Chapter 14
Application of the Public Health Model for Musculoskeletal Injury Prevention Within the Military

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List of Acronyms

AFEB	Armed Forces Epidemiological Board
DoD	Department of Defense
DMSS	Defense Medical Surveillance System

Introduction

Throughout history, effective military commanders have understood that maintaining the health of their soldiers is critical to their success on the battlefield [1, 2]. Early public health and preventive medicine efforts within armies can be traced back thousands of years and are referenced in the Old Testament [3]. These early public health practices focused on regulating diet, monitoring the safety of food and water sources, maintaining personal hygiene, recognizing and investigating disease outbreaks, and providing guidance to military commanders on all aspects of force health protection and camp sanitation in the field [3]. In the American military, similar preventive medicine and public health functions have been reported from the Revolutionary War through the recent conflicts in Iraq and Afghanistan [4, 3, 5, 6].

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Officially sanctioned public health functions in the US military can be traced back over more than 70 years when the Army Industrial Hygiene Laboratory was established at the beginning of World War II at the Johns Hopkins School of Hygiene and Public Health [7]. These early public health functions in the military were focused on occupational health in the Department of Defense (DoD) production base but quickly expanded to include preventive medicine functions focused on force health protection [3, 7]. Initial public health and preventive medicine initiatives in the military were primarily focused on the prevention of infectious and communicable diseases [1, 8, 9].

In 1953 the Armed Forces Epidemiological Board (AFEB) was formed. The board comprised civilian physicians, epidemiologists, public health officials, and other scientists, and their primary function was to provide consultation to the assistant secretary of defense for health affairs and the surgeon general of the Army, Navy, and Air Force [8]. Much of the early public health focus of this group was also on the prevention of infectious disease; however, this recently shifted to focus more on preventing injuries and musculoskeletal conditions in the military [8-12]. In the early 1990s, leaders within the DoD began to develop an increased appreciation for the impact that musculoskeletal injuries and conditions have on military readiness [8, 11]. As a result, the AFEB established the Injury Prevention and Control Working Group [8]. This group comprised military and civilian physicians, epidemiologists, and other key scientists and was tasked with reviewing existing injury data within the military and making recommendations for improving injury surveillance and prevention strategies within this high-risk population [8]. This seminal work applied the public health model to examine the burden of injuries within the military population [12] and yielded important recommendations for improved injury surveillance and prevention efforts [8, 11, 12]. One of the most important accomplishments of the working group was to bring light to the "hidden epidemic" of musculoskeletal injuries and conditions within military populations [9, 11]. Subsequent initiatives have continued to apply the public health model to better understand the scope of musculoskeletal injuries in this high-risk population and to evaluate the efficacy and effectiveness of prevention efforts. The US Army Public Health Command was established in 2011, and part of the organization's core mission is to promote health and prevent disease, injury, and disability among soldiers, retirees, family members, and DoD civilians [13].

The purpose of this chapter is to provide an overview of how the public health model has been applied to define the "hidden epidemic" [8, 9, 11, 12] of musculoskeletal injuries and conditions in the military and how it is being used to develop and implement evidence-based injury prevention interventions in this high-risk population. Subsequent chapters in this part focus on evidence-based injury prevention strategies that have been applied within the military population (Chap. 15) and discuss a framework for effective injury prevention, as well as strategies to overcome barriers to effective injury prevention in the military environment (Chap. 16).

Early Application of the Public Health Model for Injuries in the Military

The AFEB and the Injury Prevention and Control Working Group initially adopted a five-step public health model, which was adapted from other sources, as a framework to systematically evaluate the burden of injuries within the military population [12]. The group was specifically interested in determining how military medical information could be used for injury surveillance and to inform public health practice related to injury prevention. The five steps in the public health model were: (1) Determine the existence and magnitude of the problem, (2) identify causes of the problem, (3) determine what prevents the problem, (4) implement prevention strategies and programs, and (5) continue surveillance and monitor/evaluate the effectiveness of prevention efforts [12]. While all steps are critical, it is important to note that the steps in the public health approach to injury prevention do not need to be carried out in sequential order and often activities in several of these areas are being conducted simultaneously [4]. This section will highlight key findings from the initial work of the AFEB and the Injury Prevention and Control Working Group and describe how it provided a model for subsequent work in this area.

In determining the scope of the injury problem in step 1 of the public health model, the Injury Prevention and Control Working Group examined available military data on fatalities, disability, hospitalizations, and outpatient care that resulted from injuries [11, 12]. One of their primary objectives was to determine the quality of the available data and to evaluate its utility for injury surveillance. They reported that injuries were the leading cause of fatalities in the military in 1994, accounting for nearly 50% of all deaths [12]. They also reported that rates of medical disability rose for all military services through the 1980s and into the early 1990s. Musculoskeletal injuries and conditions were a leading cause of disability discharge from the military during this time frame, with over 50% of all disability cases reviewed by the Army and Navy being the result of injury-related musculoskeletal and orthopaedic conditions [12]. Musculoskeletal injuries and conditions were also the leading cause of hospitalization in the Army, Navy, and Marine Corps and the second leading cause of hospitalization in the Air Force in 1994 [12]. Combined, injuries and musculoskeletal conditions accounted for 21–48% of all hospitalizations among active duty military personnel across all four branches of service in 1994. High rates of injury-related outpatient visits within the military health system were also reported.

The Injury Prevention and Control Working Group's next task was to identify causes and risk factors associated with injuries in the military (step 2) [12]. To accomplish this task the group reviewed available data on causes of injury routinely collected within the military [12]. These data sources included accident reports and hospital cause of injury codes. They also reviewed the existing evidence on physical training-related injuries from military research centers. Based on the available data, sports-related injuries were the leading cause of hospitalization in both the Army and the Air Force in 1994. Sports- and physical training-related injuries were

also the second leading cause of accidents according to safety data in the Army and Air Force during the same time period. In addition to sports-related injuries, physical training-related musculoskeletal injuries and conditions were also identified as a leading cause of injury in military training populations. Privately owned motor vehicle accidents were also a leading cause of accidents and hospitalizations in the Army and the Air Force.

Once the scope, causes, and risk factors for injury in the military were quantified based on the available data, the Injury Prevention and Control Working Group turned their focus to identifying and evaluating evidence-based injury prevention interventions aligned with the causes and risk factors for injury that they had identified in earlier steps (step 3). The group noted that "To effectively prevent complex public health problems such as injuries, interventions should be tested and evaluated prior to widespread implementation." [12] To accomplish this they reviewed the available data on injury prevention interventions that had been developed and tested in military training populations. They reported that interventions to reduce running mileage during military training had been shown to substantially reduce lower extremity musculoskeletal injuries without compromising improvements in aerobic fitness. Subsequent studies have confirmed this finding and running frequency, duration, intensity, and volume now follow fairly standardized protocols during initial entry-level military training [14–16]. The group also examined the effectiveness of outside the boot ankle braces to prevent injury during airborne operations (parachuting) [12]. Level I evidence from a randomized controlled trial suggested that this injury prevention intervention produced an 85 % reduction in ankle sprains during airborne training [17], and the brace is now routinely used [12, 17, 18]. Finally, the group found that available evidence did not support the use of shock-absorbent insoles to reduce the incidence of stress fracture during military training [12, 19]. Implementing shock-absorbent insoles at a military training site, without initial testing and evaluation, would have resulted in a significant cost that would have failed to yield any injury prevention benefit. The group suggested that these examples emphasize the importance of studies to evaluate the efficacy of injury prevention intervention efforts prior to wide-scale implementation and adoption [12].

The Injury Prevention and Control Working Group did not implement or evaluate any new injury prevention interventions or programs as part of their initial work; however, they did make important recommendations related to this critical step in the public health model (step 4) [8, 11, 12]. Their work and recommendations related to injury surveillance also provided the foundation for subsequent work in this area [8, 11]. Successful injury prevention interventions require the coordination of various stakeholders (e.g., senior leaders, tactical leaders, policy developers, health-care providers, public health practitioners, etc.) and public health functions (e.g., surveillance, research, implementation science, program evaluation, etc.) [8, 12, 20]. Trials to evaluate the efficacy of interventions and the effectiveness of injury prevention programs in real-world settings are necessary to reduce the risk of musculoskeletal injuries and conditions in the military. Additional strategies to evaluate injury prevention program efficacy and effectiveness are discussed in detail in the following chapters and several models for successful injury prevention practice have been described in the literature [20, 22]. A more thorough discussion

of models for health behavior change is presented later in this chapter. The group recommended that the integration of injury surveillance and research into prevention program development, implementation, and evaluation was critical to overall program success [12]. However, they also noted that demonstrating injury prevention intervention efficacy under controlled research conditions does not ensure program effectiveness when programs are implemented in real-world military training environments [12]. Others have echoed this important aspect of injury prevention program implementation [20, 21].

As a result, the Injury Prevention and Control Working Group emphasized the critical role of ongoing injury surveillance in evaluating the intermediate and long-term effects of injury prevention efforts (step 5). They also provided examples of how injury surveillance data within the military had been used to evaluate injury prevention interventions related to fatalities, motor vehicle accidents, and aviation crashes [12]. They noted that while the data available within the DoD was very valuable for injury surveillance and program evaluation, the process of gathering, collating, and analyzing it was extremely labor intensive and time consuming because disparate data sources lacked connectivity and were widely dispersed between medical, administrative, and personnel databases across the branches of military service [12]. Based on this finding the Injury Prevention and Control Working Group recommended that the DoD should create a comprehensive military medical surveillance system to integrate critical elements of these existing databases [8, 11, 12]. As a result, the Defense Medical Surveillance System (DMSS) and Defense Medical Epidemiological Database were developed [8, 23]. These resources, as well as other surveillance assets [24] within the military, have significantly enhanced injury surveillance and prevention efforts within this high-risk population. They have also made surveillance data available in a much more efficient and timely manner to a broader range of stakeholders.

The results of these initial injury surveillance and prevention efforts utilizing the public health model were described in a special issue of the *American Journal of Preventive Medicine* in 2000 [6, 9]. This compilation of articles did not provide definitive answers on how to mitigate the impact of musculoskeletal injuries and conditions in military populations but they began to frame the critical questions for addressing this important threat to military readiness and provided compelling evidence on the magnitude of the problem [9]. These important questions included identifying which modifiable and non-modifiable risk factors and vulnerabilities place military service members at increased risk for biomechanical injury from acute and repetitive trauma [9]. They also included questions about which injury prevention intervention, or combination of interventions, result in clinically important reductions in injury. Major General James B. Peake stated that “answers to these questions can only come from accurate data collection and large population trials with active command sponsorship [9]. In addition to highlighting these questions, the work of the AFEB and the Injury Prevention and Control Working Group also provided a framework for public health practice related to injury prevention and injury prevention research and program evaluation. Over the next decade, key stakeholders made significant progress toward expanding and extending the initial work of the AFEB and the Injury Prevention and Control Working Group to address

the “hidden epidemic” of injuries in the military; however, this work was complicated by US military involvement in wars on two fronts in the Middle East. Despite this challenge, these stakeholders leveraged the public health model to accomplish this work and they expanded this model to integrate information from other scientific disciplines. These disciplines included health behavior and behavioral health interventions, implementation sciences, and risk management. These collaborations between DoD personnel and civilian researchers have aided in answering some of the important questions noted above and they have led to significant advances in our understanding of the injury problem and the effectiveness of injury prevention interventions within the military.

Contemporary Applications of the Public Health Model for Injury Prevention in the Military

In 2010, a follow-up special issue on injuries in the military was published in the *American Journal of Preventive Medicine* [5, 25, 26]. The supplement was titled “A Public Health Approach to Injury Prevention: The US Military Experience.” The volume provided a refined description of how the public health model for injury prevention had evolved and how it continued to be used to identify injury prevention priorities (Table 14.1). It also aligned the public health approach to injury prevention with the mishap risk management process utilized in the military to facilitate the implementation of injury prevention priorities among line officers, safety officers, and preventive medicine personnel (Table 14.1) [25]. This special issue also provided an update on a decade of progress toward achieving important injury prevention goals and recommendations within the military. Significant progress had been made in developing the infrastructure to support routine surveillance for musculoskeletal injuries and conditions and the ability to use these resources and surveillance data to evaluate injury prevention initiatives had been demonstrated (steps 1, 4, and 5) [4]. Despite these advances, limited progress had been made toward research to identify the causes and risk factors (modifiable and nonmodifiable) for injury, or to assess the efficacy of injury prevention interventions (steps 2 and 3). Though Major General James B. Peake noted that effective injury prevention in the military would be dependent on accurate data collection (surveillance) and large population trials with active command sponsorship in 2000 [9], the latter had yet to be realized. Jones et al. [4] noted that there was no dedicated injury prevention research objective or program for the military at the time the issue was published. Though limited progress was made in the area of research, additional advances were made in expanding the public health approach to injury prevention in the military. In addition to leveraging and applying the public health approach to injury prevention outlined in Table 14.1, key leaders recognized the need to develop and implement a systematic evidence-based approach for injury prevention in the military [4].

Table 14.1 Steps in applying the public health approach to prevent musculoskeletal injuries and conditions in the US military and alignment with the US Army mishap risk management process. (Adapted from [4, 25])

Public health process for injury prevention	Description	US Army mishap risk management
Step 1: Quantify the burden of injuries through surveillance	Routine injury surveillance quantifies the frequency, rates, and trends in musculoskeletal injuries and conditions at the population level. These data are used to identify emerging and ongoing areas of concern and can be used to help set injury prevention priorities	*Step 1:* Identify and assess hazards
Step 2: Identify the cause and risk factors	Information from observational research and public health practice is used to identify the causes and risk factors for musculoskeletal injuries and conditions. The focus should be on identifying modifiable and non-modifiable risk factors as this information can be used to target injury prevention interventions and groups at the highest risk for injury, respectively	*Step 2:* Determine risk (loss severity and probability)
Step 3: Research on injury prevention interventions	Injury prevention interventions targeting the modifiable risk factors in high-risk groups are developed and implemented. Randomized controlled trials and non-randomized studies are conducted to evaluate the efficacy of these injury prevention interventions under controlled conditions	*Step 3:* Develop risk reduction controls
Step 4: Injury prevention program and policy implementation	Key stakeholders including senior leaders, tactical leaders, policy makers, health-care providers, and public health practitioners, work together to develop and implement evidence-based injury prevention programs and policies based on the available evidence identified in steps 1–3	*Step 4:* Make risk acceptance decisions
Step 5: Ongoing program and policy evaluation and monitoring	Ongoing injury surveillance and program evaluation studies are conducted to examine the effectiveness of injury prevention programs and policies during and following implementation	*Step 5:* Implement controls, supervise implementation, and evaluate outcomes

Evidence-based decision-making has garnered significant support in public health practice and policy in recent years and has contributed to the development of research priorities. Contemporary injury prevention practice and policy should be guided by a systematic evaluation of the best evidence available. A systematic review of the available evidence can also aid in identifying knowledge gaps that need to be addressed through research to advance injury prevention priorities. Jones et al. [4] recently described a systematic process for evidence-based decision-making and injury prevention in the military. The evidence-based decision-making process described by Jones et al. [4] focused on six steps including: (1) identifying the biggest or most severe injury problems; (2) systematically searching and reviewing the existing scientific evidence on effective injury prevention interventions based on the injury prevention priorities established in step 1; (3) objectively evaluating the quality of the individual research studies identified in step 2 using established review criteria; (4) making injury prevention recommendations based on the overall strength and consistency of the evidence; (5) prioritizing injury prevention interventions based on available resources, the magnitude and severity of the problem, the efficacy and effectiveness of interventions, and feasibility; and (6) identification of research gaps and priorities. Important aspects of the evidence-based decision-making process for injury prevention outlined above include evaluating the quality and findings of individual studies, and synthesizing the results across studies, to make evidence-based recommendations grounded in the strength and consistency of the available evidence. To address the latter, the authors provided criteria for making recommendations on injury prevention strategies based on the synthesis of effects across studies [4]. They also provided criteria and tools for establishing injury prevention practice and research priorities in the military.

Canham-Chervak et al. [27] applied this systematic approach for prioritizing injury prevention activities in a separate paper in the same special issue of the *American Journal of Preventive Medicine*. Their stated objectives were to (1) refine previous prioritization efforts by systematically utilizing input from experts with public health training and experience evaluating epidemiological data and the scientific literature, and (2) apply defined criteria to identify top DoD injury causes most amenable to implementation of injury prevention programs and policies [27]. Musculoskeletal injuries and conditions due to physical training were identified as the top priority for injury prevention, followed by military parachuting injuries, injuries due to privately owned motor vehicle crashes, and sports-related injuries. These and other leading causes of injury in the military were systematically evaluated using the following criteria: (1) importance of the problem to health and military readiness, (2) preventability of the problem, (3) feasibility of injury prevention or policy interventions, (4) timeliness of implementation and results, and (5) ability to evaluate programs or policy outcomes. Though the authors applied a systematic approach to identifying injury prevention priorities, they noted some limitations associated with the process and areas for improvement. A primary limitation was that the process relied on cause of injury coding from hospitalization data and did not include cause of injury for outpatient encounters [27]. This is an important limitation because the majority of musculoskeletal injuries and conditions are treated in outpatient clinics.

Despite the significant advances in injury surveillance within the military, accurate cause of injury coding for outpatient encounters remains problematic in the military health system. A key area for improving the systematic process for establishing injury prevention priorities focused on involving the raters earlier in the process so that they could have input into the final criteria and methods used; however, the authors noted the need to balance scientific rigor with the need for a timely response to pressing public health issues might preclude this in public health practice [27].

Ruscio et al. [28] applied a similar systematic process to identify injury prevention priorities based on injury type, cause of injury, and morbidity measured by the number of limited duty days associated with injury. The authors reviewed hospitalization data and data for outpatient encounters documented in the DMSS for 2004. They identified the leading injury types by body region for acute injuries and injury-related musculoskeletal conditions. The authors also estimated the number of limited duty days for each diagnosis by body region. Limited duty days for the top five acute injuries resulting in outpatient encounters were (1) lower extremity fractures which resulted in 7928 person-years of limited duty (20%), (2) upper extremity fractures which resulted in 6450 person-years of limited duty (17%), (3) lower extremity sprains and strains which resulted in 5144 days of limited duty (14%), (4) lower extremity joint dislocations and cartilage tears resulting in 4166 person-years of limited duty (11%), and (5) sprains and strains to the spine and back which resulted in 3293 person-years of limited duty (9%). Limited duty days for the top five injury-related musculoskeletal conditions requiring outpatient care were (1) lower extremity overuse injuries (pain, inflammation, and stress fractures) which resulted in 10,420 person-years of limited duty (34.5%), (2) overuse injuries to the torso (pain, inflammation, and stress fractures) which resulted in 5933 person-years of limited duty (19.6%), (3) upper extremity overuse injuries (pain, inflammation, and stress fractures) which resulted in 3600 person-years of limited duty (11.9%), (4) unspecified overuse injuries (pain, inflammation, and stress fractures) which resulted in 2737 limited duty days (9%), and (5) lower extremity sprains, strains, and ruptures which resulted in 1896 person-years of limited duty (6.3%). These data systematically provide a measure of the impact of musculoskeletal injuries in the military population, specifically in terms of work-related disability associated with the leading diagnoses for musculoskeletal injuries and conditions among service members. In addition to quantifying the burden of these injuries in terms of military readiness, they also provide objective data for developing injury prevention priorities.

The causes of the top acute injury diagnoses were also examined [28]. Transportation-related accidents (e.g., motor vehicle or vessel) were the leading cause of upper and lower extremity fractures and sprains and strains to the back. Sports and physical training were the leading cause of lower extremity sprains, strains, and dislocations. Sports and physical training was also among the top three causes for all of the other leading diagnosis categories examined. Using the systematic process described above by Jones et al. [4], service-specific injury prevention program and policy priorities were established based on these data (Table 14.2) [28]. Sports and physical training-related musculoskeletal injuries were identified as a leading

Table 14.2 Injury prevention program and policy priorities by service. (Adapted from [28])

	Air Force		Army[a]		Marine Corps		Navy	
Cause of injury	Average score (max = 40)	Rank	Average score (max = 40)	Rank	Average score (max = 40)	Rank	Average score (max = 40)	Rank
Sports and physical training (PT)[a]	29.2	2	PT: 34.0 SPT: 28.4	PT: 1 SPT: 4	28.5	2	27.0	2
Privately owned vehicle (POV) accident	32.0	1	27.2	5	24.3	4	26.0	3
Falls	26.3	3	30.6	3	28.0	3	28.0	1
Twist/turn (w/o fall)	21.8	6	24.6	8	20.7	7	19.3	6
Nontraffic (POV and MIL)	20.3	7	19.4	10	17.8	8	19.0	7
Parachuting	20.2	8	31.8	2	NR	NR	16.0	8
Guns and explosives	24.2	4	26.2	6	36.3	1	22.8	4
Military vehicle accidents	23.0	5	26.2	6	23.5	5	NR	NR
Tools and machines	NR	NR	21.0	9	21.5	6	21.8	5

SPT sports, *PT* physical training, *POV* privately owned vehicle, *MIL* military, *NR* not rated

[a] The Army ranked sports separate from physical training; the other services provided a combined score for sports and physical training

priority for injury prevention and policy prioritization across the services. Based on these data, the authors made recommendations for injury prevention interventions [34] that included (1) evaluating environmental, behavioral, directive, or regulatory interventions to prevent injuries related specifically to sports and physical training; (2) endorse evidence-based recommendations from systematic reviews for sports and physical training-related injury prevention, including but not limited to parachute ankle braces, mouth guards, breakaway bases for softball, and ankle braces for sports with high risk for ankle injury such as soccer and basketball; (3) provide resources and policy priority to the biggest, most preventable problems identified which include, but are not limited to, sports and military physical training, falls, and privately owned vehicle accidents; and (4) endorse the Joint Services Physical Training Injury Prevention Working Group's recommendations for the prevention of physical training-related injuries [29].

Ruscio et al. [28] also made several recommendations for injury prevention research priorities and noted that addressing these strategic research priorities could greatly enhance prevention efforts across the DoD. The top research priorities identified included (1) epidemiologic research on falls and physical training in operational units; (2) enhanced methods to obtain injury data for sports, exercise, and recreation-related musculoskeletal injuries; (3) assessment of the impact of leading injuries on disability and medical separation; and (4) evaluation of current methodologies and results to ensure application in the deployed environment. The latter is particularly important as non-battle injuries are a leading cause of medical evacuation from theater during military deployments, and sports and physical training are a leading cause of these injuries [30]. See Chap. 3 in this book for a detailed review on the burden of non-battle musculoskeletal injuries and conditions during deployment.

The application of the public health model for injury prevention within the military continues to evolve. Combined with a systematic approach and evidence-based decision-making process, injury prevention efforts within the military continue to gain traction and increased attention from military leaders and policy makers. However, notable gaps, particularly in injury prevention research, remain. The lack of a dedicated injury prevention research objective or program for the military remains a significant barrier to advancing injury prevention efforts. Despite significant increases in research funding through the Congressionally Directed Medical Research Program over the past decade, very little of this funding has been allocated to align with important injury prevention goals or the injury prevention intervention and research priorities identified above.

Integrating Health Behavior into Injury Prevention Interventions: Applications for the Public Health Model

Public health research has consistently demonstrated that passive injury prevention interventions that can be engineered into the environment yield better results than active interventions where individuals or organizations must consciously modify

their behavior. Unfortunately, the efficacy and effectiveness of many injury prevention interventions is dependent on health-related behavior at multiple levels of the organization in order to initiate and sustain clinically important behavior change [31]. Despite the inherent structure within the military, this is also true for injury prevention efforts in military populations. As a result, it is critical for injury prevention research and practice to integrate theories of health behavior change, and these theories are particularly important when designing and implementing injury prevention interventions [32]. Implementation science is another emerging field in public health that can inform injury prevention practice and research. According to the National Institutes of Health (NIH) Fogarty International Center, implementation science is the study of methods to promote the integration of research findings and evidence into public health policy and practice [33]. The goal of implementation science is to understand the behavior of patients, health-care professionals, and other stakeholders as a key variable in the sustainable uptake, adoption, and implementation of evidence-based interventions in real-world settings [33]. Despite the advances that have been made toward injury prevention in the military, efforts to integrate theories of health behavior change or implementation science into injury prevention research and practice are limited [20].

Several conceptual frameworks and models have been developed to aid in designing, implementing, and evaluating evidence-based health promotion interventions [32]. These models incorporate health behavior theories and are directly applicable to injury prevention interventions. Two of the most comprehensive models that have been developed are the PRECEDE/PROCEED planning model [22] and the Diffusion of Innovations model [34]. The Reach Effectiveness Adoption Implementation Maintenance (RE-AIM) framework also provides a theory-based model that is applicable to injury prevention interventions [32]. All of these models are directly aligned with the goals of implementation science [33]. This section will provide a brief overview of how health behavior theories and the emerging field of implementation science can be used to improve injury prevention intervention effectiveness and outcomes, particularly in the military setting.

Intervention planning and implementation is an iterative process and the PRECEDE/PROCEED model is well suited for planning and evaluating injury prevention interventions that rely on changes in health behavior. The PRECEDE/PROCEED framework is an evidence-based model that has been used effectively for developing and implementing comprehensive behavioral interventions to reduce injuries and injury risk [22]. The main purpose of the framework is to provide a structure for applying health behavior theories and concepts systematically during the planning, implementation, and evaluation of behavior change interventions. The PRECEDE/PROCEED framework also provides a model for integrating key theoretical constructs into the planning and evaluation of behavioral interventions [22]. According to Gielen et al. [22], the PRECEDE/PROCEED framework can be effectively used to build comprehensive injury prevention programs that rely on behavior change through “intervention matching, mapping, pooling, and patching.” There are four steps within the PRECEDE portion of the model and these steps primarily align with the planning and development of the intervention. These

phases include (1) social assessment, participatory planning, and situational analysis of the intervention context; (2) epidemiological, behavioral, and environmental assessments; (3) educational and ecological assessment; and (4) administrative and policy assessment and intervention alignment [22]. Gielen et al. [22] provide guidelines and recommendations for how appropriate health behavior theories can be integrated into each of these for planning phases. For example, social cognitive theory might be applied to assess and address potential personal, behavioral, and environmental determinants related to the success of the behavioral change intervention.

Four phases also comprise the PROCEDE portion of the model which is primarily aligned with the implementation and evaluation of the intervention. These phases include (5) implementation, (6) process evaluation, (7) impact evaluation, and (8) outcome evaluation [22]. Process evaluation focuses on the extent to which the program is implemented according to plans. Factors that are related to process evaluation include intervention fidelity and adherence/compliance. Intervention fidelity is the degree to which interventions are implemented as intended by program planners [35]. Intervention adherence or compliance is the baseline measure of fidelity. For example, intervention adherence is focused on whether an individual performed the intervention (e.g., exercises to improve neuromuscular control) when they were supposed to, while intervention fidelity more broadly defined would also be concerned with whether the intervention exercises were performed correctly as prescribed. Impact evaluation is typically focused on assessing changes in behavioral and environmental factors, as well as predisposing, reinforcing, and enabling factors that influence the outcomes of the behavioral intervention [32]. Outcome evaluation focuses on whether important health and quality of life measures are altered due to the intervention (e.g., decrease in injury rates, decrease in attrition, etc.). Overall, the PRECEDE/PROCEDE framework can be useful in planning, implementing, and evaluating injury prevention interventions that rely on behavior change at multiple levels of an organization and this model has direct applicability to injury prevention efforts within military settings. Gielen et al. [32] provide a detailed description of the PRECEDE/PROCEDE framework and examples of its use for intervention planning and evaluation for readers who are interested in more information about this model.

The Diffusion of Innovations model is focused on the factors that facilitate and/or inhibit evidence-based interventions from being adopted and translated to injury prevention practice [36]. A detailed description of the model is provided by Oldenburg and Glanz [34], but we will provide an overview here. In the model, diffusion is defined as the process by which the spread or adoption of an innovation (e.g., injury prevention intervention) over time occurs across key stakeholders within a social system [34]. We will use innovation and intervention interchangeably in this section. The Diffusion of Innovations model relies on key concepts in two broad categories that include (1) foundational concepts and stages of diffusion, and (2) characteristics of interventions that determine diffusion [34]. The primary stages of diffusion include intervention development, adoption, implementation, maintenance, sustainability, and institutionalization [34]. Characteristics of interventions

that influence diffusion focus on key questions and attributes. These questions include: (1) Is the intervention better than what was there before? (Attribute: relative advantage); (2) Does the intervention fit with the intended audience and within the intended intervention context? (Attribute: compatibility); (3) Is the intervention easy to implement? (Attribute: complexity); (4) Can the intervention be tested before making a decision to adopt? (Attribute: trialability); and (5) Are the results of the intervention readily apparent, easily measureable, and clinically important? (Attribute: observability) [34]. Overall, the Diffusion of Innovations model has been widely used to translate evidence-based interventions that require behavioral change into public health practice. While all models have noted limitations, aspects of the Diffusion of Innovations model have direct applicability to injury prevention efforts within the military which may aid in improving intervention diffusion and dissemination.

Other theoretical models and conceptual frameworks have also been described that could inform injury prevention intervention development, implementation, and evaluation [20, 21, 32, 37]. Some of these models may have direct applicability to injuries in young and physically active populations comparable to the military. The RE-AIM framework outlines important dimensions and critical questions that should be addressed when evaluating injury prevention intervention programs that rely on behavior change [32]. Chapter 16 in this book provides a detailed description of the RE-AIM framework and how it might be used to overcome barriers to effectively implementing evidence-based injury prevention interventions in the military. Additional information about the RE-AIM framework is also available [32, 38].

Finch and colleagues [21, 38-42,] have played a leading role in integrating implementation science into injury prevention interventions in active populations. Specifically, the Translating Research into Injury Prevention Practice (TRIPP) model described by Finch [21] focused on the importance of intervention effectiveness in addition to efficacy and raised important questions about program development and implementation that might affect translation of research results to practice. More recently, Padua et al. described seven steps that are critical to intervention development and implementation specifically within the context of a military training environment [20]. These steps include (1) establishing administrative and leadership support, (2) developing an interdisciplinary team that includes key stakeholders, (3) identifying potential logistical barriers to effective implementation and identifying solutions to address these concerns, (4) developing an evidence-based injury prevention program that is aligned with stakeholder objectives and contextual constraints, (5) training intervention personnel, (6) evaluating intervention fidelity through process evaluation, and (7) developing an exit and transition strategy that promotes sustainability and institutionalization. Overall, there are several established theoretical models that could be readily applied to improve injury prevention implementation, sustainability, and institutionalization within the military. These models directly align with the public health approach and systematic evidence-based decision-making processes that have been applied to tackle the musculoskeletal injury challenge within the military population.

Summary

In combination with a systematic evidence-based decision-making process, the public health model for injury prevention can significantly improve injury prevention practice, policy, and research within the military. In addition, this framework can be used to set important injury prevention priorities and to make decisions about resource allocations that are aligned with these priorities. Because the success of many injury prevention interventions within the military relies on behavior change at the individual or organizational levels, established theories of health behavior should be integrated into intervention planning, implementation, and evaluation. Some of the more comprehensive models available include the PROCEDE/PRECEDE model, the Diffusion of Innovations model, and the RE-AIM framework. While all of these models have strengths and weaknesses, they provide a conceptual framework grounded in theory that is likely to improve injury prevention outcomes. The emerging field of implementation science will also play a critical role in the future success of injury prevention interventions within the military.

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