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Intrinsic risk factors for exercise-related injuries among male and female army trainees

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ABSTRACT

Physical training-related injuries are common among army recruits and other vigorously active populations, but little is known about their causation. To identify intrinsic risk factors, we prospectively measured 391 army trainees. For 8 weeks of basic training, 124 men and 186 women (79.3%) were studied. They answered questionnaires on past activities and sports participation, and were measured for height, weight, and body fat percentage; 71% of the subjects took an initial army physical training test. Women had a significantly higher incidence of time-loss injuries than men, 44.6% compared with 29.0%. During training, more time-loss injuries occurred among the 50% of the men who were slower on the mile run, 29.0% versus 0.0%. Slower women were likewise at greater risk than faster ones, 38.2% versus 18.5%. Men with histories of inactivity and with higher body mass index were at greater injury risk than other men, as were the shortest women. We conclude that female gender and low aerobic fitness measured by run times are risk factors for training injuries in army trainees, and that other factors such as prior activity levels and stature may affect men and women differently.

Musculoskeletal injury rates are high in military recruit populations.[2,4,6,7,10] These high rates generally are attributed to the strenuous exercises and other vigorous physical activities of military trainees. Despite the general knowledge that injuries, such as stress fractures, sprains, and strains, occur frequently during military basic training, little is known about the risk factors for such injuries. The few risk factors that have been identified include gender,[2,6,7,10] age,[4] and past physical activity.[4]

Civilian data on risk factors associated with exercise and physical activity are also meager. The scientifically confirmed risk factors for exercise-related injuries in nonmilitary populations include higher amounts of training,[1,8,9,12-14,16] past injuries,[13] and body mass index (BMI).[12]

Knowledge of risk factors for injury is essential if unnecessary injuries are to be prevented. Development of such knowledge is important to military and civilian populations alike. Military trainers need to understand the causes of injuries because of the requirement for physical fitness and because of the amount of disability to soldiers from injuries associated with training. Likewise, the civilian community requires a better understanding of the short-term risks of exercise. This is especially true because the Department of Health and Human Services has established that increased fitness and physical activity are to be among the nation's health promotion objectives for the year 2000.[18]

This study was the first in a series of studies; as such, it was viewed as a hypothesis-generating study. Its purpose was to examine the association between several potential intrinsic risk factors (i.e., characteristics of individuals) and the occurrence of injuries to male and female recruits during army entry training. The risk factor categories examined included body stature, physical fitness, and life-style. Our hypothesis was that the more physically fit individuals entering the service would be less likely to sustain injuries during the 2 months of basic training.

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MATERIALS AND METHODS

Subjects were 310 army trainees (124 men and 186 women) who were informed of the nature of the study and of the right to withdraw at any time. After giving consent, all volunteers answered questionnaires about their physical activities and sports participation before entering the service. Measurements were recorded of each trainee's height, weight, and percentage of body fat. On a specified day during the 1st week of training, all available trainees (79 men and 140 women) were required to complete a "diagnostic" army physical training test (1-mile run, push-ups, and sit-ups). The medical records of all 310 subjects were reviewed at the end of the 8th week of the basic training course.

Loss to followup

Potential subjects included every new trainee who arrived at the reception station of a large army basic training post on 1 weekend. All 391 trainees (156 men and 235 women) volunteered to participate. Of these, 21% ($N = 83$) were lost to followup, most by early discharge from the army. The discharge rate of this training post during the year before our study was 20.6% (unpublished U.S. Army report, 1983), which was similar to the rate observed in this study. Because medical and personnel records were forwarded to another location when trainees were discharged, we had no clinical medical records or physical fitness scores on those lost to followup. Post personnel records, however, indicated that 15.4% (13 of 83) of those discharged were boarded out for medical conditions that were deemed to exist before entry in the army. Army-wide, an estimated 24.0% of the discharges the year before our study were for medical reasons. That year, it also was calculated that 52% of the army-wide discharges were for failure to adapt to military life, 5% for physical fitness failures, and 20% were for other reasons.

Questionnaire

The questionnaire was administered to groups of 50 or more trainees. Each question was read aloud to the group by 1 of the investigators. The volunteer was requested to state age and gender.

Past physical activity was assessed by two questions. First, subjects were asked to indicate from a list of common physical activities and sports the ones in which they had participated during the previous 6 months. Then for each activity designated, they were asked to report the number of days per week on average that they had performed it, and how many minutes per day that they had engaged in the activity. Subjects were not restricted to the activities listed and were encouraged to include any other activities that they had performed. This information was used to estimate the number of kilocalories per week that each subject expended during physical activities and sports.

Another physical activity question asked the subjects to compare their life-styles (in terms of their physical activity levels) with others of their age and gender. They rated themselves on a 4-point scale (1 = inactive, 4 = very active). A question similar to this one was validated previously.[20]

Subjects also were questioned about their participation in sports during high school or college. If they answered "yes," they were asked how many years they participated and whether the activity was with friends, or was in an organized intramural school sport, or a varsity team competing against other schools or colleges.

Anthropometric measures

Height and weight of the subjects were measured with the trainees barefoot and wearing shorts and t-shirts. The percentage of body fat was estimated using skin-fold measurements at four sites, according to the equations of Durnin and Wormersley.[3] A commonly used surrogate for percentage of body fat, BMI, was calculated by dividing the participant's weight by the height squared.[12,13,20] A higher BMI suggests that an individual has more body fat than someone who has a lower BMI.

Physical fitness assessment

Raw scores from the army physical fitness test were used to assess the fitness of subjects. The initial, baseline test consisted of a 1-mile run for time and the number of sit-ups and push-ups completed by trainees in a 2-minute period. The test was identical for men and women, and it was given and scored in a standard fashion as specified by army regulation. The physical fitness test was a competitive event in which all trainees were encouraged to do their best. All trainees were required to take the test unless they were assigned to work details, which accounted for most absences, or unless they were on sick call. Fewer than 1% of the trainees attended sick call on any given day.

Injury data

Information on injuries was collected by a complete review of the medical records of every recruit who participated. Two physicians reviewed the charts and transcribed the records. Information extracted from the records included the date of the visit, a verbatim diagnosis, the side and body part injured, the disposition, and the number of days of limited duty resulting from the injury for those who did not return to duty.

Several operational definitions of injury cases were employed in the analysis of data. The first category simply included any individuals who reported to sick call and who received a diagnosis of a musculoskeletal injury. The second category included only those with lower extremity injuries. The third category included only those who had a diagnosed injury and were placed on limited duty for 1 or more days by a physician or physician's assistant. The other category that was analyzed included patients who experienced a stress fracture. Detailed analyses of every risk factor were conducted using the more rigorous definition of time-loss injuries, unless otherwise specified.

Physical training

Physical training was conducted in company-size units; therefore, the daily training of recruits within units was the same each day. All of the men were assigned to one company and the women to two other separate companies, but the training schedules were standardized postwide so the training of all units was similar. The amount of time allotted for calisthenics, running, road marching, and other vigorous activities for men and women was the same; however, the program was structured so that women did slightly less running and marching.

ANALYSIS

Means and standard deviations for continuous variables, such as age or mile run times, were calculated for male and female subjects of this study to document and compare personal characteristics and physical performance. Statistical comparisons of mean values for men and women were done with t-tests.

Risks of injury were calculated as the cumulative incidence (percentage) of individuals with one or more musculoskeletal injuries that were diagnosed during the 8 weeks of basic training. Relative risk ratios for injury were calculated by dividing the percentage of individuals in a risk group by the number of individuals in a baseline or referent group. For continuous variables, risk groups were established by dividing subjects into quartiles (i.e., four equal-sized groups) from low to high, fast to slow, and so forth. Because our primary hypothesis was that the fittest soldiers on entry to the army are at lower risk of injury, the baseline risk group chosen for comparisons was, a priori, the one exhibiting the highest level of fitness or activity, unless some other group displayed a lower level of risk, and this was consistent for both men and women.

For the percentage of body fat and BMI, one or both of the middle two quartiles was chosen as the referent or baseline risk group for comparisons with other risk groups. The basis for this choice was the assumption that the most healthy body weight is somewhere between the extremes of body fatness.

Statistical comparisons between risk groups were made using chi-square tests. For variables in which small numbers were a problem, contiguous strata of risks were collapsed, and partitioned chi-square techniques were employed to test contrasts. If chi-square table cell sizes were small, Fisher's exact test was used. Ninety or ninety-five percent confidence intervals (CI) were reported for all relative risks, and point estimates of P values were provided for intervals that did not include the value 1.0 (i.e., for P values <0.1 or 0.05, respectively).

RESULTS

The mean physical characteristics (height, weight, percentage of body fat, and BMI) and physical fitness (sit-ups, push-ups, mile run times) of subjects are presented in Table 1. This was a young, fit population. The median age for men was 19 years, and the median age for women was 20 years. Men were significantly younger, taller, leaner, and more physically fit than women.

Incidence of injury

Table 2 shows the incidence of different categories of injury for men and women and the relative risk of injury for women compared with men. Significantly more women reported musculoskeletal injuries than did men, regardless of how the injuries were defined. Women also experienced more days of limited duty because of injuries (32 days per 100 person-weeks, compared with 10 days per 100 person-weeks for men).

The incidence of the five most commonly diagnosed injuries during the 8 weeks for men in order of frequency were low back pain (7.3%), tendinitis (6.5%), sprains (4.8%), muscle strains (3.2%), and stress fractures (2.4%). For women, the incidence of the most frequent injuries were muscle strains (15.6%), stress fractures (12.3%), sprains (5.9%), tendinitis (5.5%), and overuse knee complaints (2.1%), such as chondromalacia patellae. Most injuries of men and women were to the lower extremity; 77% of these were among men and 88% among women.

Risk factors for injury

The incidences of time-loss injuries associated with body stature (height, percentage of body fat, and BMI) for men and women are shown in Tables 3 and 4, respectively. The shorter women in our study were at significantly greater risk than the taller 75% (relative risk = 1.7; 90% CI: 1.2 to 2.4; $P = 0.02$). Those in the highest and lowest BMI groups for both men and women had a greater risk of injury than those in the more "average" BMI in the middle groups for their gender. Differences across quartiles of BMI, however, were significant only for men. Men in the group with the highest BMI were at 2.8 times greater risk than the middle quartiles (90% CI: 1.4 to 5.8; $P = 0.02$), while the lowest quartile was at 2.3 times the risk of the middle two (90% CI: 1.0 to 4.4, $P = 0.08$). A higher percentage of body fat appeared to be associated with a higher risk for men but not for women. Weight was not a risk factor for either gender.

Tables 5 and 6 display the incidences and relative risks of injuries by level of physical fitness and activity for men and women. For both genders, there are significant trends of higher risks of injury for trainees with lower levels of aerobic fitness as measured by mile run times. The three least fit quartiles of men as measured by push-ups were at significantly greater risk than the most fit group (relative risk = 5.0; 90% CI: 1.1 to 25.8; Fisher's exact test, $P = 0.04$). We observed no association of injuries with push-ups among women or with sit-ups for men or women.

Among past activity and sports participation factors, only the self-ratings of physical activity of men were associated with risks of injury (Table 5). For men, we documented a

TABLE 1
Descriptive characteristics and physical fitness test results of male and female army trainees

Variable	Women			Men			P value
	N	Mean	±SD	N	Mean	±SD	
Age (years)	186	21.1	3.58	124	20.2	2.70	0.0084
Height (cm)	186	163.3	6.58	123	175.2	6.62	0.0000
Weight (kg)	186	58.7	5.76	124	73.6	10.90	0.0000
Body fat (%)	186	25.2	9.36	124	16.9	3.10	0.0000
BMI (weight/height^2)	186	22.4	1.97	123	24.3	4.85	NA[a]
Initial fitness test (1st week)							
Mile time (min)	140	9.7	1.34	79	7.2	1.0	0.0000
Sit-ups (N)	163	37.9	11.9	98	54.5	13.8	0.0000
Push-ups (N)	138	12.4	9.9	97	31.0	9.3	0.0000

[a] Not applicable. Body mass index for women cannot be meaningfully compared with that for men, since average BMIs for women are lower than for men even though women have higher measured percentages of body fat.

TABLE 2
Relative risks (RR) of musculoskeletal injury for women compared with men during 8 weeks of army basic combat training

Type of injury	Women: Risks (%) (N = 186)	Men: Risks (%) (N = 124)	RR	(95% CI) P values
All	50.5	27.4	1.8	(1.3–2.5) 0.00001
Lower extremity	44.6	20.9	2.1	(1.5–3.1) 0.0002
Time loss	30.1	20.2	1.5	(1.0–2.3) 0.05
Stress fractures	12.3	2.4	5.1	(1.4–15.3) 0.002

TABLE 3
Men: Incidence of time-loss injuries, relative risks (RR), and 90% CIs by quartile (Q) of measures of body stature

Risk factor (median, range, and Q1, Q3 cut points)	N	Incidence (%)	RR	90% CI	P values
Height (cm) (174.4, 158–194, 170, 180)					
Q1 Short	32	21.9	1.00		
Q2	28	21.4	0.98	0.4–2.2	NS[a]
Q3	33	24.2	1.11	0.5–2.3	NS
Q4 Tall	31	12.9	0.59	0.2–1.5	NS
Body fat (%) (16.6, 7–29, 13.1, 20.6)					
Q1 Lean	33	18.2	1.40	0.5–3.6	NS
Q2	30	13.3	1.00		
Q3	33	18.2	1.40	0.5–3.6	NS
Q4 Fat	28	32.1	2.40	1.3–9.4	0.09
BMI (weight/height^2) (23.7, 19–31, 22.1, 26.5)					
Q1 Low	31	25.8	2.80	1.0–7.7	0.09
Q2	32	9.4	1.00		
Q3	29	13.8	1.40	0.5–4.8	NS
Q4 High	31	32.3	3.40	1.3–9.4	0.02

[a] Not significant.

significant downward trend of decreasing degree of risk of injury with an increasing level of self-assessed activity ($P = 0.004$). We noted no association with activity among women. Energy expenditure (in kilocalories) per week, years of exercise, and past sports participation were not associated with risks of injury with risk ratios for all groups ranging between 0.8 and 1.2 (data not shown).

Table 7 shows the relative risks of the slowest 50% of men

TABLE 4
Women: Incidence of time-loss injuries, relative risks (RR), and 90% CIs by quartile (Q) of measures of body stature

Risk factor (median, range, and Q1, Q3 cut points)	N	Incidence (%)	RR	90% CI	P values
Height (cm) (163.4, 150–178, 158, 167)					
Q1 Short	49	44.9	1.00		
Q2	52	25.0	0.56	0.4–0.9	0.036
Q3	43	20.9	0.47	0.3–0.8	0.015
Q4 Tall	42	33.3	0.74	0.5–1.2	NS[a]
Body fat (%) (25.1, 14–37, 22.4, 28.4)					
Q1 Lean	46	23.9	0.70	0.4–1.2	NS
Q2	47	36.2	1.06	0.7–1.7	NS
Q3	47	34.0	1.00		
Q4 Fat	46	30.4	0.89	0.5–1.5	NS
BMI (weight/height^2) (22.5, 18–27, 21.1, 23.6)					
Q1 Low	45	35.6	1.53	0.9–2.6	NS
Q2	48	29.2	1.26	0.7–2.2	NS
Q3	47	23.4	1.00		
Q4 High	46	37.0	1.59	0.9–2.7	NS

[a] Not significant.

and women on the mile run compared with the fastest men and women of their respective gender groups. The table compares the risk of the slowest with the fastest groups for four categories of injury: any training injury, a lower extremity injury, a time-loss injury, and a stress fracture. For every category of injury, the risks of the slower men and women were significantly higher than for their faster peers of the same gender.

DISCUSSION

Our prospective study design, the population studied, and the standardized army training program provided us with a unique opportunity to examine the association between individual characteristics and injuries resulting from vigorous physical training. We identified several intrinsic risk factors for exercise-related injury: gender, low levels of running performance for both men and women, high BMI and inactive life-style among men, and short stature for women.

The male and female trainees who participated in this study were similar to other populations of army trainees in

TABLE 5
Men: Incidence of time-loss injuries, relative risks (RR), and 90% CIs by quartile (Q) of measures of physical fitness and level of self-assessed activity

Risk factor (median, range, and Q1, Q3 cut points)	N	Incidence (%)	RR	90% CI	P values
Run time (min) (7.0, 5.9–11.5, 6.4, 7.7)					
Q1 Fast	21	0.0			NS[b]
Q2	20	0.0			
Q3	19	21.1			0.05[a]
Q4 Slow	19	36.8			0.003[a]
Push-ups (N) (31, 4–53, 26.5, 36)					
Q4 High	22	4.5	1.00		
Q3	24	25.0	5.56	1.0–30.4	0.10
Q2	27	22.2	4.93	0.9–27.1	NS
Q1 Low	24	20.8	4.62	0.8–26.0	NS
Activity level					
Very active	29	3.4	1.00		
Active	51	15.7	4.56	0.8–25.0	0.09
Average	37	35.1	10.19	1.9–53.5	0.002
Not very active	7	42.9	12.43	2.1–72.9	0.02

[a] P value where the referent group had zero injuries, calculated using Fisher's exact test.
[b] Not significant.

TABLE 6
Women: Incidence of time-loss injuries, relative risks (RR), and 90% CIs by quartile (Q) of measures of physical fitness and level of self-assessed activity

Risk factor (median, range, and Q1, Q3 cut points)	N	Incidence (%)	RR	90% CI	P values
Run time (min) (9.75, 6.0–16.3, 9.0, 10.4)					
Q1 Fast	36	19.4	1.16	0.5–2.7	NS[a]
Q2	36	16.7	1.00		
Q3	35	40.0	2.40	1.2–4.8	0.028
Q4 Slow	33	36.4	2.18	1.1–5.0	0.063
Push-ups (N) (11, 1–30, 5, 17)					
Q4 High	32	28.1	1.00		
Q3	33	33.3	1.21	0.6–2.1	NS
Q2	36	38.9	1.38	0.8–2.4	NS
Q1 Low	37	24.3	0.86	0.4–1.6	NS
Activity level					
Very active	33	30.7	1.00		
Active	69	33.3	1.08	0.7–1.8	NS
Average	64	29.7	0.97	0.6–1.7	NS
Not very active	20	30.0	0.98	0.5–2.0	NS

[a] Not significant.

age, height, weight, percentage of body fat, and physical fitness.[15,19] For this reason, we believe that the results of this study should be applicable to other populations of military trainees, and possibly to other similarly active young men and women.

The overall incidence of injuries for men and women in our population of trainees was consistent with rates reported for other populations of army basic trainees.[6,10] Likewise, the incidence of stress fractures observed in our population was in accord with other reports on military recruits.[2,4,7] The incidences of injuries for male trainees observed by us are comparable with the rates reported for high school cross country and track athletes, and are lower than those for wrestlers and football players.[5,11] The types and distributions of injuries in our population were similar to those reported for distance runners.[6,14] These similarities suggest our results might have particular relevance to individuals in the general population who run or engage in other routine weightbearing activity.

Our finding that female trainees were at greater risk of training injuries is consistent with published reports on army populations[6,10] and with the experience of others. Stress fractures, in particular, are known to occur more frequently among female trainees.[2,7] On the other hand, the authors of several well-designed studies of civilian runners and adult exercise participants[8,13,14,17] have concluded that there are no differences in the rates of injury to men and women. Selection bias[9] and lack of uniformity of training in civilian populations may account for the different results of these studies. Whatever the case, our data indicate that women are more likely to report to the clinic for injury than men when both engage in the same types of activities, under similar conditions for the same amounts of time.

It has been suggested that characteristics of body stature may be risk factors for exercise and running-related injuries.[9] We observed that the shortest women were at greater risk of injury. This is consistent with observations of Army Medical Corps personnel that led to recommendations that the shortest women march at the front of columns to prevent them from overstriding in keeping pace with the tallest ones. We also documented that men at both the high and low extremes of BMI appear to be at greater risk of injury than the more average middle groups. Several other authors reported that higher BMI was associated with the risk of exercise- or running-related injuries,[1,17] and one group reported a bimodal pattern of risk[14] similar to what we observed.

We found that physical fitness as measured by mile run times is strongly associated with injuries for both men and women, regardless of how the injuries were defined. The fact that the recruits in our study trained in groups that controlled for the amount and intensity of training may explain our ability to identify aerobic fitness as an injury risk factor. It is logical that low physical fitness as measured by a weightbearing activity such as running would be associated with a higher risk of injury during army basic training because trainees must walk, march, or run everywhere they go. Also, those who were more aerobically fit may have been protected from lower extremity injuries, which accounted for 80% to 90% of those experienced, because they had done weightbearing training such as running and jogging before entering the army. The conclusion that slow run times are associated with greater risk of injury was supported using several operational definitions of injury.

Among men, a lower self-assessed level of physical activity before entering the service was also associated with a higher risk of injury. A study of marine recruits documented a similar trend of strong association between lower levels of self-assessed physical activity and higher risks of sustaining a stress fracture.[4] These findings suggest that previous ac-

TABLE 7

Men and women: Incidence of time-loss injury for slow versus fast runners with relative risks (RR), and 90% CIs

Injury category	Gender	Group incidence (%)		RR	90% CI	P values
		Slow[a]	Fast[b]			
Any	Men	34.2	12.2	2.80	1.2–6.7	0.02
	Women	58.9	34.7	1.69	1.2–2.4	0.004
Lower body	Men	28.9	9.7	2.97	1.1–7.9	0.03
	Women	54.4	30.5	1.78	1.2–2.6	0.004
Time loss	Men	29.0	0.0			0.0002[c]
	Women	38.2	18.5	2.12	1.2–3.7	0.0007
Stress fracture	Men	4.8	0.0			0.23[c]
	Women	17.6	6.9	2.54	1.0–6.6	0.05

[a] Slow runners = slowest two quartiles on initial mile run test.
[b] Fast runners = fastest two quartiles on initial mile run test.
[c] *P* values for comparisons where the referent group had no injuries were calculated using Fisher's exact test.

tivity at higher levels may protect men from the injuries associated with army basic training.

CONCLUSION

We identified several potentially important intrinsic risk factors for training- or exercise-related injuries. These factors included gender, low levels of running performance (slower run times) among men and women, low levels of previous physical activity and high BMI for men, and short stature in women. Two risk factors, gender and low levels of running performance, were strongly associated with the occurrence of morbidity from injuries, regardless of the severity or operational definition employed in analysis. Clear trends of a higher incidence of injury with successively slower mile run times were observed for men and women. The similarity and overlapping nature of these trends for men and women, coupled with the knowledge that women enter the army with significantly lower levels of fitness, suggest that gender per se may not be an independent risk factor for injury. Perhaps the underlying risk factor is physical fitness. To resolve this and other issues surrounding risks for exercise- and activity-related injuries requires further study and the development of multivariate models.

Furthermore, to develop successful strategies to prevent exercise-related injuries, we need knowledge not only about intrinsic risk factors, such as we examined in this study, but also about extrinsic factors, such as the amount and types of exercise and physical activity, the intensity of training, and the personal equipment used. Larger, more comprehensive epidemiologic studies of varied populations clearly are needed for a full understanding and prevention of exercise-related injuries. When modifiable risk factors for injury have been identified, the strategies to alter these factors must be tested to determine whether injuries can be prevented.

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