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Epidemiology of Stress Fracture and Lower-Extremity Overuse Injury in Female Recruits

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¹Naval Health Research Center, San Diego, CA; ²Graduate School of Public Health, San Diego State University, San Diego, CA; ³Science Applications International Corporation, San Diego, CA; ⁴Graduate Program in Orthopaedic and Sports Physical Therapy, Rocky Mountain University of Health Professions, Provo, UT; and ⁵Joint Doctoral Program in Public Health Epidemiology, University of California, San Diego/San Diego State University, San Diego, CA

ABSTRACT

RAUH, M. J., C. A. MACERA, D. W. TRONE, R. A. SHAFFER, and S. K. BRODINE. Epidemiology of Stress Fracture and Lower-Extremity Overuse Injury in Female Recruits. *Med. Sci. Sports Exerc.*, Vol. 38, No. 9, pp. 1571–1577, 2006. **Purpose:** The purpose of this prospective study was to examine rates and risk factors for overuse injuries among 824 women during Marine Corps Recruit Depot basic training at Parris Island, SC, in 1999. **Methods:** Data collected included training day exposures (TDE), baseline performance on a standardized 1.5-mile timed run, and a pretraining questionnaire highlighting exercise and health habits. The women were followed during training for occurrence of stress fracture and other lower-extremity overuse injury. **Results:** There were 868 lower-extremity overuse injuries for an overall injury rate of 12.6/1000 TDE. Rates for initial and subsequent injury were 8.7/1000 and 20.7/1000 TDE, respectively. There were 66 confirmed lower-extremity stress fractures among 56 (6.8%) women (1.0/1000 TDE). Logistic regression modeling indicated that low aerobic fitness (a slower time on the timed run (> 14.4 min)), no menses in six or more consecutive months during the past year, and less than 7 months of lower-extremity weight training were significantly associated with stress fracture incidence. Self-rated fair–poor fitness at baseline was the only variable significantly associated with other non–stress fracture overuse injury during basic training. **Conclusions:** Among this sample of women, the risk of lower-extremity overuse injury was high, with a twofold risk of subsequent injury. The results suggest that stress fracture injury might be decreased if women entered training with high aerobic fitness and participated frequently in lower-extremity strength training. Furthermore, women reporting a history of menstrual irregularity at their initial medical exam may require closer observation during basic training. **Key Words:** FITNESS, MENSTRUAL IRREGULARITIES, MILITARY TRAINING, OVERUSE SYNDROME, PROSPECTIVE COHORT

Since the 1980s, women's participation in competitive sports and military training has increased. This increase in participation has led to a concomitant increase in the risk of musculoskeletal injury within this population. In civilian settings, sports injuries can result in reduced playing time and loss of productivity. In the military, depending on severity of the injury, the consequences can be

significant, including reduced operational readiness or military separation (1,3).

Prospective studies among civilian recreational and competitive female runners (20,24,30) and among female recruits (1,3,12,15) demonstrate varied injury rates of the lower extremity, but suggest that the cumulative incidence is high. However, these studies are difficult to compare because of the variability in the definitions used to determine injuries and populations at risk. Few studies have used a denominator to account for factors that may affect the reported incidence of injury, such as exposure to training (24). More importantly, identifying injury rates across a specified number of training day exposures (TDE) allows comparisons of injury rates across military training cycles and athletic seasons.

Among lower-extremity musculoskeletal injuries, stress fractures are regarded as one of the more severe overuse injuries in military recruit or civilian runner populations because of increased rehabilitation period and time lost

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from training activities (10,12,13,20,28). The identification of risk factors is needed to help devise preventive strategies for stress fracture and other common lower-extremity overuse musculoskeletal injuries in recruits during basic training. The most consistent intrinsic risk factor for stress fracture among female trainees is low aerobic fitness (13,28). Although less clear, other common risk factors studied include low physical activity levels prior to training, shorter stature, and low body mass (12,13). Whereas previous injury (20,30) and history of menstrual dysfunction (2,18,22) have increasingly gained support in civilian studies as risk factors for stress fracture, the findings among female recruits are less clear (13,14,26,28).

The objectives of this study were 1) to describe the incidence of stress fracture and other lower-extremity non-stress fracture overuse injury in female Marine Corps recruits using a denominator that would account for actual training days at risk of injury; and 2) to identify risk factors for stress fracture and other lower-extremity non-stress fracture overuse injury.

METHODS

Subjects. Of the 891 female Marine Corps recruits aged 17–31 yr who arrived at the Parris Island Marine Corps Recruit Depot (MCRD) in 1999, 824 recruits (92.5%) volunteered to participate in the study. All participants received the Privacy Act statement and signed a consent form in accordance with the guidelines of the institutional review board of the Naval Health Research Center in San Diego, CA.

Injuries. We followed the recruits for occurrence of lower-extremity stress fracture or non-stress fracture overuse injuries from the first official day of recruit training until the last day of training or separation from Marine Corps training. Upon completion of training or separation, the subject's medical records were reviewed to collect information on injury occurrence, site, onset, and diagnosis. Diagnosis of stress fracture was based on 1) clinical presentation of localized pain of insidious onset, without prior acute trauma, aggravated by repetitive weight-bearing activities, and relieved with rest; and 2) a confirmatory radiograph and/or bone scan at a site consistent with the clinical presentation. Non-stress fracture overuse injuries were diagnosed by a sports medicine physician and recorded in the recruit's medical record.

Injuries were categorized as lower-extremity stress fracture or non-stress fracture overuse injury. Overall injuries, including both stress fracture and non-stress fracture overuse injury, were divided into initial or subsequent injuries. An initial injury was the recruit's first lower-extremity stress fracture or non-stress fracture overuse injury during basic training. Subsequent injury was any lower-extremity stress fracture or non-stress fracture overuse injury that occurred after the initial injury to the same or different body part. We also collected training day exposure (TDE) information. A training day was any day in which the recruit was not held out of training activity because of an injury and was at risk of

sustaining a lower-extremity stress fracture or non-stress fracture overuse injury.

Aerobic fitness measurement. Performance on a 1.5-mile timed run, conducted prior to the start of training, was used to assess entry-level aerobic fitness. The run times were categorized into quartiles 1 (≤ 12.5 min), 2 (> 12.5 – 13.5 min), 3 (> 13.5 – 14.4 min), and 4 (> 14.4 min), with quartile 1 (fastest runners) as the referent group.

Anthropometric measurements. Anthropometric measurements included height and weight as continuous values. Each recruit's weight and height were measured by a standard calibrated physician's beam scale and stadiometer. Body mass index (BMI) was calculated from weight (kg) and height (m) as weight/height^2 . BMI was categorized using standard cut points: low (≤ 18.4), normal (18.5–24.9), and high (≥ 25), with normal BMI as the referent group.

Questionnaire measurements. Prior to basic training, subjects completed a study questionnaire that included demographic information as well as injury history, physical activity and fitness practices, and menstrual history. Age was used as a categorical variable (17–19/ ≥ 20 yr), with those ages 17–19 as the referent group. For race/ethnicity, black women were the referent group (17,28). History of previous lower-extremity stress fracture or non-stress fracture overuse injuries were used as categorical variables in the logistic regression models. Those without a history of previous lower-extremity stress fracture or non-stress fracture overuse injury were the referent group. Self-rated fitness of excellent–very good was the referent group compared with those who rated their fitness as good or fair–poor. Several physical activity questions assessed exercise or sports participation, frequency of working up a good sweat when participating in an exercise or sport, and running behavior, including average frequency (per week), mileage (per run), and distance (per session) during the 2 months prior to entering MCRD training. For all variables, the group with the highest level of activity was the referent group.

Five menstrual and birth control hormone use variables were identified based on experiences during the 12 months prior to basic training. These variables included 1) primary amenorrhea (women whose age of menarche was 16 yr or older) (23); 2) irregular menstrual activity during the past year, with 10–12 menses considered as the referent group; 3) oligoamenorrhea (menstrual cycles > 35 d); 4) secondary amenorrhea (six or more consecutively missed menses during the past year) (14,23); and 5) birth control hormone use (oral contraceptive, Depo-Provera).

Analyses. Cumulative risks of injury were calculated as the incidence (percentage) of recruits with at least one lower-extremity stress fracture (or non-stress fracture overuse injury) divided by the total number of subjects. We calculated several types of injury rates. The initial injury rate was the number of initial injuries per 1000 training day exposures (TDE) at risk. Only TDE up to the initial injury were counted. The subsequent injury rate was the number of injuries occurring after the initial injury per

1000 TDE, with only TDE after the initial injury counted in the denominator.

Crude odds ratios were calculated separately for lower-extremity stress fracture and non-stress fracture overuse injury, respectively, comparing the proportion of individuals in a high-risk group versus the proportion of individuals in a baseline or referent group for each of the potential risk factors. Women who reported being pregnant during the 12 months prior to training ($N = 24$) were excluded from the univariate and multivariate analyses involving women's reports of recent menstrual history. For multivariate analyses, the measure of association was the adjusted odds ratios, which were generated from a multiple logistic regression analysis. Items in the logistic regression model analyses included age, race/ethnicity, and those with significant univariate associations.

RESULTS

Subjects

The average age of the recruits was 18 yr (standard deviation (SD) = 1.5) and did not vary by injury group status. For each injury group (stress fracture and non-stress fracture overuse), mean values of height (163.3 cm, SD = 6.7), weight (57.8 kg, SD = 6.8), BMI (21.7; SD = 2.0), and age of menarche (12.6 yr, SD = 1.4) were compared with the uninjured group using the analysis of variance test. None of the comparisons were statistically significant.

Injury Rates

Overall overuse injury. During the 13 wk of Marine Corps basic training, 399 of 824 women (48.4%) incurred 868 lower-extremity overuse injuries, with 68,686 TDE or a rate of 12.6 per 1000 TDE. The rate for initial overuse injuries ($N = 399$, TDE = 46,061) was 8.7 per 1000 TDE, and the rate for subsequent overuse injuries ($N = 469$, TDE = 22,625) was 20.7 per 1000 TDE. The rate of subsequent overuse injury was over twofold higher than an initial overuse injury, incidence rate ratio = 2.4 (2.1, 2.7).

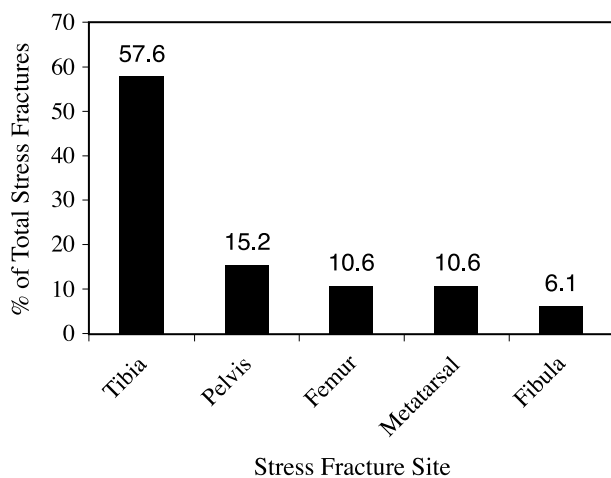


FIGURE 1—Lower-extremity stress fracture sites ($N = 66$) in 56 female Marine Corps recruits at Parris Island, 1999.

TABLE 1. Lower-extremity overuse injury sites ($N = 868$) in 399 female Marine Corps recruits, Parris Island, 1999.

	Stress Fracture		Non-Stress Fracture Overuse Injury		Overall Overuse Injury	
	N	Rate	N	Rate	N	Rate
Overall	66	0.96	802	11.68	868	12.64
Lower back	0	0	40	0.58	40	0.58
Hip/pelvis/groin/iliotibial band	10	0.15	141	2.05	151	2.20
Hip/pelvis	10	0.15	74	1.08	84	1.23
Groin	0	0	14	0.20	14	0.20
Iliotibial band	0	0	53	0.77	53	0.77
Upper leg	7	0.10	41	0.60	48	0.70
Femur (thigh)	7	0.10	3	0.05	10	0.15
Quadriceps	0	0	9	0.13	9	0.13
Hamstring	0	0	29	0.42	29	0.42
Knee	0	0	194	2.82	194	2.82
Lower leg	42	0.61	213	3.10	255	3.71
Tibia (shin)	38	0.55	151	2.20	189	2.75
Fibula	4	0.06	6	0.09	10	0.15
Calf/Achilles tendon	0	0	56	0.82	56	0.82
Ankle	0	0	52	0.76	52	0.76
Foot	7	0.10	121	1.76	128	1.86
Metatarsals (toes)	7	0.10	11	0.16	18	0.26
Other foot	0	0.00	110	1.60	110	1.60

Rate, number of injuries per 1000 training day exposures (68,686).

Stress fracture. Fifty-six of the 824 women (6.8%) incurred a total of 66 stress fractures. Initial, subsequent, and overall stress fracture rates were 0.86/1000 TDE ($N = 56$, TDE = 65,373), 3.0/1000 TDE ($N = 10$, TDE = 3,313), and 1.0/1000 TDE ($N = 66$, TDE = 68,686), respectively. The rate of subsequent stress fracture was 3.5 times higher than an initial injury stress fracture, incidence rate ratio = 3.5 (1.6, 6.7). The most common sites of stress fractures were the tibia (57.6%) and the pelvis (15.2%) (Fig. 1).

TABLE 2. Crude odds ratios for lower-extremity stress fracture and non-stress fracture overuse injury by demographic characteristics, physical body stature, and prior lower-extremity injury, female Marine Corps recruits, Parris Island, 1999.

Variable	Category	N	Stress Fracture		Non-Stress Fracture Overuse Injury	
			(%)	OR (95% CI)	(%)	OR (95% CI)
Race/ethnicity	Black	149	6.0	1.0	43.0	1.0
	Caucasian	481	7.5	1.3 (0.6, 2.7)	43.0	1.0 (0.7, 1.5)
	Hispanic	141	5.0	0.8 (0.3, 2.2)	36.9	0.8 (0.5, 1.2)
	Asian	28	7.1	1.2 (0.2, 5.9)	32.1	0.6 (0.3, 1.5)
	American Indian/Other	25	8.0	1.4 (0.3, 6.7)	44.0	1.0 (0.4, 2.5)
Age (yr)	17–19	738	6.4	1.0	42.0	1.0
	≥ 20	86	10.5	1.7 (0.8, 3.6)	38.4	0.9 (0.6, 1.4)
BMI	Underweight (≤ 18.4)	63	11.1	1.9 (0.8, 4.5)	42.9	1.1 (0.6, 1.8)
	Normal (18.5–24.9)	737	6.1	1.0	41.8	1.0
	Overweight (≥ 25.0)	20	15.0	2.7 (0.8, 9.6)	35.0	0.8 (0.3, 1.9)
History of lower-extremity stress fracture	No	784	6.5	1.0	41.6	1.0
	Yes	40	12.5	2.1 (0.8, 5.5)	42.5	1.0 (0.6, 2.0)
History of lower-extremity non-stress fracture injury	No	546	6.6	1.0	39.4	1.0
	Yes	278	7.2	1.1 (0.6, 1.9)	46.0	1.3 (0.9, 1.8)

OR, odds ratio; CI, confidence interval; BMI, body mass index (calculated by weight (kg)/height (m)²).

TABLE 3. Crude odds ratios for lower-extremity stress fracture and non-stress fracture overuse injury by measures of physical fitness and activity, female Marine Corps recruits, Parris Island, 1999.

Variable	Category	N	Stress Fracture		Non-Stress Fracture Overuse Injury	
			(%)	OR (95% CI)	(%)	OR (95% CI)
Run time*	Q1 Fastest	204	4.4	1.0	37.7	1.0
	Q2	209	5.7	1.3	40.7	1.1
	Q3	195	5.1	(0.5, 3.2)	45.6	(0.8, 1.7)
	Q4 Slowest	204	10.8	2.6 (0.5, 3.0)	44.6	1.4 (0.9, 2.1)
Self-rated fitness	Excellent-very good	133	2.3	1.0	33.1	1.0
	Good	399	5.5	2.5 (0.7, 8.6)	42.4	1.5 (0.9, 2.2)
	Fair-poor	292	10.6	5.1 (1.5, 17.1)	44.5	1.6 (1.1, 2.5)
Frequency of sweating during exercise†	All/quite a lot	306	5.6	1.0	37.9	1.0
	Fairly often	248	7.3	1.3 (0.7, 2.6)	46.8	1.4 (1.0, 2.0)
	Never/occasionally	270	7.8	1.4 (0.7, 2.8)	41.1	1.1 (0.8, 1.6)
Exercise times per wk†	5-7	265	4.9	1.0	39.2	1.0
	2-4	451	6.7	1.4 (0.7, 2.7)	42.6	1.2 (0.8, 1.6)
	0-1	107	12.1	2.7 (1.2, 6.0)	43.9	1.2 (0.8, 1.9)
Change in exercise‡	More/much more	417	7.7	1.4 (0.8, 2.5)	40.3	1.0 (0.7, 1.3)
	Same	300	5.7	1.0	41.0	1.0
	Less/much less	106	6.6	1.2 (0.5, 2.9)	49.1	1.4 (0.9, 2.2)
Frequency run (per week)†	≥ 4	254	5.9	1.0	39.0	1.0
	1-3	514	7.2	1.2 (0.7, 2.3)	42.8	1.2 (0.9, 1.6)
	Nonrunner	55	7.3	1.3 (0.4, 3.9)	43.6	1.2 (0.7, 2.2)
Mean run (miles per day)†‡	≥ 3.0	122	2.5	1.0	39.3	1.0
	1.5-2.9	442	6.8	2.9 (0.9, 9.6)	45.0	1.3 (0.8, 1.9)
	< 1.5	202	8.9	3.9 (1.1, 13.5)	35.6	0.9 (0.5, 1.4)
Mean run time (min per session)†‡	≥ 20	165	4.2	1.0	38.2	1.0
	< 20	601	7.5	1.8 (0.8, 4.1)	42.3	1.2 (0.8, 1.7)
Months run, past year	≥ 7	184	4.3	1.0	36.4	1.0
	0-6	640	7.5	1.8 (0.8, 3.8)	43.1	1.3 (0.9, 1.9)
	≥ 7	130	1.5	1.0	43.8	1.0
Months lower extremity weight training, past year	0-6	694	7.8	5.4 (1.3, 22.3)	41.2	0.9 (0.6, 1.3)
	≥ 2	620	5.5	1.0	42.6	1.0
Frequency lower extremity stretching, per week†	0-1	204	10.8	2.1 (1.2, 3.7)	38.7	0.9 (0.6, 1.2)

OR, odds ratio; CI, confidence interval.

*Timed run; quartiles based on 1.5-mile run time (measure of aerobic fitness).

†Activity 2 months prior to reporting to training at Parris Island.

‡Women who reported being nonrunners ($N = 55$) were excluded from analysis.

Overall injury rates by body location and by stress fracture and non-stress fracture overuse injury status are shown in Table 1. The lower legs (specifically the tibia) were the most common site (3.7/1000 TDE) of overall overuse in-

jury followed by the knee (2.8/1000 TDE) and hip (2.2/1000 TDE). For stress fracture, the lower leg (specifically the tibia) was the most common site (0.61/1000 TDE) followed by the hip/pelvis area (0.15/1000 TDE).

Risk Factors

The sample was primarily Caucasian (58%), followed by African American (18%) and Hispanic (17%). Using the African American women as the reference group, the risk of lower-extremity stress fracture or non-stress fracture overuse injury did not vary by race/ethnicity (Table 2). When using age and BMI as categorized variables, neither was associated with stress fracture or non-stress fracture overuse injury incidence or risk (Table 2).

As shown in Table 3, being in the slowest quartile (> 14.4 min) in the timed run was associated with a 2.6-time increase in lower-extremity stress fracture risk. In addition, most of the self-assessed measures (self-rated fitness, exercise participation, running mileage, weight training, and stretching) were also inversely related to the incidence of stress fracture. For lower-extremity non-stress fracture overuse injury, only fair-poor self-rated fitness was associated with increased risk.

Women who reported secondary amenorrhea (six or more consecutive missed menses during the past 12 months) demonstrated almost a threefold increase in lower-extremity stress fracture risk (Table 4). No significant associations were found for other menstrual variables or birth control hormone use.

TABLE 4. Crude odds ratios for lower-extremity stress fracture and non-stress fracture overuse injury by measures of self-reported menstrual status and birth control hormone use, female Marine Corps recruits, Parris Island, 1999.

Variable	Category	N	Stress Fracture		Non-Stress Fracture Overuse Injury	
			(%)	OR (95% CI)	(%)	OR (95% CI)
Age at menarche (yr)	< 16	800	6.8	1.0	41.9	1.0
	≥ 16	22	9.1	1.4 (0.3, 6.1)	31.8	0.7 (0.3, 1.6)
No. menses, past year*	10-12	647	6.0	1.0	41.3	1.0
	1-9	135	8.1	1.4 (0.7, 2.8)	43.0	1.1 (0.7, 1.6)
	0	17	11.8	2.1 (0.5, 9.4)	43.1	1.3 (0.5, 3.3)
Secondary amenorrhea*†	No	760	6.1	1.0	41.1	1.0
	Yes	40	15.0	2.7 (1.1, 6.9)	52.5	1.6 (0.8, 3.0)
Oligoamenorrhea*‡	No	757	6.5	1.0	41.0	1.0
	Yes	37	8.1	1.3 (0.4, 4.3)	54.1	1.7 (0.9, 3.3)
Birth control hormone*	Nonuser	532	6.2	1.0	41.1	1.0
	Depo-Provera	72	5.6	0.8 (0.3, 2.4)	44.4	1.1 (0.7, 1.8)
	Other	194	7.7	1.3 (0.6, 2.4)	45.9	1.3 (0.9, 1.8)

OR, odds ratio; CI, confidence interval.

*Women who reported being pregnant during 12 months prior to training ($N = 24$) were excluded from the analysis.

†Secondary amenorrhea: six or more consecutive missed menstrual cycles in past year.

‡Oligoamenorrhea: menstrual cycles > 35 d.

TABLE 5. Adjusted odds ratios for potential risk factors for lower-extremity stress fracture and non-stress fracture overuse injury, Parris Island, 1999.

Risk Factor	Category	Stress Fracture*	Non-Stress Fracture Overuse Injury†
		AOR (95% CI)	AOR (95% CI)
Run time‡	Q1 Fastest	1.0	
	Q2	1.4 (0.5, 3.9)	
	Q3	1.1 (0.4, 3.2)	
	Q4 Slowest	3.3 (1.4, 8.1)	
Secondary amenorrhea§	No	1.0	
	Yes	4.1 (1.5, 10.9)	
Weight training (months)	≥ 7	1.0	
	0–6	4.5 (1.1, 18.9)	
Self-rated fitness	Excellent–very good		1.0
	Good		1.5 (0.9, 2.3)
	Fair–poor		1.7 (1.1, 2.6)

AOR, odds ratios adjusted for all variables in the table plus age, race/ethnicity, and body mass index; CI, confidence interval.

*N = 785 women (women who reported being pregnant 12 months prior to training (N = 24) were excluded).

†N = 820 women.

‡Run time; quartiles based on 1.5-mile run time (measure of aerobic fitness).

§Secondary amenorrhea: six or more consecutive missed menstrual cycles in past year.

Even though age, race/ethnicity, and BMI were not associated with lower-extremity stress fracture or non-stress fracture overuse injury, these variables were controlled for in the final model. When also adjusting for factors that were associated with risk of stress fracture in the univariate analyses, the final logistic regression model for stress fracture included slow initial run time, secondary amenorrhea during the past year, and lack of consistent participation in a weight-training program for the lower extremities in the past year (Table 5). For non-stress fracture overuse injury, the final model included one variable: fair-poor self-reported fitness.

DISCUSSION

Injury rates. In this study, we found overall lower-extremity overuse injury and stress fracture rates of 12.6/1000 and 1.0/1000 TDE, respectively. To our knowledge, this is the first study to assess lower-extremity stress fracture and non-stress fracture overuse injury rates using this method of exposure in female recruits. Thus, these findings cannot be directly compared with prior reports of injuries of female recruits because the incidence of injury reported in these studies was calculated as a percentage of injured recruits (1,3,12,15) or injuries per weekly exposure (1,29). However, the overall lower-extremity overuse injury rates were comparable with females in a study of high school runners that used a per athletic exposure denominator (24). For comparison purposes, our overall incidence of overuse injury (48.4% of recruits) and stress fracture (6.8%) was similar to other female recruit prospective studies (1,6,12,17,27,29).

The difference between initial and subsequent injuries has been examined in a study of interscholastic high school runners, but has not been studied in female recruits. The purposes for reporting the injury rates in this manner were that 1) the incidence of initial injury estimates the rate at

which previous healthy recruits experience a first injury during training (24), and 2) the occurrence of an injury may be a risk factor for a subsequent injury at the same site or new body part (7,24,25). Our findings indicate that once injured, the female recruit had more than a 2- and 3.5-fold risk of a subsequent overall overuse and stress fracture injury, respectively. These findings suggest that 1) injured recruits may alter their gait with and without loads to compensate for an injury and inadvertently increase their risk of subsequent injury, especially for stress fracture; 2) injured recruits may achieve a state of fatigue more rapidly postinjury that predisposes them to subsequent injury in a shorter time course than initially experienced; and 3) an injured recruit's ability to adapt to new or repeated stressors may diminish postinjury.

Our finding that the lower leg (i.e., shin/calf) region was the most frequently injured area is consistent with many civilian studies of female runners (24,30) but only a few military studies (8). Similarly, our finding that the tibia was the most common site of stress fracture injury concurs with other female recruit (28) and athlete studies (2,5). The conflicting injury distributions among female recruit studies may be attributable to differing injury definitions or data collection methodologies, footwear, training practices, terrain, or that we included only overuse, not acute, injuries in our definition of injury.

Risk factors. The lowest level (slowest quartile) of aerobic fitness as measured by the initial 1.5-mile timed run was strongly associated with an increased risk of stress fracture injury. Our finding is consistent with other military studies that have found slower run times to be associated with a higher risk of lower-extremity injury among women during training (3,6,12,16,28).

At present, little is known about the possible effects of heavy resistance exercise, such as weight training, and the likelihood of stress fracture. Resistance training has been shown to increase muscle mass and strength as well as bone mineral density and bone strength, as indicated by measures of bone geometry in female athlete and premenopausal populations (9,11,19). Thus, in theory, progressive heavy resistance training of the musculoskeletal system should induce positive adaptations in bone that are proportional to the increased load (i.e., resistance), thereby increasing muscle mass and bone's resistance to stress fracture. We found that women who had participated in weight-training activities on a consistent basis for seven or more months were less likely to incur a stress fracture. However, as in other studies (19), we did not observe a significant association between lower-extremity muscle weight-training and non-stress fracture overuse injury.

Although self-rated fitness of fair-poor was statistically significant for both lower-extremity stress fracture and non-stress fracture overuse groups in the univariate analysis, it only remained significantly related to non-stress fracture overuse injury in the adjusted model. However, an objective measure of aerobic fitness (slow run time) remained in the adjusted model for stress fracture, but not for non-stress fracture overuse injury. This finding may be due to the

differing mechanisms of injury and may help explain why studies have not found consistent results even though stress fracture is a subset of overuse injury. Several of our other self-reported measures of exercise habits—participation in an exercise/sport $0-1 \times \text{wk}^{-1}$, average run of less than 1.5 miles per day, and lower-extremity stretching less than twice a week for 2 months prior to basic training—were significant for stress fracture or non-stress fracture overuse injury in our univariate risk estimates but not in our final adjusted models. Others have reported similar findings among female recruits (14,28).

Our finding that recruits who reported a history of secondary amenorrhea during the year prior to basic training were at increased risk for stress fracture injury supports other military (8,10,28,31) and civilian women athlete (2,4,18,22) studies that have reported a relationship between menstrual irregularity/amenorrhea and increased risk of stress fractures. These studies indicate that menstrual irregularity or amenorrhea may result in an increased risk of musculoskeletal injuries in women participating in vigorous, repetitive, weight-bearing activities. Although some studies (18,31) have reported that recruits or athletes (primarily runners) with menstrual irregularity were at increased risk for stress fracture/musculoskeletal injury using a criterion of less than 10 menses during the past year, our data confirm findings from other studies (2,10,28), which suggest that prolonged lack of menses may be a better predictor of injury during this structured training program.

Consistent with other studies (4,8,28), we did not find a protective effect between birth control hormone use and incidence of stress fracture. There is a growing concern that Depo-Provera, an injectable birth control hormone that lasts 3 months and that has the potential to lower bone mineral density and, possibly, increase stress fracture incidence. However, we found no association between Depo-Provera use during the 12 months prior to basic training and lower-extremity stress fracture or non-stress fracture overuse injury. Additional studies between birth control hormone methods and risk of stress fracture are needed.

Consistent with Shaffer et al. (28), we did not find an association between history of lower-extremity injury and stress fracture or non-stress fracture overuse injury during basic training. However, several reports from military (26), recreational (20,30), and competitive running (24) studies found that those with previous lower-extremity injury are at increased risk to incur some form of future overuse injury. We speculate that the difference in these findings may be partially related to the severity of the previous injury. Those who may have incurred a previous stress fracture or similar significant injury may be less likely to join the military for fear of a subsequent stress fracture. We suggest that future studies examine the association between type, severity, and time of previous overuse injury and occurrence of lower-extremity stress fracture and other non-stress fracture overuse injuries.

Consistent with other studies of military women (17,28,31), we did not find significant associations between potential risk factors such as height, body weight, or BMI and stress

fracture. Using standard cut points for BMI, we observed increased, but nonsignificant, trends for stress fracture for those considered overweight and underweight. The lack of significant finding, however, may be partially due to the small numbers of recruits classified as overweight (2.4%) and underweight (7.7%). We did not find any associations between age or race/ethnicity status and lower-extremity stress fracture or non-stress fracture overuse injury.

Several strengths of this study included the use of a prospective design and a large study sample. The prospective design allowed the risk profile of each recruit to be established before the lower-extremity stress fracture or non-stress fracture overuse injury occurred, thus reducing the likelihood of recall or measurement bias. The sample size provided adequate power to examine multiple risk factors concurrently. Additionally, our method of determining injury rates that adjusted for actual daily training exposure should allow for better comparisons between injury rates of past and future military and athletic studies using a similar denominator for training/participation exposure (21).

Several limitations of our study should be noted. Some self-reported measures for prior exercise, strength, stretching, or sport activities did not capture the frequency or intensity of the activity and may have accounted for some of our nonsignificant associations. We also did not assess any lower-extremity anatomical or biomechanical factors of the recruits, thus limiting our ability to examine factors that may play a role in the development of stress fracture and other overuse injuries. Finally, although these findings may not generalize to all active women, they provide useful information for assessment of lower-extremity stress fracture and non-stress fracture overuse injury risk in women undergoing Marine Corps basic training.

In conclusion, our results confirm that female recruits have high rates of lower-extremity stress fracture and non-stress fracture overuse injury. The manner in which we reported the injury rates should allow appropriate comparisons with other military and civilian running studies using the same methodology. Because a high rate of subsequent injury was also observed, efforts to explore reasons for subsequent injuries are warranted. Our finding on subsequent injury among the female recruits is important because it indicates additional time lost toward Marine Corps recruit training goals. This point is exemplified as 30 of the 56 stress fractures (53.6%) were preceded by a non-stress fracture overuse injury during basic training. We identified several risk factors for lower-extremity stress fracture or non-stress fracture overuse injury including baseline low aerobic fitness (slow run time), fair-poor self-reported fitness, secondary amenorrhea, and infrequent or no participation in a lower-extremity weight-training program. Because three of these factors involve aerobic and physical fitness abilities, efforts to have recruits participate in aerobic and strength-training programs on a consistent basis at least 7 months prior to basic training may be beneficial, and further study is warranted. The association between secondary amenorrhea and stress fracture provides additional support for menstrual dysfunction as an important risk

factor for injury among female recruits. Early screening efforts to identify those with a history of menstrual irregularity, followed by proper medical management, are recommended.

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REFERENCES

1. ALMEIDA, S. A., D. W. K. M. WILLIAMS, R. A. SHAFFER, and S. K. BRODINE. Epidemiological patterns of musculoskeletal injuries and physical training. *Med. Sci. Sports Exerc.* 31: 1176–1182, 1999.
2. BARROW, G. W., and S. SAHA. Menstrual irregularity and stress fractures in collegiate female distance runners. *Am. J. Sports Med.* 16:209–216, 1988.
3. BELL, N. S., T. W. MANGIONE, D. HEMENWAY, P. J. AMOROSO, and B. H. JONES. High injury rates among female Army trainees: a function of gender? *Am. J. Prev. Med.* 18:141–146, 2000.
4. BENNELL, K. L., S. A. MALCOLM, S. A. THOMAS, et al. Risk factors for stress fractures in track and field athletes. A twelve-month prospective study. *Am. J. Sports Med.* 24:810–818, 1996.
5. BENNELL, K. L., S. A. MALCOLM, S. A. THOMAS, J. D. WARK, and P. D. BRUKNER. The incidence and distribution of stress fractures in competitive track and field athletes. A twelve-month prospective study. *Am. J. Sports Med.* 24:211–217, 1996.
6. BIJUR, P. E., M. HORODYSKI, W. EGERTON, M. KURZON, S. LIFRAK, and S. FRIEDMAN. Comparison of injury during cadet basic training by gender. *Arch. Pediatr. Adolesc. Med.* 151:456–461, 1997.
7. CHALMERS, D. J. Injury prevention in sport: not yet part of the game? *Inj. Prev.* 8(Suppl. IV):S22–S25, 2002.
8. CLINE, A. D., G. R. JANSSEN, and C. L. MELBY. Stress fractures in female Army recruits: implications of bone density, calcium intake, and exercise. *J. Am. Coll. Nutr.* 17:128–135, 1998.
9. ENGELKE, K., W. KEMMLER, D. LAUBER, et al. Exercise maintains bone density at spine and hip EFOPS: a 3-year longitudinal study in early postmenopausal women. *Osteoporos. Int.* 17: 133–142, 2006.
10. FRIEDL, K. E., J. A. NUOVO, T. H. PATIENCE, et al. Factors associated with stress fracture in young Army women: indications for further research. *Mil. Med.* 157:334–338, 1992.
11. HEINRICH, C. H., S. B. GOING, R. W. PAMENTER, C. D. PERRY, T. W. BOYDEN, and T. G. LOBMAN. Bone mineral content of cyclically menstruating female resistance and endurance trained athletes. *Med. Sci. Sports Exerc.* 22:558–563, 1990.
12. JONES, B. H., M. W. BOVEE, J. M. HARRIS III, and D. N. COWAN. Intrinsic risk factors for exercise-related injuries among male and female Army trainees. *Am. J. Sports Med.* 21:705–710, 1993.
13. JONES, B. H., S. B. THACKER, J. GILCHRIST, et al. Prevention of lower extremity stress fractures in athletes and soldiers: a systematic review. *Epidemiol. Rev.* 24:228–247, 2002.
14. KELLY, E. W., S. R. JONSON, M. E. COHEN, and R. SHAFFER. Stress fractures of the pelvis in female Navy recruits: an analysis of possible mechanisms of injury. *Mil. Med.* 165:142–146, 2000.
15. KNAPIK, J. J., M. CANHAM-CHERVAK, K. HAURET, et al. Seasonal variations in injury rates during US Army Basic Combat Training. *Ann. Occup. Hyg.* 46:15–23, 2002.
16. KNAPIK, J. J., M. A. SHARP, M. CANHAM-CHERVAK, K. HAURET, J. F. PATTON, and B. H. JONES. Risk factors for training-related injuries among men and women in basic combat training. *Med. Sci. Sports Exerc.* 33:946–954, 2001.
17. LAPPE, J. M., M. R. STEGMAN, and R. R. RECKER. The impact of lifestyle factors on stress fractures in female Army recruits. *Osteoporos. Int.* 12:35–42, 2001.
18. LLOYD, T., S. J. TRIANTAFYLLOU, E. R. BAKER, et al. Women athletes with menstrual irregularity have increased musculoskeletal injuries. *Med. Sci. Sports Exerc.* 18:374–379, 1986.
19. LOHMAN, T., S. GOING, R. PAMENTER, et al. Effects of resistance training on regional and total bone mineral density in premenopausal women: a randomized prospective study. *J. Bone Miner. Res.* 10:1015–1024, 1995.
20. MACERA, C. A., R. R. PATE, K. E. POWELL, et al. Predicting lower-extremity injuries among habitual runners. *Arch. Intern. Med.* 149:2565–2568, 1989.
21. MEEUWISSE, W. H., and E. J. LOVE. Athletic injury reporting. Development of universal systems. *Sports Med.* 24:184–204, 1997.
22. MYBURGH, K. H., J. HUTCHINS, A. B. FATAAR, S. F. HOUGH, and T. D. NOAKES. Low bone density is an etiologic factor for stress fractures in athletes. *Ann. Intern. Med.* 113:754–759, 1990.
23. OTIS, C. L., B. DRINKWATER, M. JOHNSON, and A. LOUCKS. American college of sports medicine position stand. The female athlete triad. *Med. Sci. Sports Exerc.* 29:i–ix, 1997.
24. RAUH, M. J., A. J. MARGHERITA, T. D. KOESELL, S. G. RICE, and F. P. RIVARA. High school cross-country running injuries: a longitudinal study. *Clin. J. Sports Med.* 10:110–116, 2000.
25. RENSTROM, P. A. Mechanism, diagnosis, and treatment of running injuries. *Instr. Course Lect.* 21:225–234, 1993.
26. ROSS, J., and A. WOODWARD. Risk factors for injury during basic military training. Is there a social element to injury pathogenesis? *J. Occup. Med.* 36:1120–1126, 1994.
27. SHAFFER, R. A., S. K. BRODINE, S. I. ITO, and A. T. LE. Epidemiology of illness and injury among U.S. Navy and Marine Corps female training populations. *Mil. Med.* 164:17–21, 1999.
28. SHAFFER, R. A., M. J. RAUH, S. K. BRODINE, D. W. TRONE, and C. A. MACERA. Predictors of stress fracture susceptibility in young female recruits. *Am. J. Sport Med.* 34:108–115, 2006.
29. SNEDECOR, M. R., M. S. BOUDREAU, B. E. ELLIS, J. SCHULMAN, and M. HITE. U.S. Air Force recruit injury and health study. *Am. J. Prev. Med.* 19:129–140, 2000.
30. WALTER, S. D., L. E. HART, J. M. MCINTOSH, and J. R. SUTTON. The Ontario cohort study of running-related injuries. *Arch. Intern. Med.* 149:2561–2564, 1989.
31. WINFIELD, A. C., J. MOORE, M. BRACKER, and C. W. JOHNSON. Risk factors associated with stress reactions in female Marines. *Mil. Med.* 162:698–702, 1997.

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14. ABSTRACT (maximum 200 words)

Purpose: To examine rates and risk factors for overuse injuries among 824 women during Marine Corps Recruit Depot basic training at Parris Island, SC, in 1999.

Methods: Data collected included training day exposures (TDEs), baseline performance on a standardized 1.5-mile timed run, and a pretraining questionnaire highlighting exercise and health habits.

Results: There were 868 injuries for an overall injury rate of 12.6/1000 (TDEs). There were 66 confirmed lower extremity stress fractures among 56 (6.8%) women (1.0/1000 TDEs). Logistic regression modeling indicated that low aerobic fitness (a slower time on the timed run), less than 7 months of lower extremity weight training and no menses for 6 consecutive months during the past year were significantly associated with stress fracture overuse injury. Women who reported "fair-poor" baseline fitness were at increased risk for non-stress fracture overuse injury.

Conclusions: Stress fractures and other lower extremity overuse injury might be decreased if women entered training with high aerobic fitness and prior participation in lower extremity strength training. Furthermore, women reporting menstrual irregularity and injury during the previous year may require additional evaluation.

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