Chapter 10

MUSCULOSKELETAL INJURIES IN THE MILITARY TRAINING ENVIRONMENT

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INTRODUCTION

Injuries in general have a greater impact on the health and readiness of the US military than any other category of medical complaint, and training injuries treated on an outpatient basis may have the biggest single impact on readiness. Physical training and physical fitness are required to accomplish military missions, and many military occupations routinely require a higher level of physical exertion and fitness than most civilian occupations, a fact recognized and enforced by regulation (eg, AR 350-41, *Training in Units*, Chapter 9, Physical fitness). During military training, all military personnel must attain and then afterward maintain a level of fitness much higher than usually found among civilians of the same age. In the military, physical training takes place in schools and in operational units. Generally, the training in schools is oriented toward rapidly increasing the physical strength and endurance of personnel, while training in units is oriented toward maintaining the level of fitness appropriate for the type of unit.

Physical training in basic training units accelerates healthy, young soldiers, sailors, airmen, and marines with varying levels of fitness to a fairly high level of fitness over a period of 8 to 13 weeks (Figure 10-1). After finishing basic training, individuals are either assigned to an operational unit or go on to further training. The fitness needed to function in an operational unit varies by the type of unit but, in general, will be higher in combat arms units (especially infantry) than in combat support or combat service support units. The level of fitness required in the schools that follow basic training varies by the type of school, with substantially more rigorous training required in special schools (eg, Airborne, Air Assault, Ranger, Special Forces, SEAL [Sea, Air, and Land] training) than in combat support or combat service support training programs. Indeed, physical training in special schools will often take servicemembers already in good physical condition and train them at levels similar to those of elite athletes.

Fig. 10-1. Military training usually involves substantial amounts of running and marching. Some aspects of training, particularly running, are associated with increased risks of overuse injury. Photograph: Courtesy of Colonel Bruce Jones, US Army (Retired).

In addition to differences between types of units, there are often substantial differences in the personnel within the units. While most military personnel are young and fit, senior non-commissioned officers and officers are generally older, more sedentary, less fit, and may be less healthy. Many studies in civilian and military populations have demonstrated that being physically fit and active is protective against many health hazards, including injury.[1–5] However, obtaining desired levels of fitness through physical training is accompanied by substantial risk of injury. High risks of injury have been documented in many training situations, and the association between low levels of preexisting physical fitness and activity and the risk of injury in this environment has been established by numerous epidemiologic studies.

The need for fitness and the requisite physical training to maintain mission-readiness, the burden and impact of training injuries, and the protective effects of fitness in preventing subsequent injuries result in a complex and dynamic matrix of competing requirements. Understanding this matrix and optimizing the competing requirements is a difficult challenge for military policymakers, planners, commanders, and medical personnel. Nonetheless, only coordinated, well-planned, and multifaceted approaches based on an understanding of the many factors involved will have a positive impact on reducing the levels of injuries. Because of their importance, training-related injuries will be the primary focus of this chapter.

THE MAGNITUDE OF THE PROBLEM

The frequency of injuries and their effects on the military are not widely appreciated. Among US military personnel, injuries cause more deaths (about 50% more) than any other cause.[6] Injuries are implicated in a substantial proportion of disability discharges: nearly 50% of Army Medical Examination Board reviews of personnel assigned to an Army infantry division in 1994 were directly related to injury. Evaluation of Physical Examination Board data indicates that many chronic conditions leading to disability may result from service-related injuries. Acute and chronic effects of injuries are a major cause of hospitalization, causing about 30% of Army hospitalizations among active duty personnel in 1992. Injuries, particularly training injuries, create an enormous load on outpatient facilities. Among Army and Marine Corps trainees, rates of outpatient visits due to injuries of 20% to 40% per month have been observed, and rates of 20% per month have been reported among trained infantry soldiers. Furthermore, these problems are not unique to the US military; many other countries recognize the impact of injuries on their armed forces.[7]

For each death due to injuries among active duty Army personnel there are many more disabilities, hospitalizations, and outpatient visits (Figure 10-2). While deaths and disabilities due to injury cause concern because of their catastrophic and tragic impact on individuals, injuries resulting in less severe outcomes, such as loss to training, outpatient clinic visits, and hospitalizations, are of concern because of their frequency. In particular, it is noteworthy that the base of the Army injury pyramid is very broad, with more than 1,100 outpatient visits occurring for every death. Most of the injuries seen in military outpatient clinics are lower-extremity training-related injuries.[3,5,7] Injuries at all levels of severity cause a huge drain on military manpower and health care services and inflict enormous direct and indirect costs.[8]

Injury Incidence

As a consequence of their intense physical training, both basic training and combat unit populations have a high incidence of exercise-related injury. The volume of injured servicemembers seeking care in outpatient clinics creates long waiting times, reduces the time available per patient, and generally clogs the health care delivery system. In a study of Army infantry soldiers, the incidence of injuries was slightly higher than the incidence of illness (risk ratio = 1.3), but the number of lost duty days was 11 times higher for injury than for illness.[9] In another study,[10] training injuries among women trainees resulted in nearly 22 times as many lost training days compared to days lost due to illness. Numerous studies of military trainees[2,3,11–13] have documented the high risk of exercise-related injuries, ranging from 14% to 42% among men and from 27% to 61.7% among women. Most injuries are to the lower extremities, and most of these are overuse injuries.

Injury Types and Locations

The types of injuries experienced by military populations have been examined in several studies. Jones and colleagues[3] found that pain due to overuse was diagnosed in 24% of male trainees, muscle strains in 9%, ankle sprains in 6%, overuse

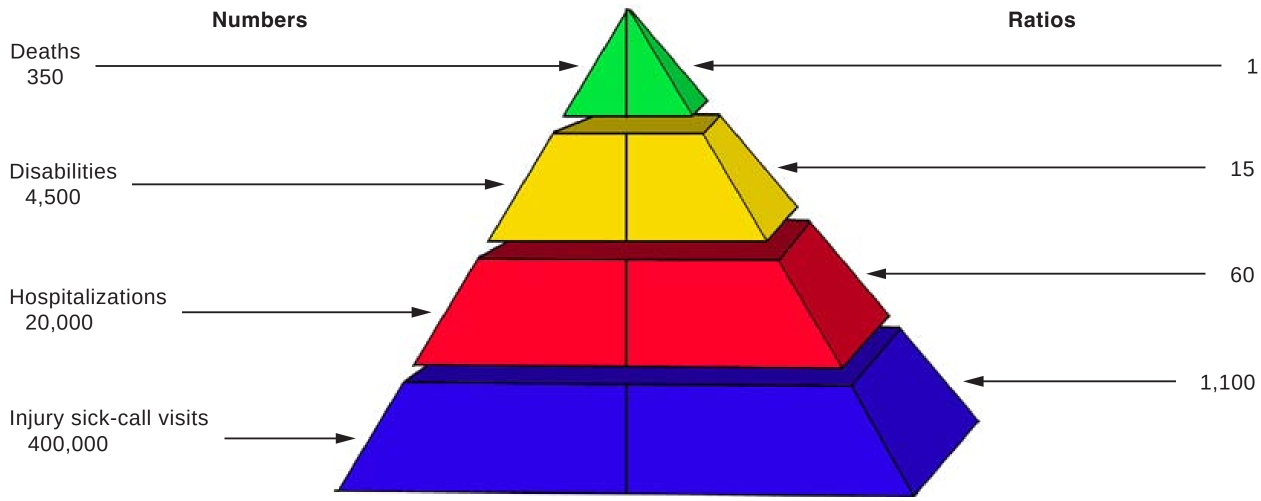


Fig. 10-2. The Army Injury Pyramid. Army population figures and data from calendar year 1994 are the basis for this graphic. Reprinted from Jones BH. Conclusions and recommendations. In: The Injury Prevention and Control Work Group of the Armed Forces Epidemiological Board. *Injuries in the Military: A Hidden Epidemic*. Washington, DC: Armed Forces Epidemiological Board; 1996.

knee injuries in 6%, and stress fractures in 3%. Among 298 infantry soldiers, Knapik and colleagues[5] reported that musculoskeletal pain was most common, followed by strains, sprains, and cold-related injuries. Among male Marine Corps trainees, iliotibial band syndrome occurred most frequently, followed by blisters, stress fractures, ankle sprains, patellar tendinitis, shin splints, and patellofemoral syndrome.[14] The types of injuries diagnosed in male Navy trainees are also due mainly to overuse, with overuse knee injuries being the most common, followed by back pain, shin splints, ankle sprains, arm and shoulder pain, and stress fractures. Naval Special Warfare trainees were also evaluated and their most common injuries were found to be iliotibial band syndrome, stress fractures, patellofemoral syndrome, contusions, ankle sprains, low back injuries, periostitis, and Achilles tendinitis.[15]

In addition to experiencing higher risks of injury, the patterns of injury types found among female trainees differ somewhat from those found among men in the same program,[2] as shown in Table 10-1. Low back pain and tendinitis are the most common injuries among men, while muscle strains and stress fractures are the most common among women.

Impact of Injuries: Lost Time and Financial Costs

Most training injuries are not catastrophic or life threatening—most result only in limited duty for several days. The high incidence of injuries, however, places a substantial burden on the medical care delivery system and leads to many lost training days and, frequently, to recruits having to repeat the training program (recycling). The costs are impressive. It has been estimated that stress fractures alone among 22,000 Marine Corps trainees in 1 year resulted in 53,000 lost training days and cost more than $16.5 million.[15] Extrapolation from the Marine Corps to all military trainees provides a reasonable estimate of costs related to all training injuries on the order of $100 million annually. Although stress fractures and stress reactions of bone occur fairly infrequently in basic training (risks reported include

TABLE 10-1

THE MOST COMMON INJURIES AMONG MEN AND WOMEN IN THE SAME ARMY BASIC COMBAT TRAINING PROGRAM

Injury Rank	Among Men	Among Women
1	Low back pain	Muscle strain
2	Tendinitis	Stress fracture
3	Sprain	Sprain
4	Muscle strain	Tendinitis
5	Stress fracture	Overuse knee injury

Data Source: Jones BH, Bovee MW, Harris JM 3d, Cowan DN. Intrinsic risk factors for exercise-related injuries among male and female army trainees. *Am J Sports Med*. 1993;21:705–710.

3.0%,[3] 2.4%,[2] 3.9%,[4] and 9.8%[15]), they are very debilitating and lead to more lost days of training and recycling than most other training-related injuries. The mean number of days lost per injury among Army infantry soldiers for stress fractures was 103, compared to 17 for sprains, 8 for other traumatic injuries, 7 for tendinitis, and 3 each for strains and musculoskeletal pain.[5]

RISK FACTORS FOR TRAINING-RELATED INJURIES

Identifying and understanding risk is key to developing effective prevention and treatment strategies for overuse injuries. Successful prevention depends on identification of *modifiable* risk factors. Since the early 1980s, much has been learned regarding risk factors for training- or exercise-related injuries in military populations (Exhibit 10-1), offering clues for effective interventions. These factors can usually be categorized as intrinsic (an attribute of the individual) or extrinsic (an attribute from some other source).

Intrinsic Risk Factors

A number of intrinsic risk factors have been identified among military populations. They include age, sex, anatomy, fitness, flexibility, and smoking.

EXHIBIT 10-1

RISK FACTORS FOR PHYSICAL TRAINING INJURIES IN MILITARY POPULATIONS

Intrinsic Factors

- Age (risk generally increases with age)
- Sex (risk is usually higher for women)
- Anatomy (risk is associated with both leg and foot morphology)
- Physical activity and fitness (risk is generally lower for more-fit individuals)
- Flexibility (risk appears to be higher for those at the extremes of flexibility)
- Smoking (risk is higher for cigarette smokers)

Extrinsic Factors

- Absolute amount of training (risk is higher for more total distance covered)
- Type of training (risk is higher for running versus walking or marching)
- Acceleration of training (risk is higher after rapid increases in level of training)
- Shoes and orthotics (inconsistent findings)
- Training surface (inconsistent findings)

Age

Age has been evaluated as a risk factor for injury in a number of settings, but the findings have not been consistent. A number of studies have found that risks increase for older persons[3,5,16] even starting as early as age 25.[17] Others,[9,18–20] however, have found no association with age or an inverse association,[21] with the youngest at highest risk. The effect of age on risk has not been resolved and may prove to be a complex issue involving sex, previous history of exercise, existing level of fitness, nutritional and hormonal status, smoking, and the training environment, as well as the specific type of injury in question. If other risk factors are the same, older individuals are probably at greater risk of injury.

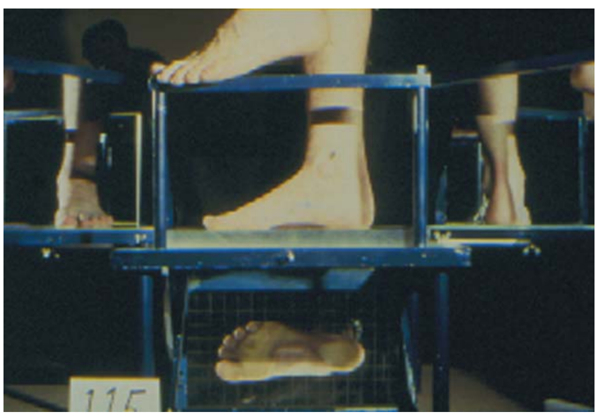
Sex

Most military studies have found women to be at increased risk of injury compared to men in the same training program.[1–3,22–24] Women entering military service are generally less fit than men, and this may account for some of the increase in risk among women. For example, Jones and colleagues[25] found that while female recruits were at an overall increased risk of injury, if the level of fitness was controlled for, there was no significant difference in risk of injury between the men and women. In addition, women have different lower extremity anatomy than men, including larger quadriceps angles (Q-angles) and greater degree of genu valgum (knock-knee).[26] Cowan and colleagues[27] found that among male trainees, these factors are associated with increased risk of overuse training injuries. The degree that these morphologic differences may account for differences in risk of injury has not yet been investigated. In contrast to women in training, women in operational units have been found not to be at increased risk of injury.[16] Lower rates of injury among women in operational units are probably due to lower levels of exposure to injury-causing activities relative to that found in training units.

Anatomic Factors

The effect of anatomic variations on the risk of injury has been discussed for decades, but there has been remarkably little epidemiologic research conducted on this topic. Based on clinical impressions and case series, many characteristics have been proposed as risk factors, including flat feet and high arches (Figure 10-3), genu varum and valgum (Figure 10-4), excessive Q-angle, hyperextension of the knee (genu recurvatum), and leg length differences. However, a review of the literature conducted by Powell and colleagues[28] in 1986 concluded that the actual effect of lower limb anatomical variation on the risk of injuries in active populations has not been studied adequately in well-designed epidemiologic studies. He went on to state that "[n]one of the epidemiologic studies evaluated the role of anatomic factors in running injuries," that "case studies are unable to establish causality," and that "[c]areful, abnormality-specific studies should be a top priority for future research."[28(p100–101)]

a



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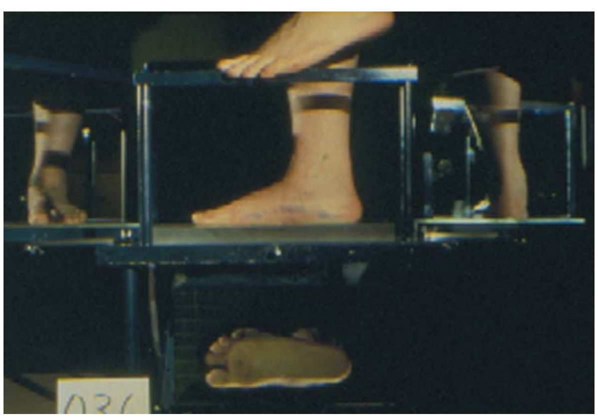

Fig. 10-3. Persons with high arches (**a**) are at increased risk of training injuries, while those with flat feet (**b**) may have a reduced risk, compared to those with "normal" arches. Photograph: Courtesy of John Robinson, Nike Sports Research, Nike, Inc., One Bowerman Drive, Beaverton, OR 97005-6453.

Fig. 10-4. Army infantry trainees with genu valgum, or knock-knees, were found to be more likely to experience an overuse injury. Photograph: Courtesy of Peter Frykman, MS, Research Physiologist/Biomechanist, US Army Research Institute of Environmental Medicine, Natick, Massachusetts.

In the decade since that review, a few studies (mostly conducted by military scientists) evaluated prospectively the association between anatomic variables and risk of injury. The Israeli military studied anatomic risk factors for stress fractures and identified several factors that may be involved, including shorter tibial length, genu valgum, and excessive external rotation of the hip.[29,30] In US Marine Corps trainees, males diagnosed with stress fractures were shorter, lighter, and smaller in most bone structural girth dimensions than were uninjured trainees. In addition, bone structural geometric properties, such as cross-sectional areas, moments of inertia, section moduli, and width, were significantly smaller in those with stress fracture.[31]

The impact of foot[32] and leg[27] morphology on the risk of overuse training injuries was evaluated in the population studied by Jones and colleagues.[3] As shown in Table 10-2, infantry trainees with flat feet were at lowest risk, and those with high arches were at significantly increased risk. These findings are consistent with the findings of Giladi and colleagues,[33] who reported that low-arched Israeli sol-

TABLE 10-2

LOWER-EXTREMITY ANATOMY AND RISK OF INJURY AMONG ARMY TRAINEES

Characteristic	Injury Risk (%)	Source
Foot Morphology		1
Flattest 20% of arch heights	22	
Mid-60% of arch heights	39	
Highest 20% of arch heights	53	
Leg Morphology		2
Quintile 1 (most knock-kneed)	41	
Quintile 2	34	
Quintile 3	22	
Quintile 4	27	
Quintile 5 (most bowlegged)	28	
Quadriceps angle		2
≤ 10°	27	
> 10° to ≤ 15°	31	
> 15°	40	

Data Sources: (1) Cowan DN, Jones BH, Frykman PN, et al. Lower limb morphology and risk of overuse injury among male infantry trainees. *Med Sci Sports Exerc*. 1996;28:945–952. (2) Cowan DN, Jones BH, Robinson JR. Foot morphologic characteristics and risk of exercise-related injury. *Arch Fam Med*. 1993;2:773–777.

diers were at lowest risk of stress fractures. The findings of Kaufman and colleagues,[34] however, did not support those of Cowan.[32] Using different methods of measuring foot morphology among their population of SEAL candidates, they found that the flattest—and highest—arched tertiles had higher (but not significantly higher) risk of stress fracture, Achilles tendinitis, and iliotibial band syndrome. Army infantry trainees with genu valgum, shown in Table 10-2, had significantly increased risk of injury, as did those with excessive Q-angle. Genu recurvatum and leg length differences were not associated with increased risk of injury. This research provides some of the first quantitative descriptions of anatomic variances and estimates of risks for certain characteristics that should be further evaluated. As mentioned above, the anatomic differences between men and women may explain some portion of the differences in risk of training injuries, and this could best be evaluated in training units that contain both sexes.

Physical Activity and Fitness

Past physical activity and preexisting physical fitness are both important predictors of risk of training injury, and this is reflected in repeated findings that persons who enter military service with a history of high levels of activity and fitness are at significantly lower risk of injury.[1–5,9,35] There are several health-related parameters of fitness, including cardiorespiratory endurance, muscle endurance, strength, flexibility, and body composition. Not all of these factors are equally or consistently associated with risk of injury.

In a study of 303 infantry trainees,[3] there were significant univariate associations between risk of training injuries and several self-reported indicators of physical activity before entry into the Army. Compared to those reporting higher levels of activity, those reporting a more average activity level had a relative risk (RR) of injury of 1.8, while those who reported being inactive had an RR of 1.6. Compared to those running 4 or more days per week, those reporting running 1 to 3 days per week had an RR of 1.9, and those running less than 1 day per week had an RR of 2.2. Exercise frequency less than 1 day per week (RR = 1.5) was a significant predictor, but investigator-estimated energy expended per week in exercise (based on the reported intensity of exercise) was not associated with risk of injury. When fitness was assessed by several different methods, some measures of fitness were more strongly associated with injury than others. Body fat percentage was not a consistent predictor of injury, while those with both low and high levels of flexibility were at substantially increased risk (RR = 2.5 and 2.2, respectively) when compared to those of average flexibility. Dynamic lifting strength was not related to injury, but the number of pushups done (in 2 minutes) and 2-mile run time were somewhat associated with injury risk.

One- and two-mile run times have been found to be one of the most consistent predictors of injury risk in a number of studies, although there have been slight differences found in patterns and relative risks. Jones and colleagues[25] found that both men and women who ran faster had lower injury risks during basic training than those who ran slower, as is shown in Table 10-3. Faster women had a reduced risk of stress fracture.[2] Similar findings among trainees[20,36] and among trained infantry soldiers[5,9] have been reported by others. Based on the available evidence, it appears that endurance (as measured by run times) is the best fitness predictor of injury, with risks substantially higher among the worst performers.

TABLE 10-3

RUN-TIME PERFORMANCE AND RISK OF INJURY AMONG US ARMY PERSONNEL

Population	Sex	Distance (mile)	Grouping	Risk (%)	Source
Trainees	Male	1	Quartiles		1
			Q1 (Fastest)	14.3	
			Q2	10.0	
			Q3	26.3	
			Q4 (Slowest)	42.1	
Trainees	Female	1	Quartiles		1
			Q1 (Fastest)	36.1	
			Q2	33.3	
			Q3	57.1	
			Q4 (Slowest)	60.6	
Trainees	Female	2	Quintiles		2
			Q1 (Fastest)	50.0	
			Q2-Q4	67.3	
			Q5 (Slowest)	77.4	
Trainees	Male	2	Quintiles		3
			Q1 (Fastest)	25.9	
			Q2	34.6	
			Q3	42.9	
			Q4	55.5	
			Q5 (Slowest)	40.7	
Trainees	Male	2	Quartiles		4
			Q1 (Fastest)	25	
			Q2	24	
			Q3	39	
			Q4 (Slowest)	49	
Infantry Soldiers	Male	2	Quintiles		5
			Q1 (Fastest)	37.5	
			Q2	20.6	
			Q3	35.3	
			Q4	45.9	
			Q5 (Slowest)	61.1	
Infantry Soldiers	Male	2	Quartiles		6
			Q1 (Fastest)	33*	
			Q2	40*	
			Q3	48*	
			Q4 (Slowest)	52*	

*All data estimated from graph in Figure 3 in: Directorate of Information and Operations, Department of Defense. *Worldwide U.S. Active Duty Military Personnel Casualties Report, October 1979 through 1994*. Washington, DC: DoD; 1994.

Data sources: (1) Jones BH, Manikowski R, Harris J, et al. *Incidence and Risk Factors for Injury and Illness among Male and Female Army Basic Trainees*. Natick, Mass: US Army Research Institute of Environmental Medicine; 1988. Technical Report T-19-88. (2) Westphal KA, Driedl KE, Sharp MA, et al. *Health, Performance, and Nutritional Status of U.S. Army Women during Basic Combat Training*. Natick, Mass: US Army Research Institute of Environmental Medicine; 1996. Technical Report No. T96-2. (3) Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN. Epidemiology of injuries associated with physical training among young men in the Army. *Med Sci Sports Exerc*. 1993;25:197–203. (4) Canham ML, McFerren MA, Jones BH. The association of injury with physical fitness among men and women in gender integrated basic combat training units. *Medical Surveillance Monthly Report.* 1996;2(4):8–12. (5) Reynolds KL, Heckel HA, Witt CE, et al. Cigarette smoking, physical fitness, and injuries in infantry soldiers. *Am J Prev Med*. 1994;10:145–150. (6) Knapik J, Ang P, Reynolds K, Jones B. Physical fitness, age, and injury incidence in infantry soldiers. *J Occup Med*. 1993;35:598–603.

Lack of flexibility has been cited as a risk factor for injuries,[37,38] but this issue has not been adequately resolved. Jones and colleagues[3] found that infantry trainees at both extremes of flexibility were at increased risk of overuse injury, as did Reynolds and colleagues (Table 10-4).[9] Knapik and colleagues[5] reported a similar bimodal pattern in a study of female college athletes. While some have called for specific efforts to increase flexibility and range of motion,[39,40] there is no epidemiologic evidence that greater flexibility or stretching reduces injury risk. Military studies[3,5,9] suggest that maintenance of average or normal flexibility may be important.

Smoking

Cigarette smoking remains quite prevalent among military personnel, particularly among enlisted members. Currently, smoking is not permitted during basic training, but after completion of training, many individuals who were smokers before entry into service resume smoking, and some proportion of previous non-smokers begin smoking. Cigarette smoking has been found to be associated with lower levels of fitness among trainees, even when other factors such as the level of exercise were controlled for.[41] Smoking has also been identified as a possible risk factor for overuse injury among military personnel. Jones and colleagues[3] found that infantry trainees smoking 10 or more cigarettes per day were approximately 50% more likely ($p < .05$) to experience a training injury than nonsmokers, as is shown in Table 10-5. Among trained infantry soldiers, smokers in one study[9] experienced a greater-than-65% increase in risk of injury ($p < .05$), and a survey[17] of 2,312 active duty female soldiers found that smokers had about a 50% increase in risk ($p < .001$) of stress fracture. Shaffer,[4] however, found no significant association between smoking and risk of stress fracture among male Marine Corps trainees. Ross and Woodward[19] found that among Australian Air Force trainees, smokers had increased risk of all training-related and overuse injuries, but that these increases in risk were not statistically significant.

Extrinsic Risk Factors

Several extrinsic factors have also been identified, and these may be even more appropriate ar-

TABLE 10-4

FLEXIBILITY AND RISK OF INJURY AMONG ARMY PERSONNEL

Grouping	Risk (%)	Source
Quintiles		1
Q1 (least flexible)	49.2	
Q2	38.3	
Q3	20.0	
Q4	33.3	
Q5 (most flexible)	43.6	
Quintiles		2
Q1 (least flexible)	48.5	
Q2	41.0	
Q3	33.3	
Q4	44.4	
Q5 (most flexible)	47.1	

Data Sources: (1) Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN. Epidemiology of injuries associated with physical training among young men in the Army. *Med Sci Sports Exerc*. 1993;25:197–203. (2) Reynolds KL, Heckel HA, Witt CE, et al. Cigarette smoking, physical fitness, and injuries in infantry soldiers. *Am J Prev Med*. 1994;10:145–150.

TABLE 10-5

SMOKING AND RISK OF INJURY AMONG ARMY PERSONNEL

Cigarettes Smoked	Risk (%)	Source
None in last year	28.7	1
None in last month	36.7	
1–9/day	34.5	
10–19/day	52.8	
≥ 20/day	49.2	
None	37.0	2
1–10/day	59.2	
> 10/day	64.0	
Nonsmokers	61.8	3
Smokers	77.4	

Data Sources: (1) Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN. Epidemiology of injuries associated with physical training among young men in the Army. *Med Sci Sports Exerc*. 1993;25:197–203. (2) Reynolds KL, Heckel HA, Witt CE, et al. Cigarette smoking, physical fitness, and injuries in infantry soldiers. *Am J Prev Med*. 1994;10:145–150. (3) Westphal KA, Driedl KE, Sharp MA, et al. *Health, Performance, and Nutritional Status of U.S. Army Women during Basic Combat Training*. Natick, Mass: US Army Research Institute of Environmental Medicine; 1996. Technical Report No. T96-2.

eas for intervention efforts than are intrinsic factors. The training itself (the total amount of activity and the scheduling of it), footwear, and running surface have all been postulated as being contributors to training injuries. Running more miles and a rapid increase in the level of activity have both been shown to be associated with a higher risk of injury. This is in contrast to running surface (which has not been tied to higher risk of injury) and various insoles (which have not been shown conclusively to protect military personnel from injury).

Training

Training itself has been identified as a risk factor for injuries. Rapid increases in the amount and intensity of training are postulated to be associated with increased levels of injury. Studies of civilian runners have found that those running high mileage have more frequent injuries.[42,43] An elegant experiment conducted in the mid-1970s demonstrated the association between the amount of training and risk of injury.[43] The researchers found that men who did not run had no injuries; those who ran 15 minutes (3 days per week) had an incidence of 22%; those who ran 30 minutes experienced 24% injuries; and those who ran 45 minutes had an injury rate of 54%.

The pattern of training among military recruits may also affect the risk of injury. As with any physical training program, the frequency, intensity, duration, and type of activity must take into account the physical condition of the trainees entering the program to prevent "training error," which increases the risk of injury. Military trainees who enter service with a history of being physically active are at reduced risk of injury, while those who have been more sedentary, and thus experience a rapid acceleration in activity when they enter the military, are at significantly higher risk of injury.[3] These populations must have gradual and appropriate "ramp-up" of physical activity with adequate rest included. Training patterns throughout basic training must also include the physical activity involved in personnel movement throughout the training schedule. For example, in 1996, Navy recruits marched in formation 25 miles in the first 5 days of training.[44] But Jones and colleagues[45] found that running mileage, rather than walking or marching, was most strongly associated with rates of injury. When they compared two companies of infantry trainees, they found that although both groups covered approximately the same total distance of running and marching, the company that did more running had significantly higher rates of injury but did not score any higher on the final physical fitness test. A safe and effective exercise program will count all weight-bearing, and especially running, mileage and will ensure that all trainees develop an aerobic fitness base that balances running, marching, and other physical activities to avoid training levels above which injury rates increase but fitness does not.

Footwear

Footwear and orthotic devices have been proposed as risk (or protective) factors, but there is little evidence based on solid scientific investigation. US military personnel do not usually run in combat boots, but they routinely march, negotiate obstacle courses, conduct land navigation, train, and fight in boots. The combat boot has been evaluated and considered as an injury hazard.[12,46] Static and dynamic testing of existing combat boots in the laboratory suggests that properties theoretically associated with overuse injury, such as shock attenuation and stability, can be significantly improved with existing technology.

The use of inserts in military footwear as a method of reducing injuries has been evaluated in different settings with inconsistent findings. Smith and colleagues[47] conducted a controlled experiment among Coast Guard trainees in which randomly selected subjects received one of two inserts or no insert. At the end of training, the authors reported dramatic (greater than 50% for both types of insert) reductions in risk of injury, but the relevance of this study is questionable because over half of the injuries were calluses or blisters and no tests of statistical significance were given. Gardner and colleagues[36] conducted a similar randomized trial among Marine Corps recruits in which viscoelastic polymer insoles were provided to some while others used the standard non–shock-absorbing insoles. No significant reduction in the risk of musculoskeletal injury was demonstrated. (A planned, large-scale introduction of these insoles was canceled.) Another study[48] found that insoles made of this viscoelastic polymer did not reduce loading on the legs and feet. The material used in the inserts may be an important factor in determining the efficiency of inserts in reducing injuries. A study of South African military trainees[49] reported a significant and substantial reduction in the incidence of overuse injuries when neoprene (a different material) insoles were used during 9 weeks of training. The contradictory results of these studies indicate that using insoles as an injury reduction effort needs to be further studied before it is either rejected or accepted.

Running Surface

Some have speculated that a hard running surface is a risk factor in exercise-related injuries,[50] while others have found no association.[42] An interesting but not well-explained finding by Shwayhat and colleagues[20] indicated that men who ran on hard surfaces in preparation for entrance into an elite military school were at reduced risk of injury when compared to those who ran on soft surfaces. At present, there is inadequate evidence available for recommending any particular running surface for military training.

INJURY PREVENTION AND CONTROL

An appreciation of the magnitude and impact of training- and exercise-related injuries on military budgets, medical delivery systems, and mission readiness leads to an understanding of the importance of developing effective preventive methods and programs. However, the process of moving from identifying to resolving this problem is complex.

The problem—training injuries—is caused by certain intrinsic and extrinsic factors, including the training itself. There are no "magic bullets" that will eliminate the problem, but each promising intervention should be investigated and considered for implementation. Commanders and military policymakers need to be educated about all aspects of training injuries so they can make broad changes to effect improvements. Finally, research and evaluation of training injuries and intervention programs must be ongoing to identify the most effective and efficient preventive activities.

From a narrower, more scientific perspective, it is known that musculoskeletal injuries in military training populations result from multiple causes and are associated with a variety of risk factors acting together. Prevention of these injuries involves a combination of efforts and should have four main thrusts: (1) identification of intrinsic and extrinsic risk factors for injury, (2) pretraining modification of intrinsic risk factors, (3) modification of extrinsic risk factors, and (4) education of military training and medical personnel on the proper prevention and management of musculoskeletal injuries. There is no one plan or program that alone will be effective.

Once the problem in a military training program is identified, the next step in any effective prevention program is the sound scientific identification of the risk factors for injury. The nature of military training programs provides a controlled environment for valid assessment of injury incidence, physical activity, and lifestyle factors. Sound epidemiologic studies can be performed prospectively or retrospectively, generally in large sample situations. The largest logistical challenge in conducting these studies is integrating the research protocol into the daily activities of the training program and eliciting the support of the training cadre. The scientific challenge is understanding the relative contributions of the constellation of risk factors that make up the injury susceptibility profile.

Once the risk factors for injury have been identified for a given training population, targeted and successful modifications can begin to reduce the operational, fiscal, and health impact of these problems. The modification of any one factor will not eliminate the problem; because of the arduous nature of these training programs and the necessarily abrupt change to the trainee's lifestyle, some level of injury incidence will always be a cost of training. However, the potential for the reduction of injury incidence through modification of one or more factors can be great. For example, among 1,137 Marine Corps recruits in 1994, individuals who exercised less than 3 times per week at low intensity in the 2 months before training and ranked their level of fitness as fair to poor had a 40% excess risk of stress fracture during training.[14] By improving their level of fitness before beginning Marine Corps training, it may be possible to substantially lower their risk of injury. The general challenge of intrinsic risk factor modification is that it usually must be started before training, and in the case of basic training that involves dealing with individuals before enlistment or commission in the military. Regardless of when the modification of intrinsic risk factors begins, it must continue throughout the individual's military career. Screening of individuals with known risk factors for injury can also be employed, but these restrictions are usually only applicable to specific occupational specialties. For example, it may be possible to identify persons with specific risk factors or constellations of factors for injury and assign them to military occupations that require less marching and running than does the infantry.

Extrinsic factors such as operational training activities, physical fitness training activities, and training equipment should be evaluated for safety and effectiveness. Two of the goals of military training are instilling in a recruit an active military lifestyle and improving his or her physical fitness, so it is important to employ sound principles of physical conditioning in all aspects of the training schedule to minimize the effects of overuse injuries. A safe and effective physical conditioning program must consider all daily activities throughout training, such as military-specific training, movement mileage, and structured exercise. Modification of training activities to prevent injuries and improve fitness will have a goal of total body fitness that includes cardiovascular endurance, anaerobic capacity, muscular strength and endurance, high lean-body mass relative to body fat, and joint flexibility for optimal range of motion. The balanced training program for total body fitness is gradual and progressive (weekly training load increases not to exceed 10% to 15%). It stresses the cardiovascular and musculoskeletal systems, includes adequate rest, and is targeted to improve those activities that are important to the military goals of the program. These activities must be continued on a regular basis throughout training. An intervention to reduce injuries that followed these principles was implemented for males in Marine Corps basic training in 1995. An evaluation of this program compared to the existing training schedule demonstrated a significant reduction in overuse injuries, including a 50% reduction in stress fractures, with equal improvement in the physical fitness of recruits at the end of the program (Brodine SK, Shaffer RA, Naval Health Research Center, unpublished data, 1996).

The final and most important aspect of musculoskeletal injury prevention is the education of the military training and medical personnel in safe and effective methods for training and proper management of musculoskeletal problems. The military training cadre must understand and practice the principles of general conditioning and injury prevention with every trainee. The medical personnel supporting these programs need training in the prevention, early identification, and management of overuse injuries. Both of these groups must work closely in each training population to produce the optimum reduction of training injuries.

SUMMARY

Injuries in general, and training related injuries in particular, are a major cause of morbidity, lost duty time, and financial costs to the military. They are also a primary source of crowding in the military outpatient care system. Several modifiable risk factors have been identified, including physical fitness, cigarette smoking, and fitness training. It is known that training programs can be modified to prevent injuries yet still produce physically fit soldiers, sailors, airmen, and marines. Additional study is needed to evaluate the efficiency and effectiveness of modifying other factors, such as footwear. When intervention programs are implemented, rigorous evaluation is required to determine their benefits.

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