

Prevention of Physical Training–Related Injuries

Recommendations for the Military and Other Active Populations Based on Expedited Systematic Reviews

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Background: The Military Training Task Force of the Defense Safety Oversight Council chartered a Joint Services Physical Training Injury Prevention Working Group to: (1) establish the evidence base for making recommendations to prevent injuries; (2) prioritize the recommendations for prevention programs and policies; and (3) substantiate the need for further research and evaluation on interventions and programs likely to reduce physical training–related injuries.

Evidence acquisition: A work group was formed to identify, evaluate, and assess the level of scientific evidence for various physical training–related injury prevention strategies through an expedited systematic review process. Of 40 physical training–related injury prevention strategies identified, education, leader support, and surveillance were determined to be essential elements of a successful injury prevention program and not independent interventions. As a result of the expedited systematic reviews, one more essential element (research) was added for a total of four. Six strategies were not reviewed. The remaining 31 interventions were categorized into three levels representing the strength of recommendation: (1) recommended; (2) not recommended; and (3) insufficient evidence to recommend or not recommend.

Evidence synthesis: Education, leadership support, injury surveillance, and research were determined to be critical components of any successful injury prevention program. Six interventions (i.e., prevent overtraining, agility-like training, mouthguards, semirigid ankle braces, nutrient replacement, and synthetic socks) had strong enough evidence to become working group recommendations for implementation in the military services. Two interventions (i.e., back braces and pre-exercise administration of anti-inflammatory medication) were not recommended due to evidence of ineffectiveness or harm, 23 lacked sufficient scientific evidence to support recommendations for all military services at this time, and six were not evaluated.

Conclusions: Six interventions should be implemented in all four military services immediately to reduce physical training–related injuries. Two strategies should be discouraged by all leaders at all levels. Of particular note, 23 popular physical training–related injury prevention strategies need further scientific investigation, review, and group consensus before they can be recommended to the military services or similar civilian populations. The expedited systematic process of evaluating interventions enabled the working group to build consensus around those injury prevention strategies that had enough scientific evidence to support a recommendation.

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Introduction

In 2003 the Secretary of Defense (SECDEF) directed that rates of accidents and injuries must be markedly reduced.¹ In response to the SECDEF's instruction, the Defense Safety Oversight Council (DSOC) was formed to provide governance on Department of Defense (DoD)-wide efforts to reduce preventable injuries and mishaps. The Under Secretary of Defense for Personnel and Readiness chairs the DSOC, who chartered nine task forces to develop recommendations for policies, pro-

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grams, and other investments to reduce preventable injuries and accidents. The Military Training Task Force (MTTF) was chartered to support the SECDEF's accident and injury prevention directive with a focus on interventions that relate to all aspects of military training.

Injury is undisputedly the leading health and readiness threat to the armed forces. Injuries are the leading cause of service member hospitalizations and outpatient visits, many resulting in preventable discharges, and account for over 25 million limited duty days DoD-wide annually.^{2–4} Training-related injuries have been identified as the leading cause of clinic visits and have a substantial impact on the readiness of the force due to the amount of limited duty time they cause.^{5,6} Most of the preventable acute and traumatic injuries sustained by military personnel are due to the cumulative effect of weight bearing physical training activities such as running, particularly for military basic trainees.^{7–16} A working group of civilian and military injury experts from the Johns Hopkins Center for Injury Research and Policy and the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) identified physical training as the largest and most severe health problem for the U.S. Army and the one with the greatest possibility for prevention success.^{17,18}

The Joint Services Physical Training Injury Prevention Working Group (JSPTIPWG, hereafter referred to as working group, except in the tables) was created under the Military Training Task Force in September 2004 to evaluate military physical training injury prevention programs, policies, and research for recommendations to reduce physical training-related injuries during and after initial military training within the four U.S. military services (army, navy, air force, and Marine Corps). An expedited systematic review process used by the working group served three primary purposes:

1. Establish the evidence base for making recommendations to prevent physical training-related injuries;
2. Prioritize the recommendations for prevention programs and policies; and
3. Substantiate the need for further research and evaluation of interventions and programs likely to reduce physical training-related injuries.

Evidence Acquisition

A working group was formed which included 29 military and civilian researchers, public health practitioners, clinicians, training officers, epidemiologists, and analysts representing the four U.S. military services and injury experts from the CDC as well as professors at academic institutions. The working group initially met twice by teleconference and discussed a strategy for accessing pre-

vious subject matter expert panel recommendations, determined how to systematically review the scientific literature, developed inclusion and exclusion criteria for studies identified in the search process, and divided responsibility for each of the intervention topics to be reviewed.

In order to formulate a list of interventions, the working group looked to the past work of six expert panels to identify commonalities among the services. This included a 1994 panel of injury prevention experts and military leaders from the U.S. Navy and Marine Corps who met to evaluate and discuss improvements to physical training. As a result of this meeting, recommendations were published by the Naval Health Research Center.¹⁹ Later, guidelines for preventing injuries in sailors in accession training were published.^{20,21} A panel of army injury and fitness experts met in 1999 at the army's largest basic training post, Fort Jackson SC, under the direction of the Army Surgeon General and the Commander of the Army Training and Doctrine Command, and prioritized their findings and recommendations.²² In 2000, the Morbidity and Mortality Weekly Report (MMWR) summarized recommendations to reduce injury risk in women.²³ The Army Musculoskeletal Injury Prevention Plan (MIPP) represented a collection of evidence-based interventions compiled by the USACHPPM for the Army Surgeon General in 2003. This compilation of recommendations for the prevention of musculoskeletal injuries in basic training was endorsed by the Army Surgeon General and provided to the Army Training and Doctrine Command as medical recommendations to reduce physical training-related injuries.²⁴ In addition, scientists from the U.S. Army Research Institute of Environmental Medicine summarized the literature on the prevention and control of musculoskeletal injuries associated with physical training.²⁵

Working from the interventions identified by these expert panels, an initial list of topics included 27 prevention strategies, divided into the following categories: Exercise/Training Programs; Equipment and Environment; Education; Nutrition, Supplements and Hydration; Medication and Medical Care; Leadership/Accountability Issues; and Surveillance and Evaluation. The working group expanded this list to a total of 40 strategies with potential to reduce the incidence of physical training-related injuries.

An expedited literature review process was defined in five steps to be completed before a face-to-face meeting. The first step was to conduct an online literature search for the specific prevention strategies assigned. The focus was on the primary prevention of injuries related to physical training. Working group members were encouraged to use a variety of online search engines, but a minimum

of the following three were required: MEDLINE, Defense Technical Information Center Scientific and Technical Information Network, and Cochrane databases. Searches were limited to human studies published after 1970 and written in English. Working group members were asked to record the total number of hits per search as well as to document the scientific reference of the studies meeting the inclusion criteria.

Studies that met the review inclusion criteria were research studies that presented the methods, results, and conclusions of an original scientific investigation which included injury as a measured outcome. Systematic reviews that described the results of original scientific investigations and included injury as a measured outcome represented the highest level of evidence and were also included. However, public health decisions must often consider all available scientific evidence, not just randomized controlled trials.^{18,26} Intervention studies, risk factor/cause studies, descriptive epidemiology studies, and case series (as defined in *A Dictionary of Epidemiology*²⁷) were listed and categorized if injury was a measured outcome. Although not the primary focus of the search, other original research studies (e.g., field, epidemiologic, lab, or biomechanical) related to topics that did not measure injury, but rather measured intermediate outcomes (e.g., a stretching study measuring flexibility, a physical training program measuring improvements in fitness, or biomechanical studies examining shock absorbency of footwear) were listed but were not considered to have an influence on the recommendations for preventing injury. Original scientific investigations not directly relevant to the topic or nonresearch publications such as editorials, letters, expert opinion papers, and educational articles were excluded from further assessment.

The next step was to classify the literature on injury outcomes by the study type (i.e., systematic reviews, intervention studies, risk factor/cause studies, descriptive epidemiology, case series, and other non-injury outcome research) within a classification matrix and assess the consistency of the studies. Table 1 is an example of a completed classification matrix for the Prevent Overtraining strategy. Injury outcomes were of prime importance as they most clearly demonstrated the effect of a given strategy on the ultimate goal of reducing injuries. Other outcomes that represented markers of muscle damage or were related to performance were considered less conclusive. The strength and quality of the evidence (including markers of muscle damage in one instance) eventually factored into the decision-making process.

As a third step, the working group members were asked to indicate whether or not the study included other interventions in addition to the intervention in question. For exam-

ple, a study was considered to be a multi-interventional study if more than one strategy may have influenced the injury outcome. If the study included multiple interventions, it was annotated as such in the multiple-intervention column. Additionally, if the study had an overall positive effect on injuries or injury rates (i.e., a reduction in injuries), the investigators would annotate a plus sign in the direction column. Conversely, if the study had an overall negative effect (i.e., increase in injuries or injury rates) or there was no effect measured on injuries, a negative sign (–) or an “x” was annotated respectively.

The fourth step in the process was to assess the quality of the individual intervention and risk factor/cause studies in order to gain some appreciation for the strength of the science. Each intervention study was qualitatively rated using an adaptation of a ten-point scoring system developed by Thacker and colleagues, which included sample, design, methodology, and statistical analysis using a quality scoring form (Table 2).²⁸ Each individual working group member performed their own scoring and in the cases where more than one member scored the study, the average of all scores were reported. A similar quality scoring form (Table 3) was adapted for risk factor/cause studies. Once a score had been calculated it was transferred to the appropriate column on the classification matrix. Quality scores were not computed for descriptive epidemiology, clinical case series, or reviews, as these study types were not expected to contribute meaningfully to the evidence supporting the final recommendations.

The fifth and final step of the literature review process involved a preliminary interpretation of prevention efficacy using a format adapted from the U.S. Preventive Services Task Force (USPSTF).²⁹ The USPSTF grades the quality of the overall evidence for a strategy, service, or intervention on a three-point grading scale (good, fair, and poor) and categorizes its recommendations according to one of five classifications reflecting the strength of the evidence and magnitude of net benefit (benefits minus harms). Good evidence includes consistent results from well-designed, well-conducted studies in representative populations that directly assess effects on health outcomes. Fair evidence is sufficient to determine effects on health outcomes, but the strength of the evidence is limited by the number, quality, or consistency of the individual studies, generalizability to routine practice, or indirect nature of the evidence on health outcomes. Poor evidence is insufficient to assess the effects on health outcomes because of limited number of studies, lack of homogeneity, low statistical power, important flaws in study design or conduct, gaps in the chain of evidence, or lack of information on important health outcomes.

In keeping with military classification schema, recommendations were color coded on a three-color scale (red,

Table 1. Example classification matrix of literature search results: prevent overtraining

Reviews	Interventions	Risk factor/cause			Descriptive epidemiology	Case series	Non-injury research		
Study	Study	M	+/-	Score	Study	+/-	Score	Study	Study
			x			x			
Almeida ¹⁹ (1997)	Knapik ^{7,9} (2004)	M	+	8	Koplan ³⁹ (1995)	+	7.3	Beck ⁴⁴ (1985)	Johnston ³²⁶ (2003)
Gillespie ⁸² (2000)	Knapik ^{10,80} (2003)	M	+	8	Koplan ³⁸ (1982)	+	5.3	Browning ⁴⁵ (2000)	
Jones ⁸³ (2002)	Rudzki ¹⁶ (1999)	M	+	5	Marti ⁴¹ (1988)	+	7.3	Fredericson ⁴⁶ (1996)	
Kellett ⁸⁴ (1986)	Pope ¹² (1999)	M	+	5	Macera ⁴⁰ (1989)	+	9.3	Haverstock ⁴⁷ (2001)	
Renstrom ⁸⁵ (1985)	Pollock ⁶⁶ (1977)	M	+	4	Sullivan ³²⁷ (1984)	+	1.3	Hreljac ⁴⁸ (2004)	
VanMechelen ⁸⁶ (1992)	Rudzki ¹⁴ (1997)		+	8	Jacobs ³⁷ (1986)	+	6.0	Jones ⁴⁹ (1994)	
Yeung ²⁰⁴ (2001)	Rudzki ¹⁵ (1997)		+	8	Brunet ³⁵ (1990)	+	2.0	Jones ³ (1999)	
	Pester ¹¹ (1992)	M	+	1	Bennell ³⁴ (1999)	+	Not scored	Kaeding ⁵¹ (2001)	
	Yeung ⁸⁷ (2001)				Deuster ³⁶ (1997)	+	Not scored	Karlsson ⁵² (2004)	
	Rice ¹³ (2002)		+	Not scored	Reynolds ⁴² (1990)	+	Not scored	Kaufman ⁵ (2000)	
	Buist ³²⁸ (2008)		x	Not scored				Kennedy ⁵³ (2005)	
								Macera ⁵⁴ (1992)	
								McCully ⁵⁵ (1986)	
								McKeag ⁵⁶ (1992)	
								Paty ⁵⁷ (1988)	
								Paty ⁵⁸ (1994)	
								Pell ⁵⁹ (2004)	
								Reeder ⁶⁰ (1996)	
								Sherrard ⁶¹ (2004)	
								Watson ⁶² (1998)	
								Wexler ⁶³ (1995)	

M, multiple intervention study; +, positive effect (reduces injuries or injury rates); -, negative effect (increases injuries or injury rates); x, no effect on injuries or injury rates

amber, and green) plus one additional color (gray). Green included strategies with fair to good evidence to recommend or strongly recommend, where the benefits clearly outweigh the harms; amber included those strategies where no recommendation for or against could be made, due to fair evidence supporting the strategy but a balance of benefits and harms too close to justify a general recommendation; and red indicated sufficient evidence to recommend against the strategy either due to evidence of ineffectiveness and/or where harms outweighed the benefits. Gray was added to indicate those strategies for which there was insufficient evidence in the literature to make a recommendation for or against. Working group members were asked to classify each intervention strategy into one of the four colors based on the combined assess-

ment of the strength of the evidence by the amount, homogeneity, and quality of the evidence according to the adapted USPSTF format (Table 4).

All intervention strategies that were considered to have sufficient scientific evidence by the reviewers were discussed among all members of the working group. Each working group member had an opportunity to review and comment on the quality scores and preliminary recommendations from each review. Some of the factors considered in the discussion were: (1) the number of intervention studies demonstrating effectiveness (systematic reviews, randomized controlled trials, and other epidemiologic studies); (2) the homogeneity or consistency of the evidence (the number of studies showing efficacy versus no efficacy, or harm); (3) the quality of the

evidence (scores ≤ 3 = low quality, 4–6 = moderate quality, ≥ 7 = high quality); and (4) the number of other interventions included in each study (multiple versus single). After discussing all of the intervention topics on which literature searches had been completed, the working group members agreed that to be considered effective, strategies had to be shown to reduce injury rates by at least two prospective, randomized or observational studies or at least one systematic review showing a reduction across multiple studies, and the quality of at least some of the studies had to be high. Intervention strategies with these characteristics were considered to have sufficient strength of scientific evidence to make recommendations for immediate implementation among all military services. However, in the absence of direct injury outcomes, if there was an overwhelming reduction of validated markers for injury (e.g., biomarkers indicating muscle damage) it was accepted as having sufficient evidence.

For those strategies that were found to have sufficient scientific evidence to make recommendations for the prevention of injury among all military services, the working group prioritized them using a refined set of criteria initially developed through a joint effort between the USACHPPM and the Johns Hopkins Center for Injury Research and Policy.^{17,18} Criteria were adapted for use with the working group, which provided a quantitative means of objectively rating and ranking injury prevention interventions to arrive at a prioritized list of recommended interventions to reduce military physical training-related injuries (Table 5). Three of the seven criteria assessed were weighted as more important factors than the others: (1) strength of the evidence (including the quality of the science); (2) magnitude of the effect (e.g., size of health benefit and the population affected); and (3) practicality of implementation (e.g., existing infrastructure to support the intervention, feasibility, acceptability, and start-up cost). Other less important

Table 2. JSPTIPWG Intervention Studies Quality Scoring Form

Author/year/title of intervention study:	
Date of Review:	
Problem and sample	Score
1. Is there a clear statement of research question or hypothesis? If yes, score 1.	
2. Is there a source of subjects or sample described (e.g., inclusion criteria listed)? If yes, score 1.	
3. Is there a clear description of intervention? If yes, score 1.	
Study design and methodology	
4. Is it a randomized controlled trial? If yes, score 2.	
5. Is it an observational study with data on relevant confounders? If yes, score 1.	
6. Is there collected data on important covariates used in the analysis? If yes, score 1.	
Data presentation and statistical analysis	
7. Are statistical methods clearly described? If yes, score 1.	
8. Are confidence intervals or <i>p</i> -values used? If yes, score 1.	
9. Are multivariate methods in analysis (e.g., regression) used? If yes, score 1.	
10. TOTAL SCORE—Maximum score possible is 10 (transfer total to the Classification Matrix)	

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criteria included; (1) timeliness of reduction (e.g., time to implement and see reduction); (2) sustainability (e.g., effort to keep going, maintenance cost, and training); (3) measurable outcomes (measurable reductions are less noteworthy if implementing a strategy that has already been demonstrated as effective); and (4) collateral benefit (e.g., increased military readiness, decreased attrition, or decreased other health problem). Each recommended intervention was rated on a 5-point scale, with 1 being low and 5 being high, for each of these seven criteria. The points given by raters were then divided by 5 and multiplied by the maximum number of points for specified criteria, and the products added to get the total points for a particular intervention (100 points maximum) (Table 5).

Evidence Synthesis

There were 40 physical training-related injury prevention strategies identified by the working group. Three were determined to be critical components of a successful injury prevention program and not independent injury prevention strategies: (1) education of military leaders; (2) leadership support; and (3) unit injury surveillance. The working group agreed to categorize them as “essential elements” of an injury prevention program. During the process of the face-to-face meeting, the working group added a fourth essential element to the list: adequate resources for injury research and program evalua-

Table 3. JSPTIPWG Risk Factor/Cause of Injury Studies (Analytic Epidemiology) Quality Scoring Form

Author/year/title of risk factor/cause study:	
Date of Review:	
Name of Reviewer:	
Problem and sample	Score
1. Is there a clear statement of research question or hypothesis? If yes, score 1.	
2. Is it stated that a power or sample size calculation was done? If yes, score 1.	
3. Is the source of subjects or sample described (e.g., inclusion and exclusion criteria listed)? If yes, score 1.	
4. Is the measurement of exposures/risk factors and outcomes clearly described? If criterion fully met, score 2; if partially met, score 1.	
Study design and methodology	
5. Is this a prospective cohort study? If yes, score 2.	
or	
Is it a retrospective cohort or case control study or other appropriate design? If yes, score 1.	
6. Is data on relevant confounders provided and controlled for appropriately? If criterion fully met, score 2; if partially met, score 1.	
7. Is there data collected on important covariates used in the analysis? If yes, score 1.	
Data presentation and statistical analysis	
8. Are statistical methods clearly described and appropriate? If yes, score 1.	
9. Are incidences (rates), risks (percentages), or odds of injury reported appropriately? If yes, score 1.	
10. Are confidence intervals or <i>p</i> -values used appropriately? If yes, score 1.	
11. Are multivariate methods in analysis (e.g., regression) used appropriately? If yes, score 1.	
12. Are demographic variables and associated risks/rates described appropriately? If yes, score 1.	
13. TOTAL SCORE—Maximum score possible is 15.	
14. TOTAL SCORE CORRECTED TO 10-POINT SCALE=POINTS FROM LINE 13 × .667 (transfer total to the Classification Matrix)	

*Significant contributions to content and design of this form made by the following Joint Physical Training Injury Prevention Working Group members: LtCol Vincent Fonseca, Dr. Julie Gilchrist, and Dr. Stephen Marshall. JSPTIPWG, Joint Services Physical Training Injury Prevention Working Group

tion (generally limited to service-level injury prevention efforts).

Six intervention strategies were not reviewed (pre-assessment fitness programs, individualized training, knee braces, forearm and elbow straps, early intervention, and psychosocial issues related to injury). These strategies still require a literature review, objective quality assessment, and working group discussion and consensus (Table 6).

Six interventions (20%) of the 31 injury prevention strategies evaluated had strong enough evidence to become working group recommendations for implementation in all four military services (prevent overtraining,

agility-like training, mouthguards, semi-rigid ankle braces, nutrient replacement, and synthetic socks). The recommended injury prevention strategies are provided in Table 7 in order of the strength of the evidence, magnitude of the effect, practicality, timeliness of reduction, sustainability, measurable outcomes, and collateral benefit as measured by the scoring instrument. Included within this table are the average quality scores, the number of studies with a positive effect (a reduction in injuries or injury rates), negative effect (an increase in injuries or injury rates), and the number of those studies that demonstrated no effect on injuries or injury rate.

Two interventions (6%) were not recommended (i.e., back braces and pre-exercise administration of anti-inflammatory medication) due to at least fair evidence of ineffectiveness or harm, respectively.

Twenty-three (74%) interventions (stretching, restarting exercise at lower levels, muscle strengthening, new running shoes, warm-up and cool-down, group running by body height, change in stride length, graduated hiking or marching, graduated loading, avoiding hazardous exercise, separating body weight and fitness assessments, insoles, prescribing running shoes based on foot shape, ankle tape, improved running surfaces, improved landing surfaces, seasonal adjustments in training, smoking cessation programs, safe lifting education, ice, oral contraceptives for women, unit reconditioning program, and predictive modeling using an injury risk

Table 4. Format for JSPTIPWG recommendations^a

Color code	Recommendation template
Green	The JSPTIPWG strongly recommends [prevention strategy] for the prevention of injuries. The working group found good evidence that [prevention strategy] reduces injuries and concludes that benefits substantially outweigh harms. or The JSPTIPWG recommends [prevention strategy] for the prevention of injuries. The working group found at least fair evidence that [prevention strategy] reduces injuries and concludes that benefits outweigh harms.
Amber	The JSPTIPWG makes no recommendation for or against [prevention strategy] for the prevention of injuries. The working group found at least fair evidence that [prevention strategy] can reduce injuries but concludes that the balance of benefits and harms is too close to justify a general recommendation for all Services and/or [but] may be appropriate for individual Services or high risk individuals.
Red	The JSPTIPWG recommends against [prevention strategy] for the prevention of injuries. The working group found at least fair evidence that [prevention strategy] is ineffective or that harms outweigh benefits.
Gray	The JSPTIPWG concludes that the evidence is insufficient to recommend for or against [prevention strategy] for the prevention of injuries. The working group found evidence that [prevention strategy] is an effective prevention strategy is lacking, of poor quality, or conflicting, and the balance of benefits and harms cannot be determined. Therefore, the working group recommends further research on the [prevention strategy].

^aAdapted from United States Preventive Services Task Force (USPSTF)²⁹
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index) reviewed from the scientific literature could not be recommended due to lack of evidence, poor quality studies, or a balance of conflicting evidence (no homogeneity) (Table 8).

Discussion

As the essential elements of an injury prevention program were not considered independent injury prevention strategies, they were not reviewed with the same scrutiny as the other strategies. The following discusses the rationale for selecting these four components as essential elements of an injury prevention program.

Essential Elements of an Injury Prevention Program

Education. There are only three randomized trials that demonstrate the effect of education on musculoskeletal injury risks or rates, but those are in conjunction with other interventions as part of community-based programs.^{7,30,31} One such program demonstrated a 75% reduction in soccer injuries when coaches and players were educated and supervised by physicians and physiotherapists.³⁰ Injuries were reduced 30% in Army initial entry trainees when education was included as a primary component of an injury prevention program.⁷ While it is difficult to precisely measure the effect of education alone on injury rates, the dissemination of information regarding the proven strategies for the prevention of injury is vital to the support of military commanders in their responsibility to protect service members.³¹ Therefore, the

working group determined that education was an essential element of any successful injury prevention program.

Leadership support. The value of leader responsibility and accountability cannot be overemphasized. It is well understood that when those who are responsible are held accountable, the rate of progress improves. While the literature does not specifically address the impact of leadership responsibility and accountability on injury rates, the working group deemed leadership support as an essential element of any successful injury prevention program.

Surveillance. Surveillance provides the data necessary for determining current status of a problem, setting goals for improvement, and targeting interventions, and serves as an instrument to evaluate intervention success. The working group agreed that military commanders could influence their injury rates by simply understanding their current state of injuries, what causes the injuries, setting goals to improve, and monitoring their success. This is not possible unless surveillance of injuries and fitness are routine and easily summarized. Unit injury rates should be used as a barometer of physical training program success or failure just as is traditionally done with fitness test scores. As the physical training program is a major cause of injuries in the military (particularly in the new recruit environment), high injury rates indicate a need to modify that program. Regular reporting of injury data through the chain of command may have the effect of encouraging greater command responsibility for unit physical performance and musculoskeletal health. The working group agreed that surveillance and re-

Table 5. JSPTIPWG criteria for ranking recommended injury prevention strategies

Intervention Name: _____

Purpose: This score sheet is a tool that provides a systematic means of rating an injury prevention intervention and objectively comparing total scores of competing interventions.**How to use this score sheet:** Complete a score sheet for each intervention under consideration. First, decide on a *preliminary rating* (1=low, 5=high) for each criterion. Then assign a *final score* for each criterion using the formula presented. Adding the final scores will provide a *total score*. The maximum total score is 100.

Criterion	Total points possible	Preliminary score	Final score (preliminary score/5 × total points possible)
1. Strength of the evidence (quality of science)	20	1 2 3 4 5 Low High	—/5 × 20 =
2. Magnitude of Net Effect	20	1 2 3 4 5 Low High	—/5 × 20 =
■ Size of health benefit		Low High	
■ Size of population affected			
3. Practicality	20	1 2 3 4 5 Low High	—/5 × 20 =
■ Feasible		Low High	
■ Start-up cost			
■ Acceptable			
■ Existing infrastructure			
4. Timeliness of reduction	10	1 2 3 4 5 Low High	—/5 × 10 =
■ Implementation time		Low High	
■ Result time			
5. Sustainability	10	1 2 3 4 5 Low High	—/5 × 10 =
■ Effort to keep going		Low High	
■ Maintenance cost			
■ Training			
6. Measurable outcomes	10	1 2 3 4 5 Low High	—/5 × 10 =
■ Measurable reductions		Low High	
7. Collateral benefit (e.g.):	10	1 2 3 4 5 Low High	—/5 × 10 =
■ Increase readiness		Low High	
■ Decrease attrition			
■ Decrease in other health problem, etc.			
TOTAL SCORE	100		

Date of review: _____ Name of reviewer: _____

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porting of standardized injury metrics³² is an essential program element of any successful injury prevention program.

Research and program evaluation. The working group discovered a lack of scientific evidence in the literature from which to make broad recommendations to the military services. In many cases, there simply were no scientific studies to indicate whether strategies were effective. In other cases the evidence was of poor quality or was conflicting, or the balance of the benefits and harms could not be determined. As a result, the working group added

“Adequate Resources for Research and Program Evaluation of Training-Related Injury Prevention Interventions” as a fourth essential element of a successful injury prevention program. Without military branch or Service-level research and program evaluation of injury prevention strategies in military populations (and in comparable civilian populations), the rate of physical training-related injuries will continue to be a burden on the military services and a health threat to force readiness. This paper identifies 23 injury prevention strategies which do not yet have sufficient evi-

Table 6. Intervention strategies without a completed review^a

1. Provide pre-basic training fitness assessment and fitness programs for the least fit
2. Individualize physical training versus training as a group or unit
3. Wear knee braces
4. Wear forearm or elbow straps
5. Utilize allied health professionals in a Pre-Military Treatment Facility (MTF) care setting
6. Accommodate for psychosocial issues related to injury

^aInterventions that require a systematic literature review, working group discussion, and objective assessment

dence to support as broad recommendations to the military services and six prevention strategies that have not yet been evaluated. This total of 29 strategies represents a good starting point for researchers interested in studying the prevention of injuries in the military and similar civilian populations.

The literature related to six injury prevention strategies was not searched for and, therefore, was not reviewed, or discussed by the working group. There are currently no working group recommendations for these interventions except that they be reviewed and discussed by a group of experts in a systematic manner. The following discusses some key points from the supporting literature and provides some rationale behind the classification of the six prevention strategies found to have sufficient evidence to recommend immediate implementation to all branches of the military Services.

Prevention Strategies with Sufficient Scientific Evidence to Recommend

Finding only six prevention strategies with enough scientific evidence to make recommendations to the four mil-

Table 8. Intervention strategies without sufficient evidence to recommend at this time

1. Stretch muscles before or after exercise
2. Reinitiate exercise at lower intensity levels for detrained individuals
3. Target specific muscles to strengthen
4. Replace running shoes at standard intervals
5. Warm-up and cool-down before and after activity
6. Place shorter service members in front of formations to set running pace and cadence
7. Manipulate stride length
8. Participate in a standardized, graduated marching (a.k.a hiking) program
9. Gradually increase load-bearing during marching
10. Avoid hazardous exercises or exercise machines (e.g., sit-ups, flutter kicks, etc.)
11. Separate body weight assessment and maximal effort physical fitness tests
12. Wear shock-absorbing insoles
13. Prescribe running shoes based on individual foot shape
14. Wrap ankle with athletic tape prior to high-risk activity
15. Run on improved surfaces that minimize injury risk
16. Improve obstacle course landing surfaces
17. Adjust training loads by seasonal variations
18. Encourage smoking cessation programs to prevent musculoskeletal injuries
19. Educate service members on safe lifting techniques
20. Apply ice to injuries early to prevent re-injury
21. Take oral contraceptives to decrease injury if female
22. Standardize unit reconditioning program after rehabilitation from injury
23. Predict injury risk by injury risk index modeling

itary services (Table 9). was surprising, given that many others have been proposed by expert opinion or professional organizations or promoted in lay magazines, or are common traditional practices. Each of the following six prevention strategies (presented in order of priority) were deemed by the working group to have sufficient scientific evidence for immediate implementation in all

Table 7. Recommended injury prevention strategies in order of priority

Order	Strategy	Priority score	SD	Quality score (M)	# positive effect	# negative effect	# no effect
1	Prevent overtraining	86.3	8.5	5.9	8	0	0
2	Perform multiaxial, neuromuscular, proprioceptive, and agility training	77.7	7.8	5.9	12	0	3 ^b
3	Wear mouthguards during high-risk activities	74.2	11.6	2.9 ^a	16	0	3 ^b
4	Wear semirigid ankle braces for high-risk activities	70.1	10.3	6.4	11	0	0
5	Consume nutrients to restore energy balance within 1 hour following high-intensity activity	67.0	11.6	5.5	13	0	2 ^b
6	Wear synthetic-blend socks to prevent blisters	No score: added after group scoring		7.3	5	0	0

^aTwo of the most recent studies on this topic were of high quality.

^bLow-quality studies

four military branches. In each case there were ample systematic reviews or randomized controlled trials demonstrating effectiveness; the evidence across multiple studies consistently demonstrated a reduction of injury rates; and at least some of the evidence was of moderate to high quality.

The prevention of overtraining. Overtraining is a term with which the literature collectively refers to the physiology of musculoskeletal overuse due to exercise or physical training. Physical training is necessary to condition service members for their occupational and military tasks and to provide protection against cardiovascular and bone health threats.^{20,33} In classic military tradition however, efforts to exceed the standards and/or execution of training errors have contributed to the injury epidemic present today. There is a preponderance of military and civilian research^{34–43} and descriptive epidemiology^{3,5,44–63} that demonstrates that high running volume substantially increases the risk for lower-extremity injury. During initial military training about 25% of men and about 50% of women incur one or more physical training–related injuries. Roughly 60%–80% of these injuries occurs to the lower extremities and are of the overuse type—a condition brought about by physical training–volume overload (presumably excessive running relative to initial fitness level and individual running capability).

Given the very strong evidence showing higher running mileage as an injury risk factor, an obvious intervention is to reduce the amount of running performed by service members. A study of recruits in U.S. Marine Corps boot camp demonstrated that a 40% (22 mile) reduction in running distance was associated with a 54% reduction in stress fracture incidence with an insignificant increase (3%) in run times.⁶⁴ Thus, reducing running mileage reduced stress fracture incidence with essentially no effect on aerobic fitness. In 1995 dollars it was estimated that this intervention saved \$4.5 million in medical care costs and nearly 15,000 training days in just 1 year.

In a study of U.S. Army soldiers⁴⁹ showed those who ran 74 fewer miles during 12 weeks of basic combat training (BCT) decreased their injury incidence by 24%, and maintained their aerobic fitness. It is interesting to note that while they decreased the running mileage, they increased the miles marched (high-mileage run group marched 68 miles; low-mileage run group marched 117 miles).

In a more recent study during 9 weeks of army BCT, one battalion that ran a total of 17 miles (plus an undetermined amount of interval training) lowered their injury rates by one third with similar improvements in their 2-mile run times, as compared to a battalion that ran a

total distance of 38 miles during the same time frame.¹⁰ Most of the miles run in the 17-mile group were performed toward the end of BCT and very few in the early weeks.

A U.S. Navy study comparing male recruits assigned to basic training divisions reduced the amount of running by 20 miles during naval recruit training and demonstrated a reduction of injuries by 20% without negatively affecting physical fitness.⁶⁵ Similar results were obtained with Australian Army recruits when running was replaced with a graduated program of foot marches with backpack loads,^{14,15} which reduced all lower limb injuries by 43% and knee injuries by 53%. The Australians also demonstrated that multi-interventional injury prevention programs that include the reduction of running mileage as the primary prevention strategy can reduce serious lower extremity stress fractures by 91%.¹²

The U.S. Army Training and Doctrine Command (TRADOC) Standardized Physical Training Program for BCT, which incorporates less running mileage and a greater variety of exercises, was implemented in April 2004. Since that time, injuries have been reduced by 21% compared to a traditional BCT physical training program.⁹

While running is an excellent way to build aerobic power or cardiovascular fitness, there are physiological thresholds of overtraining above which increases in running duration and frequency do not result in a commensurate increase in fitness, but do result in higher injury rates. Among previously sedentary young male adults, running above thresholds for duration and frequency dramatically increases risk of injury with little improvement on VO₂ max (the single best measure of cardiovascular fitness). A classic study⁶⁶ demonstrated that a running duration of 45 minutes versus 30 minutes three times a week increases the injury incidence by 125% without a significant change in VO₂ max. Similarly a running frequency of five times per week versus three times per week for 30 minutes increases the injury incidence by 225% without a significant change in VO₂ max. Not only can the amount of running be dramatically reduced to prevent injuries without adverse effects on service member cardiorespiratory endurance, but injuries can be expected to increase disproportionately with fitness improvements when thresholds are exceeded.^{67–70} Overtraining thresholds are not necessarily absolutes, and they may vary between services and between units.⁷¹ Findings from the American College of Sports Medicine⁷² and others^{69,73–76} are consistent with this idea of the disproportionality of fitness and injury when exceeding thresholds of overtraining.

The minimum threshold for physical training required to achieve desired training effects has been less well char-

acterized for service members. However, if cardiorespiratory fitness improvements require aerobic exercise at an intensity that produces heart rates between 55% and 90% of a person's maximum heart rate, the lower end of this broad range would be appropriate for initially low-fit individuals. Those who have been training for longer periods can work at higher levels. Cardiorespiratory fitness can be improved by many activities other than running. Aerobic activities that provide alternatives to linear distance running include: graduated walking or marching, stair climbing, swimming, bicycling, cross-country skiing, rope-skipping, exercising to music, nonlinear running, and sprinting.

Combining strenuous military training and traditional physical exercise may cause units to exceed physiologic thresholds of overtraining, which results in higher injury rates without the expected improvements in physical fitness.⁷⁷ Commanders can monitor limited duty excusal (also known as the physical profile) rates and fitness test pass rates and run times to determine if their units are overtraining. Signs that a unit is overtraining might include high or increasing lower body injury profile rates, decreased fitness test pass rates, and slower average run times.^{77–79}

Research in military populations has demonstrated that the gradual introduction of running mileage reduces injury incidence.^{7,9–16,80} A program that starts with very low mileage and progressively increases running mileage to a maintenance point keeps total running mileage low, which reduces injury rates while improving physical fitness. Several reviews of the literature repeat the common theme that standardized running programs that begin with low mileage and intensity, and gradually progress distance and speed, allow the body to gradually adapt to increasing stressors.^{19,81–87} These types of programs are particularly important for lower fit individuals who are just starting or restarting a physical training program (e.g., new recruits, those changing units, and those returning to physical training after time off for an injury or leave).

Physical training injury prevention programs that target service members at the highest risk of injury (those of average or below average fitness) ensure that the running mileage for the least fit service members is appropriate for their fitness level. The use of initial fitness test performance (run times) to place service members in ability groups of similar fitness levels provides each service member with a more appropriate level of physiological stimulus to enhance fitness and minimize injury risk.⁸⁸ For example, asking a unit to run for a fixed time, not a fixed distance, allows the slower (less fit) groups to run shorter distances than the faster (more fit) groups, thus accommodating low and high fitness groups simulta-

neously. This strategy can be ideal for military training schedules as groups can start and end at the same time. Formation running (large group running at the same pace) not only may overtrain the least fit but may provide an inadequate training effect for the fittest individuals, who need a greater cardiovascular stimulus.

The least fit service members are two to three times more likely to be injured as their more fit counterparts, especially in the recruit training environment.^{7,9,10,89} Therefore, giving the least fit trainees extra sessions of training only increases injury risk in this population with little or no fitness improvement. To reduce injuries and attrition rates while maximizing physical performance requires that the core of the physical training program be targeted at individuals of average and below average fitness levels. Furthermore, the common military practice of utilizing physical exercise as a punitive, corrective, or motivational tool has the potential to lead to overtraining due to its unpredictable frequency and volume—particularly when overstressing the lower extremities.

Interval training is an excellent way to train the cardiovascular system while minimizing repetitive strain on the lower extremities.⁹⁰ Military studies that have included interval training with reduced total running mileage have shown fitness improvements as great as or greater than those with long, slow sustained running.^{7,9,10,19–21,33,80,81} Interval running is performed with multiple bouts of all-out (high intensity) running interspersed with periods of recovery (e.g., intervals, shuttle runs, and hill/stair running). Intervals are performed by adhering to a progressive work to recovery ratio. For example, a work-to-recovery ratio of 1:3 would be an intense run of 10 seconds followed by a relative relief period (walk or slow jog) of 30 seconds (progressively 15:45 and 20:60). Interval running can be conducted individually as well as in ability groups.⁸⁸

Soft tissue, such as muscles, tendons, and cartilage, needs time between exercise bouts to recover and build. It is during this recovery time that structures are strengthened. If recovery is not allowed, the rate of breakdown outpaces the body's ability to build up and injuries are the likely result. Periodization training is a performance strategy used to optimize performance and minimize injury in athletics. This type of training is characterized as an on-again, off-again type of training, and the literature discusses this as a sound way to prevent overtraining.^{77–79} Furthermore, delayed onset muscle soreness peaks around 48 hours after an intense exercise bout and makes exercise difficult.⁹¹ Military physical training that balances the body's need for a physiologic overload with the demand for recovery and rebuilding may provide the service member with the greatest protection against injury.

Multi-axial, neuromuscular, proprioceptive, and agility training. Rehabilitation of soccer players with ankle sprains using a wobble board for balance, coordination, and proprioceptive training has been shown to be effective in improving postural sway, reaction times, and preventing subsequent ankle sprains.^{28,92–107} Evidence from research with handball players^{106–111} and soccer players^{30,112} suggest that this training may also prevent ankle sprains and anterior cruciate ligament injuries in healthy athletes. These and other studies utilize exercises that are designed to improve awareness and control of knees and ankles during standing, running, cutting, jumping, and landing. Some programs consist of exercises and partner-perturbation with an inflatable ball, wobble board, and balance mat. A prospective cluster randomized controlled trial demonstrated that some neuromuscular and proprioceptive activities specifically designed for a single-sport (team handball) significantly reduced musculoskeletal injuries in youth aged 15–17 years.¹¹³ Recent effectiveness of a neuromuscular and proprioceptive training program in competitive female youth soccer players in decreasing anterior cruciate ligament injuries has been demonstrated over a 2-year period. The program, which consisted of a number of activities in addition to sport-specific agility drills (such as strengthening, stretching, education, and plyometrics), resulted in a 74% reduction in anterior cruciate ligament tears.¹¹⁴ A 6-week, preseason neuromuscular training intervention program, performed three times a week for one to 1 ½ hours reduced the rate of noncontact ACL injuries in women by 72%.^{115,116} Military research on exercises that develop core body stabilization (trunk control), agility, and multi-axial movement skills in basic trainees without the aid of balls, balance mats, and wobble boards have demonstrated reductions of injury rates by 20%–30%.^{7,9,10,19–21,80,81}

Aside from the neurophysiological learning that takes place to assist athletes and military service members in moving their bodies in smoother, more coordinated fashion, including neuromuscular, multi-axial, proprioceptive, and agility conditioning in physical training sessions may reduce injury risk for other reasons: (1) incorporating these activities into a finite training period reduces the trainees' excessive exposure to running activities, thereby reducing lower-body injury risk; (2) musculoskeletal stresses of training are more evenly distributed across the body (and in different axes of motion) by these types of drills (unlike linear running, which focuses stress in the lower body in one plane), thereby reducing injury risk; and (3) strength and stabilization exercises directed at the body core (trunk) represent many of the same movements required during more complex combat activities and this may increase the likelihood of improved military

occupational task performance and possibly reduce injuries.

The majority of these exercise programs involve several neuromuscular, multi-axial, and proprioceptive exercises; however, as all exercises have the same goal, none would be considered multi-interventional.^{5,50,117–201} Several systematic reviews are supportive of this type of training for the reduction of musculoskeletal injuries.^{28,105,202–205}

Mouthguards. Orofacial injuries are often caused by the same vigorous activities and exercises that can lead to musculoskeletal injuries.²⁰⁶ Mouthguards are mandated as essential protective equipment in such sports such as football, ice hockey, men's lacrosse, and boxing. The American Dental Association and the International Academy of Sports Dentistry currently recommend that mouthguards be used in 29 sport or exercise activities including acrobatics, basketball, bicycling, boxing, equestrian events, extreme sports, field events, field hockey, football, gymnastics, handball, ice hockey, inline skating, lacrosse, martial arts, racquetball, rugby, shot put, skateboarding, skiing, skydiving, soccer, softball, squash, surfing, volleyball, water polo, weight lifting, and wrestling. Studies have compared mouthguard users and nonusers in many sports including football, rugby, basketball, and hockey. Despite the fact that there are study design problems in virtually all the investigations, most intervention studies support the concept that mouthguards reduce or tend to reduce the incidence of orofacial injuries in sports that involve contact to the face.^{207–225}

The military, not surprisingly, engages in a number of activities that pose considerable risks of oral facial injuries. A pilot study was initiated at Fort Leonard Wood MO in 1999 that targeted injuries during pugil stick training, M16 with bayonet training, and confidence course training. Providing army trainees with mouthguards for these activities decreased the total number of dental injuries by 74%.^{226,227}

Semirigid ankle braces. The epidemiology and risk factors for ankle injuries are well described.^{104,228–237} Ankle braces have been consistently demonstrated as effective in reducing ankle injuries during high-risk activities such as basketball, soccer, and parachute landings in a number of intervention trials.^{43,238–247} Systematic reviews employing meta-analysis methods estimate the relative risk of ankle injury while wearing an ankle brace is 53% of the injury risk without bracing.^{28,248,249} Among civilian athletes, the protection is greatest among those with previous ankle injuries but remains significantly high as a prophylactic measure for uninjured athletes as well. During U.S. Army Airborne operations, 30%–60% of injuries involve the ankle.²³⁸ Studies have demon-

Table 9. Recommended injury prevention strategies (based on sufficient scientific evidence)

<p>1. Prevent overtraining (strongly recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group recommends a standardized physical training program that controls the amount of total body overload performed; particularly for the lower extremities. Lower extremity overtraining (caused largely by excessive distance running) results in higher injury rates, lowered physical performance, decreased motivation, and increased attrition. Good evidence was found that physical training programs, especially in initial military training, that reduce distance running miles prevent overtraining and reduce injury rates while maintaining or improving physical fitness. The elements described below should be incorporated to assist in reducing running mileage.</p> <ul style="list-style-type: none"> ● Commanders at all levels should actively avoid combinations of physical and military training that exceed physiologic thresholds of training, as exceeding these thresholds result in higher injury rates with minimal or no improvement in fitness. Commanders can monitor profile (limited duty excusals) rates and fitness test pass rates and run times to determine if their units are overtraining. Signs that a unit is overtraining include high or increasing lower body injury profile rates, decreased fitness test pass rates, and slower average run times. ● Other ways to achieve this objective include the following recommendations: <ul style="list-style-type: none"> ○ Follow a gradual, systematic progression of running distance and speed beginning with lower mileage and intensity, especially for those just starting a physical training program (e.g., new recruits, changing units, or returning to physical training after time off for an injury or leave). This practice provides for less total running over a finite period of time. ○ Structure physical training injury prevention programs to target those Service members at the highest risk of injury (those of average or below average fitness) by ensuring that the running mileage for the least fit Service members is appropriate for their fitness level. <ul style="list-style-type: none"> a. Group Service members according to physical ability. For example, fitness test performance (run times) can be used to place Service members in groups of their peers with similar fitness levels. This provides each Service member with a more appropriate level of physiological stimulus to enhance fitness and minimize injury risk. b. Run for specified time periods, not distance. Running for specified time periods, not distance, allows the least fit to run shorter distances than the most fit, thus accommodating low and high fitness groups simultaneously. c. Limit running in formation. Placing limits on unit formation running allows a greater chance that Service members are provided an adequate training effect for maximum improvement through ability group running. d. Avoid the practice of giving extra physical training sessions to the least fit Service members, especially recruits, since this will increase the risk of overtraining and injury with little or no fitness improvement. (Gradual, progressive ability group training programs improve fitness with less risk of overtraining and injury.) e. Refrain from or modify use of physical training as a punitive, corrective, or motivational tool as it has the potential to cause excessive training overload that can lead to overtraining. Other methods to discipline new recruits should be sought or the amount and type of physical demands placed on a new recruit should be limited and standardized (e.g., a maximum number of push-ups allowed per day). An activity that we want Service members to embody for a career and a lifetime should not be used for punishment. ○ Replace some distance runs with interval running (multiple bouts of short distance, high intensity running interspersed with periods of recovery) that increase speed and stamina more rapidly than distance running while limiting total running miles. ○ Balance the body's need for a physiologic training overload to improve fitness with the need for recovery and rebuilding by coordinating military and physical training to: <ul style="list-style-type: none"> a. Avoid exhaustive military or physical training (e.g., obstacle courses, long road marches with heavy loads, longer runs, maximal-effort physical fitness testing, etc.) on the same or successive days b. Allow adequate recovery time between administrations of maximal effort physical fitness tests to prevent overtraining and increase the likelihood of improved physical performance. (Since muscle soreness peaks at 48 hours the minimum recovery time would be 3-5 days.) c. Alternate training days that emphasize lower body-weight bearing physical activity with training days focused on upper body conditioning. d. Minimize the accumulated weight-bearing stress on the lower body from marching/hiking, movements to training sites, drill and ceremony, obstacle courses, running, etc., by not overscheduling such activities on the same or successive days.
<p>2. Perform multiaxial, neuromuscular, proprioceptive, and agility training (recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group recommends that multiaxial (many planes of motion), neuromuscular (coordinated muscular movement), proprioceptive (body position sense), and agility (nonlinear movement) exercises be included as a regular component of military physical training programs. The working group found good evidence that injuries are reduced by increasing the proportion of physical training time devoted to exercises that vary musculoskeletal stress in multiple planes and improve body coordination, position sense, and agility.</p>

(continued on next page)

Table 9. (continued)

<p>3. Wear mouthguards during high-risk activities (recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group recommends all Services provide mouthguards for all Service members participating in activities with a high risk for orofacial injuries. The working group found good evidence that mouthguards reduce orofacial injuries when worn during activities with high orofacial injury risk. Examples of potential high-risk activities listed by the working group include combatives, obstacle and confidence courses, rifle/bayonet training, etc., and contact sports such as basketball, football, etc. The evidence is insufficient to recommend for or against mouthguards as a means of preventing concussion injuries.</p>
<p>4. Wear semirigid ankle braces for high-risk activities (recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group strongly recommends that semirigid ankle braces be utilized during participation in high-risk physical activity. The working group found good evidence that semirigid ankle braces reduce ankle injuries when participating in high-risk physical activity such as airborne operations (parachuting), basketball, and soccer; and may prevent ankle injuries in other similar high-risk activities. Additionally, the working group found good evidence that semirigid ankle braces reduce re-injury among individuals with previous moderate or severe ankle sprains.</p>
<p>5. Consume nutrients to restore energy balance within 1 hour following high-intensity activity (recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group recommends consuming 12–18 g of protein and 50–75 g of carbohydrate and a fluid replacement beverage within 1 hour after very strenuous, continuous physical activity (e.g., road marching/hiking lasting longer than 1 hour) to minimize muscle damage and optimize recovery. The working group found sufficient evidence that consuming this balance of nutrients within a 1-hour time frame restores energy balance and optimizes recovery from musculoskeletal breakdown caused by the activity. Collateral benefits such as reduced risk of heat-related illness and enhanced physical performance can be expected.</p>
<p>6. Wear synthetic blend socks to prevent blisters (recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group recommends the use of synthetic blend socks (e.g., polyester, acrylic, and nylon versus cotton socks) to prevent blisters to the feet during physical training. The working group found at least fair evidence that synthetic blend socks prevent blisters to the feet, especially during long-distance marching.</p>

strated that during airborne jump operations; those wearing an outside-the-boot brace had 0.6 ankle inversion injuries/1000 jumps compared to 3.8 injuries/1000 jumps for those who did not wear the brace. In an operational research study of Rangers over a 3-year period, ankle injuries were three times higher among those not wearing braces.²⁴⁵ In spite of the demonstrated effectiveness of ankle braces in reducing ankle injuries among parachutists, this intervention was discontinued over concerns of cost and anecdotal reports of parachute entanglements. During the period after the brace was discontinued, hospitalizations for severe ankle injuries rose by 70%. The ankle brace was reinstated for airborne training in February 2005, and a central funding mechanism was established to pay for and replace the braces.²⁴⁴ Ankle braces are particularly appropriate for high-risk sports activities and military parachuting, especially in individuals with a history of a previous ankle sprain.

Restoration of energy balance and injury biomarkers. Research shows a link between muscle glycogen depletion and markers of muscle damage, fatigue and musculoskeletal pain.^{250–254} Studies of active women also indicate a negative energy balance is a risk factor for stress fractures of the bone.^{255–258} These same risk factors and descriptive epidemiologic studies indicate that stress fractures may well be related to nutritional deficiencies.

^{255–258} Sustained physical activity and intermittent, high-intensity activity deplete the body's glycogen stores and fatigue muscles, which then reduce their strength and ability to protect joints. On balance, most original research^{251–253,259–270} and systematic reviews^{250,271–274} indicate that restoring muscle glycogen decreases markers of muscle damage due to physical activity.

While both civilian and military research have provided evidence that consuming foods that restore energy balance overcomes fatigue, minimizes muscle damage, and protects against heat injury, the timing of the nutritional intervention appears to matter. Research indicates that consuming a combination of carbohydrates and protein within a 60-minute window immediately following very strenuous exercise initiates repair of muscles damaged during the activity and begins the replenishment of muscle glycogen stores.^{250,251,253–258,260–262,267,268,270} During this time, metabolic environment is optimized for rebuilding what was metabolized during the exercise.^{250,251,253,254,260–262,268} It appears that when the nutrients are consumed more than 60 minutes after the end of the exercise bout, the metabolic environment is less able to absorb the nutrients; thus diminishing recovery.^{250,254,261,262}

The ideal balance of nutrients needed to allow for the most rapid replenishment of muscle glycogen to opti-

mize and accelerate the recovery process is roughly 12 to 18 grams of protein and 50 to 75 grams of carbohydrate (a ratio of 1 gram of protein for every 4 grams of carbohydrate).^{250,253,254,261}

Synthetic-blend socks for blister prevention. Blisters appear to be caused by friction between the skin and sock; that friction is exacerbated by moisture produced by sweating.^{275–281} Special hydrophobic (having little or no affinity for water) socks designed to reduce foot moisture appear to reduce the likelihood of foot blisters.^{282–286} In marine recruits undergoing 12 weeks of training, 39% of those wearing the standard U.S. military wool/cotton sock experienced blisters or cellulitis resulting in limited duty. Among those wearing a liner sock composed of polyester (thought to “wick” or draw away moisture from the skin) worn with the standard sock, the foot friction injury rate was 16% (a 56% decrease in blister injuries). A third group of recruits had a comparable 17% injury rate while wearing the same polyester liner with a very thick wool/polyester blended sock designed to assist with the wicking action while reducing friction. Thus, both experimental sock systems were successful in reducing blisters.

Interventions Not Recommended

Two common intervention strategies that have been promoted as practices to reduce low-back injuries and other musculoskeletal injuries in general are back braces (or similar devices) and pre-physical training administration of nonsteroidal anti-inflammatory drugs (NSAIDs) respectively. There is sufficient evidence not to recommend these strategies. The following discusses the rationale behind these strategies and how they may have physiologic risks that do not justify prophylactic use. Recommendations against their use are presented in [Table 10](#).

Back braces, harnesses, or support belts. Back belts have been aggressively promoted as a preventive measure against back injuries in healthy individuals during lifting activities for a couple of reasons: it is theorized that back belts increase the intra-abdominal pressure, which is thought to decrease compressive forces on the lumbar spine, and also minimize movement of some lumbar segments. These theories have not been substantiated in the literature. In fact, in 1992, the Director of the National Institute for Occupational Safety and Health (NIOSH) formed a working group to review the scientific literature on back belt usage in healthy individuals. The CDC/NIOSH report concluded that back belt effectiveness was unproven.²⁸⁷ That same year, the Office of the Surgeon General (OTSG) issued a memorandum stating, “The blanket use of back belts to prevent or minimize back injuries resulting from lifting is not supported by the Office of the Surgeon General” because the Occupational

Table 10. Intervention strategies not recommended (due to evidence of ineffectiveness or harm)

<p>1. Wear back braces, harnesses, or support belts (not recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group does not recommend the use of back braces, harnesses, or support belts for the prevention of low back injuries. The working group found at least moderate to strong evidence that back belts/supports are ineffective or that the potential harms outweigh the benefits. These findings support the Department of Defense position that back support belts are not personal protective equipment, and use of these devices for the prevention of back injuries is not endorsed (see DoDI 6055.1, DoD Safety and Occupational Health Program, para E6.1.3).</p>
<p>2. Take anti-inflammatory medication prior to exercise (not recommended)</p> <p>The Joint Physical Training Injury Prevention Working Group does not recommend taking anti-inflammatory medication prior to exercise for the prevention of injuries. The working group found insufficient evidence for the efficacy of pre-administration of anti-inflammatory medication for the prevention of injuries. The potential harms outweigh any potential benefits.</p>

Safety and Health Administration did not accept back belts as personal protective equipment.²⁸⁸ A systematic review on the prevention of back injuries concluded that there was no evidence for the effectiveness of lumbar supports.²⁸⁹ In 1998, Department of Defense Instruction (DoDI) 6055.1 directed that “DoD does not recognize back support belts or wrist splints as personal protective equipment, or the use of these devices in the prevention of back or wrist injuries.”²⁹⁰ Two independent systematic reviews published in 2001 came to the same conclusion; there is moderate to strong evidence that lumbar supports or back belts are not effective in primary prevention, and there is no evidence that back belts are effective for secondary prevention of low-back injury.^{291,292} Another literature review in 2003 came to the same conclusion.²⁹³ Based on the amount of scientific evidence showing the ineffectiveness of back belts, as well as the number of government agencies that do not support their use, it was the consensus of the working group that back belts could not be endorsed as a low back–injury prevention intervention in healthy individuals.

Anti-inflammatory medication prior to exercise. Contraction-induced muscle damage, especially from eccentric muscle contractions, is known to cause an inflammatory response. This response itself can cause tissue damage beyond that originally sustained by the muscle. It is hypothesized that administration of an NSAID prior to exercise would control that inflammatory response, thus diminishing tissue damage. However,

NSAIDs have been the cause of more than 76,000 hospitalizations and 7600 deaths in the U.S. annually.²⁹⁴ While one study demonstrated that the pre-administration of diclofenac sodium significantly reduces measures of exercise-induced skeletal muscle damage,²⁹⁵ the results are inconsistent with regard to NSAID use prior to activity.^{296–299} Intervention studies have demonstrated no effect on delayed onset muscle soreness or observed markers for muscle damage as a surrogate for injury.^{300–302} No study has demonstrated a reduction in injury rates from pre-exercise NSAIDs.

Furthermore, there are harmful risks to taking NSAIDs that must be considered. Some of the most common risks of NSAID use are stomach discomfort, gastrointestinal bleeding, and ulceration.^{303–305} One way to counter these common side effects is to ingest food with the medication. The consumption of food immediately prior to a vigorous activity to buffer the effects of the medication may, itself, cause considerable discomfort during activity. Kidney, heart, liver, and skin problems can also occur, most related to the inhibition of prostaglandin synthesis. Kidney failure has been reported during marathons, in part due to these substances in the body combined with dehydration and the strenuous effort that takes place over several hours. The majority of gastrointestinal side effects of NSAIDs are symptomatic responses, such as bloating, cramping, pain, acid reflux, and diarrhea or constipation.³⁰⁶ These are not symptoms that would be favorable to experience while participating in physical activity.

Interventions Without Sufficient Evidence to Recommend

What stands out as a singularly important outcome of this working group effort is the majority (74%) of the injury prevention strategies that had some theoretical basis for efficacy was found to have insufficient evidence to recommend as injury prevention strategies to the military services at this time (Table 8). Either the science has not been done; what has been done is of poor to fair quality research and evaluation; or there are too many studies showing either a negative effect or no effect on injuries which cast too much doubt on their efficacy. It is not recommended that military leaders implement these strategies; they should, at least, carefully weigh the benefits and costs of implementing any of these 23 unproven strategies in their units in order to conserve resources and maximize training time. An example of one such strategy, stretching, is discussed below and concise recommendations are given in Table 11.

Example: stretching muscles before or after exercise. For many years sports medicine professionals have advocated stretching prior to physical activity as a

Table 11. Example recommendation when there is insufficient evidence to support

Stretching muscles before or after exercise has no scientific basis for recommendation (insufficient evidence to support)

The Joint Physical Training Injury Prevention Working Group cannot recommend organized stretching as a means for preventing physical training-related injuries. The working group found good evidence that stretching is ineffective as an injury prevention strategy in a generally young, healthy population. While the working group does not endorse stretching as a method to prevent musculoskeletal injury, there is insufficient evidence that it may cause harm in those who perceive a benefit. Additionally, studies to date have not specifically targeted individuals with limited range of motion. Because epidemiological data suggest that both extremes of flexibility (too much or too little) are risk factors associated with increased injury rates, the working group recommends research selectively targeting individuals with limited range of motion only to determine the effect of stretching in this select population.

method for reducing the risk of injury.⁶⁷ One of the authors of this paper (JG) co-authored a recent systematic review³⁰⁷ on the topic and provided extensive references and insight into stretching efficacy. This review exceeded the level of review performed for other potential interventions addressed by the working group. This literature review and others^{89,203,308–310} examined hundreds of citations only to come to the same conclusion; that neither stretching prior to exercise nor stretching prior to and after exercise, reduces the risk of injury. Other systematic reviews^{54,86,311–323} address injury or soreness but are focused on non-injury outcomes (such as increased flexibility). There is not sufficient evidence to endorse indiscriminate and routine stretching before or after exercise to prevent injury among service members (or competitive or recreational athletes alike).

The few risk-factor and intervention studies that did show an effect of stretching on injuries suffered from serious design flaws, such as including pre-exercise stretching with warm-up in the intervention. Since epidemiologic data indicate that both extremes of flexibility (too much or too little) are associated with increased injury rates,^{50,324} studies to date have not specifically targeted individuals with limited flexibility. Thus, future stretching studies should selectively target individuals with low flexibility to determine whether stretching timing can increase flexibility and reduce injuries for the least flexible individuals. Furthermore, it would not seem prudent to invest limited military training time in performing indiscriminate group stretching exercises when the literature demonstrates this strategy has no proven injury prevention efficacy when performed in this manner.

A discussion of rationale and a list of references regarding the remaining 22 prevention strategies found to have insufficient evidence to make recommendations to the military services is available by reviewing the USACHPPM technical report.³²⁵

Limitations

Literature searches were limited to published articles in the English language only. Reviewers had varying degrees of epidemiologic and online medical literature searching skills and expertise. While definitions of various epidemiologic studies and how to classify them were provided to the reviewers, some had more experience than others in identifying and classifying the literature appropriately.

This paper was not designed to be a critical systematic review or meta-analysis for any one intervention strategy. The expedited nature of the literature review was necessary for the purpose of working group–consensus building and prioritization of evidence-based strategies that prevent military physical training–related injuries.

The expedited review process of assessing the quality of the scientific studies may not have been consistently applied. Abstracts were considered an adequate source if they provided sufficient information to complete the quality scoring instrument. In cases where the abstract was limited, it is unknown how thoroughly working group members reviewed the full text article. Additionally, reviewers were asked to report if confidence intervals or *p*-values were used in the study but were not asked to make a judgment as to the strength of the intervals or values when completing the quality scoring instrument.

Working group members provided other research studies with non-injury outcomes in varying degrees, especially in the absence of systematic reviews and RCTs. However, as the principal focus was on the primary prevention of physical training–related injuries utilizing systematic reviews, randomized controlled trials (RCTs), and risk-factor/cause studies with injury as the primary outcome, the completeness of the classification matrix with other studies of less power or significance had little effect on the final recommendation.

In the years following the face-to-face meeting, an editor provided additional reviews of some topics when it appeared that critical data were missing. When the editor included new research in the classification matrices that appeared to affect the recommendation content, the original reviewer and all other members of the working group were contacted by electronic mail for their input to the changes. Consensus was achieved only among those who responded.

Conclusion

An expedited systematic process of evaluating common strategies enabled the Joint Physical Training Injury Prevention Working Group to build consensus around those injury prevention interventions that had good scientific evidence to recommend to all military services. The systematic, criteria-based process and adaptation of guidelines that required a standardized level of scientific evidence before making any recommendation was central to the formulation of evidence-based recommendations and their prioritization. While the initial effort of the working group sought to elucidate “proven” strategies to reduce physical training–related injuries in the basic training environment, we believe the principles behind the six recommended interventions can be broadly and inexpensively applied to operational training environments within the military services and to similar populations who have high activity demands. Military leaders should discourage the use of back braces, advise their troops against the prophylactic use of nonsteroidal anti-inflammatory drugs before activity, and carefully weigh the costs and benefits of implementing any of the 23 strategies with insufficient scientific evidence in their units (such as indiscriminate stretching before physical training). The unproven strategies identified in this article provide a starting point for further investigation into interventions that may prevent physical training–related injuries in service members of the military and in those of similar populations who may have frequent physical training requirements (e.g., firefighters, police officers, and athletes).

This review was completed as a result of collaboration between the U.S. Army Center for Health Promotion and Preventive Medicine and injury prevention and fitness experts for the Military Training Task Force of the Defense Safety Oversight Council. Individual contributors and their organizations are listed in the USACHPPM technical report.³²⁵ A special thanks to Barbara Weyandt for facilitating the working group, and Judith B. Schmitt and Val Buchanan for their editing.

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