

# Chapter 3

## The Burden of Deployment-Related Non-battle Injuries (NBIs) and Their Impact on the Musculoskeletal System

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### List of Acronyms

BCT	Brigade Combat Team
DNBI	Disease and Non-battle Injury
FORECAS	Medical Casualty Forecasting System Software
NBI	Non-battle Injury
OIF	Operation Iraqi Freedom
OEF	Operation Enduring Freedom
ODS	Operation Desert Storm/Shield
TRAC <sup>2</sup> ES	US Transportation Command's Regulating and Command and Control Evacuation System
TRANSCOM	US Transportation Command
WWI	World War I
WWII	World War II

### Introduction

In the previous chapter, Schoenfeld and Belmont discuss the burden of traumatic combat-related injuries in the military and note that the majority of these injuries impact the musculoskeletal system. Despite the large volume of news reports focused on battle-related injuries resulting from the recent conflicts in Iraq and Afghanistan, these injuries are only the tip of the iceberg. Soldiers have traditionally been two to five times as likely to be hospitalized or medically evacuated from combat zones due to disease and non-battle injuries (DNBIs) than for injuries directly related to combat [1–9], and trends in the distribution of DNBIs have significantly shifted

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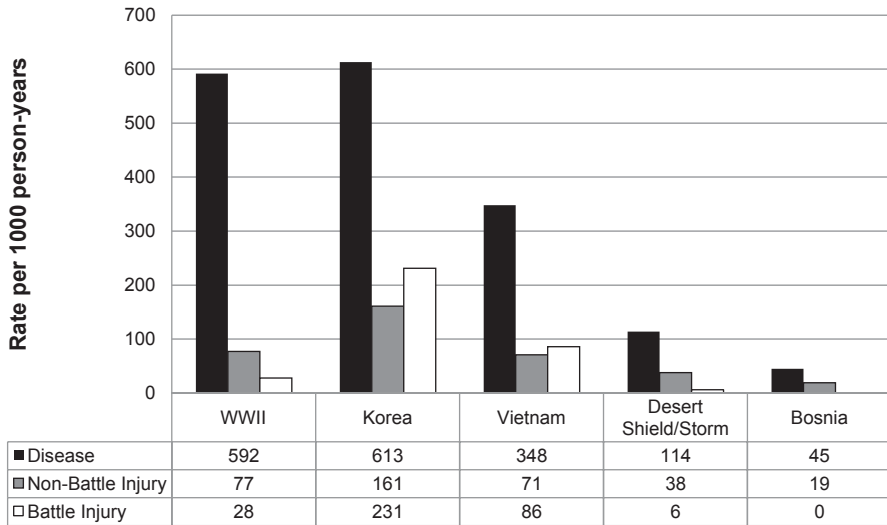
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over the last century [3, 6, 10]. Understanding the factors associated with the distribution and impact of DNBI is critical information for effective logistical planning and providing adequate medical support during combat operations [7]. Understanding the burden of DNBI is also important in planning for the subsequent care that will be needed following deployment [11, 12]. The purpose of this chapter is to provide an overview of the burden that non-battle injuries (NBIs) pose during military operations and deployments. We will discuss historical trends in the distribution of NBIs and also review the most recent data on NBIs from the Gulf War and the conflicts in Iraq and Afghanistan. Finally, we will discuss the prevention of NBIs during military deployments.

## The Historical Impact of Disease and Non-battle Injury

Historically, DNBI in the military have resulted in more deaths during deployments when compared to injuries sustained in combat; however, when morbidity is examined in addition to mortality, it is clear that DNBI result in far more combat ineffectiveness than casualties due to battle [13]. Holland and Long [4] reported that DNBI during World War II (WWII) accounted for 82.8% of all lost duty days when compared to battle injuries. They also noted that the large majority of time loss was due to disease (82.7%) in comparison to NBIs (17.3%) when only lost duty days due to DNBI were examined [4]. Though disease accounted for the majority of lost duty days, NBIs resulted in nearly four times as many deaths when compared to disease during WWII [4]. Nearly one third of these deaths were due to injuries sustained in motor vehicle accidents.

Rates of hospitalization for disease, NBIs, and battle injuries among US Army personnel during deployments from WWII through operations in Bosnia are presented in Fig. 3.1 [6]. These data suggest that hospitalizations during deployment that are due to disease have decreased substantially over time, while the proportion of hospitalizations for NBIs has increased. Similar results were observed when the distribution of casualties in the Navy and Marine Corps was examined from World War I (WWI) through the Vietnam conflict [3]. During WWI, sailors and marines were 16 times more likely to be admitted to the hospital for DNBI than for battle wounds; however, admissions for traumatic injuries were only slightly higher when compared to prewar data. During WWII, sailors and marines were 88 times more likely to be hospitalized during deployment for DNBI than for combat injuries, and admissions for NBIs increased 28% in comparison to prewar data. Similar results were observed during the Korean War with 84 admissions for DNBI for every combat injury admission. Though the ratio of hospitalizations due to DNBI compared to battle injuries fell to 17:1 during the Vietnam conflict, the lowest since WWI, for the first time acute traumatic injury emerged as the top reason for DNBI admission [3]. Among marines serving in Vietnam, NBIs were the leading cause of hospitalization with a rate of 116.9/1000 person-years, which was 2.5 times higher when compared to marines not serving in theater [7]. This was primarily attributed



**Fig. 3.1** US Army hospitalization rates for disease and non-battle injuries during deployment compared to battle injuries from World War II (*WWII*) through Bosnia. (Adapted from Jones et al. [6])

to an increase in combat wounds combined with a decrease in admissions due to disease [3].

While our ability to control and treat infectious diseases has led to substantial reductions in the number of troops that require hospitalization and medical evacuation during combat operations, the burden of NBI has remained relatively constant [3, 14]. Military service members were much more likely to be hospitalized for infectious diseases during deployment in the early half of the last century through the conflict in Vietnam [3, 6]; however, injuries and musculoskeletal conditions accounted for a much larger proportion of DNBI casualties during Operation Desert Shield/Storm (ODS), Operation Iraqi Freedom (OIF), and Operation Enduring Freedom (OEF) [2, 6, 14, 15]. Hauret et al. [2] reported that 83% of medical evacuations from OIF and OEF were due to DNBIs and that 34.8% of these were due to NBIs compared with 48.2% that were due to disease. When only examining medical evacuations due to DNBIs, 58% were due to disease while the remaining 42% were due to NBIs, with the majority of these injuries impacting the musculoskeletal system.

Overall, these data suggest that DNBIs have historically impacted force readiness to a much larger degree than injuries sustained in combat and that DNBIs consistently account for 75–85% of all hospitalizations and medical evacuations during military operations. This has remained relatively persistent since WWI. They also indicate that over 80% of DNBIs were due to diseases in the early half of the last century when compared to NBIs; however, according to recent data, NBIs resulted in nearly half of all DNBIs medical evacuations during OEF and OIF and over half of all hospital admissions during ODS. As a result, a much larger proportion of

soldiers are being hospitalized and medically evacuated from deployment during contemporary military operations due to NBIs than has been reported in the past.

## **Non-battle Injuries During Contemporary Military Operations**

In the previous section, we discussed the historical impact of DNIBs during military deployments and how trends related to the impact of disease and NBIs have shifted during recent military conflicts. During contemporary military operations, we have observed that musculoskeletal injuries and conditions have emerged as leading causes for hospitalization and medical evacuation due to DNIBs [2, 14, 15]. An increased emphasis on injury surveillance during and following recent military operations and deployments [12, 14] has resulted in a much clearer picture of the total burden that these NBIs place on military service members and the Military Health System and Veterans Administration as well as the impact they have on military readiness. This section will review the recent literature related to NBI, including data from ODS and other military and humanitarian operations through OIF and OEF.

### **Operation Desert Storm/Shield and Military Deployments in the Early 1990s**

Writer et al. [14] reported on NBI casualties within the US Army during ODS and other military and humanitarian deployments during the early 1990s. Improved medical surveillance made these data available sooner than they had been during previous military operations; however, in the case of ODS they were still not available for analysis until 3 years following the operation. NBIs were the leading cause of death during ODS with 183 fatalities compared to only 147 due to combat injuries [14, 16]. This may have been due, in part, to the long buildup phase, and relatively short combat phase, during the first Gulf War. During ODS, NBIs and musculoskeletal injuries and conditions were the leading causes of hospitalization, accounting for 25 and 13% of all hospitalizations, respectively. The most common types of NBIs treated during ODS were primarily acute orthopedic injuries, including fractures, sprains and strains, and joint dislocations among the top four types of injuries treated. The three most common causes of NBI hospitalization during ODS were motor vehicle accidents (4.0/1000 person-years), falls (4.0/1000 person-years), and sports and athletics (3.6/1000 person-years), which accounted for 56% of all NBI hospitalizations [14]. The authors also reported that injury was also among the leading causes for hospitalization and outpatient visits during deployments to Somalia and Haiti and military exercises in Egypt, where 70% of all cases

were sprains and strains with three quarters being acute injuries and the remaining one quarter being due to chronic conditions or aggravation of a prior injury [14]. Overall, NBIs primarily affecting the musculoskeletal system were a leading cause of both inpatient and outpatient visits during all of these operations.

## Operations Enduring Freedom and Iraqi Freedom

In contrast to prior military operations, a number of publications documenting the impact of DNBIs during OIF and OEF across the various branches of military service have appeared in the literature [1, 2, 8–12, 15, 17–19]. Additional advances to injury and illness surveillance infrastructure [17, 18] as well as individual efforts by military medical providers have provided more robust data on DNBIs than have been available for previous military deployments. These data have also been available sooner, which has enabled early and ongoing assessments of the impact of NBIs during OIF and OEF. This has also been possible due to the long duration of sustained military operations in Iraq and Afghanistan compared to previous military engagements.

Several studies have examined the frequency and causes of NBIs significant enough to require medical evacuation from Iraq and Afghanistan [9–11, 15, 17, 19]. Most of these studies have relied on data from the US Transportation Command's (TRANSCOM) Regulating and Command and Control Evacuation System (TRAC<sup>2</sup>ES), which is used for tracking aeromedical evacuations from theater [17]. The TRAC<sup>2</sup>ES was developed as an administrative tool to track the movement of military service members requiring medical air evacuation [18]. The system integrates logistical and transportation information as well as clinical decision-support elements in support of the Department of Defense's medical transportation mission [17]. Data elements from TRAC<sup>2</sup>ES are now routinely provided for medical surveillance purposes to the Armed Forces Health Surveillance Center via the Assistant Secretary of Defense for Health Affairs, and these data are integrated with data from the Defense Medical Surveillance System [15, 17].

The potential utility of TRAC<sup>2</sup>ES for medical surveillance among troops deployed in support of OEF and OIF was initially described by Hauret et al. in 2004 [18]. Their preliminary analysis examined medical evacuation data from TRAC<sup>2</sup>ES for all military personnel that were evacuated from the US Central Command Area of Responsibility (OEF and OIF) between 1 January 2003 and 22 November 2003. The majority of service members medically evacuated during the study period were less than 30 years of age, were in the junior enlisted ranks (E1–E4), and were deployed in support of OIF. Furthermore, nearly half of all medical evacuations during the study period were due to injuries, and over 75% of those injuries were classified as NBIs. Injuries and musculoskeletal conditions were the leading diagnoses requiring medical evacuation from theater during the study period, accounting for nearly 40% of all evacuations. In a 10% random sample ( $n=954$ ), the ICD-9-CM codes and patient history text fields in TRAC<sup>2</sup>ES were reviewed to validate the data in the

system and determine causes of injury codes. Overall, there was a high degree of consistency between the data in TRAC<sup>2</sup>ES and the results from the random sample that was reviewed. Similar to data reported for ODS, the most common causes of NBIs during the study period were (1) falls, (2) motor vehicle accidents, (3) sports and physical training, (4) crushing and blunt trauma, and (5) lifting, pushing, and/or pulling.

A more detailed analysis of medical evacuation data from TRAC<sup>2</sup>ES among military service members deployed in support of OIF between 1 January 2003 and 31 December 2003, combined with data elements from the Defense Medical Surveillance System, was subsequently published [17]. The results of this study essentially confirmed and extended the preliminary findings reported by Hauret et al. [18]. Nearly 75% of all medical evacuations from OIF during 2003 occurred during the second and third quarters of the year [17]. The most common reason for medical evacuation was DNBI, which was responsible for 86.5% of all evacuations from OIF during the study period. Nearly all medical evacuations (94%) during the study period were classified as routine, suggesting that the patient could safely be evacuated within 72 h of their initial medical encounter [17]. The remaining medical evacuations were classified as priority (4.6%) requiring transportation with 24 h with minimal delays, or urgent (1.4%) requiring immediate transport to save life or limb or to prevent serious complications. The leading diagnoses requiring medical evacuation during the study period were injuries and musculoskeletal conditions (40.8%), similar to the findings reported by Hauret et al. [18] In addition, orthopedic surgical care was the leading specialty care category required to treat the medical conditions of evacuees, when the need for specialty care was evaluated among those requiring medical evacuation from OIF during the study period.

Another study examined combat and DNBI casualties among US Army and marine corps personnel that were significant enough to require hospitalization during the Major Combat Phase, and the subsequent Support and Stability Phase, of OIF [9]. Similar to previous studies, the authors utilized medical evacuation and hospitalization data from TRAC<sup>2</sup>ES for the Major Combat Phase of OIF (March 21–April 30, 2003); however, they relied on data from the Joint Patient Tracking Application to document casualties during the subsequent Support and Stability Phase of OIF (March 1, 2004–April 30, 2005). While both systems are part of the Theater Medical Information Program-Joint, it is unclear whether data from these two administrative systems are comparable and equally effective for surveillance purposes. Regardless, the study reported some interesting findings. Notably, the phase of OIF was significantly associated with the type of casualties requiring hospitalization during the study period. Specifically, a significantly greater proportion of DNBI casualties were reported during the Support and Stability Phase of OIF (76.4%) when compared to the Major Combat Phase (63.4%). Overall, DNBI's accounted for 75% of all hospitalizations during both phases combined. As reported previously in other studies, the majority of casualties were males (90%) and serving in the Army (83.5%); however, those serving in the Marine Corps were more likely to sustain combat-related injuries. Among the DNBI's reported, injury and muscu-

loskeletal conditions were again reported as the leading reasons for hospitalization regardless of phase, and the distributions were similar among males and females.

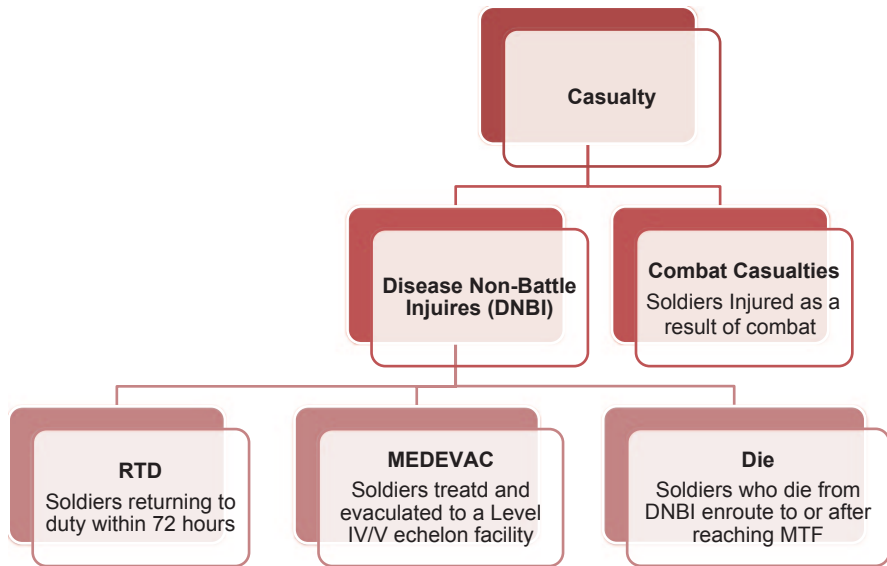
In a series of follow-up studies [2, 3, 19] to their preliminary work [18], Hauret and colleagues examined the distribution and causes of NBIs significant enough to require medical evacuation from OEF and OIF. They conducted an analysis of medical evacuation data from TRAC<sup>2</sup>ES among military service members deployed in support of OIF between March 2003 and December 2006 and among service members deployed in support of OEF between October 2001 and December 2006 [2]. They also supplemented the air evacuation data with information obtained from accident investigations and casualty reports. Overall, they reported that 83% of medical evacuations from OIF and OEF during the study period were due to DNBIs and that 34.8% of these were due to NBIs compared with 48.2% that were due to disease. When only examining medical evacuations due to DNBIs, 58% were due to disease while the remaining 42% were due to NBIs, with the majority of these injuries impacting the musculoskeletal system. Similar to previous reports, over 90% of soldiers evacuated for NBIs were males, over half were less than 30 years of age, and most were in the junior-enlisted (OIF) and senior-enlisted (OEF) ranks. The top five diagnostic categories for injuries significant enough to require medical evacuation were (1) fractures, (2) inflammation and pain due to overuse, (3) joint dislocations, (4) sprains and strains, and (5) internal joint derangement [2]. Fractures, joint dislocations, and sprains and strains accounted for over 71% of all NBIs requiring medical evacuation from OIF and OEF. Notably, all of these diagnoses represent orthopedic injuries affecting the musculoskeletal system. The top five anatomic locations of NBIs significant enough to require medical evacuation from OIF or OEF included the low back and upper and lower extremities, specifically the (1) back, (2) knee, (3) wrist and hand, (4) foot and ankle, and (5) shoulder [2]. Overall, 75% of all NBIs requiring medical evacuation impacted the upper or lower extremities. Approximately 53% of all NBIs were documented as acute traumatic injuries, and 28% were classified as injury-related musculoskeletal conditions. By and large, more than 80% of all NBIs requiring medical evacuation from theater fell into these two major diagnostic subgroups. The four leading categories for cause of injury requiring medical evacuation for NBIs from OIF and OEF in rank order included: (1) sports and physical training, (2) falls and/or jumps, (3) motor-vehicle-related accidents, and (4) crushing or blunt trauma. It is noteworthy that sports and physical-training-related injuries were the leading causes of medical evacuation for NBIs from both Iraq and Afghanistan during the study period. A follow-up study reported that sports and physical-training-related injuries remained the leading cause of NBIs significant enough to require medical evacuation through 2011 in Iraq and 2012 in Afghanistan [19]. When sports and physical-training-related injuries were examined in this follow-up study, basketball (24%), physical training (19%), weightlifting (17%), and American football (16%) resulted in the highest proportion of injuries in this category. The most common types of sports-related NBIs requiring medical evacuation were sprains and strains (29%), fractures (22%), and joint dislocations (16%) [19]. Finally, the most commonly affected body parts were the knee (26%), ankle and foot (15%), hand and wrist (14%), and shoulder (14%)

[19]. Another follow-up study [1] reporting on medical evacuation data from Iraq between 2003 through 2011 confirmed and extended many of the findings initially reported by Hauret et al. [2].

Cohen et al. [10] examined medical evacuation data from OIF and OEF and factors associated with return to duty within 2 weeks between January 2004 and December 2007. The authors reviewed medical evacuation data contained in a database maintained by the Deployed Warrior Medical Management Center in Landstuhl, Germany. Similar to previous studies, approximately 75% of all medical evacuations were due to DNBIs. In each of the 4 years examined during the study period, NBIs affecting the musculoskeletal system were the leading causes for medical evacuation. Approximately 33% of those medically evacuated from OEF returned to their unit in Afghanistan within 2 weeks of evacuation, and only 21% of those medically evacuated from OIF returned to their unit within 2 weeks in Iraq [4]. The majority of those returning to duty were medically evacuated for DNBIs, with only 4% of those sustaining combat injuries returning to duty within 2 weeks. Musculoskeletal injuries and injury-related musculoskeletal conditions were among the leading diagnostic categories that prevented military service members with NBIs from returning to duty within 2 weeks of medical evacuation. Specifically, 87% of those with musculoskeletal injuries or conditions and 86% of those with back injuries or pain were unable to return to duty following medical evacuation for NBIs. Overall, military service members who were evacuated due to a NBI that affected the musculoskeletal system were 54% less likely to return to duty, and those evacuated with back injuries or pain were 59% less likely to return to duty within 2 weeks of evacuation in multivariable statistical models [10]. The authors noted that the most common NBIs requiring medical evacuation from theater were also the same injuries that were less likely to permit a service member to return to duty following evacuation (e.g., musculoskeletal injuries and conditions, back injuries, and pain). This noteworthy finding has important implications for injury prevention and force health protection among deployed troops.

Another group of authors examined DNBIs sustained by a single US Army Brigade Combat Team (BCT) during a 15 month deployment to Iraq in support of the counterinsurgency campaign during OIF known as “The Surge” [1]. They conducted a retrospective cohort study to identify all injuries and illnesses among the 4,122 deployed soldiers during the study period. In addition to examining fatalities and medical evacuations due to DNBIs, they also examined NBIs and illnesses that were treated in theater and returned to duty within 72 h of initial medical evaluation (Fig. 3.2). Similar to previous reports, 77.2% ( $n=1324$ ) of all casualties during the deployment were due to DNBIs. Of the DNBI casualties sustained by the BCT during the study period, only 15.5% were significant enough to require medical evacuation from theater, with the majority (83.9%) being managed within theater and returned to duty within 72 h. Significantly higher rates of DNBIs were observed in female soldiers when compared to males, regardless of whether they were managed in theater and returned to duty or medically evacuated. Rates of DNBIs were also significantly higher in the enlisted ranks as reported previously in other studies. Again, musculoskeletal injuries represented the majority of all DNBI casualties





**Fig. 3.2** Definitions and classification scheme of military casualties. *MTF* military treatment facility, *RTD* return to duty, *MEDEVAC* medical evacuation. (Adapted from Waterman et al. [8])

(50.4%) during the 15-month deployment; however, nearly all of these injuries (91.5%) were managed in theater and returned to duty within 72 h. While the majority of studies on NBIs have primarily been limited to injuries significant enough to require medical evacuation or cause fatality, this study provided unique insight into NBIs that were managed in theater and returned to duty; though a later report suggests that some of these injuries were significant [13]. Musculoskeletal injuries comprised the majority of all patients managed in theater (54.9%) and returned to duty. Musculoskeletal NBIs were almost evenly distributed between the lower extremity (42.6%) and the upper extremity (40.5%), with the remaining injuries affecting the axial spine (16.9%). The most common site of NBIs in rank order included the (1) hand (17.5%); (2) knee (13.5%), ankle (13.5%), and lumbar spine (13.5%); and (3) shoulder (11.8%). Though several studies suggest that DNBI make up 75–85% of all casualties significant enough to require medical evacuation; this study suggests that they also make up the majority of injuries and illnesses managed within theater and that musculoskeletal injuries account for the largest burden among these NBIs.

While the majority of studies have looked at NBIs during deployments within the US Army and US Marine Corps, Eaton et al. [12] recently examined NBI casualties among US Air Force personnel deployed in support of OEF and OIF. They examined NBIs documented among all Air Force personnel deployed to the Middle East between September 11, 2001 and October 31, 2006. They queried data on NBIs for all clinical visits at fixed medical facilities in the Middle East via the Global Expeditionary Medical System database. Similar to previous studies, they

also examined data in TRAC<sup>2</sup>ES for all NBIs significant enough to require medical evacuation during deployment. Musculoskeletal injuries including sprains and strains accounted for over half (53.0%) of all NBIs during the study period. As reported previously, incidence rates for NBIs were highest in the enlisted ranks and decreased with increasing military rank. Contrary to their original hypotheses, the authors reported that Guard and Reserve component airmen were less likely to experience NBIs when compared to those on active duty.

In a series of survey studies, Sanders and colleagues attempted to document the burden of DNBI that was not significant enough to require medical evacuation from OEF and OIF [20, 21]. They reported that 34.7% of service members surveyed reported at least one NBI with the majority of these injuries affecting the musculoskeletal system [20]. They reported no differences in NBIs when injuries sustained by service members in Iraq and Afghanistan were compared, which is similar to the results reported by Hauret et al. [2]. The greatest single cause for NBIs reported was participation in sports and physical training, which is also consistent with the data reported by Hauret et al. [2] for injuries significant enough to require medical evacuation. In a follow-up survey, the authors extended their work related to NBIs [21]. They reported that 84.8% of those reporting NBIs obtained medical care for their injuries. Furthermore, 42.2% reported that their NBIs impacted job performance and 36% reported being placed on limited duty for an average of 6 days. Approximately 5% of the injuries reported were significant enough to require hospitalization in theater to manage the injury, and only 2.4% reported NBIs that were significant enough to require medical evacuation from theater but not significant enough to prevent the service member from eventually returning to duty. Again, sports and physical training and heavy lifting were the most common causes of the most severe NBIs reported [21].

As noted previously, Belmont et al. [1] reported that musculoskeletal injuries represented the majority of all DNBI casualties (50.4%) during the 15-month deployment among members of a US Army BCT; however, nearly all of these injuries (91.5%) were managed in theater and returned to duty within 72 h. Musculoskeletal injuries comprised the majority of all patients managed in theater (54.9%) and returned to duty. As a result, many of these non-emergent NBIs required definitive care upon return from deployment [13]. In a follow-up study, Goodman et al. [13] examined these non-emergent orthopedic injuries in the same BCT following deployment. Based on their observations, many soldiers returning from a full combat deployment presented with non-emergent musculoskeletal injuries and conditions that required medical care. These injuries may be disregarded as insignificant in the combat environment, may be ignored by soldiers wanting to stay with their unit and fellow soldiers, or may be identified as insufficient to warrant medical evacuation where service members are treated in theater and returned to duty [1, 12]. A total of 731 orthopedic consultations were conducted among the 3787 soldiers that completed the deployment without being medically evacuated. Nearly 90% of the injuries or conditions warranting consultation were the result of non-battle musculoskeletal injuries or exacerbation of a previous injury or condition during deployment. Of the soldiers ( $n = 140$ ) returning from deployment, 4% required an

orthopedic surgical procedure as a result of their injury. While the authors were unable to systematically document the cause of injury among these service members, it is reasonable to assume that a large proportion of these injuries and conditions were likely due to sports participation and physical training based on the available epidemiological data [2, 19–21]. The surgical procedures were to treat internal derangement of the knee (e.g., meniscus tears, ACL rupture, articular cartilage lesions, etc.), shoulder instability (e.g., dislocations and subluxations), and superior labrum anterior to posterior (SLAP) lesions. These injuries included 19 first-time anterior or shoulder dislocations/subluxations and 18 anterior cruciate ligament ruptures. These data, combined with the observations reported by Sanders and colleagues [20, 21], suggest that even when NBIs are managed in theater, these injuries can have significant long-term impact on the health of military service members, can impact their ability to do their job during the remainder of their deployment, and can contribute to long-term morbidity after deployment affecting force readiness in the future.

Overall, these studies suggest that NBIs are a substantial problem during contemporary military operations and deployments, and these injuries significantly impact force readiness. Furthermore, these studies consistently demonstrate that the majority of NBIs affect the musculoskeletal system and primarily the lower and upper extremities. The top five anatomic locations of NBIs significant enough to require medical evacuation from OIF or OEF include the (1) back, (2) knee, (3) wrist and hand, (4) foot and ankle, and (5) shoulder [2]. Specifically, orthopedic injuries to the low back, fractures, sprains and strains, joint dislocations, and inflammation due to overuse are common among deployed service members. Musculoskeletal injuries are a leading cause of NBIs, whether these injuries are significant enough to require medical evacuation [2, 10, 18] or less significant where they can be managed within theater [1, 20, 21]; however, even musculoskeletal NBIs managed in theater may require additional definitive care and surgery following deployment [12]. While many musculoskeletal NBIs are significant enough to require medical evacuation during modern combat operations, over 90% of these injuries may be initially managed within theater and returned to duty within 72 h [1]. These data suggest that traditional military medical planning based on “inpatient beds” may be obsolete and insufficient to support the large burden of the outpatient mission during contemporary military deployments [5]. Military service members medically evacuated from OIF and OEF due to musculoskeletal NBIs are much less likely to return to duty in theater within 2 weeks of medical evacuation [10]. The most common causes of musculoskeletal NBIs include sports and physical training, falls and jumps, motor vehicle accidents, crushing or blunt trauma, and heavy lifting. Those serving in the Army and Marine Corps as well as those in the enlisted ranks are at the greatest risk for NBIs during deployment; however, those in the other services are still at substantial risk for NBIs during deployment.

## Estimating the Burden and Resource Impact of Non-battle Injuries During Military Deployments

A critical component in planning for successful military operations is ensuring that adequate medical personnel, equipment, and supplies are available and positioned where needed to provide the medical care necessary to save lives and mitigate the impact of combat casualties and DNBI during deployment.<sup>24</sup> Based on the data reviewed so far, the latter task of caring for DNBI during deployments will likely require the majority of medical resources and have the greatest impact on the Military Health System and force readiness. Though several attempts have been made to project combat and DNBI casualties [22–25], projecting accurate estimates of injury patterns and medical resource needs have been challenging.

Blood and O'Donnel [22] utilized historical data on Marine Corps casualties from WWII, Korea, and Vietnam to develop a medical casualty forecasting system (FORECAS). The system was designed to estimate casualties during military operations based on several input variables including combat intensity (none, light, moderate, heavy, intense) type of casualty (battle injury, DNBI, or both combined), troop strength by category (infantry, combat support, and service support), region (Europe, East Asia, Southwest Asia), and duration of the operation in days (15, 30, 60, 90, 120). While the statistical models in FORECAS accurately depicted the statistical patterns in the empirical data on which the models were based, these models may have little relevance to modern combat operations, particularly in the Middle East and Persian Gulf regions. This is because the empirical data used to develop the models are limited to Marine Corps casualties, and combat operations and wounding patterns have significantly changed in recent conflicts (ODS, OEF, OIF) compared to previous military engagements (WWII, Korea, Vietnam) upon which FORECAS projections are based. As noted previously, these models may not account for the significant increase in musculoskeletal NBIs relative to disease observed in recent years. Finally, the casualty estimates derived from FORECAS are based primarily on hospital admissions data. As Belmont et al. [1] noted, many of the DNBI casualties during contemporary military deployments are treated in theater and returned to duty within 72 h. It is likely that the models based solely on hospital admissions do not account for the medical resources needed to care for these injuries during deployment.

Traditionally, models for estimating daily casualty incidence rates, including battle injuries and DNBI, for resource planning purposes have relied on measures of central tendency such as average daily rates [24, 25]. Several limitations have been noted with this method, most notably among them is that using the average daily casualty incidence rates for estimating resource requirements can lead to critical shortfalls when casualty rates are above the mean [25]. As a result, percentile estimates and confidence intervals have been advocated as alternate approaches that may address these limitations in estimating casualty rates and resource requirements during military deployments [24, 25].

More recently, Wojcik et al. [24, 26] attempted to model DNBI rates based on hospital admissions data for US Army personnel deployed in support of ODS [24] and subsequently refined their model based on DNBI data from OEF and OIF [26]. In their initial models using data from ODS, they focused on percentile estimates as an alternative to the mean as recommended by Zouris and Blood [25], in addition to reporting average daily rates. This approach is helpful to planners as it provides a range of daily rates based on actual data. They also examined rates for three distinct phases of ODS including the buildup phase, the ground combat phase, and the post-combat phase. The DNBI rates for hospital admissions were comparable between the buildup and post-combat phases, but were substantially higher during the ground combat phase which only lasted for 4 days during ODS. The most commonly occurring diagnoses for all three phases were related to NBIs. Approximately 23% of all admissions were due to NBIs during the buildup and post-combat phases; however, over 44% of all admissions during the ground combat phase were due to NBIs. Musculoskeletal diseases and conditions were also a leading cause of NBI hospital admission during ODS. Combined, NBIs and musculoskeletal diseases and conditions accounted for approximately 37% of all DNBI hospital admissions during ODS. The authors concluded that the phase of each military operation is associated with the rate of admission for DNBI and recommended that separate rates associated with each phase should be used for future planning. They also recommended that the 95th percentile, rather than the average daily rate of admission for each phase of military operations, should be used during planning. Based on their data, planning using the average daily rate would have resulted in inadequate medical resources to meet the needs during 40% of the days in theater, including all but one of the days during the ground combat phase. While these data are more relevant to contemporary military operations, the short ground combat phase during ODS may not be applicable to sustained military operations as observed in Iraq and Afghanistan.

To address this limitation and expand on their previous work, Wojcik et al. [26] incorporated data from OEF and OIF to refine and extend their DNBI model in a subsequent study. They examined data from the start of each operation through December 2004. Despite previous recommendations, the three separate phases (e.g., buildup, ground combat, post-combat stabilization) were only applied to OIF, as these distinct phases were not applicable to operations in Afghanistan during the study period. Overall, the authors noted that DNBI rates were comparable but lower during both OEF and OIF when compared to their previous data on ODS. While they attributed the observed reductions to improved force health protection efforts, data to suggest that any specific force health protection initiatives were responsible for the observed reductions were not provided. Furthermore, the DNBI models only included admissions data from the early years of both OEF and OIF. The authors noted this limitation and suggested that a complete analysis using complete data from both campaigns would be needed to support changes in policy and doctrine.

Similar to their previous study, NBI diagnoses were the leading cause for hospital admission due to DNBI during the follow-up study by Wojcik et al. [26] In a multivariable risk analysis for NBIs, the authors noted that demographic variables

including age, component (e.g., active, guard, reserve), military rank, gender, and unit type (e.g., combat, combat support, combat service support) were associated with the risk of NBIs. Regardless of whether they were serving in support of OEF or OIF, the risk of NBI was greatest in service members less than 20 years of age and decreased with increasing age. Reserve and National Guard component service members were 48 and 17%, respectively, more likely to be hospitalized for NBIs when compared to active duty service members deployed in support of OIF; however, there were no differences in the rate of admission by component in OEF. Those serving in the enlisted ranks were 82% more likely to be admitted for NBIs in Iraq and over four times more likely to be admitted for NBIs in Afghanistan. Females were 43% less likely to be admitted for NBIs in both OEF and OIF when compared to males. Finally, those serving in combat units were significantly more likely to be admitted for NBIs when compared to those serving in combat support or combat service support units, regardless of operation. These findings are consistent with the majority of studies that have looked at NBI rates and risk factors in recent years.

Combined, the studies reviewed in this section suggest that the military has made significant progress in understanding the burden of DNIBs and NBIs during deployments, and these data are being utilized to estimate medical resource needs with increasing accuracy. However, as noted by Wojcik et al. [26], a complete analysis of all data from OEF and OIF will be needed to further refine these models for sustained military operations across several years. Another limitation of these studies is that they do not account for NBIs that are seen and managed in theater. As noted previously, the vast majority of musculoskeletal NBIs experienced by deployed soldiers are managed in theater [1], despite the fact that many service members still require definitive care for these injuries following deployment [12]. Johnson et al. [5] noted that managing a large outpatient population is fundamentally different and more difficult in comparison to patients who are admitted for care due to differences in medical care needs and administrative tracking and processing requirements in a deployed setting. They also suggested that medical planning based solely on hospital admissions data, as has been the standard in the past, is “a relic from the Cold War” [5]. Further development of the models described in this section for medical planning should anticipate a large outpatient mission during future military deployments [5]. This will also require planners to incorporate data on the burden of outpatient care for NBIs in future models that estimate DNBI rates and medical resource needs.

## **Preventing Non-battle Injuries During Military Deployments**

The available data consistently indicate that musculoskeletal-related NBI is a leading cause for soldiers seeking medical care in theater and for medical evacuations from theater. The data also suggest that participation in sports and physical training are a leading cause for these NBIs. Those serving in the Army and Marine Corps, as

well as younger soldiers and those in the junior and senior enlisted ranks, appear to be at the greatest risk for NBIs during deployment. Though many of these injuries are likely preventable, there is limited data available on the efficacy or effectiveness of injury prevention interventions among soldiers deployed in support of OIF or OEF.

While injury prevention during deployment is ultimately the responsibility of the unit commander, this duty may fall to the unit surgeon or medical officer. While most medical officers understand the importance of preventive medicine during deployments, many may lack formal training, may be uncertain how to practice it, or may have limited time and resources to focus on preventive efforts [27]. Even if they do have training in preventive medicine, they may lack expertise in evidence-based strategies to prevent sports and physical-training-related musculoskeletal injuries, which are the leading cause of medical evacuation from theater. Withers et al. [27] presented a preventive medicine framework that could be used during deployments to assist medical officers and support staff in organizing and coordinating prevention efforts. While NBI was included as a priority in this framework, specific strategies to prevent NBIs were lacking. Two of the top prevention priorities identified for the unit surgeon included (1) developing a preventive medicine plan and (2) obtaining command support for the plan. More recent work has described processes for identifying military injury prevention priorities [28] and presented a framework for building command support for injury prevention efforts in the military [29]. Furthermore, there have been significant advances in lower extremity injury prevention in the sports medicine literature in recent years; however, it is unclear if this information has been translated within military populations during deployments. While later chapters in this book will primarily focus on evidence-based injury prevention strategies, the need for preventing NBIs during military deployments cannot be overstated.

## Conclusion

The significant burden of NBIs that impact the musculoskeletal system within military populations during deployment cannot be ignored. This is a critical public health problem within the military that negatively impacts force readiness. Several recent studies during OEF and OIF have provided a clearer picture of the factors that contribute to NBIs during deployment. Most of these studies have focused on NBIs significant enough to require medical evacuation from theater; however, the majority of the NBIs experienced during deployment may be treated in theater and returned to duty within 72 h. Regardless, many of those who are originally managed in theater will require definitive care and surgical intervention for their NBIs sustained during deployment upon returning from theater at the end of their deployment. While NBI has been recognized as a significant challenge, there is limited data to support the efficacy of force health protection interventions to mitigate the impact of NBIs during military deployments. Emerging strategies from the sports

medicine literature may play a role in preventing acute and chronic overuse NBIs during military deployments; however, data to confirm whether these findings can be translated to military populations during deployment will be needed.

**Disclaimer** The author is an employee of the US Federal Government and the Department of the Army. The opinions or assertions contained herein are the private views of the author(s) and are not to be construed as official or reflecting the views of Keller Army Hospital, the Army Medical Department (AMEDD), the Department of Defense, or US government.

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