

*clinical epidemiology*

Epidemiology of injuries associated with physical training among young men in the army

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ABSTRACT

JONES, B. H., D. N. COWAN, J. P. TOMLINSON, J. R. ROBINSON, D. W. POLLY, and P. N. FRYKMAN. Epidemiology of injuries associated with physical training among young men in the army. *Med. Sci. Sports Exerc.*, Vol. 25, No. 2, pp. 197-203, 1993. It is widely acknowledged that musculoskeletal injuries occur as a result of vigorous physical activity and exercise, but little quantitative documentation exists on the incidence of or risk factors for these injuries. This study was conducted to assess the incidence, types, and risk factors for training-related injuries among young men undergoing Army infantry basic training. Prior to training we evaluated 303 men (median age 19 yr), utilizing questionnaires and measurements of physical fitness. Subjects were followed over 12 wk of training. Physical training was documented on a daily basis, and injuries were ascertained by review of medical records for every trainee. We performed univariate and multivariate analyses of the data. Cumulative incidence of subjects with one or more lower extremity training-related injury was 37% (80% of all injuries). The most common injuries were muscle strains, sprains, and overuse knee conditions. A number of risk factors were identified, including: older age, smoking, previous injury (sprained ankles), low levels of previous occupational and physical activity, low frequency of running before entry into the Army, flexibility (both high and low), low physical fitness on entry, and unit training (high running mileage).

MUSCULOSKELETAL INJURIES, LOWER EXTREMITY INJURIES, RISK FACTORS, EXERCISE, PHYSICAL ACTIVITY, INCIDENCE, MULTIVARIATE ANALYSIS

Musculoskeletal injuries occur frequently in association with exercise and vigorous physical activity (9,12,13,15,24). Although it is widely acknowledged that musculoskeletal injuries occur as a result of physical training activities, little is known about the etiology, incidence of, or risk factors for training-related injuries. This is true even for common activities, such as walking, cycling, racquet sports, or running (9,13,15,24). For many activities even the incidence of injuries is not known.

The benefits of exercise and physical activity, improved fitness (2,36), and decreased morbidity and mortality (4,21,27) are firmly established. Knowledge of the benefits of physical activity and exercise has led public health officials in the United States to promote greater activity and fitness levels in the population as major health objectives for the nation (32).

For some populations, such as the military, however, there is a strong need to know not only the benefits, but also the short-term risks of exercise. Even relatively benign injuries, such as sprained ankles, can be costly in terms of lost training time and reduced "combat readiness" of soldiers. Because physical fitness is considered to be an essential element of readiness, the Army places great emphasis on physical training. As a consequence, the incidence of training-related injuries, such as stress fractures, tendinitis, and muscle strains, is high in the Army and other military populations (5,7,9,10,14,30).

We conducted this hypothesis generating study to lay the foundation for Army training injury prevention strategies. The primary purposes of the study were to document the impact of past physical activity, current physical fitness, and Army physical training on the incidence of injuries among new recruits.

METHODS

Subjects and study design. Subjects were 303 male Army Infantry trainees from two basic training companies. Three hundred thirty-eight trainees were briefed on the nature of the study and 335 volunteered and signed consent forms. Thirty two of those volunteering were lost to follow up due to transfers to other units ($N = 24$), early discharge ($N = 5$), and unknown reasons ($N = 3$).

This study was conducted in two phases: 1) baseline evaluation and 2) follow-up. Baseline evaluation was conducted on the weekend that trainees arrived for duty and prior to the onset of any military training.

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The first part of baseline evaluation consisted of a questionnaire, followed by measurements of body stature and composition, and physical fitness. Follow-up consisted of documentation of training activities, results from the final Army physical fitness test, and documentation of all sick call visits for injuries during the training cycle. Follow-up was terminated at the end of the 12th wk, the last full week of the infantry basic training cycle.

Questionnaire. A questionnaire was given to all volunteers. The questionnaire was read aloud by the same investigator to the subjects from each company as a group.

The questionnaire instructed subjects to provide their birth date, age in years, gender, race (American Indian/Alaskan Native, Asian/Oriental, Black, Hispanic, White non-Hispanic), number of years education, and dates of graduation. Subjects also provided the name (title) of their most recent job, the year of last employment, and rated the physical activity level entailed by their primary job (occupation) in the last year. They rated their job activity level on a 5-point scale (1 = no activity—unemployed; 2 = very light—typist, office worker, etc.; 3 = light—service person in a restaurant or store clerk, etc.; 4 = moderate—construction, house painter, mechanic, etc.; 5 = heavy—miner, lumberjack, bricklayer, etc.).

Subjects were asked if they had smoked one or more cigarettes in the last year, and if "yes," how many cigarettes they smoked per day on average in the last month. Participants indicated past injuries to their lower extremities by checking on a list those experienced in the last 10 yr. For each injury checked they indicated the body part injured and the year of occurrence.

Subjects rated their level of previous physical activity compared with others of their same age and gender. Rating was on a 5-point scale (1 = very inactive, 3 = "average," and 5 = very active). Washburn et al. (35) previously validated a similar question. Volunteers also indicated how frequently they ran each week ($d \cdot wk^{-1}$) in the month before entering the Army, and how much they ran ($min \cdot d^{-1}$) on each occasion. They provided additional information on the frequency and duration of exercise, other than running, and sports participation in high school and college.

A series of questions similar to the Minnesota Leisure Time Activity questionnaire (29) were used to estimate the average weekly energy expenditures in metabolic equivalents (METs) for subjects over the last year. METs were calculated employing methods and tables in common clinical usage (1).

Physical fitness measurements. Anthropometric and physical fitness measurements were made immediately following the questionnaire. Height, weight, and neck and waist girths were measured with subjects in

shorts and bare feet. Quetelet body mass index (BMI) was calculated as WT/HT^2 ($kg \cdot m^{-2}$). Percent body fat was estimated from neck and waist circumferences according to a standard Army equation for measurements in cm: percent body fat = $43.782 - (68.68 * LOG(HT)) + (76.46 * LOG(\text{abdominal circumference} - \text{neck circumference}))$.

Back and hamstring flexibility were measured with a sit-and-reach test (23). Degree of flexibility was recorded in number of centimeters reached toward the toes (negative numbers before the toes, positive numbers beyond the toes). Muscle strength was measured with an incremental weight-lifting machine. Strength was defined as the maximum weight a subject could lift from the floor to overhead with arms extended (maximum load = 90.7 kg = 200 lb).

Additional baseline measurements of physical fitness were obtained on one of the two training companies from the results of a physical training test on the third day of training. These consisted of 2-mile run times and the number of push-ups and sit-ups completed in 2 min.

Physical training. One unit (company) was selected because it placed heavy emphasis on running to build endurance, and the other because it deemphasized running. Company commanders documented unit physical training in a daily log that was picked up by an investigator every 2 or 3 d. We directly observed training on a frequent basis to validate the accuracy of log entries. Outside of programmed unit training, there was little or no time for trainees to engage in individual extracurricular recreational or sports activities.

Except for the amounts of running and marching, the training of the two companies (units) was virtually identical. Both companies engaged in physical training $5-6 d \cdot wk^{-1}$. On average both companies did 20 $min \cdot d^{-1}$ of calisthenics, 10 min of stretching, and 20 min of drill and ceremony. Both companies devoted about 40 $min \cdot d^{-1}$ to marching and running. But the amounts of time spent running for the two companies were quite different: 18 $min \cdot d^{-1}$ for the high mileage company and 8 min for the other. The company that did more running, ran a total of 130 miles over the 12 wk of training and marched 68 miles. The low mileage unit ran 56 miles and marched 121 miles.

Injury data. Musculoskeletal injuries were diagnosed by health care professionals not connected with the study. Injury data were collected via periodic reviews of the medical charts of every trainee. Reviews were conducted by a physician (BHJ). Information extracted from medical records included the date of each clinic visit, the verbatim diagnosis, the side and anatomic location of each injury, the disposition and days of restricted duty.

Injury cases were defined as any individual recorded as having received treatment for one or more lower

extremity musculoskeletal injuries. The cumulative incidence of individuals with one or more such injuries was used in the analysis. Only lower extremity (low back and below) musculoskeletal injuries, such as strains, sprains, stress fractures, and tendonitis, were included in the analyses presented in this paper. Injuries, such as lacerations, contusions, and blisters, were not included.

ANALYSIS

All data were double entered on a microcomputer and then up-loaded to a minicomputer for analysis. Analysis was conducted using standard statistical packages (BMDP and SAS).

For univariate analysis, categorical variables with 5-point scales or strata were collapsed down to 3-point scales or strata in a manner that preserved the symmetry of the scales around the middle or "average" group. Categorical variables were created from continuous ones, such as % body fat or run times, by assigning individuals to one of five equal size groups (quintiles) from low to high, based on their measured fitness values.

The incidence of injury was calculated for each category or level of a variable. The measure of association for univariate analysis was relative risk (RR) - (% injured in one risk group) * (% injured in the baseline risk group)⁻¹. Chi-squares were employed to test contrasts between baseline and successive risk groups. Partitioned chi-square methods were utilized to test contrasts between grouped strata (33) and Mantel-Haenszel (MH) chi-squares to test for trends. For multivariate analysis the measure of association was the adjusted odds ratio (AOR), which was generated from "back-stepping" multiple logistic regression output (BMDP). Ninety-five percent confidence intervals (95% CI) for relative risks were calculated using the methods described by Rothman (26) and for adjusted odds ratios by those of Lemeshow and Hosmer (16).

Terms (variables) for the logistic regression model were selected to represent distinct categories of physical activity and components of physical fitness and to control for the influence of important demographic and health characteristics. Correlations between terms in the model were low, $r < 0.6$. Limits for removal and reentry were set at $P = 0.15$.

RESULTS

Subjects. Table 1 provides descriptive characteristics of study participants. Trainees in this study were young (median age = 19 yr), predominantly white males (80% white), most of whom graduated from high school (84%). Over 40% were current smokers. Most (94%) had been employed in the last year, primarily at jobs

TABLE 1. Descriptive characteristics of Army trainees

Measurement	N	Mean	(SD)	(Min-Max)	Median
Age (yr)	303	20.2	(3.1)	19.0	(17-35)
Height (cm)	303	175.4	(6.4)	175.5	(158.8-193.3)
Weight (Kg)	303	75.5	(11.9)	73.6	(51.7-120.7)
Body mass index	303	24.6	(3.4)	24.0	(17.8-32.5)
Body fat (%)	302	16.9	(4.5)	16.0	(4.1-30.7)
Flexibility (cm)	303	4.8	(9.9)	4.3	(-23.9-+28.4)
Lift strength (kg)	300	71.6	(12.1)	72.6	(36.3-90.7)
2-Mile run (min)	135	15.6	(2.0)	15.3	(11.9-22.3)
Push-ups (N)	137	27.2	(11.3)	27.0	(1-57)
Sit-ups (N)	136	38.0	(10.6)	38.0	(10-77)

that required moderate (50.5%) or heavy work (19.5%).

The prevalence of the five most common past lower extremity injuries were sprained ankles (34%), pulled muscles (strains, 28%), fractures (7.3%), torn ligaments (5.6%), and torn cartilage (4.3%). Also, 2.3% of trainees reported stress fractures prior to the Army.

Trainees reported high self-rated physical activity levels (60.6% more active than "average," and only 9.9% inactive). Many did some running in the month before entering the Army (14.9% 4 or more d·wk⁻¹, and 49.3% 1-3 d). Most also reported exercise other than running in the prior month (28.1% 4 or more d·wk⁻¹, 49.5% 1-3 d). Among subjects, 23% had earned varsity sports letters in high school or college, 62% played in organized sports without earning letters, and 15% engaged in no sports.

Incidence of injuries. Of the 303 subjects in the study, 45.9% ($N = 139$) sustained one or more injuries severe enough to require a sick call visit. The cumulative incidence of subjects with one or more lower extremity musculoskeletal injuries was 37.0% ($N = 112$). Eight-six individuals (28.4%) experienced lower extremity overuse injuries, such as stress fractures, Achilles tendonitis, and patellofemoral syndrome.

Cumulative incidence of injury at the five most common sites were 10.9% to feet, 10.9% to ankles, 10.2% to knees, 8.6% to calves, and 5.9% to the low back. Cumulative incidences of the five most commonly diagnosed conditions were 23.8% for pain attributed to "overuse" or "stress syndrome," 8.6% muscle strains, 6.3% ankle sprains, 5.9% overuse knee injuries, such as patellofemoral syndrome, and 3.0% for stress fractures.

Risk factors for injury. Univariate associations of demographic characteristics, smoking, and job activity level with risk of injury are displayed in Table 2. The relative risks of lower extremity injury for individuals who were older than 24 yr were higher than for those under 19 yr old, and the trend of increasing risk with increasing age was significant (MH chi-square, $P = 0.01$). Relative risks of individuals who smoked more than 10 cigarettes·d⁻¹ were also significantly greater than nonsmokers. Race, years of education (not shown), and job activity levels were not found to be significantly associated with risk.

TABLE 2. Demographic, lifestyle, and occupational traits with associated incidence and relative risk (RR) of injuries during training with 95% confidence interval (CI)

	N	Injury Incidence (%)	RR	(95% CI)
Age group				
17-19	165	33.3	1.0	
20-21	61	37.7	1.1	(0.8, 1.7)
22-23	34	24.2	0.7	(0.4, 1.4)
24-25	22	58.3	1.8	(1.2, 2.6)*
26 Plus	20	60.0	1.8	(1.2, 2.7)*
Race				
White	241	39.0	1.0	
Black	29	27.6	0.7	(0.4, 1.3)
Hispanic	17	23.5	0.6	(0.3, 1.4)
Other	15	33.3	0.9	(0.4, 1.8)
Cigarettes smoked · d⁻¹†				
None in last year	143	28.7	1.0	
None in last month	30	36.7	1.3	(0.7, 2.2)
1-9	29	34.5	1.2	(0.7, 2.1)
10-19	36	52.8	1.8	(1.2, 2.9)*
20 Plus	61	49.2	1.7	(1.2, 2.5)*
Job activity				
Moderate to Heavy	211	33.6	1.0	
Light	51	45.1	1.3	(0.9, 1.9)
Very Light	39	41.0	1.2	(0.8, 1.9)

† In past 1 month.

* $P \leq 0.05$, for RR (comparison to baseline).

Individuals who sustained ankle sprains in the past were at significantly greater risk of lower extremity injuries during Army training than those with no history of injury (45.1% vs 32.1%, RR = 1.37, 95% CI: 1.03-1.84, $P = 0.05$). Injuries in general and other specific past injury were not associated with current injuries, but the numbers of most other injuries were small.

The associations of physical activity and exercise with incidence of training injuries are shown in Table 3. Trainees who rated themselves as being less active than average or who exercised less were at significantly higher risk of injury than their more active counterparts. The strongest and most significant association was between lower running frequency and higher incidence of injury. Low frequency of prior exercise other than running was also associated with higher risk (Table 3) but past sports participation (not shown) was not.

The average number of METs · wk⁻¹ of physical activity was significantly correlated with self-rated physical activity level ($r = 0.44$, $P = 0.0001$). Also, both METs of activity per week and self-rated physical activity level were significantly correlated with aerobic fitness as measured by 2-mile run times ($r = -0.27$, $P = 0.002$ and $r = -0.26$, $P = 0.003$, respectively). However, unlike self-rated activity level, the estimated METs per week of activity was not associated with risk of injury (Table 3).

Table 4 shows the associations between measures of entry level physical fitness and incidence of lower extremity injuries. There was no association between percent body fat and risks of injury (Table 4), nor was there an association with BMI (not shown). Flexibility

TABLE 3. Physical activity and exercise prior to the Army with associated incidence and relative risks (RR) of lower extremity injuries during training with 95% confidence intervals (CI)

	N	Injury Incidence (%)	RR	(95% CI)
Past activity				
Active	183	28.9	1.0	
Average	89	50.6	1.8	(1.3, 2.4)*
Inactive	30	46.7	1.6	(1.0, 2.5)*
Running frequency in previous month				
≥4 d · wk ⁻¹	45	20.0	1.0	
1-3 d · wk ⁻¹	149	37.6	1.9	(1.0, 3.5)*
0 < 1 d · wk ⁻¹	108	43.5	2.2	(1.2, 4.1)*
Running time · wk⁻¹ in previous month				
≥60 min · wk ⁻¹	85	25.9	1.0	
<60 min · wk ⁻¹	136	40.4	1.6	(1.0, 2.4)*
None	79	43.0	1.7	(1.1, 2.6)*
Exercise frequency† in previous month				
≥4 d · wk ⁻¹	85	29.4	1.0	
1-3 d · wk ⁻¹	150	38.0	1.3	(0.9, 1.9)
0 < 1 d · wk ⁻¹	68	44.1	1.5	(1.0, 2.3)
METs exercise · wk⁻¹ in last year (min-max)				
Q1 (10,535-66,238)	62	37.1	1.0	
Q2 (6,135-10,212)	60	41.7	1.1	(0.7, 1.8)
Q3 (3,394-6,025)	60	36.7	1.0	(0.6, 1.6)
Q4 (2,046-3,334)	61	28.8	0.8	(0.5, 1.3)
Q5 (0-2,019)	60	41.2	1.1	(0.7, 1.8)

† Other than running.

* $P \leq 0.05$, for RR (comparison to baseline).

TABLE 4. Levels of physical fitness on entry to the Army with associated incidence and relative risk (RR) of lower extremity injuries during training and 95% confidence intervals (CI)

Fitness Measure	(Min-Max)	N	Injury Incidence (%)	RR	(95% CI)
Body fat (%)					
Q1 Low	(4.4-12.3)	56	41.1	1.0	
Q2	(12.5-14.5)	57	29.8	0.7	(0.5, 1.2)
Q3	(14.6-17.4)	57	36.8	0.9	(0.6, 1.4)
Q4	(17.5-21.2)	60	40.0	1.0	(0.6, 1.5)
Q5 High	(21.3-30.7)	55	40.0	1.0	(0.6, 1.5)
Flexibility (cm)					
Q1 Low	(-23 to -4)	61	49.2	2.5	(1.5, 4.2)*
Q2	(-4 to 1)	60	38.3	1.9	(1.1, 3.4)*
Q3	(1 to 7)	60	20.0	1.0	
Q4	(7 to 13)	60	33.3	1.7	(0.9, 3.1)
Q5 High	(13 to 24)	62	43.6	2.2	(1.3, 3.8)*
Initial push-ups (N)					
Q1 Highest 20%	(35-57)	27	18.5	1.0	
Q2	(30-34)	28	46.5	2.5	(1.1, 5.7)*
Q3 Mid	(25-29)	30	33.3	1.8	(0.7, 4.5)
Q4	(17-24)	24	58.3	3.2	(1.5, 6.8)*
Q5 Lowest 20%	(1-16)	28	50.0	2.0	(1.2, 6.0)*
Initial 2-mile run (min)					
Q1 Fastest 20%	(11.9-13.8)	27	25.9	1.0	
Q2	(13.9-14.8)	26	34.6	1.3	(0.6, 3.0)
Q3 Mid	(14.9-15.6)	28	42.9	1.7	(0.8, 3.5)
Q4	(15.7-17.0)	27	55.5	2.1	(1.1, 4.2)*
Q5 Slowest 20%	(17.1-22.3)	27	40.7	1.6	(0.7, 3.4)

* $P \leq 0.05$, for RR (comparison to baseline).

demonstrated a significant U-shaped relationship with incidence of injury. Individuals at both extremes of flexibility were at more than two times greater risk than the "average" group (Table 4).

The least fit individuals as measured by push-ups were at significantly greater risk of injury than their most fit peers. The upward trend of risk for lower push-

up groups was significant (MH chi-square for trend $P = 0.02$). For 2-mile run time the fastest (most fit) quintile was at lower risk than each of the subsequent slower groups, but only significantly different from the third. A partitioned chi-square comparing the fastest two quintiles with the slowest three was significant (RR = 1.5, 95% CI: 1.0–2.4, $P = 0.04$) and a MH chi-square for trend was marginally significant ($P = 0.09$). There was no association between strength or strength to weight ratio and risk on univariate analysis (not shown).

The unit doing the most running had an incidence of lower extremity injuries of 41.8% compared with 32.5% for the low mileage company (RR = 1.3, 95% CI: 1.0–1.7). Despite the difference in incidence of injuries between companies, the distribution of injuries by site and type were similar.

Table 5 exhibits the values of adjusted odds ratios for terms (variables) remaining in the logistic regression model for lower extremity injuries. Twelve terms were candidates for the model. These terms were age group, ethnic group, smoking, history of injury, last job activity level, physical activity level, running frequency in the month before the Army, other previous exercise, % body fat, flexibility, strength, and unit training. Because there were no data on push-ups and run times for one entire unit, terms for these were not candidates for entry in the multivariate model.

Seven terms remained in the lower extremity injury model after the backward stepping process (see Table 5). Five of these had odds ratios that were significantly

greater than the baseline odds—older age, smoking 10 or more cigarettes per day, sedentary to light job activity level, low physical activity level, and flexibility level (both high and low).

DISCUSSION

The primary purposes of our study were to document the impact of past physical activity and exercise, and current physical fitness and training on the risks for musculoskeletal injuries. To accomplish these objectives, we employed the distinctions between physical activity and physical fitness defined by a workshop on the "epidemiologic and public health aspects of physical activity and exercise" held at the Centers for Disease Control in 1984 (6,25). We assessed job-related activity and several categories of leisure time activity including sports, running, and other exercise activities. We also measured the five components of health-related physical fitness (body composition, flexibility, strength, muscle endurance, and aerobic endurance) defined by the workshop (6,25).

In designing our study, we also endeavored to incorporate the recommendations for identifying risk factors for exercise-related injuries established by the workshop (13,25). We made initial evaluations of all participants and conducted close follow-up to document physical training and occurrence of medical complaints during the 12-wk training period. Our population of male Army trainees reported diverse prior lifestyles and activity levels and exhibited a wide range of physical characteristics and performance capabilities. We also documented demographic characteristics (age, race, and education) and controlled for these in our multivariate models. The uniformity of training within units controlled for the usual confounding effects of the association of physical training and exercise with other potential risk factors such as age, body composition, and physical fitness.

The incidence injuries in this study was consistent with those reported for other military studies (9,10,14). Comparison with civilian studies employing similar operational definitions of injury suggests that the cumulative incidence of injury to Army trainees was slightly higher than the seasonal incidences reported for male high school cross-country and track athletes, but was much lower than those for athletes in contact sports such as football or wrestling (8,15).

Regarding risk factors for exercise-related injuries, the only one consistently identified by previous studies has been volume of training, i.e., the amount of time spent exercising or running (3,12,13,17,18,20,22,24). Past injuries, also, appear to be an important contributing factor (18,20). Among infantry trainees, we identified several risk factors in addition to these, which will be discussed briefly.

TABLE 5. Risk factors for lower extremity (LE) musculoskeletal injuries with adjusted odds ratios from logistic regression (and 95% confidence intervals (CI)) controlling for effects of other risk factors in the model

Factor	LE Injuries Odds Ratio (95% CI)
Age (yr)	
<24	1.0
≥24	4.3 (2.0, 9.2)*
Cigarettes · d ⁻¹	
<10 · d ⁻¹	1.0
≥10 · d ⁻¹	1.9 (1.1, 3.3)*
History of injury	
No injury	1.0
Injury (no sprain)	0.6 (0.3, 1.3)
Ankle sprain	1.7 (0.9, 3.2)
Job activity	
Heavy-moderate	1.0
Light-very light	1.8 (1.0, 3.2)*
Physical activity	
Above average	1.0
Average or less	2.2 (1.3, 3.8)*
Flexibility	
1 Lowest 20%	3.6 (1.5, 8.6)*
2	1.7 (0.9, 5.4)
3 Mid 20%	1.0
4	1.9 (0.8, 4.8)
5 Highest 20%	3.3 (1.3, 7.9)*
Training unit	
Low mileage	1.0
High mileage	1.6 (0.9, 2.7)

* $P \leq 0.05$, for odds ratio (comparison to baseline).

Several studies have reported that age is not associated with risk of running or exercise-related injuries among individuals exercising at their own chosen intensities and amounts (12,17,18). However, in a sports medicine review Taimela et al. (28) stated that the impact of age on risk of sports injuries varies from study to study. Our data suggest that when younger and older trainees all exercise the same amount at similar intensities, the older ones are at greater risk of injury (Tables 2 and 5). This is consistent with other military studies that demonstrate a higher incidence of stress fractures among older trainees (5,7,11).

Several military studies have found that white recruits are more likely to experience stress fractures than blacks or Hispanics (5,7,11). Blacks have been shown to have higher bone density than whites (31), a possible explanation for this observation. Also, a recent survey of working whites and blacks reported higher rates of nonfatal injuries for white workers (34). In this study, although the cumulative incidence of injuries among whites was higher than for other racial groups, the differences were not significant.

Smoking cigarettes was a risk factor for training injuries even with the confounding effects of physical activity and other factors controlled for (Table 5). Research indicates that smokers are more likely to be "risk takers" and to be involved in "accidents" (19,37), so it may be that greater risk taking behavior or some other factor associated with smoking is the "true" underlying, predisposing factor.

Past injuries are reported to be associated with current risk of training injury by other authors (18,20,28). Consistent with this we found that trainees who reported previous ankle sprains were at higher risk of injury on univariate analysis. Our inability to demonstrate associations with other past injuries may be a function of small sample size and small numbers of other relatively serious injuries.

Past physical activity and exercise were significantly associated with risk of injury. Low levels of job activity were associated with higher risk of injury on multivariate analysis (Table 5) and low levels of physical activity in general were associated with greater risks of injuries by univariate and multivariate analysis (Tables 3 and 5). Less frequent running prior to the Army was also associated with higher risk of lower extremity injuries on univariate analysis (Table 3). Two other military studies have found that lower levels of past activity are a risk factor for training-related injuries among recruits (7,10). The combination of these data suggest that higher past physical activity or exercise is protective against current injury among individuals who are engaged in the same amounts and intensity of physically demanding training.

Although stretching to increase flexibility is widely recommended to prevent training injuries, data to sup-

port the practice are lacking (18,24). Our data indicate that both the most flexible and least flexible individuals are at higher risk of lower body injuries (Tables 4 and 5). It has been suggested that athletes with tight muscles (low flexibility) are more susceptible to muscle strains (28), whereas those with ligamentous laxity (greater flexibility) are predisposed to a higher risk of sprains and dislocations (28). Whatever the underlying reason, the finding that both extremes of flexibility experience more injuries, and its implications for the prevention and rehabilitation of injuries deserves further study.

Lower levels of muscle endurance (low numbers of push-ups) and stamina (slow run times) are other fitness characteristics we found to be associated with higher risk of training injuries (Table 4). Other military studies report the same association (10). The observed association of higher risk among less fit soldiers may be due to the fact that at any given absolute level of physical performance less fit individuals will be under greater relative physiologic stress.

Amount of training is the most consistently documented risk factor among runners (3,12,13,18,20,22,24). Although unit training, probably higher running mileage, was only marginally significant as a risk factor for injury (Table 5), the pattern and location of injuries to trainees suggested that weight-bearing physical training and running in particular were the most important factors causing injuries among the infantry trainees studied.

We conclude from our findings that epidemiologic methods can be successfully employed to identify risk factors for training injuries. Furthermore, the etiologies of these injuries are complex and multifactorial. More specifically, our results lead us to hypothesize that the risks of injuries will be higher among those trainees entering the Army who smoke, have been less physically active, and who exhibit lower levels of muscle endurance and aerobic ability. Also, we suspect that individuals of both very high and very low flexibility will be more prone to injury. Ultimately, more epidemiologic studies of military and other populations are needed to verify and identify risk factors, which can be used to design population specific preventive strategies for physical training and exercise-related injuries.

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REFERENCES

1. AMERICAN COLLEGE OF SPORTS MEDICINE. *Guidelines for Exercise Testing and Prescription*, 3rd Ed., S. N. Blair (Ed.). Lea and Febiger: Philadelphia: 1986, pp 38-39, 159-160.
2. ATHA, J. Strengthening muscle. *Exerc. Sports Sci. Rev.* 9:1-73, 1981.
3. BLAIR, S. N., H. W. KOHL, AND N. N. GOODYEAR. Rates and risks for running and exercise injuries: studies in three populations. *Res. Q. Exerc. Sport* 58:221-228, 1987.
4. BLAIR, S. N., H. W. KOHL, R. S. PAFFENBARGER, D. CLARK, K. H. COOPER, AND L. W. GIBBONS. Physical fitness and all-cause mortality: a prospective study of healthy men and women. *J.A.M.A.* 262:2395-2401, 1989.
5. BRUDVIG, T. J., T. D. GUDGER, AND L. OBERMEYER. Stress fractures in 295 trainees: a one-year study of incidence as related to age, sex, and race. *Mil. Med.* 148:666-667, 1983.
6. CASPERSEN, C. J., K. E. POWELL, AND G. M. CHRISTENSON. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep.* 100:126-131, 1985.
7. GARDNER, L. I., J. E. DZIADOS, B. H. JONES, ET AL. Prevention of lower extremity stress fractures: a controlled trial of a shock absorbent insole. *Am. J. Public Health* 78:1563-1567, 1988.
8. GARRICK, J. G. AND R. K. REQUA. Injuries in school sports. *Pediatrics* 61:465-469, 1978.
9. JONES, B. H. Overuse injuries of the lower extremities associated with marching, jogging, and running: a review. *Mil. Med.* 148:783-787, 1983.
10. JONES, B. H., M. W. BOVEE, AND J. J. KNAPIK. Association among body composition, physical fitness, and injury in men and women Army trainees. *Body Composition and Physical Performance*. B. M. Marriott (Ed.). Washington, DC: National Academy Press, 1992, pp. 141-173.
11. JONES, B. H., J. M. HARRIS, T. N. VINH, AND C. RUBIN. Exercise-induced stress fractures and reactions of bone: epidemiology, etiology, and classification. *Exerc. Sports Sci. Rev.* 17:379-422, 1989.
12. KOPLAN, J. P., K. E. POWELL, R. K. SIKES, R. W. SHIRLEY, AND C. C. CAMPBELL. An epidemiologic study of the benefits and risks of running. *J.A.M.A.* 248:3118-3121, 1982.
13. KOPLAN, J. P., D. S. SISCOVICK, AND G. M. GOLDBAUM. The risks of exercise: a public health view of injuries and hazards. *Public Health Rep.* 100:189-195, 1985.
14. KOWAL, D. M. Nature and causes of injuries in women resulting from an endurance training program. *Am. J. Sports Med.* 8:265-269, 1980.
15. KRAUS, J. F. AND C. CONROY. Mortality and morbidity from injuries in sports and recreation. *Ann. Rev. Public Health* 5:163-192, 1984.
16. LEMESHOW, S. AND D. HOSMER. Estimating odds ratios with categorically scaled covariates in multiple logistic regression analysis. *Am. J. Epidemiol.* 119:147-151, 1984.
17. MACERA, C. A., K. L. JACKSON, G. W. HAGENMAIER, J. J. KRONENFELD, H. W. KOHL, AND S. N. BLAIR. Age, physical activity, physical fitness, body composition, and incidence of orthopedic problems. *Res. Q. Exerc. Sports* 60:225-233, 1989.
18. MACERA, C. A., R. R. PATE, K. POWELL, K. L. JACKSON, J. S. KENDRICK, AND T. E. CRAVEN. Predicting lower extremity injuries among habitual runners. *Arch. Intern. Med.* 149:2565-2568, 1989.
19. MCGUIRE, F. L. Smoking, driver education, and other correlates of accidents among young males. *J. Saf. Res.* 4(1):5-11, 1972.
20. MARTI, B., J. P. VADER, C. E. MINDER, AND T. ABELIN. On the epidemiology of running injuries: the 1984 Bern Grand Prix. *Am. J. Sports Med.* 16:285-294, 1988.
21. PAFFENBARGER, R. S., R. T. HYDE, A. L. WING, AND C. HSIEH. Physical activity, all-cause mortality, and longevity of college alumni. *N. Engl. J. Med.* 314:605-613, 1986.
22. POLLOCK, M. L., L. R. GETTMAN, C. A. MILESI, M. D. BAH, L. DURSTEIN, AND R. B. JOHNSTON. Effects of frequency and duration of training on attrition and incidence of injury. *Med. Sci. Sports Exerc.* 9:31-36, 1977.
23. POLLOCK, M. L., J. H. WILMORE AND S. M. FOX. *Exercise in Health and Disease: Evaluation and Prescription for Prevention and Rehabilitation*. Philadelphia: W. B. Saunders Company, 1984, pp. 233-234.
24. POWELL, K. E., H. W. KOHL, C. J. CASPERSEN, AND S. N. BLAIR. An epidemiologic perspective on the causes of running injuries. *Phys. Sportsmed.* 14:100-114, 1986.
25. POWELL, K. E. AND R. S. PAFFENBARGER. Workshop of epidemiologic and public health aspects of physical activity and exercise: a summary. *Public Health Rep.* 100:118-125, 1985.
26. ROTHMAN, K. J. *Modern Epidemiology*. Boston: Little, Brown and Company, 1986, pp. 214-216.
27. SISCOVICK, D. S., R. E. LAPORTE, AND J. M. NEWMAN. The disease-specific benefits and risks of physical activity and exercise. *Public Health Rep.* 100:180-188, 1985.
28. TAIMELA, S., U. M. KUJALA, AND K. OSTERMAN. Intrinsic risk factors and athletic injuries. *Sports Med.* 9:205-215, 1990.
29. TAYLOR, H. L., D. R. JACOBS, B. SCHUCKER, J. KNUDSEN, A. S. LEON, AND G. DEBACKER. A questionnaire for the assessment of leisure time physical activities. *J. Chronic Dis.* 31:741-755, 1978.
30. TOMLINSON, J. P., W. M. LEDNAR, AND J. D. JACKSON. Risk of injury in soldiers. *Mil. Med.* 152:60-64, 1987.
31. TRUTTER, M., G. E. BROMAN, AND R. PETERSON. Densities of white and Negro skeleton. *J. Bone Joint Surg.* 42A:50-58, 1960.
32. U.S. Department of Health and Human Services. *Public Health Service. Healthy People 2000: National Health Promotion and Disease Prevention Objectives*. Washington, DC, 1991.
33. VOLICER, B. J. *Advanced Statistical Methods with Nursing Research Applications*. Bedford, MA: MERESTAT, 1981, pp. 75-78.
34. WAGNER, D. K. AND D. W. WINN. Injuries in working populations: black-white differences. *Am. J. Public Health* 11:1408-1413, 1991.
35. WASHBURN, R. A., L. ADAMS, AND G. T. HAILE. Physical activity assessment for epidemiologic research: two simple approaches. *Prev. Med.* 16:636-646, 1987.
36. WENGER, H. A. AND G. J. BELL. The interactions of intensity, frequency, and duration of exercise training in altering cardiorespiratory fitness. *Sports Med.* 3:346-356, 1986.
37. WILLIAMS, A. F. Personality and other characteristics associated with cigarette smoking among young teenagers. *J. Health Soc. Behav.* 14:374-380, 1973.

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