



Use of Simple Measures of Physical Activity to Predict Stress Fractures in Young Men Undergoing a Rigorous Physical Training Program

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Among a population of randomly selected US Marine Corps recruits at Marine Corps Recruit Depot, San Diego, California, the authors developed a screening tool to identify individuals at high risk for lower extremity stress fracture when beginning a rigorous physical training program. The screening tool was developed among 1,286 recruits, then tested and refined among 1,078 additional recruits. The refined algorithm, consisting of five physical activity questions and a 1.5-mi (2.4-km) run time, revealed that 21.6% of "high risk" subjects suffered more than three times as many stress fractures as "low risk" subjects. These data suggest that risk of stress fracture during rigorous physical training is increased by poor physical fitness and low levels of physical activity prior to their entry into the program. *Am J Epidemiol* 1999;149:236-42.

exercise; fractures, stress; military personnel; physical fitness; wounds and injuries

One of the challenges of beginning or accelerating an existing exercise program, whether it is for health, fitness, or military training, is to determine the physical activity level that is both effective and safe (1, 2). Musculoskeletal injury is one of the more common risks of excessive exercise, and lower extremity stress fractures are regarded as one of the more severe injuries (3-18). A screening tool to identify persons at elevated risk for injury and especially for stress fractures would greatly assist in the establishment of appropriate levels of exercise. Such a screening tool would benefit not only the individual, but also coaches, exercise program directors, health care providers, and military trainers.

In this prospective study, we established the rates and risk factors for stress fractures in persons undergoing rigorous physical training in order to develop an algorithm to identify those entering training with a higher probability of stress fracture. This algorithm was evaluated and further refined in a second phase of the study. Varying patterns of activity have been shown to be associated with changes in stress fracture incidence (3, 5, 6, 8, 9, 19-21). US Marine Corps recruits

in training provided an ideal population for this study because the physical activity during the follow-up period is uniformly standardized and is of high intensity.

MATERIALS AND METHODS

Study subjects

The study population for the first phase of algorithm development was 1,286 males of 1,347 randomly selected US Marine Corps recruits at Marine Corps Recruit Depot, San Diego, California. The study population for the second phase of algorithm testing and refinement was 1,078 of 1,136 additional male recruits. The average age of the first population was 18.9 ± 2.3 years (range 17-28 years) and 18.4 ± 1.1 years (range 17-27 years) for the second population. Both populations were predominantly white, non-Hispanic (70 percent, 68 percent), followed by Hispanic (19 percent, 17 percent), African American (6 percent, 8 percent), Asian-Pacific Islander (2 percent, 5 percent), and Native American (2 percent, 2 percent). In both phase one and two, all participants signed informed consent, completed a questionnaire, and were followed through the 12 weeks of recruit training for stress fracture outcomes.

Questionnaire

In the first phase, a 39-item questionnaire including age, race, history of prior musculoskeletal injury, recent physical activity and exercise patterns, and past alcohol and tobacco use was administered within the

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Abbreviations: CI, confidence interval; IST, Initial Strength Test; MCRD, Marine Corps Recruit Depot; RR, relative risk.

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first 3 days after arrival at training. In the second phase, subjects were administered a shorter questionnaire, which consisted of age, race, and five items derived from the phase 1 questionnaire.

Physical fitness/stress fracture assessment

In the second phase of the study, baseline physical fitness was objectively measured by a standardized field fitness test, the Initial Strength Test (IST), which includes a 1.5-mi (2.4-km) maximal effort run. Stress fractures were documented by review of each subject's medical record. A diagnosis of stress fracture required an appropriate clinical presentation and a confirmatory radiograph and/or triple-phase bone scan (15).

Statistical analysis

All computer analyses were performed using the Epi Info Version 6.0 (Centers for Disease Control and Prevention, Atlanta, Georgia) and the SAS Version 6.0 (SAS Institute, Inc., Cary, North Carolina) programming packages. Data were double-entered and checked using the Validate utility in Epi Info. Stress fracture incidence ratios were presented as the number of individuals who were diagnosed with at least one stress fracture during the follow-up period, per 100 subjects.

Phase 1. Risk factors for stress fracture incidence and algorithm development. Data from the first population were used to examine univariate associations of each questionnaire item with the outcome variable by comparing stress fracture incidence ratios among the categorical responses to each variable using relative risk with 95 percent confidence interval and chi-square as a test of significance. Cox proportional hazards modeling was used to assess the effect of baseline risk factors on the incidence of stress fracture by including all variables that were univariately associated with stress fracture incidence. The first two-stage algorithm (figure 1) was developed based on the results of the univariate and multivariate analyses to categorize subjects as "high risk" or "low risk" for stress fracture.

Phase 2. Algorithm evaluation and refinement. On enrollment of the second population, the phase I algorithm was used to assign subjects at baseline as "high" or "low" risk for subsequent stress fracture. At the end of the follow-up period, success of the algorithm was assessed using relative risk, 95 percent confidence interval, and chi-square. A second, "refined" algorithm (figure 2) was developed by adding the 1.5-mi (2.4-km) run time from the IST as an objective measure of physical fitness (16). Subjects' data from the second population were examined with this new algorithm.

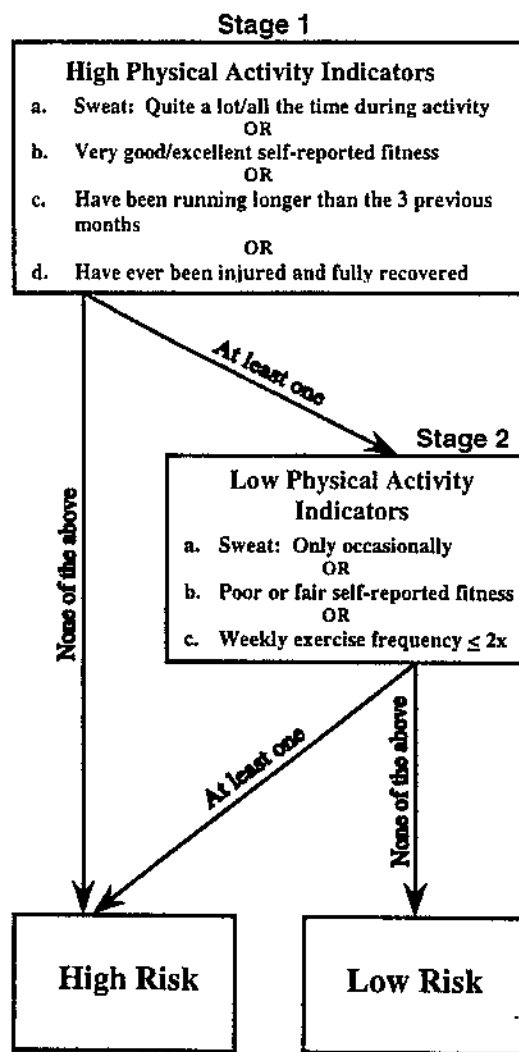


FIGURE 1. Algorithm for the assignment of subjects to a high or low risk group for stress fracture based on a self-report questionnaire, US Marine Corps recruit training, San Diego, California, 1993–1994. In the two-stage algorithm, the first stage identifies individuals in the high range of physical activity. The remaining subjects were in the low range of physical activity ("high risk"). The second stage assesses any indications of low physical activity in the very active subjects. If so, these individuals are assigned to the "high risk" category.

RESULTS

Phase 1. Stress fracture incidence and algorithm development

Of the 1,286 subjects in the first population, 52 (4.0 percent) were diagnosed with a total of 56 lower extremity stress fractures with an anatomical distribution including the tibia (46.4 percent), foot (39.3 percent), fibula (5.3 percent), heel (5.3 percent), femur (1.8 percent), and pelvis (1.8 percent). Eleven percent of stress fractures were diagnosed during the first 3

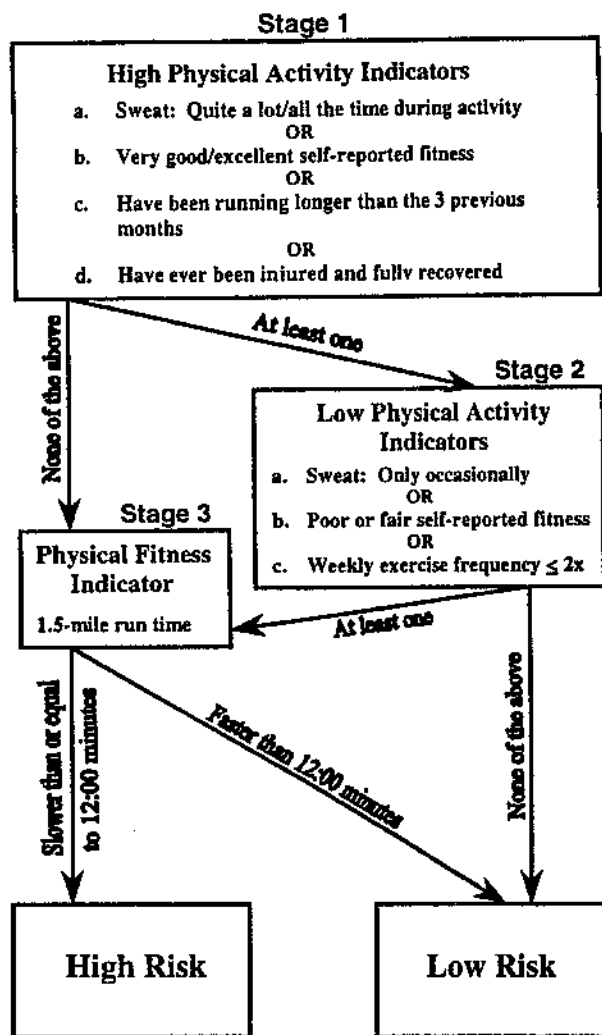


FIGURE 2. Algorithm for the assignment of subjects to a high or low risk group for stress fracture based on a self-report questionnaire and a 1.5-mi (2.4-km) run, US Marine Corps recruit training, San Diego, California, 1993–1994. The refined algorithm has a third stage with a physical fitness measure.

weeks of training, 52 percent in weeks 4–9, and 37 percent in the last 3 weeks.

There was no association between stress fracture incidence and age, ethnic category, current cigarette smoking (25.8 percent), or alcohol consumption (68 percent). Five of the 39 questionnaire items were univariately associated with stress fracture incidence, including four items about physical activity and exercise patterns and one item about prior injury (tables 1 and 2).

Table 3 shows that individuals assigned to high risk ($n = 645$) from this two-stage algorithm were 2.45 times (95 percent confidence interval (CI) 1.36–4.42) more likely to suffer a stress fracture during training than individuals in the “low” risk category ($n = 641$).

Phase 2. Stress fracture incidence and algorithm evaluation and refinement

Of the 1,078 subjects in the second population, 40 (3.7 percent) were diagnosed with 45 lower extremity stress fractures. The distribution of stress fractures by anatomical site in order of frequency was foot (64.4 percent), tibia (26.7 percent), femur (6.7 percent), and heel (2.2 percent). Twenty-four percent of stress fractures were diagnosed during the first 3 weeks of training and a further 76 percent in weeks 4–9.

The univariate associations of each of the five items used in the initial algorithm with stress fracture are displayed in table 1. Of the five items, only the question about frequency of sweating was associated with stress fracture incidence in this population. Table 3 shows that individuals assigned to the high risk category for stress fracture at the beginning of training according to the first algorithm were 2.00 times (95 percent CI 1.03–3.90) more likely to suffer a stress fracture during training.

Slower IST run time was also associated with an increased risk of stress fracture during training (table 1). The results of the assessment of the refined algorithm (figure 2) demonstrate that after adding a third stage with the physical fitness measure, the 21.6 percent of subjects assigned to the high risk category were 3.26 times (95 percent CI 1.78–5.97) more likely to suffer a stress fracture than were those in the low risk category (table 3).

DISCUSSION

We developed, tested, and refined an algorithm to identify individuals at elevated risk for lower extremity stress fracture at the beginning of an arduous physical training program. The refined algorithm consisted of three questions about recent physical activity, one question about previous injury, one question about self-perceived fitness, and the time of a 1.5-mi (2.4-km), maximal effort, field fitness test. Individuals categorized as high risk had low levels of recent physical activity and were over three times more likely to suffer a stress fracture than individuals with greater levels of recent physical activity (low risk category). In contrast, other factors, such as age, ethnicity, tobacco or alcohol use, and type of training surface, were not associated with subsequent stress fracture. A screening tool, such as the algorithm developed in this study, could assist individuals, coaches, exercise program directors, and military trainers to identify subjects at elevated risk for significant overuse injuries and in establishing safe and effective levels of exercise.

The components of the algorithms developed in this study are measures of recent physical activity and

TABLE 1. Univariate associations of self-reported risk factors, 1.5-mi (2.4-km) run times, and stress fracture incidence (SFI), US Marine Corps recruit training, San Diego, California, 1993-1994

Risk factor	First population (n = 1,286)			Second population (n = 1,078)				
	No.	SFI (%)	RR*	95% CI*	No.	SFI (%)	RR	95% CI
Frequency of sweating during exercise								
Quite a lot/all the time	595	1.6	1.00		493	1.8	1.00	
Fairly often	408	3.6	2.25	0.99-5.15	376	5.1	2.77	1.27-6.05
Occasionally/never	283	8.3	5.05	2.36-10.8	209	6.2	3.41	1.48-7.85
Self-reported physical fitness								
Very good/excellent	359	1.8	1.00		187	2.1	1.00	
Good	649	3.6	2.01	0.82-4.91	573	3.3	1.55	0.53-4.50
Fair/poor	278	6.5	3.64	1.45-9.09	315	5.7	2.69	0.89-7.52
If injured, fully recovered								
Never injured	553	5.3	1.00		564	4.3	1.00	
Injured, not recovered	116	5.7	1.06	0.45-2.50	54	1.85	0.44	0.06-3.15
Injured, fully recovered	617	1.9	0.36	0.18-0.71	460	3.5	0.82	0.44-1.52
Exercise frequency/week (no. of times) in prior 2 months								
≥4	658	2.6	1.00		531	3.4	1.00	
3	300	3.2	1.22	0.54-2.72	275	3.2	0.97	0.44-2.12
≤2	328	6.9	2.04	1.28-4.65	272	5.1	1.52	0.77-3.01
Total running experience (in months) immediately prior to training								
>3	263	1.6	1.00		165	2.4	1.00	
2-3	464	2.3	1.43	0.45-4.50	384	4.4	1.83	0.62-5.34
≤1	343	5.9	3.63	1.25-10.50	405	3.7	1.53	0.51-4.53
None	216	5.7	3.49	1.14-10.65	124	4.0	1.66	0.46-6.07
Initial Strength Test by 1.5-mi (2.4-km) run time								
Q1 8:10-10:29	267				267	2.3	1.00	
Q2 10:30-11:19	255				255	1.9	0.87	0.27-2.82
Q3 11:20-12:14	284				284	3.9	1.72	0.65-4.6
Q4 12:15-17:10	272				272	7.0	3.11	1.26-7.66

* RR, relative risk; CI, confidence interval.

TABLE 2. Relative hazards for stress fracture during US Marine Corps recruit training, first population (*n* = 1,296 males), San Diego, California, January–September 1993*

Variable	Relative hazard	95% CI†
Age (years)	1.07	0.92–1.24
Ethnic category, white vs. other	1.04	0.58–1.88
Frequency of sweating during exercise		
Fairly often vs. most often/all the time	1.78	0.81–3.91
Occasionally/never vs. most often/all the time	2.97	1.32–6.73
Self-reported physical fitness		
Good vs. very good/excellent	1.35	0.56–3.25
Fair/poor vs. very good/excellent	1.60	0.60–4.27
Never injured or previous injury without full recovery	1.89	1.05–3.44
Exercise frequency/week in prior 2 months		
≥4 vs. 3/week	0.97	0.45–2.10
≥4 vs. ≤2/week	1.24	0.60–2.55
If currently running, how long (months)		
>3 vs. 2–3 months	1.01	0.35–2.93
>3 vs. ≤1 month	2.09	0.75–5.84
>3 vs. nonrunner	1.49	0.48–4.66

* Model –2 log likelihood chi-square: 34.963 (12 df), *p* = 0.0005; Wald chi-square: 32.66 (12 df), *p* = 0.0011.
 † CI, confidence interval; df, degrees of freedom.

TABLE 3. Incidence of stress fractures among algorithm-derived risk categories in the first and second populations, US Marine Corps recruit training, San Diego, California, 1993–1994

	Risk category	No.	≥1 stress fracture	Incidence (%)	RR*	95% CI*	<i>p</i> value†
Population 1		1,286	52	4.04			
First algorithm	Low	641	15	2.34	1.00		
	High	645	37	5.74	2.45	1.36–4.42	0.0002
Population 2		1,078	40	3.71			
First algorithm	Low	498	12	2.41	1.00		
	High	580	28	4.82	2.00	1.03–3.90	0.04
Refined algorithm	Low	844	21	2.48	1.00		
	High	234	19	8.12	3.26	1.78–5.97	0.00001

* RR, relative risk; CI, confidence interval.

† Chi-square test.

physical fitness. Three of the five questions—frequency of sweating, frequency of exercise, and length of recent running experience—have been used in other studies to measure physical activity in self-report questionnaires (22–30). Low levels of physical activity have been shown to be associated with subsequent injury and stress fracture in other investigations (6–9, 14, 15, 31, 32). Most studies of risk factors for injury have shown previous injury to be associated with subsequent injury (8, 9, 32). The latter finding is in contrast to our finding that individuals who reported no previous lower extremity injury were at greater risk of stress fracture compared with subjects who reported a previous injury with full recovery. In addition, in our study, subjects who reported a previous injury without full recovery were also at increased risk for stress fracture. This finding suggests that previous injury was a marker for activity.

The physical fitness component of the refined algorithm consists of one question about self-perceived fitness and an objective measure of fitness, a 1.5-mi (2.4-km) run. Initial physical fitness as measured by run times has been associated with stress fractures in some military training populations (6, 7), but not in other such populations (33). The physical fitness measures in this algorithm may be a further refinement of the overall classification of recent physical activity, because it is unlikely that aerobic capacity alone is associated with stress fracture risk.

In summary, this study demonstrated a strong association between measures of physical activity and aerobic fitness and occurrence of stress fracture in individuals who were undergoing an arduous physical training program. Further, these physical activity and fitness measures can be quantified into a simple screening algorithm consisting of five self-report ques-

tions and the time from a 1.5-mi (2.4-km) field fitness test to accurately identify individuals at elevated risk for stress fracture before beginning or changing an exercise program. Importantly, these baseline factors are modifiable, which suggests that overuse injuries, such as stress fractures, are often preventable. Successful interventions could include screening combined with recommendations for an appropriate "pre-conditioning" program, where indicated.

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APPENDIX 1

Questionnaire items used in the algorithm development

1. In your *exercise or leisure activities*, how often do you "work up a good sweat?" (circle one)

- 1 - Never
- 2 - Occasionally
- 3 - Fairly often
- 4 - Quite a lot
- 5 - Most or all of the time

2. How would you rate your *current physical fitness*? (circle one)

- 1 – Poor
- 2 – Fair
- 3 – Good
- 4 – Very good
- 5 – Excellent

3. During the *2 months before coming to training*, how often did you *exercise or play sports*? (circle one)

- 0 – never
- 1 – 1 time or less per week
- 2 – 2 times per week
- 3 – 3 times per week
- 4 – 4 times per week
- 5 – 5 times per week
- 6 – 6 times per week
- 7 – 7 or more times per week

4. If you ran or jogged during the *last 2 months*, for how long, in *total*, had you been *consistently* running or jogging before coming to training? (*If you did not run or jog during the *last 2 months*, circle "0.") (circle one)

0 – Does not apply. I did not run or jog during the 2 months before coming to training.

- 1 – 1 month or less
- 2 – 2 months
- 3 – 3 months
- 4 – 4–6 months
- 5 – 7–12 months
- 6 – 1 year or more

5. Following any injuries occurring before training, were you able to return to 100% of the level of *physical activity* you had maintained *prior to* the injury? (*If you have *never* been injured, circle "0.") (circle one)

- 0 – Does not apply. I have never injured bone, muscle, tendon, ligament, or cartilage in one or both of my lower limbs.
- 1 – No, as a result of at least one injury, *I have never been able to perform* at 100% of the level of physical activity I had maintained before I was injured.
- 2 – Yes, *I have been able to return fully (100%)* to the level of physical activity I had maintained before I was injured.