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Burden of Musculoskeletal Disease and Nonbattle Nontraumatic Injury in Both War and Disaster Zones

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Disasters, both man-made and natural, are a known cause of morbidity and mortality among vulnerable populations. The initial phase of public health response typically addresses immediate traumatic injury or death in the wake of a disaster. However, little is known about the magnitude and cost of subsequent nontraumatic injury and illness in disaster zones. Known as ''the hidden epidemic,'' the incidence and epidemiology of disease and nonbattle injuries among military service members in deployed settings has been more extensively investigated and may serve as a proxy for the evaluation of civilian populations following natural disaster. Further, prior reports from the military setting may serve to inform the broader population on the ultimate burden of nontraumatic injury and illness in recent disasters, particularly as they relate to musculoskeletal health. (Journal of Surgical Orthopaedic Advances 20(1):23–29, 2011)

Key words: disaster, epidemiology, injury, military, musculoskeletal, nonbattle

Injury and disease occur frequently in austere environments and disaster zones. Such casualties have been increasingly highlighted in the wake of recent public health concerns arising from the 2010 earthquake in Haiti and Hurricane Katrina in 2005, which affected the United States Gulf Coast. Disasters are generally organized according to their etiology, either natural or man-made. Natural disasters may be classified by the predominant condition or weather hazard. Within this context, the epidemiology of injury and disease caused by earthquakes, floods (e.g., tidal waves, hurricanes, tsunami), and high winds (e.g., tornados, hurricanes, cyclones, typhoons) are commonly discussed.

Alternatively, so-called "man-made" disasters are characterized by a more diverse range of etiologies, but can result in comparatively profound health care burdens. Disaster zones occurring in the traditional battlefield setting have been described in the past and serve as a frequent source of personnel attrition (1). Additionally, other more contemporary disasters such as those involving harmful chemical, biological, radiation, or nuclear exposures and blast injuries in urban, nonwar settings may also yield similar, mass casualty situations and thus are receiving increasing scrutiny. Within combat zones, the contributions of disease and nonbattle injury (DNBI) are also frequently overlooked and significantly underreported and have historically accounted for a far greater proportion of casualties than all other categories combined (Table 1) (2–7).

Regardless of underlying etiology, disaster zones impose numerous specific hazards and challenges that predispose to an increased incidence of injury and disease. Such obstacles include unpredictable food and potable water supplies, disrupted transportation and communication lines, inadequate electricity or gas supplies, diminished safety and security, poor sewage and sanitation,

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TABLE 1 Comparison of combat casualties to disease and nonbattle injury casualties

	WWI European Theater	WWII European Theater	Korea	Vietnam	OIF-1/OIF-2	BCT
Casualty classification	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)
Combat casualty admissions	140.3[a] (N/A)	113.3 (599,724)[b]	121.0 (77,788)[c]	231.6 (79,011)[d]	N/A (3,263)[e]	18.5 (363)[f]
DNBI casualty admissions	1,023.5[a] (N/A)	549.0 (16,145,000)[b]	570.0 (365,375)[c]	564.7 (192,654)[d]	N/A (9,808)[e]	41.4 (1,324)[f]
Ratio DNBI:BI	8.5[a]	4.8[b]	4.7[c]	2.4[d]	3.0[e]	2.2[f]

Note: Rates are reported per 1000 combat-years (N). OIF, Operation Iraqi Freedom; BCT, brigade combat team; WIA-RTD, wounded in action–returned to duty; CRO, carded for record only.

[a] Data available on hospitalizations, excluding noxious gas inhalation casualties, in the European theater only. Does not include data on patients in the infirmary, quarters, or CRO (6).

[b] Data available on hospitalizations including data on patients in the infirmary, quarters, or CRO in the European theater only (6).

[c] Data available on hospitalizations including data on patients in the infirmary, quarters ,or CRO in the European theater only (5).

[d] Hospitalization data U.S. Marine Corps in Southwest Asia from 1965 to 1972 (3).

[e] Hospitalization data available from OIF-1 March 21 to April 30, 2003 and OIF-2 March 1, 2004 to April 30, 2005 (4).

[f] Data from an Army BCT (WIA-RTD) deployed from 2006 to 2007 to Iraq during ''The Surge'' (2).

and the prevalence of communicable diseases (8). Furthermore, compromised health care infrastructures, economic losses, and psychosocial sequelae exacerbate existing health conditions and promote neglect or failure to seek care for new medical concerns that may arise.

While the epidemiology of traumatic injury during combat deployments and natural disasters has been described, the epidemiology of nontraumatic injury in the disaster zone has not been thoroughly examined. Rather, previous reports have primarily focused on the principles of disaster management (9, 10), logistical frameworks of support (11, 12), outcomes among narrow demographic cohorts, and specific disease processes following disaster (13, 14). Recent investigations into the scope and cost of DNBI among the deployed military cohort may represent the best available evidence at present for other disaster settings and can serve to inform the broader civilian population on the ultimate morbidity and mortality of illness and nontraumatic injury in the modern era.

Casualty Care Statistics

Within the military setting, casualties are classically defined as any active duty service members lost to the theater of operations for medical reasons (15). Military casualties may be managed through five echelons of care as a part of an integrated trauma care system built on traditional principles of efficient triage, prompt treatment or stabilization, timely evacuation, and subsequent return to duty (10). Initial care of casualties begins at the level I echelon of care, which encompasses point-of-injury stabilization and treatment until transport to an immediate receiving facility is achieved. The level II echelon of care affords management directed by a physician but also enables emergent general surgical or orthopaedic care to be delivered. The level III echelon of care, most commonly a combat support hospital, subsequently receives casualty transfers after primary treatment and can provide intensive care unit support and a greater capacity to address more complex orthopaedic injuries or medical and surgical conditions. Once adequately stable and deemed appropriate for medical evacuation (MEDEVAC), casualties are transported from theater to Landstuhl Regional Medical Center (level IV echelon of care) in Kaiserslautern, Germany, before return to military treatment facilities within the continental United States where definitive medical care and rehabilitation occurs (level V echelon of care) (10).

Battle (combat) injury is defined as "any casualty incurred as the direct result of hostile action sustained in combat or sustained going to or from a combat mission" and should be differentiated from those casualties resulting from DNBI (16). Within military DNBI, casualties are subsequently divided into mortality (Death), MEDEVAC, or return to duty within 72 hours of onset (RTD) (Fig. 1). Previous characterizations of DNBI have largely neglected routine ambulatory visits and those soldiers treated and returned to duty, focusing strictly on rates of hospital admission (3–6), MEDEVAC (7), or mortality (7). Further studies have relied on self-reported patient surveys (17, 18), which are exposed to responder bias and incomplete sample data. As a result, DNBI incidence rates during combat operations have been dramatically underestimated. True measures of DNBI incidence must account for the more substantial subset of RTD patients, as well as those who have inadequate health care access or fail to seek medical treatment.

Disease and Nonbattle Injury During War

In response to the unconventional tactics employed by enemy combatants and the emergence of other new global threats, the traditional battlefield has undergone a dramatic transformation in the past 20 years, and the

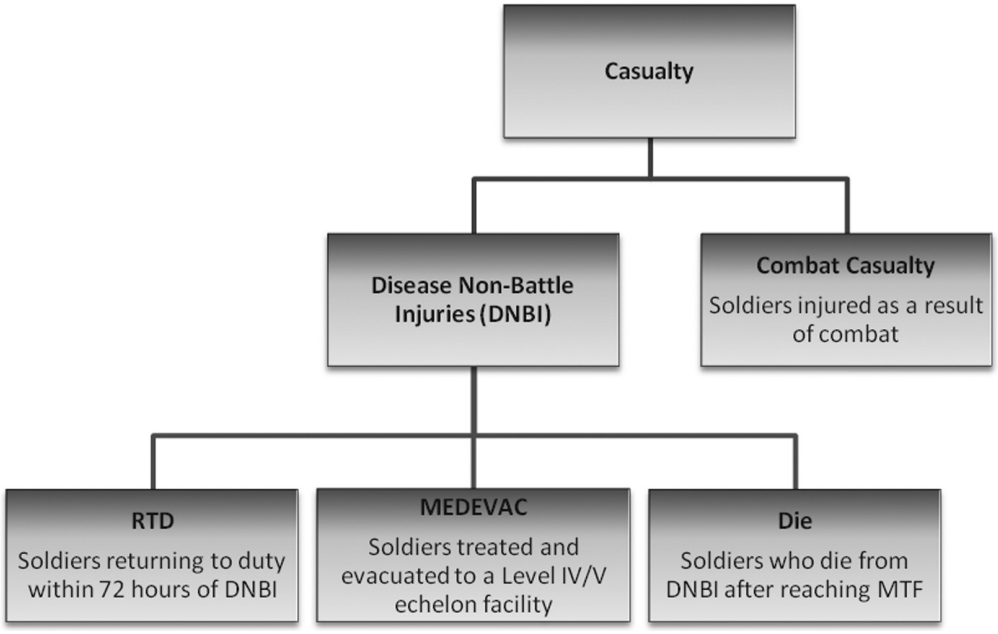

FIGURE 1 Definitions and classification scheme of military casualties. MTF, military treatment facility.

United States military has adapted by employing a more dynamic and mobile force. Given this operational and tactical shift, increased emphasis is currently placed on individual readiness and effectiveness within a given unit. As a result, personnel losses due to illness or injury, even on an individual level, may significantly impair combat operations and thus remain an important epidemiological focus.

Historically, DNBIs have resulted in a significantly greater number of casualties than combat-related injuries. When compared with battle injuries, DNBIs have been responsible for more substantial personnel losses in every military conflict since the American Revolution (18). Since World War I, American service members have been at a 2- to 8-fold increased risk of admission for DNBI when compared to battle injury (Table 1) (2–7). However, while the incidence of DNBI has shown a measurable decline since World War I due to advances in antimicrobial therapy and improved logistical support to U.S. troops, the importance of DNBI cannot be underestimated. Endemic or epidemic infectious diseases, particularly those involving the integumentary, gastrointestinal, and respiratory systems, still result in substantial personnel attrition (4, 18). Additionally, in the current conflicts, psychiatric illness and combat stress reaction represent the second-leading cause for DNBI presentation after musculoskeletal complaints and remain an important command concern (19).

Termed "the hidden epidemic" of the modern military era (20), DNBI still represents the single leading source of attrition during a time of war. Since the beginning of the joint operations in Iraq and Afghanistan, more than 1222 DNBI deaths and 51,499 DNBI MEDEVAC have occurred (7). In a recent longitudinal cohort study, DNBI resulted in 75% more casualties than battle-related injuries among a deployed brigade combat team during "the Surge" portion of Operation Iraqi Freedom (19). Similarly, Cohen et al. (21) reported that 76% of those medically evacuated to a level IV echelon of care were DNBI during both Operation Enduring and Iraqi Freedom from 2004 to 2007. In this study, only 28% of all DNBI MEDEVAC casualties were ultimately found to return to duty. Additional studies have documented alarmingly higher rates of DNBI casualties among those medically evacuated, with reported rates up to 87% (17, 22–24).

During combat operations (18, 21, 25), DNBI incidence rates are significantly greater than during mobilization precombat or postcombat periods. In the early stages of Operation Iraqi Freedom, DNBI accounted for approximately 75% of all hospitalizations (4). Cohen et al. (21) demonstrated corresponding increases in both battle-related injuries and DNBI after the invasion of Iraq during Operation Iraqi Freedom. These findings are largely reflective of the rapidly responsive nature of aggressive military action during combat and the difficulty in providing a mobile logistical infrastructure. Similar to other disaster settings, the increased incidence of DNBI during combat is caused by the diminished capacity to provide potable water sources, hygienic conditions, and health care resources at forward operating positions. Although variably reported, additional factors that impact DNBI casualty care statistics are branch of

TABLE 2 Comparison of nonbattle injury to battle injury for casualties mortality

	WWI European Theater	WWII European Theater	Korea	Vietnam	Iraq/Afghanistan
Casualty classification	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)
Battle deaths	N/A (53,402)[a]	N/A (291,557)[a]	N/A (33,739)[a]	N/A (47,434)[a]	N/A (4,171)[a]
DNBI deaths	N/A (63,114)[a]	N/A (113,842)[a]	N/A (2,835)[a]	N/A (10,786)[a]	N/A (1,167)[a]
Ratio deaths DNBI:BI	1.1[a,b]	0.33[a,c]	0.08-0.1[a,d]	0.23[a]	0.28[a]

Note: Rates are reported per 1000 combat-years (N).

[a] Data available on all casualties in Operation Iraqi Freedom and Operation Enduring Freedom available from March 19, 2003 to February 6, 2010 (7).

[b] Data available on hospitalizations, excluding noxious gas inhalation casualties, in the European theater only. Does not include data on patients in the infirmary, quarters, or CRO (6).

[c] Data available on hospitalizations including data on patients in the infirmary, quarters, or CRO in the European theater only (6).

[d] Data available on hospitalizations including data on patients in the infirmary, quarters, or CRO in the European theater only (5).

military service, type of unit, service component, and duration of deployment (17, 24–27). Likewise, climate and local environment are also important intrinsic factors related to the incidence and type of DNBI in the deployed setting.

Mortality rates are still significantly greater for battle-related injuries than those resulting from DNBI. Given the significant increase in explosion and blast-type mechanisms, battle injuries still have greater propensity for significant morbidity. While advances in body armor and protective vehicles have led to a corresponding decrease in ballistic deaths, the increasing prevalence of improvised explosive devices or other blast mechanisms result in a percentage killed in action of up to 25% of cases (2), largely due to polytrauma, complex extremity wounds, and head injuries. Nonetheless, the rates of DNBI should not be underappreciated. Comprehensive nonbattle and battle mortality rates and respective ratio comparisons are listed in Table 2. Even in the contemporary setting, there is one DNBI mortality for every four battle-related deaths (2–7).

Nontraumatic Musculoskeletal Injury and Disease

Nontraumatic musculoskeletal injury and disease rarely result in mortality, but contribute significantly to the morbidity among military service members. Sanders et al. reported that 34.7% of deployed service members reported at least one noncombat injury, and the majority of such wounds involve the musculoskeletal system (18). Furthermore, orthopaedic injuries and complaints account for between 25% and 50% of all DNBI ambulatory visits (4, 18, 19, 26, 28) and represented the single most common reason for DNBI-related presentation among a brigade combat team in the Iraq War (19).

The mechanism of musculoskeletal DNBI varies by combat environment, geographical topography, and other at-risk exposures (23). Rough, uneven terrain predisposes military service members to ligamentous injury in the lower extremities, while mountainous settings contribute to a greater incidence of falls. Soft tissue wounds and lacerations, with or without secondary infection, occur more commonly with sharp, exposed surfaces, such as in urban settings. Among individuals deployed to the Middle East, sports or physical training are the most common mechanism of injury (18%–23%), followed by heavy lifting (6.9%–19.6%), injury from falls (13.7%–19%%), motor vehicle accident (5.6%–19%), and use of machinery, tools, or weapons (3.0%–14%) (17, 23).

Musculoskeletal health significantly affects individual readiness and performance and serves a primary source of disability among deployed military service members. Of soldiers sustaining at least one DNBI, up to 85% present for treatment (17) and 77% require multiple visits for care (18). Skeehan et al. found that, of all service members reporting at least one nonbattle injury during deployment (median, 6.3 months), 38% sustained multiple nonbattle injuries and diminished job performance was documented in at least 42% (17). During Operation Restore Hope in Somalia, Kilian et al. (28) found that 24% of hospitalizations over a 9-week period were related to musculoskeletal DNBI. Belmont et al. (19) demonstrated that the cumulative incidence rate of musculoskeletal DNBI was 129.5 per 1000 combat-years, with over 90% of casualties returned to duty. However, even though only a fraction of musculoskeletal DNBI required MEDEVAC, such evacuations comprised over a quarter (27.4%) of all DNBIs requiring MEDEVAC. Although Cohen et al. (21) reported that MEDEVAC for DNBI was a positive predictor of return to duty during Operations Enduring and Iraqi Freedom, these authors also found that those with musculoskeletal or connective tissue disorders and spinal pain had a significantly lower probability of return to duty after MEDEVAC.

Several studies have evaluated the location and type of musculoskeletal injury in both the ambulatory and MEDEVAC setting within military cohorts. When

organized by injury category, Belmont et al. (19) found that the majority of DNBIs involved the upper (40.5%) or lower (42.6%) extremity, followed by the axial spine (16.9%). However, no significant differences were detected by anatomic location and rates of MEDEVAC. Rank and sex were also not significantly associated with rates of DNBI casualty or subsequent MEDEVAC. Sprain injury was the most common cause for presentation, while fracture (19.7%), joint instability (19.4%), soft tissue injury (8.2%), and musculoskeletal pain (5.4%) resulted in significantly greater rates of MEDEVAC when compared to sprain. In a separate study, Hauret and colleagues (23) showed that up to 82.2% of unintentional, nonbattle injuries requiring MEDEVAC involved the musculoskeletal system. In contrast to previous findings, the spine accounted for nearly half (49.8%–55.4%) of all musculoskeletal MEDEVAC, followed by the lower (23.1%–27.6%) and upper (14.5%–15.4%) extremity. The most common diagnostic categories in this population were fracture (18.8%–18.9%), overuse conditions (14.1–14.3%), dislocation (11.7%–12.9%), sprain/strain (10.7%–11.6%), and internal joint derangement (11.3%–12.1%).

Disease and Nontraumatic Injury During Natural Disasters

Over the past three decades, there has been a dramatic rise in natural disasters worldwide. Similar to armed conflicts, natural disasters can have significant repercussions on the health of civilian populations. More than 90% of natural disaster-related deaths occur in third world nations (29), and developing countries are most vulnerable to natural disasters because of poor public health responsiveness, insufficient health care infrastructure, and limited material resources. Recent natural disasters in New Orleans, Haiti, and Turkey share similar patterns; a first wave of mortality and morbidity from the physical event itself, followed by a delayed second wave of further acute injury, subacute or chronic illness, and last, socioeconomic challenges in the months to years following the event (8).

Natural disasters are complex events in which populations are subjected to a wide variety of risks and dangers. The degree to which disasters cause death and injury varies within and between disaster categories. With the notable exception of earthquakes, most disasters usually do not engender a significant number of death and injuries at the time of initial strike. Droughts, hurricanes, and cyclones often can be predicted to some degree, allowing for preventative measures and response to be initiated before the event. Earthquakes, however, result in significant increases in mortality and musculoskeletal morbidity within affected populations. The primary health concerns associated with earthquakes are injuries arising from structural collapse (30). Most injuries occur among individuals trapped within their homes or businesses at the time of the earthquake. However, traumatic wounds sustained as a result of falling debris or entrapment — such as crush injuries, fractures, or internal injuries of the chest, abdomen, and pelvis — may still persist after the initial event. For this reason, countries with lower socioeconomic development, which typically have poor-quality buildings, are at an increased risk of substantial morbidity and mortality following seismic disasters.

The epidemiology of nontraumatic injury and illness following natural disasters is sparsely reported in the current literature. Data from the Centers for Disease Control and Louisiana Department of Health and Hospitals recorded 7543 nonfatal injuries in the aftermath of Hurricane Katrina, the majority of which were attributed to cuts, stabs, piercing, falls, and crush injuries that occurred during poststorm cleanup (31). Most recently, during the aftermath of the Haiti earthquake, which resulted in more than 250,000 injury casualties and more than 230,000 deaths (32), an Israeli Defense Forces Medical Field Hospital on humanitarian mission reported the triage of 1111 patients and 737 hospitalizations, of which trauma accounted for only 66% of admissions (11). While trauma-related causes accounted for up to 80% of admissions in the first 3 days of the operation, admissions due to nontraumatic conditions continued to increase, ultimately accounting for over 70% of admissions by the 10th day. Bar-Dayan et al. (33) also described a similarly high incidence of nontraumatic injury or illness (90%) presenting to a field hospital after an earthquake in Duzce, Turkey, in 1999. Comparative evaluations of nontraumatic injury and illness following natural disasters are listed in Table 3 (11, 31, 33).

Conclusion

Health care needs in disasters are highly dependent on the type of event, intrinsic and extrinsic local hazards, and inherent population vulnerability. In some cases, nonmedical assistance may be most useful in mitigating disaster morbidity and mortality, including providing temporary coordinating evacuation (34). Nontraumatic injury and illness, specifically which which involves the musculoskeletal system, represent an increasingly important threat to overall public health in a disaster setting. Although difficult, adequate preparedness and provisions for anticipated health care needs in a disaster scenario are of paramount importance to efficiently and appropriately address the resultant spectrum of disease.

TABLE 3 Attendance and characteristics of traumatic and nontraumatic injury and illness to medical facilities in various natural disasters

Natural Disaster	Total Visits	Nontraumatic Injuries or Illness	Traumatic Injuries	Orthopaedic Treatment	Disposition	Mechanism of Injury/ Activity	Demographic Parameters
Duzce, Turkey Earthquake, 1999 (33)	2230	2007 (90%)	223 (10%)	468 (21%)[a]	Hospitalization[a] 84 (3.8%) Operations[a] 39 (1.7%)	NS	Age <10: 23.1% Age 20–50: 36.3%
Hurricane Katrina, New Orleans, Louisiana, 2005 (31)	26, 192	7543 (29%)	0	NS	Discharged 79.5% Hospitalization 3.6% Transfer 2.3%	20% cut/pierce/stab, 19.8% fall, 11% crush/blunt injury, 9.0% bite/sting, 7.7% MVA 20.3% cleanup, 6.1% building repair, 1.4% machinery use, 2.1% rescue/recovery, 0.1% evacuating	Male/Female 61.5%/36.0% Age 25–54 (50%)
Port-au-Prince, Haiti Earthquake, 2010 (11)	1111	251 (34%)†	486 (66%)[b]	NS	Discharged 33.7% Hospitalization 737 (63%) Operations 203 (27.5%)[b] Death 17 (2.3%)[b]	NS	Male/Female 44%/56% Age 18–50 (58.4%)

Note: NS indicates that the parameter is not specified.
[a]The authors do not distinguish between traumatic and nontraumatic injury/illness for these parameters.
[b]These values represent percentages of all hospital admissions.

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