version 2.4.2) was used, in this study, to approximate medical costs, accounting for inflation, for different diagnoses associated with skin-related infections presented in active duty Soldiers at Military Treatment Facilities (MTF). The information from the MTFs was obtained from medical surveillance data found in AFHSC and TAIHOD, but the data did not include medical facilities in operational environments (Iraq, Afghanistan, etc.). Medical cost analysis data were developed for each reportable condition in the three groups containing reportable conditions: bacterial infections, fungal infections, and female urogenital health issues. The data were then used to create a ranking system based on 1) average number of cases per year (between 2010-2012), 2) associated total medical cost, and 3) cost per case. The rankings for each group as a whole are listed in Table 1. However, the only data available on bacterial infections relevant to the military were for skin and soft tissue infections (SSTI); there were no data available for the other important area of bacterial infections: secondary infections that result from serious combat wounds. Because the number of cases does not necessarily correlate with total associated medical cost, all three categories were taken into account when ranking the conditions.

**Table 1.** Ranking of medical reportable condition groups between 2010 and 2012

Group	Cases/Year	Medical Cost/Year	Medical Cost/Case
1. Bacterial SSTI*	23,902	\$ 91.9 M	\$3,844
2. Female Health	22,141	\$ 81.0 M	\$3,660
3. Fungal	13,664	\$ 46.6 M	\$3,409

\* Only segment of bacterial infections group for which there were data.

In addition to this cost of treatment data, the overall price of AMT items need to be identified for comparison with the treatment costs to make informed decisions regarding return on investment for inclusion of antimicrobials. These values are not easily located, nor is the number of fielded items readily available. They were not identified during this study, though some relevant information was identified. According to DA PAM 670-1 [15], a new set of ACU should be purchased every 6 months, as this is the prescribed wear life. The associated costs of the SCIE Defense Logistics Agency (DLA) Troop Support (DLATS) issued clothing items, as posted on the Army and Air Force Exchange Services (AAFES) website, were:

- ACU top - \$ 41.86
- ACU trouser - \$ 42.43
- Tan t-shirt (3-pack) - \$ 13.32 / (\$ 4.44 each)
- Green boot socks (3-pack) - \$ 6.54 / (\$ 2.18 each)

It should be noted that these are prices as of April 2015 and include the permethrin-treated ACU ensemble, which had already raised the uniform cost by \$4 per item (information from NSRDEC). Enlisted Soldiers receive a yearly clothing allowance to cover the cost of these items, and price increases for potential AMT items should also be considered. Increasing the price of these items would cost the Army more due to the necessity of increases in Soldiers' clothing allowances, or would result in more direct out-of-pocket expenses for Soldiers. Information from PEO Soldier and NSRDEC clothing designers have suggested that antimicrobial treatments could increase the costs up to 25% per yard of fabric for the ACU. The antimicrobial added to the Fire-Resistant Environmental Ensemble (FREE) socks increased cost about \$2 per pair. Currently, it is unknown if these purported treatments would have any effect on the rate of skin irritation, infection, and other hygiene issues that have been previously discussed.

### *3.1 Odor*

#### 3.1.1 Background and Military Relevance

Malodor from the body, clothing, and equipment was found to be a significant quality of life concern among the Warfighter population. Considering training and field environments, several external factors contribute to this hygiene issue. Among them are constrictive clothing and/or layering techniques that protect Warfighters from elements of the environment or during a Chemical, Biological, Radiological, Nuclear, Explosive (CBRNE) situation. The clothing or uniforms can inhibit normal physiological mechanisms that cool the body when overheated such as normal sweat evaporation from the skin. In addition, warmer environments, heavy load carriage, and training exercises at high intensity and for longer durations cause increased sweat rate. The skin and innermost layer of clothing, especially when wet, essentially become media for increased bacteria and fungus growth, correlating to increased malodor.

Military personnel are a high-risk population for poor hygienic behaviors, especially when they live and work closely together for extended periods of time [16]. Poor hygiene combined with additional environmental factors (e.g., temperature/humidity) can lead to increased bacterial and fungal growth, odor, and subsequent infection. An additional factor of training in the field or going out on lengthy missions is the lack of access to laundry facilities. Without adequate laundering, bacteria and fungi continue to grow, causing increased odor production on the textile. Even when detergents are used, washing clothing at temperatures lower than 40 °C (104 °F) does not effectively kill skin bacteria, and malodor accumulates further when clothes are re-worn, wetted, and heated back up to body temperature [17].

There are problems of body odor, foot odor, and general hygiene throughout the military that presumably arise during long training exercises in the field and during deployments. Odor issues may seem to rate as a low priority, since they are typically temporary and not of medical importance. However, there are extreme circumstances, such as in special operations missions,

where simple significant body odor could give away fighting positions or affect relationships with local nationals.

### 3.1.2 Bacteriology

Body regions of particular interest with regard to odor are inherently moist, such as the axilla (underarm) and groin. The axillary region produces malodor in many individuals for several reasons. It is host to numerous hair follicles with sebaceous (fatty) and sweat glands, as well as bacteria that are primarily of the *Corynebacteria* and *Staphylococcus spp.* [18, 19, 20]. Sweat production and bacteria, along with several other physiological factors, have a synergistic effect on the production of odor [17, 21]. Specifically, *Corynebacteria spp.* Have a known correlation to odor production because their enzymes have properties for lipid-catabolism (degradation of skin lipids to volatile fatty acids) and transformation of non-odiferous precursors to odiferous compounds (e.g., androstadienone to androstenone) [18, 20, 21].

### 3.1.3 Research

There remains a lack of information specifically regarding the dynamic state of axillary microbiology and its relationship between inter- and intra-personal variability with disease states and odor production [19]. The limited data regarding odor among military personnel are all qualitative or descriptive; however, there are several methods for odor research that can be accomplished in the laboratory. Studies have looked at both *in-vivo* (in or on the body) and *in-vitro* (outside the body) methods for determining odor production [21]. While these methods work well in a laboratory setting, they may not directly translate to realistic situations. *In-vitro* analysis with AMT is possible using known strains of bacteria; however, no standardized method is available at this time. The *in-vivo* analyses include sampling of sweat and skin swabs and use a panel of trained individuals who assess odor level by sniffing either samples or the test subjects themselves [21]. This method of evaluation is simpler to conduct, but difficult to validate due to inter-rater variability. Rennie et al. [21] found a significant association between number and density of bacteria cells and underarm odor presence. Therefore, *in-vitro* assessment of sweat, skin-swabs, or sweaty garments, using quantification of bacterial population, may be valid once a standard method is established.

In 2005, field wear evaluation studies were conducted by teams from NSRDEC and MPC to determine if the SCIE treated with antimicrobial protection would be perceivable to the Warfighter. Subjective and self-reported data were collected before, during, and after Soldiers wore treated ACUs, t-shirts, and socks during a field training exercise at Fort Bliss, Texas. Questionnaires were developed with the assistance of dermatologists to assess skin problems and conditions which Soldiers typically face in the field. Laboratory testing was also completed on items worn during field trials to determine effectiveness against specific organisms [22]. Overall results of these studies were inconclusive; however, there was a perceived benefit with the treated items by some, but not a majority, of the Soldiers. The self-reported surveys indicated there may have been some diminished incidence of skin conditions, but more importantly there was interest in having AMTs as part of the uniforms [22]. Inconclusive data were caused in part by interpersonal variability; to overcome this, a large amount of data is required. However, the numerous limitations of current test methods prevent sufficient data from being collected.

Following the field evaluation trials completed by NSRDEC and MPC, certain AMT items were fielded in hope there would be some benefit of the antimicrobial technology, such as decreasing body odor, but it is not known when the items began to be distributed nor if they are still being used. It would be logical to revisit field testing in the Soldier population; recommendations for these tests are presented in Chapter 6 of this document. Between November 2014 and March 2015, the NSRDEC Consumer Research Team created and distributed, via internet, a questionnaire for Service members to complete in regards to odor issues, as well as types of AMT products they may use. Resulting data indicated perceived problems within the military regarding odor and personal hygiene. It was found that almost half of the Soldiers surveyed had used an antimicrobial product to help control foot and/or body odor. Foot odor was a prevalent condition among the Soldiers, with 63% reporting having the issue within the past year. Though most Soldiers reported that while in the field they found it difficult to avoid body odor, they also found that over the counter remedies or changing clothes helped minimize the issue more frequently than use of antimicrobials. An unpublished report summarizing this effort is included as Appendix A.

Additional analysis needs to take place within the US military to determine the scope of the odor and hygiene problems. Body odor is not a reportable condition and therefore cannot be quantified using surveillance data gathered on incidence rates based on physician diagnoses through the military health system. The previously mentioned survey demonstrates some baseline data, but more specific information from Warfighters and their perception of odor and hygiene issues are needed. One study does describe a self-administered scale developed for testing personnel from the Iranian military on their personal hygiene habits. Researchers discuss the process for the scale development. They found the scale to be valid and reliable after it had been distributed to 500 male Soldiers [16]. Conclusions from this study could be used for future quantitative testing within US military populations, at least among male Soldiers.

### 3.2 Bacterial Infections

Bacterial infections of interest include SSTI and secondary infections resulting directly from serious combat wounds; however, it is unknown if the data searched encompasses secondary infections. Reported SSTI in this data set included carbuncles/furuncles, cellulitis, and atopic dermatitis, all assumed to be caused by bacterial organisms. As shown in Table 2, the top three ranked SSTI are cellulitis – leg, site unspecified, and arm. A complete list of these conditions, indexed by International Classification of Diseases (ICD) - 9 code, appears in Appendix B. No analysis was conducted on secondary infections, as mentioned above, for the 2010-2012 collection period.

**Table 2.** Top-ranked SSTI\* between 2010 and 2012

Condition	ICD-9 Code	Cases/Year	Medical Cost/Year	Medical Cost/Case
1. Cellulitis - Leg	682.6	3,844	\$ 18.3 M	\$ 4,756
2. Cellulitis – Site Unspecified	682.9	4,067	\$ 16.4 M	\$ 4,025
3. Cellulitis - Arm	682.3	2,665	\$ 11.1 M	\$ 4,159
Total SSTI		23,902	\$ 91.9 M	\$ 3,844

Ranking scheme: 1 2 3

\* Only segment of bacterial infections group for which there were data.

### 3.2.1 Background and Military Relevance

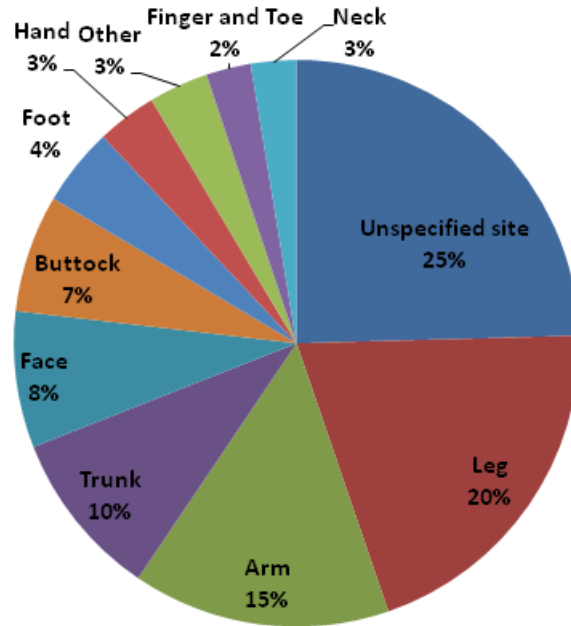
In military training and deployment, skin complications ranging from irritation to secondary infection resulting from combat wounds can account for significant lost time and negative operational impact [1]. SSTI are an important public health issue and can be exacerbated by close living quarters and communal contact [23, 24, 25]. Some skin irritations can also develop into infections if the Warfighters feel it is unnecessary to report them to and seek treatment from medics or physicians. Any breaks in the skin, such as open blisters, lesions, scratches, burns, or even minor skin irritation, can instigate development of infection, or even have systemic effects leading to fever [26]. The focus in this report will be related to SSTI that are considered Disease Non-Battle Injuries (DNBI).

### 3.2.2. Bacteriology

Knowledge regarding the skin microbiome and disruptions in its homeostasis can be applied to the incidence rates of SSTI and can help to explain why they are prevalent in the military population. *Staphylococcus aureus* (*S. aureus*) is a well-studied organism that is highly involved with epidermal and follicular infections due to its ability to adhere to, invade, and grow on mammalian cells [27]. It is also known to aggressively colonize in areas of eczematous or inflamed skin and is a mechanism for aggravation of these skin lesion conditions [28]. According to Landrum et al, between 2005 and 2010 there was a 4 to 6% rate of SSTI among military trainees, and *S. aureus* was isolated in 91% of those cases [24]. *Streptococcus pyogenes* is also an important organism to consider because of its involvement with dermal conditions such as erysipelas, cellulitis, and impetigo. Both organisms inhabit the skin as normal flora; however, due to their inherent specific toxins, they can become pathogenic when colonized in open abrasions or wounds [23, 27]. Bacteriology related to secondary infections after sustaining serious wounds is important to consider for particular medical product development; however, no such information was found in the data used in this literature search.

### 3.2.3 Infection Rates

In 2013, the Medical Surveillance Monthly Report (MSMR) summarized SSTI rates among active US troops from 2000-2012 to include cellulitis, carbuncle/furuncle, erysipelas, and other conditions [26]. Most notably, the study found that half of the infections were diagnosed as cellulitis and 40% of these cases were in the lower extremity. It was also found that most SSTI cases were most frequent during first few months of basic combat training. **Figure 3** shows the prevalence of SSTI (cellulitis and carbuncles/furuncles) by body region. This unpublished data was generated from the TAIHOD.



**Figure 3.** Prevalence of SSSI by body region (unpublished data from TAIHOD)

MSMR creates a good depiction of infection rates within troops in training and garrison from data retrieved by the Military Health System; however, there are fewer data related to DNBI sustained by troops who are in theater. One study, by May et al (2011), does discuss incidence of SSSI in deployed US troops using self-reported scales [25]. Questionnaires were voluntarily completed by approximately 2,000 Soldiers who came through a medical clinic in Qatar over the course of approximately 1 year. About 100 (5%) of these Soldiers reported one or more SSSI during their most recent deployment. This was a higher rate than expected by the researchers based on previously published incidence rates among active duty service members. The data show that many Warfighters do not report skin irritations to medical personnel and, in turn, ultimately go untreated, most likely because the irritation or infection seems uncomplicated and inconsequential. For all reported SSSI, 95% were uncomplicated, meaning they did not need extensive treatment from a medical provider; however, about 20% of the participants reported missing at least 1 day of work due to their conditions, which could significantly impact any military mission [25].

While the current paper does not go into depth regarding secondary infections which occur as a result of serious combat wounds, these conditions are important to consider since they have affected thousands of US troops during conflicts in Iraq and Afghanistan. One study [29] found that between October 2001 and January 2005 approximately 1,566 Warfighters sustained 6,609 combat wounds, more than half of which were in the extremities. Most Warfighters receive thorough training on first aid and basic lifesaving techniques; however, only a percentage of those Warfighters (i.e., combat medics or medical providers) have specific point of injury (POI) medical care skills. Over the last decade, several methods of wound debridement and POI care have been utilized. Examples of current POI techniques on the battlefield, found in a study by Murray et al (2011), are oral administration of broad-spectrum antibiotics such as moxifloxacin or fluoroquinolones or intravenous/ intramuscular injection of cefotetan or ertapenem. Of 405 wounds seen in a combat hospital over 7 years of surveillance in that study,

113 (27.9%) were previously administered POI antimicrobials in the field, and 292 (72.1%) were not. About 7% of each group (POI antimicrobial or no treatment) developed secondary infections. The authors concluded that early administration of antimicrobials does not appear to prevent infections nor be associated with increased rates of multidrug resistant bacterial infection or colonization [30].

### 3.2.4 Cost Analysis

If AMT uniform components are fielded and used and are effective against some or all of these medical conditions, medical cost avoidance can be estimated over specific time periods. Table 3 displays projected monetary savings if diagnoses are decreased by 10%, 25%, and 50% over time spans of 1 year and 5 years, based on the values in Table 2 (23,902 yearly diagnoses, costing about \$91.9 million per year). Not only do SSTI affect a significant number of Warfighters (~4%), but there is an expensive medical cost per case at almost \$4,000, which includes associated costs for lost time, clinic and hospital visit hours, and disability compensation [4]. It should be noted that assessing secondary infection incidence rate and cost is more difficult and currently these data are not available. Hospital-borne infections are also a different scope of analysis and are not discussed in this report. Both situations will have costs associated and should be considered.

**Table 3.** Estimated medical cost avoidance for SSTI at different rates of decrease in diagnosis

<b>Time Span</b>	<b>10%</b>	<b>25%</b>	<b>50%</b>
1 year	\$ 9.1 M	\$ 22.9 M	\$ 45.9 M
5 years	\$ 45.6 M	\$ 114.6 M	\$ 229.5 M

### 3.2.5 Summary

There is a large amount of discussion regarding the use of AMTs to reduce bacterial colonization on the skin surface. However, less is known about how AMTs could prevent or treat SSTI or reduce the probability of secondary infections after trauma during military exercises. There are clinical data to show the possibility of a particular AMT, such as ones impregnated with silver, helping with treatment of certain skin conditions, such as atopic dermatitis. [31, 32, 33, 34] However, to date, there is limited research regarding prevention of SSTI and treatment within a military population. Determination of how AMTs would reduce rates of SSTI or secondary infections is not easy and would have to be carried out through longitudinal surveillance studies. A cost-benefit analysis utilizing the MCAM and pricing of purchasing/distributing pieces of the uniform/equipment with antimicrobials should be done. Analysis of possible interactions with other protective substances added to the uniform (permethrin, FR, IR, etc.) should also be completed.

While secondary infections are of grave concern for the Warfighter, there were no data on secondary infections for the 2010-2012 collection period, and accordingly, no cost analyses could be completed for these conditions within this study. A separate thorough analysis should be completed for these infections and how AMT are currently being used in tactical combat casualty care (gauze, bandages, etc.).



### 3.3 Fungal Skin Conditions

As shown in Table 4, the top four ranked fungal skin conditions were nail, foot, body, and groin. A complete list of the conditions investigated in this group, indexed by ICD-9 code, appears in Appendix B.

**Table 4.** Top-ranked fungal (dermatophytoses) conditions between 2010 and 2012

Condition	ICD-9 Code	Cases/Year	Medical Cost/Year	Medical Cost/Case
1. Nail	110.1	3136	\$ 12.2 M	\$ 3,901
2. Foot	110.4	2959	\$ 10.4 M	\$ 3,500
3. Body	110.5	2068	\$ 6.72 M	\$ 3,250
4. Groin	110.3	1583	\$ 5.17 M	\$ 3,263
Total in Entire Group		13,664	\$ 46.6 M	\$ 3,409

Ranking scheme:  1 2 3 4

#### 3.3.1 Background and Military Relevance

There is a long history of fungal skin conditions, such as athlete’s foot and jock itch, in the military and a moderate amount of data regarding fungal growth and infections, especially in the feet [23]. Three known species of fungi are specifically responsible for the majority of infections: *Tricophyton rubrum*, *Tricophyton mentagrophytes*, and *Epidermophyton floccosum* [23, 35]. During field training exercises or deployment, Warfighters are exposed to increased risk factors of hot and humid ambient weather, poor skin hygiene, and close-quarter living [36]. In addition to the many reported fungal conditions and infections, most are likely unreported to medical personnel and are therefore undocumented and sometimes untreated.

#### 3.3.2 Research

Athlete’s foot (*Tinea pedis*) is a common problem not only among military personnel but also the civilian population; at any given time, up to 25% of the population may be affected [37]. Data have been collected among military personnel from numerous countries outside of the United States to assess incidence and risk factors associated with fungal foot infections. It was found that the military lifestyle imposes additional susceptibilities for infections such as high intensity training, excessive sweating, prolonged shoe/boot wearing, and decreased frequency of sock changes [35, 37, 38, 39, 40]. Another factor to consider is the repetitive pressure and constant friction the feet endure on a daily basis, causing blisters and open wounds that can increase the risk for infection [38].

Borkow (2013) discusses the potential use of copper oxide as an antimicrobial agent woven into socks [38]. Copper is a broad-spectrum bactericide and also can improve wound healing through capillary generation and stabilization of skin proteins. Tests with the Israeli Army yielded positive results even with a small cohort of test volunteers. Soldiers wore socks impregnated with copper oxide daily for 3 weeks, and a majority reported reductions in foot odor,

irritation, and other symptoms of athlete’s foot. This study gives way to alternative technologies for antimicrobials to be incorporated into socks and potentially other components of SCIE.

### 3.3.3 Infection Rates

A 2-year study, published in the MSMR in 2001, looked at a 2-year surveillance period of cutaneous fungal infections throughout the US Army and found that of over 66,000 visits to MTF for fungal- related issues, 19.1% were foot infections [36]. Locations of infection on the body are important to note for future efforts analyzing ways to minimize fungal growth by the addition of antimicrobial/antifungal formulations into SCIE. In addition to the feet, where the highest rate of fungal accumulation and infection are found, it may be beneficial to focus on the groin to assess benefits from AMT.

It is also important to note that three of four of the locations for highest incidence rate of fungal infections included basic combat training facilities (Forts Knox, Leonard Wood, and Benning) [36]. Assessing geographic location of incidence is important in determining which Soldiers are at higher risk, for instance, if rates are different between Soldiers at initial entry training locations (e.g., Ft. Benning) versus other installations (e.g., JB Lewis-McChord). Wet globe temperature conditions (ambient temperature, humidity, wind speed, and sunlight) should also be taken into account when analyzing prevalence of fungal foot infections, along with other odor or hygiene issues. There is a potential correlation with incidence and ambient environments of higher average temperature and humidity.

### 3.3.4 Cost Analysis

Table 5 displays the projected monetary savings if diagnoses are decreased by 10%, 25%, and 50%, over time spans of 1 year and 5 years, based on the values in Table 4 (13,664 yearly diagnoses, costing about \$47 million per year).

**Table 5.** Estimated medical cost avoidance for fungal-related conditions at different rates of decrease in diagnosis

<b>Time Span</b>	<b>10%</b>	<b>25%</b>	<b>50%</b>
1 year	\$ 4.7 M	\$ 11.7 M	\$ 23.3 M
5 years	\$ 23.3 M	\$ 58.3 M	\$ 117 M

### 3.3.5 Summary

Medical issues pertaining to fungi are important to consider along with bacteria-related conditions. While infections of the feet only explain 26% of total fungal infections among American Warfighters, foot infections account for almost 50% of the medical costs. Potential interventions worth exploring for infection prevention could include an AMT sock or sock liner, and/or better training and education about foot and skin health while in the field, during training exercises, or on deployment, especially in warm and temperate environments. Because the assumption is that a majority of fungal problems go unreported and untreated, antimicrobial products effective against fungi could be beneficial for the Warfighter.

### 3.4 Female Urogenital Health Conditions

As shown in Table 6, the top three ranked female urogenital health conditions are UTI and pyelonephritis, vaginitis, and candidiasis. A complete list of the conditions investigated in this group, indexed by ICD-9 code, appears in Appendix B.

**Table 6.** Top-ranked female urogenital health issues between 2010 and 2012

Condition	ICD-9 Code	Cases/Year	Medical Cost/Year	Medical Cost/Case
1. UTI & Pyelonephritis	599.0, 590.1-.11	7,859	\$ 30.9 M	\$ 3,926
2. Vaginitis	616.1	8,137	\$ 29.6 M	\$ 3,635
3. Candidiasis	112.1	3,640	\$ 12.4 M	\$ 3,406
Total in Entire Group		22,141	\$ 81.0 M	\$ 3,660

Ranking scheme: 1 2 3

#### 3.4.1 Background and Military Relevance

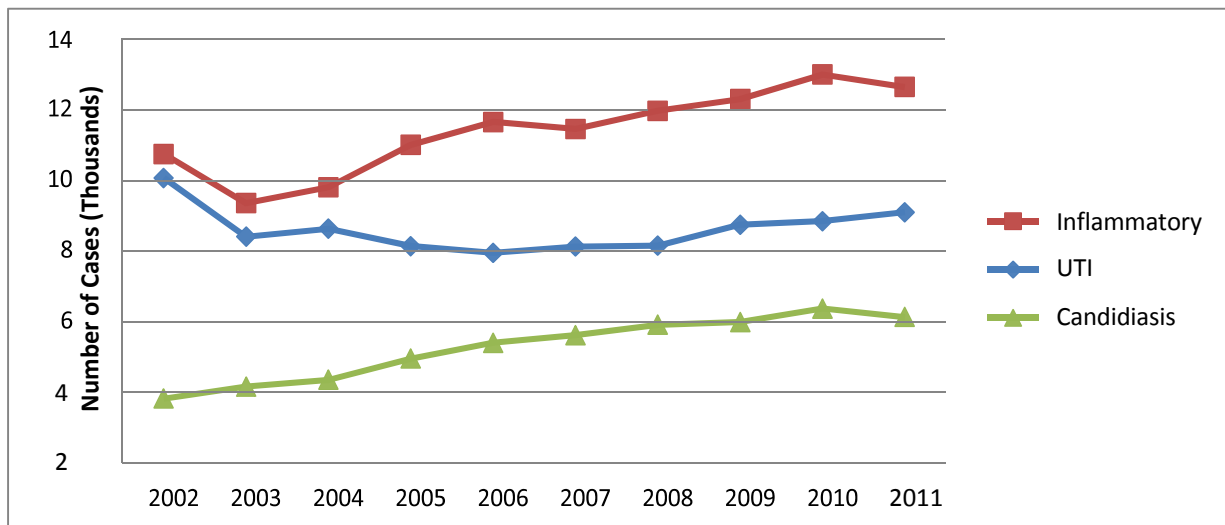
Females comprise about 15% of the Armed Forces and have particular hygiene and health issues that either do not happen as frequently or cannot occur in males. There is a significant prevalence of urinary tract infections (UTI) and other genitourinary and gynecological-related issues in garrison, as well as in theater. UTIs result from bacteria, namely *Escherichia coli*, ascending up into the urethra, and if left untreated, into the ureters and eventually the bladder, causing cystitis [41]. Vaginitis is typically caused by an imbalance of vaginal pH and normal bacterial flora [42]. Yeast infections, or Candidiasis are normally caused by *Candida albicans* but can be from other yeast as well. All of these conditions affect up to 75% of women at least once during their lifetime and while all have similar predisposing factors, each are treated in a different manner.

#### 3.4.2 Research

There are several risk factors during field training or deployment that increase susceptibility to urinary tract and vaginal conditions including inadequate personal hygiene, dehydration (either voluntary or unintended), infrequent and incomplete emptying of the bladder, use of unsanitary urination devices, constrictive undergarments, and altered immune status [41, 43]. Various literature sources, from surveillance papers to data presented from subjective surveys [41, 43, 44, 45, 46, 47], discuss the frequency of female health problems in theater. Doherty et. al (2013) discusses data collected from nurses who had deployed to Iraq and Afghanistan. Highlighted comments included the nurses not being satisfied with the conditions of latrines and shower facilities, and many times never feeling “clean”, corresponding to descriptions from other studies [41, 45]. Due to the condition of these facilities, there are trends among deployed females to avoid urination, a practice that can result in dehydration. Trego (2012) found that up to 77% of females have reported holding their urine for an extended amount of time at some point during deployment, behavior that is significantly correlated to UTIs [46]. Some females also elect to voluntarily suppress menstruation, another risk factor for vaginal complication due to shifts in hormone, pH, and bacterial balance [44, 45]).

### 3.4.3 Infection Rates

Two recent studies published in MSMR [43, 48] specifically analyzed UTIs among all branches of active US Armed Forces between 2000-2013, as well as in deployed personnel between 2008-2013. For all active duty service members, it was found that 30.4% of females had at least one medical UTI encounter and 12.5% had recurrent UTIs [43]. Of the nearly 200,000 females who suffered from at least one UTI, 69% were junior enlisted service members, and 41% were Army Soldiers. **Figure 4** illustrates the number of diagnoses of inflammatory conditions (vaginitis, etc.), UTI, and Candidiasis over a 10-year period (data from TAIHOD). For this particular data set, it should be noted that one Soldier may have been diagnosed more than one time in a given year.



This graph is based on unpublished data from TAIHOD.

**Figure 4.** Rates of female urogenital health conditions in active duty Soldiers from 2002-2011

During a 6-year surveillance of about 111,000 deployed females, it was found that 6.5% had at least one UTI [48], 2.6% were diagnosed with a yeast infection [49], and about 9.7% had a gynecologic disorder (e.g., vaginitis) [47]. A separate study [50] randomly surveyed 841 female service members who had deployed and found higher incidence rates of UTIs (18%), vaginitis (30.1%), and yeast infections (10.4%). It is important to note that 48% of service members who reported symptoms of vaginitis and cystitis were put on limited military duties during deployment and 27.4% of these females lost duty time [46, 47].

### 3.4.4 Cost Analysis

Table 7 displays the projected monetary savings if diagnoses are decreased by 10%, 25% and 50%, over time spans of 1 year and 5 years, based on the values in Table 6 (22,141 yearly diagnoses, costing about \$81 million).

**Table 7.** Estimated medical cost avoidance for female urogenital health conditions at different rates of decrease in diagnosis

<b>Time Span</b>	<b>10%</b>	<b>25%</b>	<b>50%</b>
1 year	\$ 8.1 M	\$ 20.2 M	\$ 40.5 M
5 years	\$ 36.3 M	\$ 92.4 M	\$ 185 M

### 3.4.5 Summary

There is ample evidence that UTIs and other gynecological issues are prevalent among female Service members. The high rate of incidence is a problem due to lost work time, possible duty limitations, and even hospitalization. A few methods of intervention are being assessed, but several studies discuss the need for more or better pre-deployment training on female personal hygiene and health assessment [8, 45, 46].

A potential intervention being explored is adding antimicrobials to specific parts of SCIE such as in the lining of the new Army Physical Fitness Uniform (APFU) shorts and in the crotch region of the ACU trousers. To date, there is no evidence for use of AMT in specific regions of uniforms and the effect on prevention or treatment of UTI. An example of a possible ideal combination of AMT would be one that kills pathogenic bacteria such as *E. coli* and fungi while also preserving healthy bacteria of the skin around the groin, perianal and vaginal regions. This route of prevention could be more simple and safe for the user, as well as more cost efficient than a systemic prophylaxis using oral antibiotic medications, but more research needs to be done to make this determination. Hygiene wipes impregnated with antimicrobials are a potential technology for prevention of UTIs.

Whether it is increased training of female Warfighters on better hygiene or incorporating an antimicrobial into undergarments of uniforms, decreasing rates of the particular female medical issues mentioned above by just 10% would save the military roughly \$36 million in medical costs over 5 years.

## CHAPTER 4 – POTENTIAL AMT TREATMENTS: BENEFITS AND RISKS

MPC compiled a final technical report [22] regarding potential antimicrobial treated products for use in the military that discussed field trials conducted by NSRDEC to evaluate selected garments on Soldiers in the field. MPC determined it could effectively treat the ACU, tan t-shirt, and green boot sock with antimicrobials, specifically using triclosan and polyhexamethylene biguanide (PHMB) because of their broad spectrum of efficacy. The MPC report indicates that microbe reductions were found (using laboratory testing) in items with antimicrobials which Soldiers used in the field for several days, but results are unclear for longer-term use, e.g., over 6 months to 1 year. It is important to note that Soldiers favored the use of these items, but did not indicate a perceived benefit. The next logical step in the assessment of AMT for use in Warfighter CIE would be to conduct human studies and further field evaluations.

Antimicrobial technologies can be incorporated into textiles by either encapsulation or by woven fibers [51]. Most of the antimicrobials used for textile treatments are effective against a broad spectrum of bacteria and fungi (Table 8). The first five of those listed are discussed in Sections 4.1 through 4.5, respectively. A concern is that use of antimicrobial compounds may result in a shift in the normal skin microflora composition and lead to outgrowth of pathogens. Based on the changes observed in gut microbial population with use of antimicrobials (antibiotics), it is thought that the same might occur with skin microflora [52].

**Table 8.** Performance of selected AMT compounds against target organisms

Compound	Gram-Positive	Gram-Negative	Fungi
Silver	highly active	highly active	highly active
Triclosan	active	not active	active
PHMB	active	active	active
Copper	active	active	active
Chorhexidine	active	active	not reported
Quaternary Ammonium Compounds	active	not active	not active
N-halamine	active	active	not reported

There is a paucity of data regarding the effects of AMTs on healthy skin microflora. However, insight about the effects of AMTs can be gained from application of topical antimicrobials on the skin. These topical compounds are classified as disinfectants (e.g., iodine, alcohols) that are highly active; by definition they exhibit >5 log reduction in bacterial levels. Tests with topical antimicrobials resulted in an immediate reduction of population that lasted for short periods of time, but ultimately recovered to initial levels [53, 54].

AMTs are not as active as disinfectants, exhibiting at most up to only 3-4 log reduction in standard laboratory test methods. Therefore, less microflora reduction might be expected of

AMTs than has been observed with topical compounds, resulting in a quicker recovery. The few studies conducted on the effect of AMTs on skin bacteria confirmed this expectation. Silver (Ag<sup>+</sup>) coated textiles were shown to steadily reduce the skin microflora population during 9 h of exposure. This level was maintained for an additional 9 h, followed by full recovery by 36 h [32]. In a 4-week prolonged wear study, skin microflora numbers were assessed on subjects wearing specially constructed t-shirts (placebo controlled right side and Ag<sup>+</sup> treated left side) for a minimum of 8 h/day; a new t-shirt was worn each week. There was no evidence of significant changes in the microflora levels during the study or the week after the wear period [54]. This result was not entirely unexpected, since AMTs are not in constant contact with any particular area of the skin; it is unclear what might occur with constant exposure for extended periods of time (greater than 4 weeks). It should also be noted that these studies were done without physical activity. A setting which is more relevant to the Warfighter might include field environment ambient conditions, as well as high physical activity; the effects of prolonged wear of AMTs in the presence of sweat may produce a different outcome.

#### 4.1 Silver

Silver is widely used as an AMT for medical and therapeutic products due to its ability to reduce bacterial colonization in lesions caused by conditions such as atopic dermatitis [31]. Silver's mode of action is biocidal, meaning it kills cells, and has broad-spectrum targets on the cell surface, making it effective against most microbial organisms [55]. The effectiveness of silver as an antiseptic is based on the ability of the biologically active silver ion (Ag<sup>+</sup>) to irreversibly damage key enzyme systems in the cell membranes of pathogens.

One major concern of using silver is the potential for development of long-term microbial and fungal resistance to Ag<sup>+</sup>. There have been documented chromosomal mutations and Ag<sup>+</sup> resistance in *E. coli*, *Enterobacter cloacae*, *Klebsiella pneumoniae*, and *Acinetobacter baumannii*; most resistance has been documented in high use areas such as dental care, burn care, and in the use of Ag<sup>+</sup>-coated catheters. However, the mechanisms for anaerobic bacteria and fungal resistance to Ag<sup>+</sup> are poorly researched and not understood [55].

The green boot socks issued to Soldiers from the DLA are the only known currently fielded item to incorporate antimicrobial properties into the textiles, using 99.9% Ag<sup>+</sup>-lining in the nylon [56]. An HHA was completed by the Army PHC in 2008 before the product was distributed, which concluded there was no safety concern [3]. However, there have been no tests documented nor issues reported concerning this product since its distribution. Thus, it is unclear if Soldiers are aware that these socks contain antimicrobials, and it is also unknown whether there has been any beneficial change in foot odor, fungal infection rates, and/or bacterial or fungal resistance since the socks were first fielded.

The antimicrobial yarn proposed for the APFU trunk liner is impregnated with Ag<sup>+</sup> ions and is intended to prevent mildew and odor in the material. There are several concerns regarding potential use of an antimicrobial in the APFU trunk liner and crotch of the ACU: the impact on vaginal flora, in particular the impact on *Lactobacillus sp.* (beneficial commensal bacteria) and the potential development of resistance. However, no scientific evidence exists on the impact of antimicrobial yarn or silver ions on the vaginal flora. Effects of exposure to the vaginal ecosystem via the trunk liner is unknown. For Ag<sup>+</sup> to be pharmacologically active, the

antimicrobials have to leave the material of the liner and enter the bacterial cells. Since the liner is not a direct topical application of the Ag<sup>+</sup>, the dose of Ag<sup>+</sup> that would actually come in contact with the external parts of the body, external genitalia, or the vagina is unknown [42].

#### 4.2 *Triclosan*

Triclosan is a compound that is active against bacteria, molds, and yeast by blocking the synthesis of lipids [57]. It is used in many consumer products, including soaps, cosmetics, and textiles. Triclosan can be applied directly to textiles as a surface coating or by encapsulation. In regards to safety, there are numerous reports of emerging resistance to triclosan [58]. Other health concerns relate to adverse hormonal effects for reproduction and development, which has been shown in laboratory animals [59]. The State of Minnesota is banning triclosan use in consumer products, and the US Food and Drug Administration is revisiting the safety of the product. Additionally, this compound has been banned by the European Union.

#### 4.3 *PHMB*

PHMB is a broad spectrum biocide active against bacteria and fungi. It has been shown to be active against antibiotic resistant bacteria including methicillin-resistant *S. aureus* (MRSA) and vancomycin-resistant *Enterococcus*. Because of its versatility, PHMB is commonly used in wound dressings and for infection control. It has also been used as a finish on cotton, wool, and cotton/wool blends [60]. PHMB also exhibits good durability to repeated launderings, which is important in terms of a cost analysis.

To date, PHMB has been shown to exhibit little toxicity or environmental impact. Its mechanism of action is not well known, but is thought to disrupt cell membranes. The failure of bacteria to develop resistance suggests there are multiple modes of killing action taking place [61]. In addition, this compound is typically used in wound dressings, where resistance to prolonged exposure is less likely.

#### 4.4 *Copper*

Copper is a metal-based biocide that has broad spectrum antibacterial, antiviral, and antifungal activity. Copper behaves similarly to silver by binding and inactivating intracellular proteins [58]. Certain microorganisms have developed a number of mechanisms for tolerating copper, although resistance has rarely been observed. It is thought that copper can target a number of cellular targets in parallel, reducing the likelihood of resistance [50]; however, emergence of resistance is still a concern and under active investigation.

Copper oxide impregnated fibers were incorporated into socks for a civilian population to assess its effectiveness against the fungus *Trichophyton*, the causative agent of athlete's foot. A pilot study with 56 subjects was conducted with copper socks being worn daily and laundered as normal. Subjects evaluated after 8-10 days of wear demonstrated a significant improvement in erythema (redness/inflammation) and moderate improvement in scaling and fissuring of the skin. None of the subjects exhibited any worsening of symptoms [50]. Other studies have shown that



cotton treated fibers demonstrate activity against bacteria and fungi [62]. Standardized laboratory tests showed that the fabrics retained bactericidal activity after 35 launderings.

Copper has also been shown to be effective on touch surfaces (door handles, bathroom fixtures, bed rails) in hospital settings to prevent transmission of infections [58]. Solid copper has recently been registered at the US Environmental Protection Agency as an antimicrobial material.

#### 4.5 Chlorhexidine Gluconate (CHG) Wipes

CHG is an antimicrobial formulation which has proven to be safe for use and has a broad-spectrum efficacy [63]. CHG is available as a rinse solution or in an impregnated cloth and is effective against both gram-positive and gram-negative bacteria, yeasts, and several other organisms. CHG can be combined to both cotton and polyester, as in wipes. Non-rinse CHG has significantly reduced risk of catheter-associated bloodstream infections and surgical-site infections in hospitalized adults. Also of clinical relevance, CHG wipes are used vaginally pre- and post-labor to decrease risk of infection [63].

The use of CHG items has also been studied in military field settings, and the results show a potential positive value [63, 64]. Whitman et al (2010) looked at CHG wipe use in Marines during a field training exercise, having subjects “bathe” with wipes three times a week. CHG wipes did not seem to prevent SSTI rates (n = 1562) and had limited success in reducing and preventing community-acquired MRSA skin colonization. The wipes did slow acquisition of *S. aureus* colonization. CHG may have been compromised by sweating and/or frequent showers. It should be noted that 41% of recruits were persistently colonized with *S. aureus*, which is normal skin flora. CHG caused no serious adverse reactions, but in a few subjects did cause some skin irritation, which may have contributed to increased susceptibility for SSTI [64].

A separate study [65] using Army trainees at Fort Benning had a cohort of subjects use a 4% chlorhexidine antiseptic body wash during their weekly showers and another cohort of subjects who did not use the body wash but had additional personal hygiene training and also took a shower once per week. Out of a total of 26,251 total subjects (both cohorts combined), 1,203 cases of SSTI were diagnosed, and 38% of those SSTI cases were in subjects using the CHG body wash. Overall, the results demonstrate, fungal infections, and female health are problematic, costing a significant amount of money and negatively impacting operations. Significant cost savings can be achieved by reduction or prevention of these reportable conditions, though non-reportable (mainly odor) issues are difficult to assess. There seems to be potential for mitigating these conditions through use of AMTs in Warfighter CIE. Warfighters’ exposure to specific external factors may impact if and how an AMT’s efficacy holds against pathogenic organisms. The risk factors associated with the medical conditions discussed in Chapter 3 cannot be completely prevented by one product; however, components of SCIE that are made with AMT could potentially prevent and/or treat some of these diagnosable, reportable conditions, or at least mitigate a portion of odor issues.

It is also apparent there is a large gap between what is known and the knowledge that is needed regarding the direct effects of AMTs and their efficacy in treating the health and medical conditions most commonly experienced by military personnel in order to generate requirements

and standards for incorporating anti-odor, antibacterial, and antifungal properties into SCIE. Gaps appear in four general areas:

- The magnitude and operational impact of the non-reportable conditions within the military population
- Correlation between the use of AMTs and the immediate and long-term reduction of medical and hygiene issues related to bacteria and fungi growth during Warfighter training and deployments
- Effects of various AMTs on skin flora over time: safety and potential resistance
- Price and number of AMTs that are currently fielded or expected to be fielded in the near future

These gaps are related to the fact that humans (and their variable skin microbiota) are affected differently by AMTs, a lack of adequate and accurate reporting and assessment of the conditions, and the lack of adequate and reliable evaluation of existing antimicrobials and their incorporation in SCIE to treat those conditions.

A number of textile items including T-shirts and socks that incorporate antimicrobial technology have been fielded to address hygiene issues such as odor and athlete's foot. Previous field trials have failed to definitively prove a benefit mainly because of variability between subjects. Collecting a larger amount of data by increasing the number of subjects would potentially address variability, but limitations of current test methods make this infeasible.

Non-reportable issues such as odor and skin irritation are described anecdotally but are difficult to quantitate, leading to complicated assessment of the use of AMTs as possible solutions. The survey-based data collected during field trials by NSRDEC and MPC indicated that Soldiers reported some benefit to the items with AMT, although this was purely subjective [22]. In collaboration with the NSRDEC Consumer Research Team, an online military and civilian-wide survey gave a baseline of Soldier perceptions related to antimicrobial use and impact of odor and hygiene as guidance to the pursuit of using AMTs as potential solutions to these issues.

Issues reported to medical professionals can be tracked by medical diagnosis to yield incidence rates, cost avoidance calculations, and demographic data including geographic location, gender, and military occupational specialty (MOS). Data have been presented in this report on a variety of reportable issues, including incidence rates (TAIHOD data) and calculated medical cost savings by prevention (MCAM).

The performance level that an AMT needs to achieve to effectively counter hygiene issues has not been systematically determined. Previous NSRDEC field evaluations demonstrated microbe reduction on the items (fabrics) themselves using in-vitro lab testing. A handful of in-vivo (human) tests have been used to examine the effectiveness of a particular treatment, but the data to date are inconclusive and the studies difficult to conduct.

Though some information on the health risks of existing AMTs and the ability of bacteria to resist them was found, the effect of prolonged exposure to AMT directly on skin and to

bacteria is not known, and questions remain about safety of the AMT related to wearer (i.e., toxicity, etc.) and effects on the skin microbiome. The information found, and noted in Chapter 4, include the potential for development of long-term microbial and fungal resistance to Ag<sup>+</sup> (silver), numerous reports of emerging resistance to triclosan and adverse hormonal effects for reproduction and development, and certain microorganisms have developing mechanisms for tolerating copper. On the other hand, PHMB has been shown to exhibit little toxicity or environmental impact and failure of bacteria to develop resistance to its killing action.

Though NSRDEC's MCAM modeling efforts were able to approximate costs of treating reportable conditions, the overall price of AMT items and the number of fielded AMT items were not identified in the literature survey. Informed decisions regarding return on investment for inclusion of antimicrobials cannot be without accurate, reliable AMT cost data to compare with medical treatment costs.

In addition to the potential of AMTs to mitigate medical and health and hygiene conditions experienced by Warfighters, there are contributing factors to these conditions that can be addressed by non-antimicrobial means. For example, as the Warfighter's body temperature increases, during physical activity associated with training and combat, the sweat soaks into whatever material is on the body and next to the skin, increasing potential for microbial growth on the material. Non-antimicrobial technologies, such as wicking, are available to help manage moisture from sweat, as well as other sources, to reduce this potential. Another way to reduce potential for microbial activity and growth is through better preparation for maintaining good hygiene practices in austere environments without the shower and laundry facilities typically found in garrison. Despite pre-deployment briefings, it seems that women, especially, remain ill-prepared for the hygiene challenges they face in theater [46]. Increased hygiene training and Warfighter preparation is suggested throughout several papers [41, 45, 46] cited in this report.

## CHAPTER 6: RECOMMENDATIONS FOR FUTURE EVALUATION AND TESTING

Regardless of the hygiene issue, the effective performance level for an AMT has not been systematically determined and warrants further investigation. Questions about the effects of long-term wear of AMTs remain and require additional investigation. Once a treatment performance has been identified, the effectiveness needs to be determined, and the treatment costs need to be weighed against cost savings of preventing the hygiene issue. A combination of testing under laboratory conditions and field evaluations are likely to be needed to fully determine AMT performance.

### *6.1 Non-Reportable Hygiene Issues*

- Conduct new and refined surveys to increase the number of responses that include on-site data collection. Conclusions from the Iranian military study [16] described in Section 3.1.3 could be used for future quantitative testing within military populations, at least among male Soldiers.
- Conduct field studies correlating detailed survey results with laboratory analysis to provide additional data on quality of life issues.

### *6.2 Reportable Hygiene Issues*

- Collect data related to demographics (e.g., age, occupation) as well as geographic location, to may better inform the potential need for AMTs and generation of treatment requirements.
- Determine which Soldiers (e.g., initial entry training or deployed) are having the highest number of medical encounters, and where most of these issues occur (i.e., training sites, field, Garrison, down range, etc.).
- Determine operational impact and lost time, including data from forward operating areas in theater. This data would be needed to fully understand the magnitude of these hygiene issues as they affect operational readiness.
- Focus on locations on the body in addition to the feet, such as the groin, for incorporation of AMTs to reduce fungal infections.

### *6.3 AMT Performance and Effectiveness*

- Conduct laboratory analysis under controlled conditions such as using artificial skin models. These models are currently used in place of animal studies to determine skin irritation caused by chemicals. However, there has not been much research regarding changes in the skin microbiome in these systems. NSRDEC is currently considering these methods to determine safety and the performance level needed for an effective AMT.
- Conduct environmentally controlled chamber tests and/or field tests can be completed using volunteer subjects who are in an established protocol where they undergo typical Soldier tasks and drills while being exposed to varied environmental conditions (heat,

cold, altitude). Skin swab collection and microbiome change analysis could be included as an additional research questions as part of the protocol.

- Conduct field evaluations to validate results from laboratory analysis. New test methodologies are needed to allow collection of larger amounts of data, in order to overcome the subject variability.
- Conduct a thorough analysis for secondary bacterial infections resulting from serious combat wounds and how AMTs are currently being used in tactical combat casualty care (gauze, bandages, etc.).
- Consider testing different POI techniques that include AMT materials such as gauze, bandages, or wipes.

#### *6.4 Safety Testing*

- Evaluate health hazards such as skin irritation due to the AMT as another factor in safety of the use and/or wearing the product.
- Test for potential resistance and changes in microbiota of the skin in particular regions of the body. Systematic longitudinal studies of the short- and long-term effects on skin microbiota would be required to fully understand the effect of AMT exposure. This could entail collection of skin swabs from volunteers wearing an AMT, followed by identification of the bacteria present by lab analysis. NSRDEC has discussed the possibility of inclusion in future studies conducted by organizations within the Army Medical Command such as USARIEM to collect samples for analysis. This would allow NSRDEC to generate a capability to potentially determine skin populations and a Warfighter-specific baseline microbiome. This baseline would set the stage to evaluate changes in skin population to prolonged exposure to AMTs.

#### *6.5 Return on Investment*

- Compare cost of hygiene issues with cost of medical treatment to make informed decisions regarding return on investment for inclusion of antimicrobials.

#### *6.6 Non-Antimicrobial Solutions*

- Explore incorporation of antimicrobial functionalities, such as moisture wicking technologies, in ACU textiles to potentially reduce sweat accumulation that leads to odor and infection.
- Increase education and training in areas of personal hygiene, especially before Warfighters deploy to austere environments where they will not have access to shower and laundry facilities they typically have in Garrison.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 16/012 in a series of reports approved for publication.

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## ACRONYMS

ACU – Army Combat Uniform  
AFHSC – Armed Forces Health Surveillance Center  
AMT – Antimicrobial Textile  
APFU – Army Physical Fitness Uniform  
CBRNE – Chemical, Biological, Radiological, Nuclear, Explosive  
CHG – Chlorhexidine Gluconate  
DA PAM – Department of the Army Pamphlet  
DLA – Defense Logistics Agency  
DNBI – Disease Non-Battle Injury  
FR – Flame Resistant  
FY – Fiscal Year  
HHA – Health Hazard Analysis  
MCAM – Medical Cost Avoidance Model  
MOS – Military Occupational Specialty  
MPC – Microban Products Company  
MRSA – *Methicillin Resistant Staphylococcus aureus*  
MSMR – Medical Surveillance Monthly Report  
MTF – Military Treatment Facility  
NSRDEC – Natick Soldier Research, Development and Engineering Center  
OEF – Operation Enduring Freedom  
OIF – Operation Iraqi Freedom  
PHC – Public Health Command  
PHMB - Poly hexamethyl biguanides  
POI – Point of Injury  
PS – Psychological Stress  
PUG – Protective Undergarment  
SCIE – Soldier Clothing and Individual Equipment  
SSTI – Skin and Soft Tissue Infection  
TAIHOD – Total Army Injury and Health Outcome Database  
USARIEM – US Army Research Institute of Environmental Medicine  
UTI – Urinary Tract Infection

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**APPENDIX A**  
**ANTIMICROBIAL PRODUCT USE SURVEY**  
**(Unpublished)**

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**Introduction**

Data were collected via website questionnaire, between November 2014 and March 2015, in order to explore the incidence of certain skin conditions and irritations among members of the Army and their current use of antimicrobial products. These skin conditions and irritations could potentially affect the Soldiers' well-being and their ability to execute their job duties. The antimicrobial products included items currently available for purchase which may be used both in and out of the field.

**Survey Methods**

The survey was developed by the Consumer Research Team (CRT) and made available on the Natick Research, Development and Engineering Center (NSRDEC) server in both computer access card (CAC)-enabled and non-CAC-enabled form. It was advertised through an article written by the NSRDEC Public Affairs Office. The article included links to the survey and was originally published on Army.mil. The article was picked up by different news outlets and was also promoted through social media. The survey was piloted with Soldiers at United States Army Research Institute of Environmental Medicine (USARIEM) in October 2014. The survey was publicly available on the website from November 2014 to March 2015. At the end of this period, 110 surveys had been completed.

Of the 110 Participants, 32% had never deployed. Forty-one percent had deployed on Operation Iraqi Freedom (OIF), and 36% had deployed on Operation Enduring Freedom (OEF). Twenty percent reported that they had deployed over the past year. Fifty-five percent were Enlisted, 32.7% were Officers, and 3.6% were Warrant Officers. Fifty-six percent had 1 to 10 years in service, and 79% were male. The average age was 35 years (range of 18 to 59 years). A variety of MOSs are represented.

**Data Analysis Methods**

Data were analyzed using SPSS v21. Descriptive statistics (mean, median, mode, percentiles, frequencies, percentages, and valid N, where applicable) were used to characterize the sample.

**Results**

Over half of the participants reported that they do NOT use antimicrobial sleeping bags (75%), boxers/underwear (75%), t- shirts (66%), and socks (59%). This is true across all of the suggested situations: off-duty, field, garrison, and physical training (PT).

When in the field, most (88%) said they use antimicrobial household cleansers (usually off-duty). Almost half (47.3%) reported that they use antimicrobial hand wash, usually off-duty or in garrison. Twenty-nine percent used antimicrobial socks, 27% used body wash, and 26% mouth rinse. The top reasons given for using antimicrobial products were to clean themselves while in the field or when deployed (71%) and to sanitize objects and surfaces (65%). Approximately half reported using them to control foot odor (51%) and/or body odor (47%). Thirty-percent used them to treat skin conditions.

The primary benefits they expected from antimicrobial products were cleanliness (78%) and health (68%). Over half expected the AMTs to control body odor (57%) or foot odor (55%). Twenty-eight percent reported that they never or almost never experience skin irritation or rashes while in the field, and an additional 26% reported that they seldom do.

The most prevalent conditions they reported having within the past year were athlete's foot (74%) followed by foot odor (63%).

Most of the participants stated that skin conditions (75%) and body odors (89%) did not negatively impact asleep. Twenty-two participants stated that skin conditions kept them from falling asleep, 14 said that skin conditions woke them up at night, and 11 said that the body odors of others had a negative impact on their sleep.

Most (84%) reported that skin conditions did not negatively impact their ability to do tasks. Four participants reported that their skin conditions had limited the duties they performed, and two reported that they missed time at work due to skin conditions.

Over one-third (37%) believed that it is very important to avoid body odor in the field, and only 10% believed that it is not at all important.

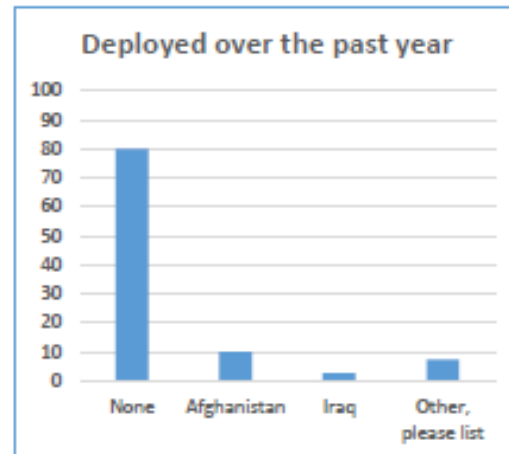
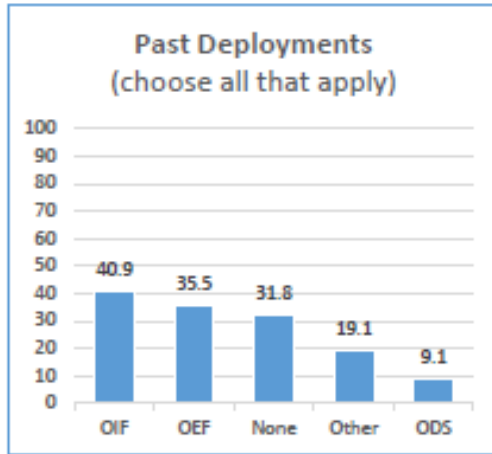
Sixty-four percent found it at least slightly difficult to avoid body odor while in the field. Most stated that they treated their athlete's foot (77%), foot odor (69%), jock itch (76%), and skin rashes (57%) by changing their clothing more often. Body odor was most often treated with over the counter remedies (64%), followed by changing clothes (51%). They reported that they rarely left those conditions untreated.

Approximately one-third reported that they change their clothes daily in the field, and 40% changed their clothes every 2 or 3 days. They reported that they change their undergarments more frequently than their other clothing and how often they change their uniforms depends on the weather or climate and on how soiled their uniforms are.

## Summary

Most of these Soldiers reported that they use antimicrobial products for cleanliness and health benefits. Most used them to clean themselves in the field or during deployments and to sanitize objects and other surfaces. Many also used them to control personal odors (body, foot). The majority had experienced athlete's foot within the past year, and many had foot odor. Some reported that their conditions had impacted their ability to complete their duties. Most had some difficulty avoiding developing body odor while in the field. Most responded to conditions (odor, itch, irritations) by changing their clothing more often. They reported that they most often changed their underwear.

The various survey questions and response summaries, beginning with the participants' demographic characteristics, are presented in the following graphs and tables:



Past Deployments: Other (write-in)
ALSO IN KUWAIT IN 2004
BOSNIA: OPERATION JOINT FORGE
BRIGHT STAR
EUROPE
HORN OF AFRICA
IRAQ: OPERATION NEW DAWN
JUST CAUSE
KOREA
KUWAIT: OPERATION ENDURING FREEDOM
NEW DAWN
NUMEROUS "SWAMP" FIELD EXERCISES
OCONUS X 10 DEPLOYMENTS
OEF - EGYPT
OEF NOT AFGHANISTAN
OEF, OUA
OND
OPERATION NOBEL EAGLE
OPERATION NOBLE EAGLE
PHILIPPINES: OPERATION ENDURING FREEDOM
SOMALIA, HAITI
TRAINING MISSIONS TO UKRAINE AND DOMINICAN REPUBLIC

Deployed over the past year: Other (write-in)
"Swamp" field exercises
10 OCONUS DEPLOYMENTS
Bosnia
Bright Star
Europe
Horn of Africa
Just Cause
Korea
Kuwait
OEF
OEF
OEF
OEF
OEF, OUA
OND
OND
OND
ONE
ONE
SOMALIA, HAITI
Ukraine, Dominican Republic

<b>Grade</b>	<b>Percent</b>
Blank	9.1
E1-E3	2.7
E4-E6	41.8
E7-E9	10.0
O1-O3	21.8
O4-O6	10.9
W1-W3	2.7
W4-W6	0.9

<b>Age</b>	<b>Percent</b>
<20	1.8
21-25	17.3
26-30	26.4
31-35	18.2
36-40	7.3
41-45	11.8
46-50	11.8
51-55	2.7
>55	2.7
Mean	34.51
Minimum	18
Maximum	59
SD	9.75

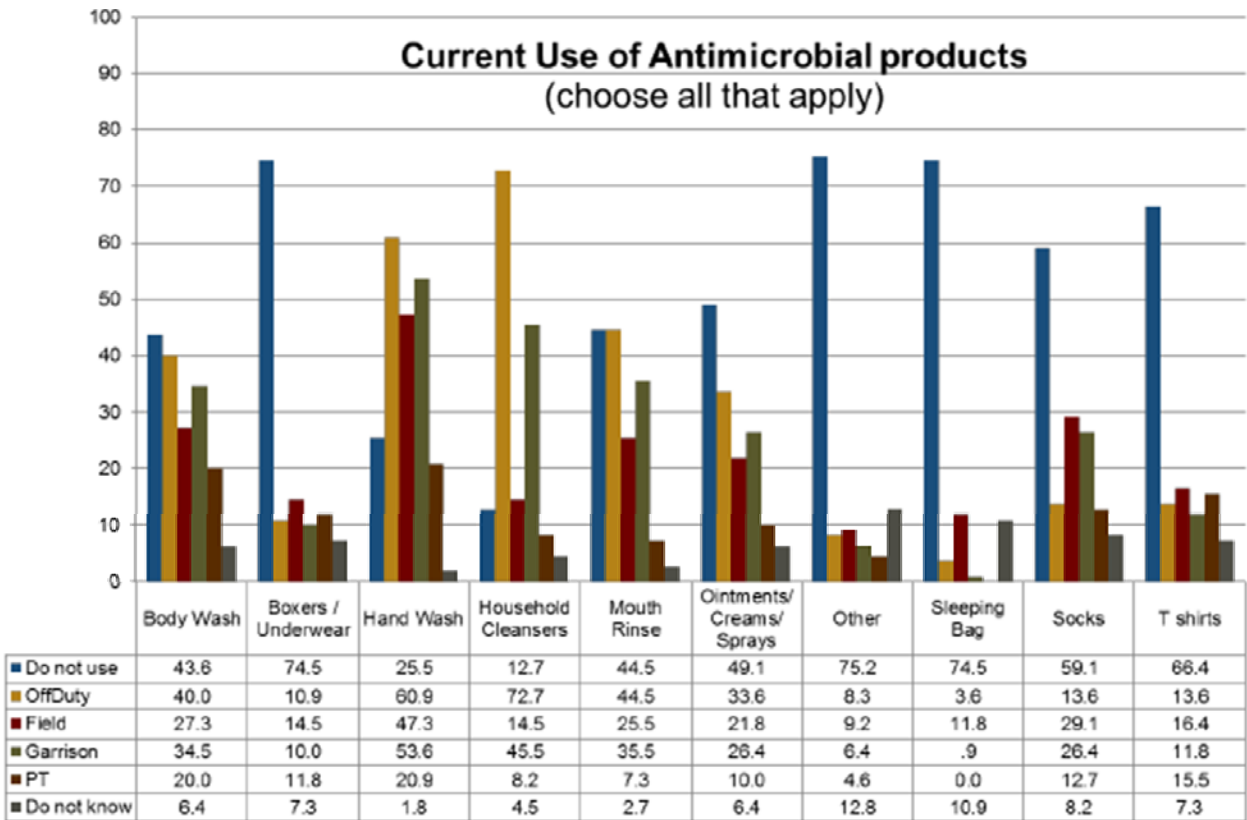


<b>Military Occupational Specialty</b>	<b>Percent</b>
11 Infantry	15.5
68 Medical	15.5
Blank	9.1
31 Military Police	5.5
35 Military Intelligence	5.5
13 Field Artillery	4.5
88 Transportation	4.5
12 Corps of Engineers	3.6
25 Communications and Information Systems Operation	3.6
92 Supply and Services	3.6
14 Air Defense Artillery	2.7
15 Aviation	2.7
67 Medical Service	2.7
90 Logistics	2.7
65 Army Medical Specialist	1.8
91 Ordnance	1.8
<b>Other: (n = 1)</b>	
12 Engineer	
19 Armor	
27 Judge Advocate General	
36 Financial Management	
37 Psychological Operations	
38 Civil Affairs	
51 Acquisition, Logistics and Technology	
56 Chaplain	
60 Medical	
61 Medical	
62 Medical	
66 Army Nurse	
74 Chemical, Biological, Radiological and Nuclear (CBRN)	
79 Recruitment and Reenlistment	
91 Mechanical Maintenance	
OTHER	

<b>Years in Service</b>	<b>Percent</b>
<1	1.9
1-10	56.1
11-20	20.6
21-30	20.6
>30	0.9

<b>Lived over the past year</b>	<b>Percent</b>
Massachusetts	16.4
Texas	7.3
Georgia	5.5
Virginia	4.5
North Carolina	4.5
New York	4.5
Missouri	3.6
Hawaii	3.6
Florida	3.6
Wisconsin	2.7
Pennsylvania	2.7
Maryland	2.7
Kentucky	2.7
Germany	2.7
Colorado	2.7
Alaska	2.7
Afghanistan	2.7
Washington	1.8
South Korea	1.8
Ohio	1.8
New Jersey	1.8
Minnesota	1.8
Michigan	1.8
Louisiana	1.8
California	1.8

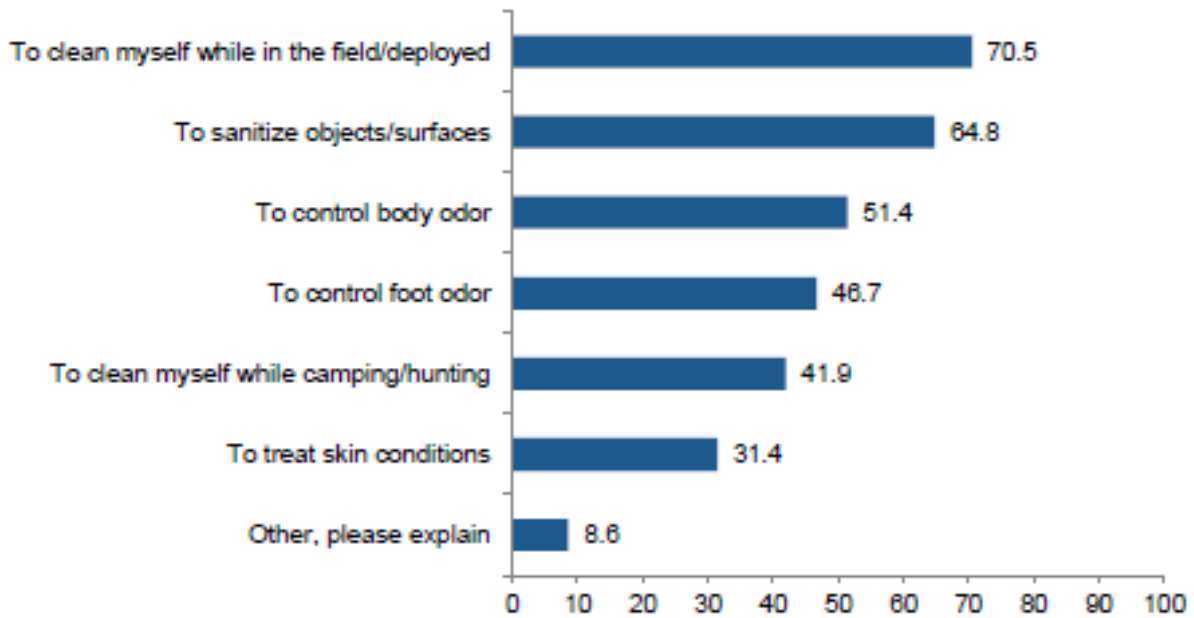
<b>Lived over the past year</b>	<b>Percent</b>
Washington, DC	.9
Utah	.9
Tennessee	.9
OTHER	.9
Oregon	.9
Montana	.9
Kansas	.9
Delaware	.9
Connecticut	.9
Arizona	.9
Alabama	.9



**Current use of antimicrobial products: Other (write-in)**

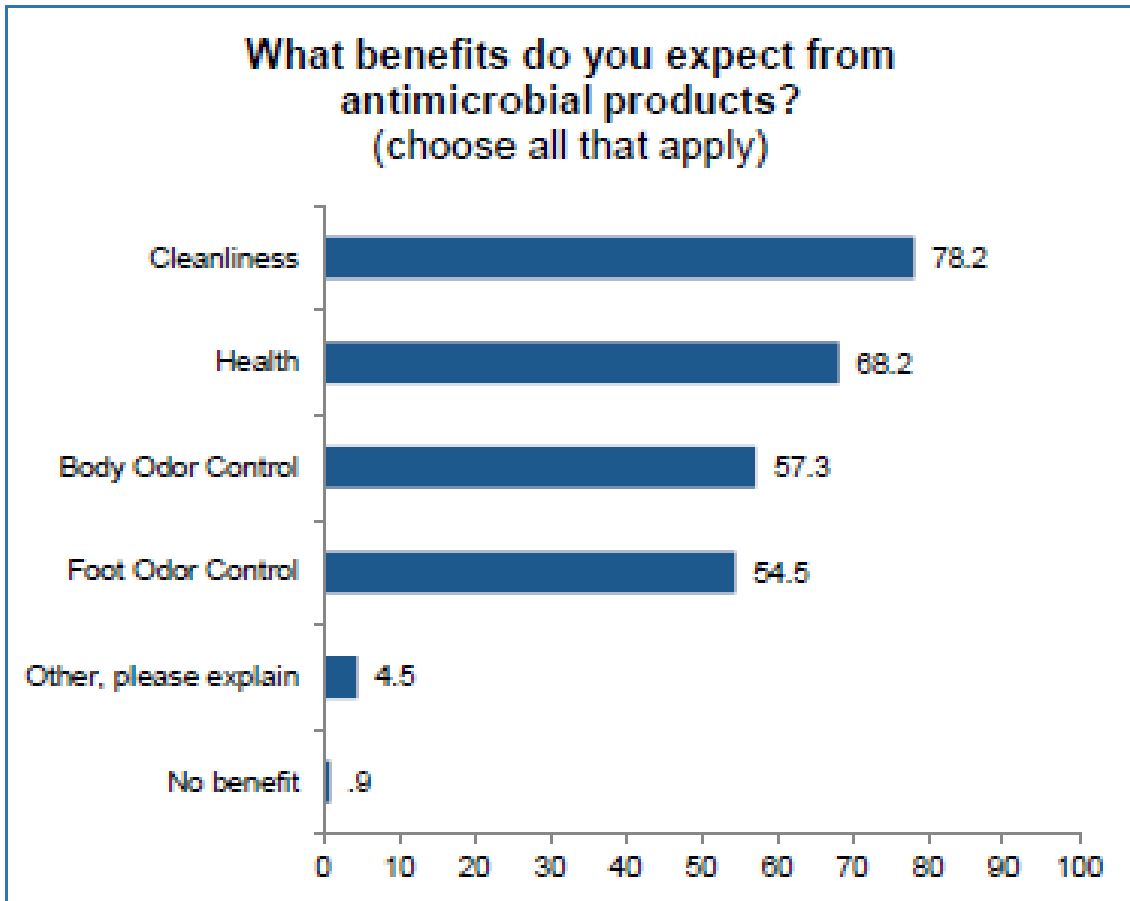
body glide. it's an anti-chafe product like a deodorant stick.
dial soap, and dial lotion
hat
Hiking shorts & boot in-soles
Household cleaning products/ Arid XXL Foot Spray
I really never pay much attention to what is microbial or not.
I use Salicylic Acid and Sulfur soap when I shower. It works for me.
Long Sleeve T-shirt
powders
Wipes
Wool socks/sweaters are naturally antimicrobial; that's one of the many reasons I wear them in the field and all the time

**What do you use these antimicrobial products for?  
(choose all that apply)**



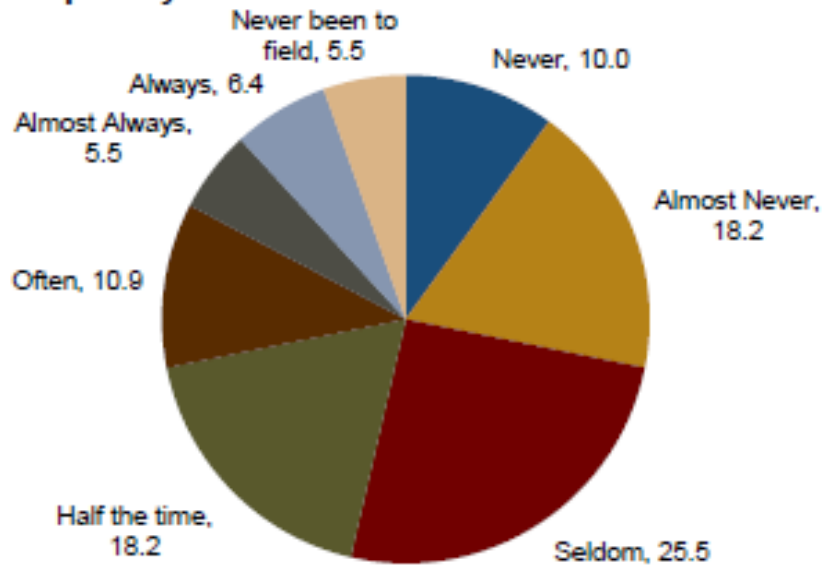
**Use of antimicrobial products: Other.**

All issued equipment if used properly works just fine. Fresh green Army socks are the best friend of any lightfighter
at home, mouthwash
Because since Desert Storm, I aquired a body odor that the doctors say is coming from within and currently taking medicine, but it seems to get worse every year and I have been trying lots of herbal medicine also but nothing seems to help
clean hands
Prevent bacteria and odor
PT shirt, standard issue
to clean myself in general
to keep myself clean
To make my socks last longer

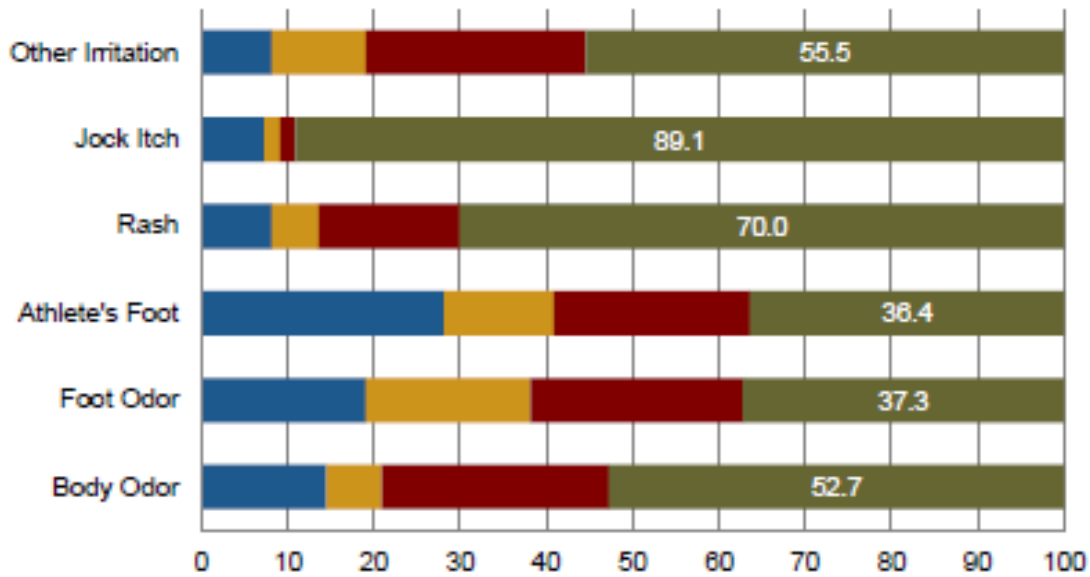


What benefits do you expect from antimicrobial products? Other, write-in
Absence or quick suppression of "jock itch" or foot ick
From clothing (mainly PT) I have to wash it less, and use it more times per week
hold up better when washed with just water and no soap
kill unwanted bacteria
most anti-microbial products don't work for me.

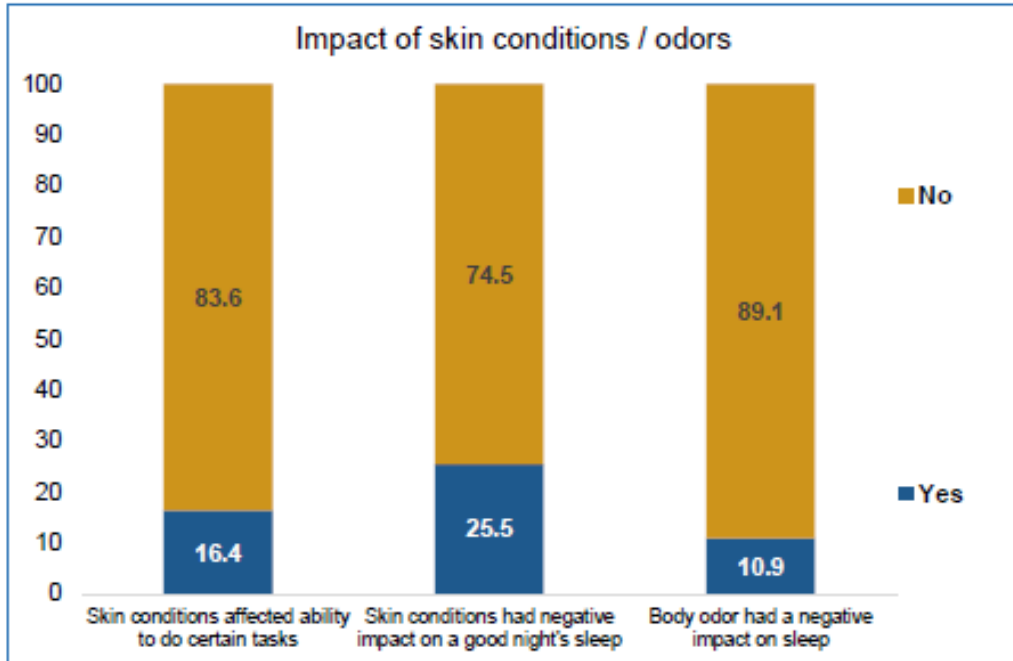
### Frequency of skin irritation/ rashes in the field.



### Most recent occurrence



	Body Odor	Foot Odor	Athlete's Foot	Rash	Jock Itch	Other Irritation
■ past week	14.5	19.1	28.2	8.2	7.3	8.2
■ past month	6.4	19.1	12.7	5.5	1.8	10.9
■ past year	26.4	24.5	22.7	16.4	1.8	25.5
■ N/A	52.7	37.3	36.4	70.0	89.1	55.5



**Skin conditions affected ability to do certain tasks (choose all that apply):**

- Limited Duties (4)
- Missed time at work (2)

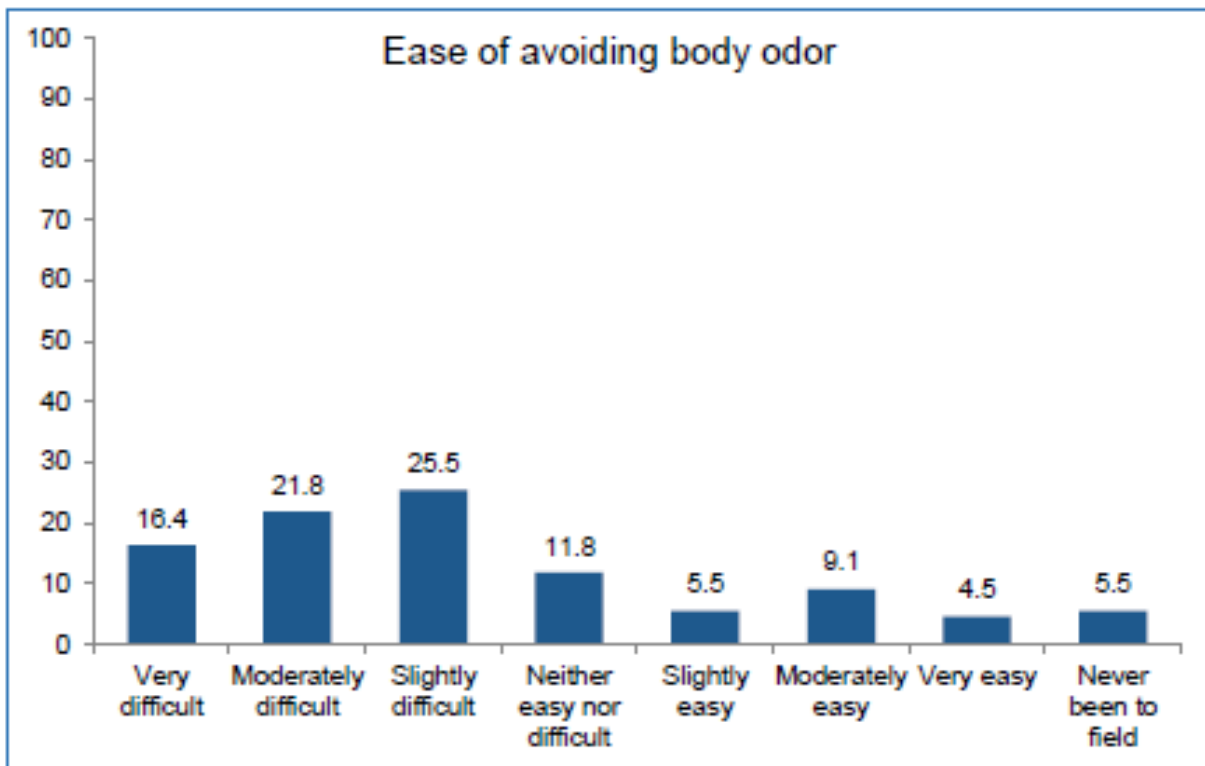
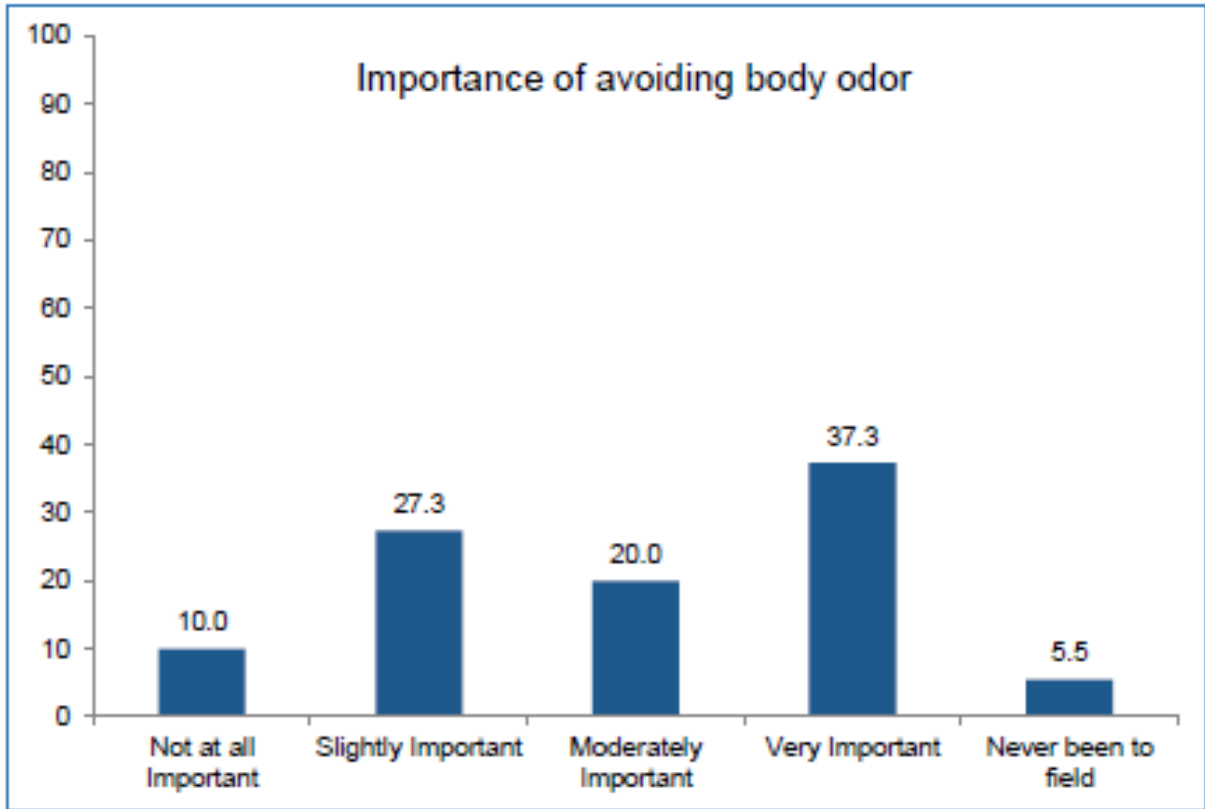
**Skin conditions interfered with getting a good night's sleep (choose all that apply):**

- Kept from falling asleep (22)
- Woke up at night (14)
- "when I'm sleeping sometimes the bumps start to puss and bleed, and it irritates" (1)

**Body odor had a negative impact on sleep (choose all that apply):**

- The body odor of others (11)
- Own body odor (3)

"I have seen many doctors and they always say that it my digestive system, and I get medicine but since I have had this since desert storm nothing seems to help" (1)





100

90

80

70

60

50

40

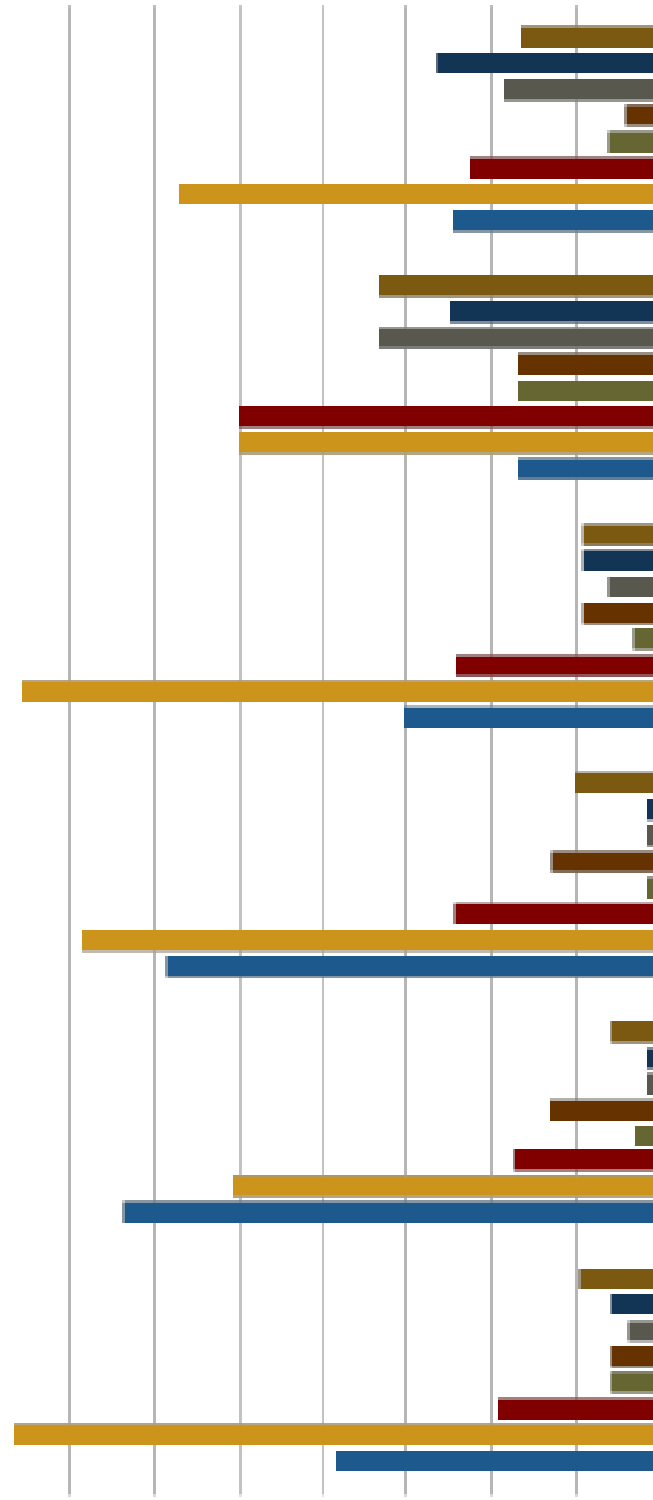
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20

10

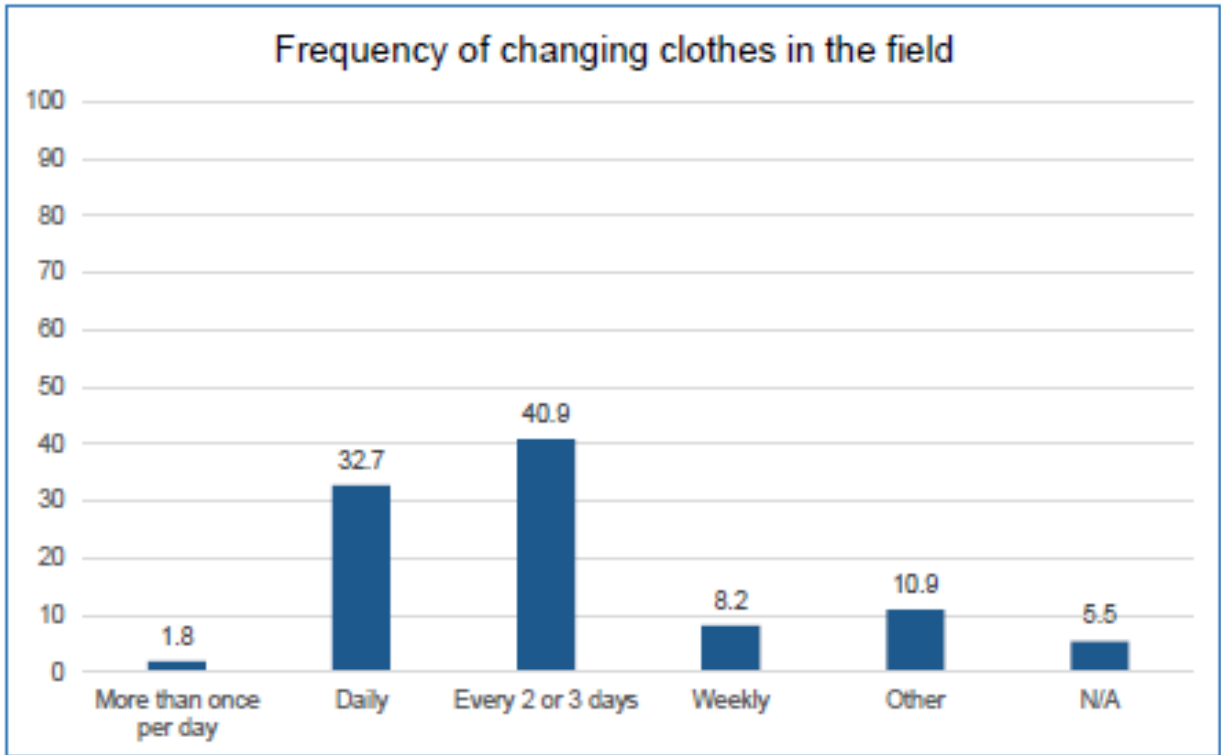
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**Remedies by Condition**  
(choose all that apply)



	Athlete's Foot	Body Odor	Foot Odor	Jock Itch	Other	Skin Rash
Over the counter	36.5	53.6	58.6	30.3	16.7	24.5
Changed clothing	76.9	50.7	66.6	75.8	50.0	57.1
Home Remedies	19.2	17.4	24.3	24.2	50.0	22.4
Left untreated	5.8	2.9	1.4	3.0	16.7	6.1
Other	5.8	13.0	12.9	9.1	16.7	4.1
Prescription	3.8	1.4	1.4	6.1	33.3	18.4
Medical: MD	5.8	1.4	1.4	9.1	25.0	26.5
Medical: medic	9.6	5.8	10.0	9.1	33.3	16.3

Athlete's Foot	Gold Bond medicated foot powder for foot maintenance and even jock itch. Soaking feet in pure vinegar for 2-4 mins seems to help greatly on all foot issues and include nail fungus- then shower.
	Shower
	tried to not walk around barefoot as often
Body Odor	bathed everyday
	changed to non-cotton socks, under armor brand.
	Different Washing Machine cleaners / soap
	Gold Bond medicated foot powder for foot maintenance and even jock itch.
	Gold Bond medicated powder
	hand sanitizer
	put on clean socks
	washed them after getting out of the field
	Washed/froze boots to kill bacteria
Foot Odor	bathed everyday
	cleaned my body when I got out of the field
	Different Washing Machine cleaners / soap
	More frequent showering
	shower
	Shower
	showered more
	showered more often
	took shower and used deodorant, BO after workouts
Jock Itch	Tinactin spray powder, followed by Gold Bond medicated powder
	Vaseline/ petroleum jelly
	washed more often
Other	Freeze-Away. Did not work.
	Sucked it up and drove on like a real soldier should. Under normal conditions it would not have happened but it was Ranger school so RTFU
Skin Rash	Doxycycline. Worked well.
	Tinactin spray powder, followed by Gold Bond medicated powder



**If "Other" please explain**

being in fort polk I go, typically, 3-4 days without changing my clothes. I might change my under clothing more often if it's really hot and humid

change uderclothes daily, rest 1-2 times a week.

Depending on the length of mission, but socks changed at least daily.

I change my underwear and socks everyday, but wear my uniform for a week or more before changing it.

It is difficult to change clothes in the field, I change undergarments (spandex/slider shorts, and socks) on a daily basis; under shirt maybe once a week; ASUs maybe once every two weeks.

socks and undershirt is changed daily if possible but the uniform is weekly or as needed.

socks, underwear, t-shirt change daily or atleast let dry for a day. Uniform 3-7 days depending how soild or dirty they are.

under garments are changed daily, ACUs are changed once or twice a week

undergarments (socks, underwear, bra) and t-shirts changed daily; uniform changed every 2-4 days depending on how dirty they are

Undershirt/socks/underwear get changed daily; ACU tops and bottoms can easily go a week during the winter but are changed daily during the summer due to sweating

Uniform, once a week unless completely soiled. Daily change of undergarments.

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## APPENDIX B

### REPORTABLE MEDICAL AND HEALTH CONDITIONS INVESTIGATED

All of the conditions investigated in the groups discussed in Sections 3.2, 3.3, and 3.4 are listed, by International Classification of Diseases (ICD) - 9 code, in Sections B.1, B.2, and B.3, respectively.

#### *B.1 MCAM Bacterial SSTI Analysis:*

##### Carbuncle/Furuncle of:

- 680.1 Face
- 680.2 Neck
- 680.3 Trunk
- 680.4 Arm
- 680.5 Hand
- 680.6 Buttock
- 680.7 Leg
- 680.8 Foot
- 680.9 Other specified site
- 680.10 Unspecified site

##### Cellulitis and abscess of:

- 681.0 Finger and toe
- 682.1 Face
- 682.2 Neck
- 682.3 Trunk
- 682.4 Arm
- 682.5 Hand
- 682.6 Buttock
- 682.7 Leg
- 682.8 Foot
- 682.9 Other specified site
- 682.10 Unspecified site

686.0 Other local infections of skin and subcutaneous tissue

691.8 Other Atopic dermatitis and related conditions

#### *B.2 MCAM Fungal Infection Analysis*

##### Dermatophytosis of:

- 110.1 Scalp and Beard
- 110.2 Nail
- 110.3 Hand
- 110.4 Groin and Perianal area
- 110.5 Foot

- 100.5 The Body
- 110.6 Deep seated Dermatophytosis
- 110.8 Other Specified sites
- 110.9 Unspecified site
  
- 111.1 Pityriasis Versicolor
- 111.2 Tinea Nigra
- 111.3 Tinea Blanca
- 111.4 Black Piedra
- 111.8 Other Specified Dermatomycoses
- 111.9 Dermatomycosis Unspecified
- 117.9 Other and Unspecified Mycoses

*B.3 MCAM Bacterial Female Health (Genitourinary and Gynecological) Condition Analyses*

- 590.1 Acute pyelonephritis without lesion of renal medullary necrosis
- 590.11 Acute pyelonephritis with lesion of renal medullary necrosis
  
- 595.0 Acute Cystitis
  
- 599.0 Urinary Tract infection – site not specified
- 599.84 Other specified disorders of Urethra
- 599.89 Other specified disorders of Urinary Tract
- 599.9 Unspecified disorder of Urethra and Urinary Tract
  
- 112.1 Candidiasis of Vulva and Vagina
- 112.2 Candidiasis of other Urogenital Sites
  
- 616.10 Vaginitis and Vulvovaginitis unspecified
- 616.11 Vaginitis and Vulvovaginitis in diseases classified elsewhere
- 616.5 Ulceration of Vulva
- 616.89 Other inflammatory disease of Cervix, Vagina and Vulva
- 616.9 Unspecified inflammatory disease of Cervix, Vagina and Vulva