

## Preventing EHI in National Guard

Exertional heat illness in the military: Exploring factors for injury prevention using Haddon's Matrix

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## Abstract

**BACKGROUND:** Exertional heat illness (EHI) presented significant risks for National Guard (NG) disaster response teams, especially when NG are performing search and rescue operations in impermeable personal protective equipment (PPE). While EHI prevention and management strategies for athletes and military trainees are well-documented, these strategies do not account for the additional heat-related risks NG confront when responding to disasters requiring ‘all-hazards’ PPE.

**METHODS:** Guided by a conceptual framework based on the Haddon Matrix epidemiological model for injury prevention, a qualitative descriptive study was conducted to identify EHI-related factors in NG during disaster response operations requiring PPE. Three focus groups were held with enlisted and officer NG personnel, civilian health professionals, and athletic trainers experienced with EHI conditions and treatment. Thematic analysis was used to organize focus group data into pre-event, event, and post-event disaster response operations reflecting four conceptual groups: human (host), agent (energy transfer), environmental, and workplace/social conditions.

**RESULTS:** Human elements including risk-taking behaviors, hyper-motivation, and alcohol use were key factors putting NG service members at risk for EHI. PPE and medications emerged as noteworthy EHI-related agents. Environmental factors conducive to EHI focused on hot/humid conditions. Workplace/social factors were prominent in focus group conversations with policies/procedures, medical personnel readiness, and differing military cultures being important factors related to EHI in the NG.

**CONCLUSION:** This study uncovers critical elements putting NG at risk for EHI in operations requiring PPE. Findings serve as an evidence-based foundation for enhancing pre-event, event and post-event assessments administered by NG medical personnel.

## **Introduction and Background**

Heat injuries affect over 2,500 U.S. Armed Forces members annually.<sup>1</sup> Incidence of military heat injuries, in general, and heat stroke, specifically, have steadily increased in recent years.<sup>2</sup> In 2018, 578 cases of heat stroke and 2214 cases of heat exhaustion were reported across all four branches of the military, reflecting an incidence rate of 0.45-1.71 per 1,000 person-years.<sup>3</sup> If each of these cases resulted in hospitalization in the civilian sector, this would equate to nearly \$9000 per case, \$25,128,000 per year or \$250 million over 10 years.<sup>4</sup> These numbers do not reflect additional personnel replacement costs should they no longer be able to fulfill their military position. From 2008-2018, military costs, estimated at nearly \$1 billion, for heat injuries resulting in life-threatening conditions include: lost duty time, medical treatment, medical evacuations, and have negative implications for mission readiness.<sup>5-7</sup> Heat injuries, which includes exertional heat injuries (EHIs), account for a significant portion of non-battle injuries.<sup>3,8</sup>

EHI is defined as a group of heat-related illnesses that are caused by body responses to physiological reactions and environmental conditions during activity.<sup>9-10</sup> Although often occurring in hot and humid environments, an EHI may occur in normal conditions depending on a person's physical condition and type of activity. EHIs include heat syncope, heat exhaustion, heat stress, and heat strokes, with each type of heat injury carrying a set of signs and symptoms that fit their respective case definitions.<sup>11</sup> Across a number of occupations, heat stress and heavy physical activity are associated with physical fatigue, impaired cognition, and improper use of personal protective equipment (PPE), putting workers at risk for on-the-job injuries, illness, and death.<sup>12-13</sup> Since military members often train or work in hot environments, heat illness is a serious injury risk. Experts express growing concern that EHI is a high priority for injury prevention within the military.<sup>14-16</sup> Understanding the predictors of EHI is important to the safety of military service members and the overall mission, especially in wartime and homeland disaster response. Despite knowledge of risk factors for heat illness and prevention strategies, annual rates of heat-related illness and injury continue to increase in the U.S. Military.<sup>3</sup>

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The National Guard (NG) is a U.S. military organization responsible for national defense and disaster response. As such, service members are often at risk for exertional heat illness, especially due to the nature of PPE designed for all hazardous situations.<sup>17</sup> full-body PPE used is impermeable, trapping heat and perspiration, and requires use of respiratory breathing masks, rubber gloves and boots. Specialized teams (e.g., Chemical, Biological, Radiological, Nuclear, Explosive Enhanced Response Force Package (CERF-P) and Homeland Response Force (HRF)) are responsible for emergency response to disasters, often in stressful, hot and/or humid environments.<sup>18-19</sup> A set of guidelines focusing on EHI and formatted as an easy-to-use EHI assessment tool with corresponding medical management application is needed to facilitate use of best practices by CERF-P/HRF medics caring for NG teams.

Despite what is known about EHI and its underlying pathophysiology,<sup>11,20</sup> we do not understand how all the underlying factors affect an individual's susceptibility.<sup>21-22</sup> Intrinsic predisposing factors for EHI include participant health status, age (middle-age and older), which contributes to EHI risk in both genders, sickle cell trait, and the fact that individuals who develop EHI are at higher risk for subsequent EHI. In addition, high motivation of military personnel to continue the mission despite physiological warning signs can lead NG servicemembers to ignore the early signs of EHI or delay in seeking treatment.<sup>15-16</sup> Extrinsic factors such as ambient air temperature, wet-bulb temperature, medication use, or clothing type worn also generate risks for EHI in military personnel.<sup>10</sup> Usual hierarchy of control are used when considering EHI: acclimatization, engineering controls, administrative controls, and personal protection.<sup>23-24</sup> General safety controls include training, heat stress hygiene practices, and medical surveillance.<sup>23-27</sup> However, it is unclear how general controls and fitness affect overall risks for EHI in NG personnel while wearing protective clothing during training and actual events. To reduce the number of servicemembers who develop EHI, it is imperative to identify inherent factors that put the individual at higher risk. In addition, identification of general controls used for treatment and management of EHI, in relation to those factors, could assist in developing a tool that could prevent or lessen EHI injury.

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Presently, a standard screening and assessment form (SF-600) is used during CERF-P/HRF exercises and live disaster deployments. Using the SF-600, NG personnel are screened prior to starting any CERF-P or HRF training event and then assessed by medics after exiting the disaster zone. A project is underway to enhance the SF-600 to include the addition of key EHI risk factors and reference best practice field and clinical management guidelines. As a final step, the revised SF-600 will serve as an EHI risk assessment tool with corresponding field and clinical management guidelines and will be trialed in two NG disaster training exercises. The research question guiding the first aim of this project was: What are the unique NG military factors that potentiate EHI risk? A conceptual framework, Haddon's Matrix, was followed to identify the factors related to EHI during NG disaster training. The purpose of this article is to describe how Haddon's Matrix was used in conjunction with focus groups to identify exertional heat illness factors related to recognition of EHI symptoms, and the risks of returning to duty during exertional military training or live action.

### **Methods**

This study used a qualitative descriptive focus group design and deductive thematic analysis reflecting a Haddon's Matrix conceptual framework to identify and prioritize factors related to EHI symptoms.

#### **Application of Haddon's Matrix to EHI Factors**

Haddon's Matrix guided the extrapolation of risk factors related to EHI during NG training exercises from the shared experiences of military health care personnel and athletic trainers who have knowledge of and experience with managing EHI. This theoretical model has been applied to injury, violence prevention, and trauma care and is appropriate for EHI.<sup>28</sup> Haddon's Matrix utilizes the epidemiological triad model (human, agent, and environment) to examine factors related to the stages of an event when injury occurs, three levels of prevention, and the development of interventions.<sup>28</sup> The matrix can be used to evaluate options for preventing/reducing harm and to identify primary, secondary, and tertiary prevention strategies for stages of an event.

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Prior to conducting the focus groups, we developed a Haddon's Matrix for EHI (Table 1) indicating the standard columns: human (host), agent (energy transfer), physical environment and social environment factors. Rows specified pre-training event, event, and post-event factors. All cells in the matrix contained EHI risk factors for NG personnel using Tyvek suits during training exercises. The current SF-600 assessment form, military and sports literature, and exiting military and health guidelines informed the main concepts for the matrix cells and the interview questions. <sup>3,9,23,24,12,29</sup>

[TABLE 1 ABOUT HERE]

### **Population and Setting**

Focus group participants included enlisted and officer NG personnel, retired NG members, civilian health professionals, and athletic trainers experienced in managing or identifying EHI and its sequelae in a military and/or athletic context. Using purposive sampling, participants were identified by research personnel who had CERF-P/HRF experience and local athletic trainers familiar with EHI. Focus groups were held over two months in 2018; military healthcare personnel completed focus groups at one of two geographically distinct military bases, and community-based participants participated in a university classroom setting.

### **Data Collection**

A summary table of existing military and non-military EHI risk assessment guidelines and the current medical history prescreening form (SF-600) were distributed to participants prior to the focus group to familiarize themselves with concepts and current recommendations for EHI. After consent was obtained, the purpose of the focus group was explained, and demographic information was collected. Focus groups took 45-60 minutes and were led by a trained moderator. Semi-structured questions, derived from the Haddon's Matrix for EHI, were posed in the focus groups, discussions were digitally recorded. Conceptual notes were recorded on display boards pre-populated with headings from the columns and rows of the Haddon's Matrix. Much of what was discussed during the focus group sessions centered on exploring and identifying possible factors that put NG personnel at risk for EHI while responding to a disaster in Tyvek suits. Institutional Review Board

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approval was obtained from \*(institution blinded) university and secondary review was conducted by Department of Defense, Human Research Protection Office for final approval.

### **Data Analysis**

A nurse researcher with qualitative methods expertise led the analysis team. Following the steps outlined in Braun and Clarke's<sup>30</sup> method for thematic analysis, researchers began the analytical process by reading each transcript multiple times while writing down initial ideas. Focused, line-by-line coding was then completed to identify ideas and themes relevant to EHI health risks. Agreed upon codes were then aligned to predetermined cells within the Haddon's Matrix for EHI. Themes with sub-themes were developed from codes to reflect the most general elements and ideas important to a matrix column and row. Finally, themes were reviewed in relation to the coded extracts and the total data set was defined and named.

### **Findings**

Across the three focus groups, twenty-seven NG personnel, civilian health professionals, and athletic trainers participated (Table 2). Most participants were men (n=20). The mean age of participants was 46.2 years. Participants reported a range of professional licensures, with over half (n=15, 56%) holding graduate degrees. Twenty-two (81%) participants were currently in military at the time of the focus groups. Over 80% (n=23) had some disaster training and over 75% (n=20) had worked in medical triage at some type of disaster training event.

[TABLE 2 ABOUT HERE]

Themes derived from the focus groups were applied to each cell of the matrix. Related subthemes explained overarching concepts from the focus group discussion and notes.

### **Human Elements**

Human elements included pre-event-controlled factors (risk-taking behaviors, withholding health information, substance use, medications) and uncontrolled factors (health conditions, genetics) that lead to overall health and fitness:

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*“Medications are huge...and peoples’ inability to recognize that their limits have changed because they are on different medication.”*

*“It doesn’t matter if they’re healthy [or] socioeconomic status. There is a lot of use of these (supplements).”*

*“I’ll see people the day before using alcohol. And then when I see their questionnaire, it’s checked no.”*

The effects of behaviors and genetics lead directly to conditions experienced during disaster training:

*“A couple of guys just completely collapsed and went unconscious.”*

*“We get people out of the suit all the time who are confused, that were tremulous... the suits are full of their sweat.”*

The training personnel are evaluated immediately after coming out of the non-permeable PPE suits and monitored for their responses and symptoms for EHI as well as treatment given:

*“We get hyponatremia and seizures.”*

*“So, mentating versus not mentating. Not sweating. Unresponsive.”*

*“They survived and did fine, but that core temperature was up in the hospital a lot longer than we wanted.”*

## Agents

Agents are those factors that have some effect on energy transfer or those factors that increase risk for or cause injury such as medications or assessment procedures. Many agents are dynamic in that they have many different effects before training exercises:

*“So, antihistamines, decongestants, nonsteroidals. It’s over the counter. No one thinks about it ...they all either dehydrate you or make it so you can’t sweat.”*

*“No acclimation at all.”*

Agents designed to protect can also be the cause of EHI during an exercise:

*“...just wearing gear that you may not always have to wear.”*

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*“It’s something (true core temperature during assessment) we can’t recognize, don’t know. We don’t have rectal temps yet.”*

Treatment also can include agents such as a provider’s lack of knowledge or whether transport is available to a healthcare facility:

*“I was worried about him. But that evening he was at the sick hall...and still seeing docs and everything. I was like: ‘We need to get him to the hospital.’ That (psych) PA was still like: ‘Oh no, I think he just needs a little bit more oral hydration.’ We ended up taking him to the hospital.”*

## **Environmental**

The environment has two components: environmental and workplace/social. There were very few physical factors discussed during the focus groups. One reason is that the participants recognized that EHI can take place even in cool weather depending on the workload and condition of the person. However, pre-event environmental factors discussed included seasons (summer) and hot and humid climates as increasing the risks. Conditions during the event included lack of shade, radiant heat in work or rest zones, and temperature spikes. The only EHI post-event factors in the physical environment were complications of geography (road conditions to access healthcare facilities) or field conditions, such as lack of availability to produce ice for cooling baths.

## **Workplace/Social Environment**

Unlike the physical environment, most discussions centered around workplace/social environment. Traditional and cultural pre-event factors included health personnel readiness, having appropriate staff and policies, military culture, and personal norms and values:

*“We have certain rest times that we give ‘em. Certain hydration times. So, there’s certain protocols that were supposed to be put into practice.”*

*“...You can see a big difference between military service [branches].... [the] mentality is put this suit on.*

*“Some of our medics are not medics full time...and they work in a bank or grocery store when they’re not here.”*

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*“It’s like the gang...they will minimize any symptoms that they’re having because they don’t want to be left out.”*

Another focus of discussion pertained to work-related factors including on-the-job performance and mentality, social conditions that impact communication, and policies and procedures:

*“Their mentality is put this suit on. I don’t care how sick you are. You’re gonna suit up again. .... some of the guys we prescreen have had like two or three heat exposure illnesses and they’re right back in the suit the next exercise. You feel the pressure of getting ‘em back in.”*

*“There’s been situations where the medical personnel had to act as advocates for the patient because their supervisor was like: ‘Okay we need to get you back out there.’ And we’re saying: ‘No they are not okay.”*

*“After they come out of their suits, if you have a good rapport with them and you know them, you can look at some of those people and be like: ‘Are you good?’ and they know you genuinely care; they’ll tell you whether they’re good to go back in the suit or not.”*

Post-event factors in the workplace/social environment emphasized taking responsibility, debriefing and reflection, and the appreciation of expert knowledge vs. a business-as-usual type mentality based on ineffective policies or “passing the buck” up the chain-of-command:

*“And the hard part is, we’ve injured a number of cadets in the training process. There were a lot of different factors. No one was trying to do it, but it ended up. So, we started doing more education up front early in the academy.”*

*“We do not have enough teams for the work/rest cycle.”*

*“I feel for the medical part, everybody does...what they need to be successful and not fall out. But when it comes to (another branch) section-the DECON team with those people going into the suits-those are the people I don’t feel are getting the education they need to take care of themselves.”*

*“We did not have experience with that (multiple people with heat exhaustion at one time). And it would be good to have a protocol so that you are prepared for that.”*

## Discussion

Haddon's Matrix has been used in studies to uncover the actual risks and cause of injuries as well as to develop prevention strategies.<sup>31-33</sup> In this study, Haddon's Matrix was used as a conceptual framework to classify EHI risk factors in a military population that were identified from literature, develop interview questions, and guide data analysis. While areas of EHI risk were found across all cells of the Haddon's Matrix, one significant finding for this study was the discovery of the overwhelming focus from all participants on workplace/social factors. Although it is known that each military branch has mission specific protocols and procedures, military medical literature from all branches recommend standardized assessment and treatment for EHI events. Without the use of the matrix to develop interview questions, this area of concern may have well been missed.

NG personnel may have increased risk for non-battle injuries (of all types) due to differences in training and baseline health and fitness.<sup>34</sup> Barriers in the workplace/social environment put military personnel at risk for EHI and thus increase morbidity and mortality rates, rather than promote prevention and risk reduction. Suggestions include policy changes to in-field treatment, such as adding core body rectal temperatures as part of post-event assessment for anyone with any level of EHI symptoms. There are ways to include this simple yet proven intervention in the field, keeping privacy intact.

Overall, themes revealed EHI risks within every cell of the matrix through the underlying concepts. New risk factors were found and identified in combination with items currently on the SF-600 as the most important screening and assessment items for a risk assessment tool. Findings are being integrated with current science as a first step towards the study goal of development of an EHI risk assessment tool for military use. The use of a content expert panel and a Delphi procedure as next steps will complete the tool development process. After development of the risk tool and guidelines for this study, the intent based on the information from the matrix, will be to test them in the field. Themes will guide the addition of an educational component about EHI prevention for military personnel that will offered prior to disaster exercises. Rigor for this study included team

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triangulation in analysis, use of knowledge experts in the focus groups, and ensuring strict coding protocols and theme comparisons with EHI studies.

### **Limitations**

One limitation is that the focus groups included both officers and enlisted personnel. It is recommended that focus groups be homogenous to avoid issues such as power or control; however, all participants volunteered information across the focus groups. The focus groups took place in two geographic areas. It is unknown if other areas would offer the same information.

### **Conclusion**

The Haddon's Matrix proved to be a useful and robust framework to list known EHI injury risks as noted in the literature for the purpose of developing interview questions and for data analysis. It allowed for coding guidelines and development of the themes. From findings that emerged related to matrix cells, next steps towards development of a risk assessment tool for the military may provide an easy-to-use field tool to prevent or lessen EHI in the future.

#### What is already known on the subject

- Heat injuries are underreported in civilian and military populations in the U.S.
- Exertional heat illness impacts military readiness.
- Incidence of military heat stroke have steadily increased in recent years.

#### What this study adds

- This study used Haddon's Matrix to identify EHI screening and risk factors that are unique to the National Guard who train and respond to disasters.
- Human-related factors and social elements as well as the military field environment emerged as key factors placing NG service members at increased EHI risk.
- Findings form the basis for development of an EHI risk assessment tool specific to NG personnel working in field environments requiring impermeable PPE.

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<b>Table 1. Haddon’s matrix for factors of exertion heat illness (EHI) during military exercise</b>				
	<b>Human</b> (Military service personnel)	<b>Agent</b> (Energy transfer-providers/equipment, behaviors, and actions)	<b>Environment</b>	
			<b>Physical Environment</b> (Terrain, Heat/weather conditions)	<b>Workplace/Social Environment</b> (military norms, culture, policies, regulations)
<b>Pre-event (pre-exercise)</b>	<ul style="list-style-type: none"> <li>• Personal characteristics (age, gender, high-risk group, BMI)</li> <li>• Fitness/acclimation</li> <li>• Behaviors/actions prior to exercise (sleep, diet, stress, hydration, use of alcohol/medications), withhold information</li> <li>• Knowledge of prevention and own signs and symptoms of EHI</li> </ul>	<ul style="list-style-type: none"> <li>• Pre-exercise health assessments</li> <li>• Set-up/organization of military health assessment areas (e.g. screening/flow of traffic)</li> </ul>	<ul style="list-style-type: none"> <li>• Hot weather conditions</li> <li>• Type of geography (hilly, flat)</li> <li>• Time of year</li> <li>• Wet bulb temperature</li> </ul>	<ul style="list-style-type: none"> <li>• Attitudes about risks</li> <li>• Support structures</li> <li>• Officer examples or orders</li> <li>• Enforcement of regulations and policies</li> <li>• Evaluation/treatment plan in place</li> <li>• Multiple assessment team members/appropriate staff</li> </ul>
<b>Event (during exercise)</b>	<ul style="list-style-type: none"> <li>• Participation in exercise? (role)</li> <li>• Quality of protective equipment?</li> <li>• Heat stress response</li> <li>• Prior heat injury?</li> </ul>	<ul style="list-style-type: none"> <li>• Tyvek suits</li> <li>• Activities they are required to do (intensity/duration)</li> <li>• Assessment team member knowledge</li> </ul>	<ul style="list-style-type: none"> <li>• Heat</li> <li>• Humidity</li> <li>• Amount of time in suit</li> <li>• Amount of sunlight</li> </ul>	<ul style="list-style-type: none"> <li>• Good communication sources/plan</li> <li>• Ability of unit to complete exercise</li> <li>• Good observation of early symptoms while in suits</li> <li>• Personnel reports signs/symptoms during exercise</li> </ul>
<b>Post-event (post exercise)</b>	<ul style="list-style-type: none"> <li>• Ability for recovery/return to duty</li> </ul>	<ul style="list-style-type: none"> <li>• Post exercise health risk assessment/Recognition of EHI</li> <li>• Referral/First aid station</li> <li>• Monitoring</li> <li>• Rapid cooling and/or immediate transport</li> </ul>	<ul style="list-style-type: none"> <li>• Area for immediate assessment or treatment</li> <li>• Rest/recovery areas</li> <li>• Distance to hospital</li> </ul>	<ul style="list-style-type: none"> <li>• Debrief team</li> <li>• Review assessment and triage protocols/regulations</li> </ul>

**Table 2. Focus group participants demographics**

<b>Demographics</b>	<b>Participant response</b>	
	<b>n=27</b>	<b>%</b>
Age (Mean, SD; Years)	(46.22,8.69)	
Sex		
Male	20	74
Female	7	26
Racial background		
White or Caucasian	19	70
Black or African American	1	4
Asian	3	11
Native Hawaiian or Pacific Islander	0	0
Other: Mexican American	1	4
Multi-racial <sup>†</sup>	3	11
Ethnic background		
Hispanic	3	11
Non-Hispanic	24	89
Highest level of education		
Associates or vocational degree	2	7
Bachelor's degree	10	37
Master's degree	5	19
Doctoral degree <sup>‡</sup>	10	37
Professional licensure		
MD	7	26
PA	3	11
RN	5	19
ATC, CRNA, PharmD	4	15
Current military involvement		
Civilian	5	19
Enlisted	6	22
Officer	16	59
<b>EHI and disaster/mass casualty training experience</b>		
Experience with disaster/mass casualty trainings or events		
No*	3	11
Yes	23	85
Role in a disaster/mass casualty training or event <sup>¶</sup>		
Participant	8	30
Medical triage	21	78
Administrative	5	19
Other	2	7

*Note:* The sample population included participants from three sites: Base 1 (n = 13); Base 2 (n = 9); Community (n = 5). Columns may not sum to total or 100% due to rounding and/or missing data. Some categories are not mutually exclusive. Abbreviations: MD, medical doctor; PA, physician's assistant; RN, registered nurse; ATC, Athletic Trainer-certified; CRNA, Certified Registered Nurse Anesthetist; PharmD, Doctor of Pharmacy; EHI, exertional heat illness; SD,

standard deviation. <sup>†</sup>Identifies as both Asian & American Indian; <sup>‡</sup>Includes MD; \*Experience with EHI at individual and not mass level. <sup>¶</sup>categories are not mutually exclusive.

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### Footnotes

**Contributors:** DAS conceived the study, acquired and had full access to data, obtained IRB approval, wrote the background section, made critical revisions and had final approval of the version to be approved. GO and MR conducted the focus groups, analyzed the data, cowrote the initial draft of the manuscript methods and findings sections, provided significant revisions and edits. TO-M, SR, LE, DD, JG and CE assisted with developing the study and provided significant revisions and edits. SR provided military consultation and coordinated activities pertaining to the focus groups.

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