Overuse Injuries in Female Infantry Recruits during Low-Intensity Basic Training

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ABSTRACT

FINESTONE, A., C. MILGROM, R. EVANS, R. YANOVICH, N. CONSTANTINI, and D. S. MORAN. Overuse Injuries in Female Infantry Recruits during Low-Intensity Basic Training. *Med. Sci. Sports Exerc.*, Vol. 40, No. 11S, pp. S630–S635, 2008. **Purpose**: The purpose of this prospective study was to investigate the epidemiology of overuse injuries and to identify common risk factors for stress fractures among female and male recruits in a new light infantry basic training designed to minimize the incidence of overuse injuries. **Methods**: Study subjects were male and female recruits in the 16-wk light infantry basic training. A control group of noncombat female medics whose military service did not include demanding physical activities was recruited to assess the female recruits' preinduction physical preparedness. Pretraining survey of all participants' medical and sports participation histories was conducted. Anthropometric measurements were performed. Subjects were followed every 3 wk for overuse injuries. Stress fractures were diagnosed by radiography or scintigraphy. **Results**: Ninety-nine female recruits, 36 male recruits, and 55 controls participated. Although 31% of the controls reported regular preinduction sports participation, less than 25% of both male and female recruits did. Stress fractures incidence was 0% among males and controls but 12% among female recruits ($P = 0.03$). The mean body mass index of female recruits with stress fractures was 19.2 ± 2.6 versus 22.5 ± 3.3 $kg \cdot m^{-2}$ of female recruits without stress fractures ($P = 0.02$, odds ratio = 1.397, 95% confidence interval = 1.065–1.833). No statistically significant difference was found between female and male military trainees in the incidence of other overuse injuries, but there was a statistical trend ($P = 0.07$) for more back pain among females. **Conclusions**: Lower body mass index was the only variable identified as a risk factor for stress fractures among female recruits in the present study. It does not explain the markedly different response of female and male recruits' bones to the low demand training. There may be an intrinsic difference between male and female bone resistance to fatigue. **Key Words:** STRESS FRACTURE, GENDER, MILITARY, BMI, RISK FACTOR, MUSCULOSKELETAL

Stress fracture has been a major problem in the military since the mid-19th century (14,15). Years of epidemiological and biomechanical research have helped to clarify the pathophysiology of stress fractures in recruits performing strenuous training programs (1,7,13,16,23,28). As a result of these studies, militaries have improved their treatment and management of the problem.

Risk factors for stress fractures have been identified in the Israel Defense Forces (IDF). These include anthropomorphic factors such as bone width (9), external rotation of the hip (11), and foot arch height (10). Recruit's age (18) and preinduction physical activity (4) have also been found to be related to the risk of stress fractures. Another major risk factor is gender. Females doing the same training as males in the Israeli border police sustain much higher rates of stress fracture (25).

The issue of female stress fractures in the IDF became a practical issue only after 1994. In that year, a female soldier petitioned the Israeli Supreme Court to open the Israel air force fighter pilot course to females. The court ruled in her favor. During the past decade, the pilots' course as well as other combat positions has been opened to females. The experience of the US Army has shown that females doing the same training as males suffer 3 to 10 times the number of overuse injuries (22). With increasing numbers of females training alongside males, the same phenomenon was observed in the IDF.

The Karakal Unit is a light infantry unit in the Israeli Army composed of 70% female and 30% male combat soldiers. The unit's training program has been specifically adapted to accommodate the high percentage of female recruits as well as the tasks the unit will eventually perform. The purpose of this prospective study was to follow and compare the incidence and epidemiology of overuse injuries between female and male Karakal recruits undergoing

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0195-9131/08/4011S-S630/0
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DOI: 10.1249/MSS.0b013e3181892ff9

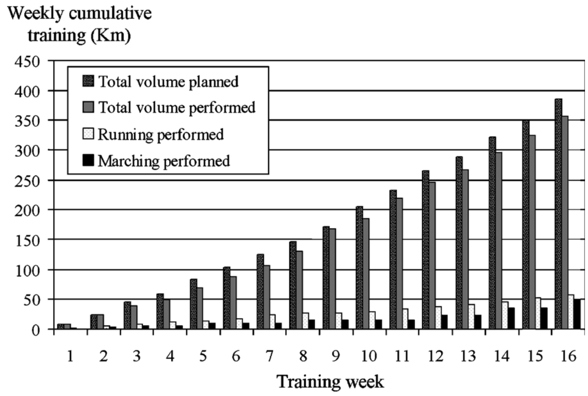

FIGURE 1—Weekly cumulative performed training versus weekly cumulative planned training during 16 wk of Karakal basic training. The total volume of cumulative training includes various training exercises and stationary standing activities apart from running and marching.

16 wk of basic training and to identify possible risk factors for overuse injuries among female recruits. The findings of this study may influence recruitment and training guidelines for other female infantry recruits.

METHODS

The study was approved by the Ethics Committee of the IDF, and written informed consent was obtained from all subjects. Service in the IDF is compulsory. Females usually do not serve as combat soldiers. Females who serve in Karakal all volunteer specifically for the unit, whereas males are drafted into the unit. To help assess the preinduction level of physical preparedness of female Karakal recruits, a platoon of females in a noncombat medics' course was recruited. They formed a female control group whose military service did not require any special physical prowess. Pretraining data collected from recruits and the control group included a detailed medical and sports participation history, an anthropomorphic and anthropometric measurement, a smoking history, and an orthopedic physical examination. Female Karakal recruits were asked about their age of menarche, the number of menstrual periods they had during the past year, and the date of their last menstrual period.

Preinduction sports participation history was classified according to the type of sport (up to three different sports), the hours spent in activity per week (or total kilometers), and the total number of months of participation. The anthropometric examination included measurements of height, weight, percent body fat (by skinfolds) (26), external rotation of the right hip at 90° of flexion, lower right extremity tibial and femoral length, and maximum quadriceps force. The maximum quadriceps force was measured using a standard gym quads press, overweighted to 58.97 kg with a scale to measure the force. The length of the lever arm from the knee joint to the quad press bar was constant for all subjects. Corrections were made for subjects' weight by dividing the measured force by subject weight. Due to the lever arm, the actual force recorded is in relative units for comparing the subjects in this study only. Pre- and posttraining fitness was assessed with the standard IDF fitness test including a 2-km run (minimum time in minutes) and the maximum number of push-ups and sit-ups able to be consecutively executed without rest. The results were normalized into scores: 70 points given to the run (scoring 0 for more than 16:30 min and 70 for less than 6:49 min), 15 points given to push-ups (scoring 0 for less than 1 and 15 for 75), and 15 points for sit-ups (scoring 1 for less than 25 and 15 for 86). The passing score was set at 55 for both genders.

All recruits were examined in the field by a team of orthopedic surgeons every 2 to 3 wk during the 16 wk of basic training and were screened for overuse injuries. A 6-h a night sleep regimen was enforced during the training. Exceptions to the sleep regimen were made for 1-h night guarding duty every other night and for night marches. Suspected stress fractures were diagnosed by radiography and scintigraphy and were treated according to the IDF protocol (17,30). All data were recorded directly into a laptop in a relative database on Access® (Microsoft Corp., Redmond, WA). Data analysis was performed on SAS reading directly from the Access® tables. Univariate analysis on nominal variables was performed using chi-square and on continuous variables using Student's *t*-test. For changes over the training period, paired *t*-tests were used. Multivariate analysis was performed using logistic regression.

RESULTS

Ninety-nine female and 36 male recruits were inducted into the Karakal basic training. Five females and one male

TABLE 1. Anthropomorphic data for recruits at induction.

	Karakal Females (n = 99)	Karakal Males (n = 36)	Control Females (n = 55)	P value
Height (cm)	162.5 ± 6.3 (n = 98)	176.2 ± 7.2* (n = 36)	162.5 ± 6.0 (n = 55)	<0.0001
Weight (kg)	60.8 ± 10.5 (n = 98)	67.8 ± 10.8* (n = 36)	58.4 ± 10.9 (n = 55)	<0.0003
BMI (kg·m^{-2})	23.0 ± 3.3 (n = 98)	21.8 ± 3.0 (n = 36)	22.1 ± 3.5 (n = 55)	NS
% body fat	33.5 ± 3.6† (n = 98)	18.2 ± 4.2* (n = 36)	31.2 ± 4.7 (n = 55)	<0.0001
Femoral length (cm)	50 ± 4 (n = 98)	55 ± 8* (n = 36)	49 ± 3 (n = 50)	<0.0001
Tibial length (cm)	36 ± 2 (n = 98)	40 ± 3* (n = 36)	36 ± 2 (n = 50)	<0.0001
Hip external rotation >65°	33% (32/98)	14%* (5/36)	26% (9/35)	<0.05
Quad lift, corrected for subjects' weight (kg)	1.45 ± 0.29 (n = 98)	2.01 ± 0.35* (n = 35)	1.42 ± 0.31 (n = 50)	<0.0001

Values are presented as mean ± SD. NS, not significant.
* Statistically significant difference between Karakal males and both female groups.
†Statistically significant difference between Karakal females and control females.

TABLE 2. Overuse injuries during Karakal basic training.

	Karakal Females (n = 99)	Karakal Males (n = 36)	P value
All stress fractures	12 (12.1%)	0 (0%)	0.03
Femoral stress fractures	7 (7.1%)	0 (0%)	0.1
Tibial stress fractures	5 (5%)	0 (0%)	NS
Fibular stress fractures	3 (3%)	0 (0%)	NS
Anterior knee pain	31 (31%)	8 (22%)	NS
Achilles tendonitis	1 (1%)	2 (6%)	NS
Back pain (total)	32 (32%)	6 (17%)	0.07
Upper back pain	15 (15%)	2 (6%)	NS
Lower back pain	13 (13%)	2 (6%)	NS
Ankle sprain	6 (6%)	2 (6%)	NS

Values are presented as n (%). NS, not significant.

did not complete the 16-wk basic training course. Their primary reason for leaving basic training was motivation and not injury. Recruit training was composed of weekly schedules of running, marching, training exercises, stationary standing activities, lessons, and miscellaneous duties. Figure 1 depicts the actual weekly cumulative running, marching, and total training volume in kilometers done by recruits versus the planned training goals. Hours spent standing by recruits were included in the total training volume with 1 h of standing considered to be equivalent to 1 km of marching. The actual cumulative running for the whole 16-wk training period was 57.7 km, the cumulative marching was 49.5 km, and the total training volume in kilometers done by recruits was 356.2 km. The planned total training volume was 384.9 km. The longest formal march with pack and gear accomplished during training was 15 km. Fifty-five females from the noncombat medics' course formed the control group. Their training did not include formal runs or marches. Twenty-three percent of the females in Karakal, 22% of the males in Karakal, and 31% of the female control group reported participating in sport activity before military induction for at least 1 yr and at least 2 h a week. The most frequent activity done by female Karakal recruits was dancing (9%). The control group of female noncombat medic recruits in this study had a higher level of sports participation, with the most frequent activity being aerobics (15%). One percent of the female recruits, 4% of the male recruits, and 3% of the female controls participated regularly in either basketball or soccer before military induction. There was no statistically significant difference between the groups.

The mean percent body fat of female Karakal recruits was significantly higher than that of the female controls. For all the other anthropomorphic measurements, there was no difference between the two female groups (Table 1). Males were taller, heavier, had longer femurs and tibia, had stronger quadriceps, and had lower percent body fat, and a lower percentage had external hip rotation above 65° than both female groups. Thirty-eight percent of the Karakal females, 36% of the males, and 29% of the controls reported smoking. There was no statistically significant difference in the smoking history between the three groups when analyzed for percentage of smokers and pack years of smoking. No statistically significant difference was found between the menstrual status of the female recruits who sustained stress fractures and those who did not.

During basic training, 12 females sustained stress fractures. None of the males or controls sustained stress fractures. The difference between the Karakal male and the female recruits was statistically significant (P = 0.03). The first symptoms compatible with stress fractures appeared from the 4th until the 14th week of basic training. For females, the only anthropomorphic variable found to have a statistically significant relationship to stress fracture risk was body mass index (BMI; P = 0.02). The mean BMI of female recruits with stress fractures was 19.2 ± 2.6 versus 22.5 ± 3.3 $\text{kg}\cdot\text{m}^{-2}$ of female recruits without stress fractures (odds ratio = 1.397, 95% confidence interval = 1.065–1.833). There was a trend (P = 0.056) for more stress fractures among female recruits with a lower mean time for the 2-km run at the beginning of basic training (643 ± 65 s) than those with a higher mean time (725 ± 75 s), but the odds ratio was not statistically significant (odds ratio = 1.011, 95% confidence interval = 0.999–1.022). By multivariate analysis, only low BMI was found to be a risk factor for stress fractures for female Karakal recruits. There was no statistically significant difference between the incidence of other overuse injuries between female and male Karakal trainees, but there was a statistical trend (P = 0.07) for more back pain among females (Table 2).

During basic training, the physical fitness of both female and male Karakal recruits improved. After training, the Karakal females completed the 2-km run in 11:41 min compared with 12:18 min at induction. Data from the standard IDF fitness tests are presented in Table 3.

DISCUSSION

The essential functional element of an army is the combat soldier. The combat soldier is surrounded by many others

TABLE 3. Standard IDF physical fitness test results at the beginning and at the end of basic training for male and female Karakal recruits.

	Scores Karakal Females (n = 99)			Scores Karakal Males (n = 36)		
	Induction	End of Training	P value	Induction	End of Training	P value
2-km run time	12:18 ± 1:16 (n = 74)	11:41 ± 1:17 (n = 36)	0.0001	9:51 ± 0:13 (n = 29)	8:38 ± 1:05 (n = 20)	0.0001
Push-ups	29 ± 13 (n = 81)	47 ± 9 (n = 37)	0.0001	37 ± 16 (n = 29)	64 ± 13 (n = 20)	0.0001
Sit-ups	47 ± 28 (n = 81)	84 ± 13 (n = 37)	0.0001	56 ± 24 (n = 29)	87 ± 10 (n = 20)	0.0001
Overall score	33 ± 12 (n = 73)	47 ± 13 (n = 36)	0.0001	59 ± 13 (n = 29)	75 ± 12 (n = 20)	0.0001
Passed	5% (4/73)	33% (12/36)		69% (20/29)	95% (19/20)	

Values are presented as mean ± SD.

who provide support and services. Females in the Israeli Army have only recently moved from providing support and services to being combat soldiers in units such as the Karakal light infantry unit in which males and females train and serve together. In these new roles, females are exposed to training that frequently causes overuse injuries in males. Because females are known to be at a higher risk for overuse injuries than males (3,6,22,29), this can potentially make the completion of necessary training more difficult.

Due to the high number of females, the Karakal basic training program was specifically designed to minimize the musculoskeletal problems of trainees while at the same time producing a good light infantry soldier. A typical regular male Israeli infantry recruit incrementally increases his formal marching during 14 wk of basic training and finishes the training with a march of 46 km. The incidence of stress fractures during such training is usually less than 12%. In contrast, the female Karakal recruits in this study finished their 16 wk of basic training with a final march of only 15 km and with a 12% incidence of stress fractures. Males doing the same Karakal training did not sustain any stress fractures.

The high incidence of stress fractures among females in the low-intensity Karakal training may be due to their lack of preinduction physical fitness. Although the female Karakal recruits were very motivated, this did not translate into efforts to prepare themselves physically for infantry service before induction. Although 31% of the noncombat female medics participated in regular sport activity before the army, less than 25% of both male and female Karakal recruits did. A standard physical fitness test is administered to Israeli combat soldiers. The scoring of the test is based on the time of a 2-km run and the maximum number of sit-ups and push-ups the subject can perform. Karakal recruits are expected to reach a score of at least 55 at the end of basic training. This is the fitness level considered to be necessary to perform the unit's future tasks, and no differentiation is made between females and males. Female Karakal recruits had a mean score of 33 at the beginning of basic training reflecting their low level of sport activity before army service. Only one third of the female recruits tested at the end of basic training reached a score of 55. The majority of female recruits did not even take the final physical fitness test either because they were injured or incapacitated at the time of the test. Sixty-nine percent of male Karakal recruits began basic training with a score already above the 55 threshold. This is also far below the fitness levels of elite infantry recruits. Ninety-eight percent of elite infantry recruits start training with fitness scores already above 70, the minimum score for passing elite infantry basic training.

In previous Israeli Army studies among male infantry recruits, physical fitness scores at the beginning of infantry basic training were not predictive of risk for stress fractures in subsequent training (5,8). This was also true for the female Karakal recruits in the current study. In previous Israeli military studies, ball sports, especially basketball played regularly before army service, was found to significantly lower stress fracture risk among males in infantry basic training (20). Armstrong et al. (1) compared young male and female recruits at the US Naval Academy who sustained lower extremity stress fracture during a military summer training program with a matched group of uninjured recruits to identify risk factors for stress fracture. No association was found between preadmission sports participation and stress fracture, but recruits who had participated in non–weight-bearing sport activities such as swimming showed a trend to stress fracture, whereas recruits who had participated primarily in weight-bearing sports such as basketball and soccer did not. Only 1% of the female Karakal recruits in the current study participated in either basketball or soccer regularly before basic training. Due to the small number, it was impossible to establish in this study whether these activities are also protective factors against stress fractures among female infantry recruits.

Narrow tibia diameter has been found to be a risk factor for tibial, femoral, and total stress fracture among male Israeli infantry recruits (9). The basis for this relationship can be explained by examining the engineering relationships for the strength of a cylinder. A human long bone can be idealized as a hollow cylinder. The compression strength of a cylinder is proportional to the radius of the cylinder to the second power and the bending and torsion strength to the radius to the fourth power (19). Although this relationship has not yet been verified for female Israeli infantry recruits, females generally have smaller and narrower tibiae than males. The tibial diameter of the Karakal recruits was not measured, but the mean tibial length of the female recruits as well as of the noncombat female medics in this study was found to be 4 cm less than that of the males.

Another established risk factor for stress fracture in male Israeli infantry recruits is external rotation of the hip greater than 65° (11). The mechanism for this relationship is not known. It is specifically true for tibial but not for femoral stress fractures. In the current study, the femur was a more frequent site for stress fracture than the tibia. Due to the lower frequency of tibial stress fractures as compared with femoral stress fractures and the small sample of subjects, the statistical power of this study was inadequate to verify a relationship between hip external rotation above 65° and tibial stress fractures in female Karakal recruits. One third of female Karakal recruits had external rotation of the hip above 65° as opposed to less than one sixth of male recruits.

Previous studies among female military recruits have reported a relationship between menstrual irregularity and amenorrhea and an increased risk of stress fractures (6,24). In the present study, there was no statistically significant difference between the menstrual status of the female recruits who sustained and those who did not sustain stress fractures.

The fact that 12% of female Karakal recruits sustained stress fractures in basic training in spite of the low physical demand is remarkable. The low physical demand level is mirrored by the fact that male Karakal recruits did not sustain stress fractures. One possible explanation for the difference might be that although both sexes were exposed to the same training demands, the females actually might have had higher workloads due to their lower level of physical fitness and strength. The hypothesis that lower aerobic physical fitness could be a risk factor for stress fracture was addressed in a prospective male military study by Swissa et al. (27). They found no correlation between the incidence of stress fractures during infantry basic training and recruits' pretraining aerobic physical fitness as assessed by the technique of Astrand and Rhyming (2). With this technique, the $\dot{V}O_2$ maximum is calculated indirectly using the Astrand nomogram of heart rate. In a more recent study by Shaffer et al. (24) in female recruits undergoing US Marine Corps basic training, low aerobic fitness as measured by a three-quarter-mile or 1-mile timed run was associated with stress fracture risk. As the run time increased, the risk of stress fracture increased. In the current study, no statistically significant relationship was found between the mean time for the 2-km run at the beginning of basic training and the incidence of stress fractures. Therefore, the explanation that higher workloads based on lower physical fitness increased the risk for stress fracture is not applicable to the present study.

Women in the Karakal training with stress fractures had lower BMI than those without stress fractures. In the study of Shaffer et al. (24) among females undergoing US Marine Corps basic training, BMI was not found to be a risk factor for stress fractures. In a 1966 military study, Gilbert and Johnson (12) stated that stress fractures were more common among the obese recruits with poor muscle tone. The group classified as asthenic had the next largest incidence, whereas stress fractures were less common among the recruits with average physical structure. However, these statements were not based on statistics but rather on the authors' observations.

None of the risk factors for stress fractures previously identified in male Israeli infantry recruits were found to be related to stress fracture risk among female Karakal recruits (8). The lower BMI, which was the only factor for stress fractures identified among female recruits in the present study, is not a clinically useful variable. It would not be logical to recommend to potential female Karakal recruits to gain weight as a means to prevent stress fracture. Low BMI by itself does not explain the markedly different response of female and male recruits' bones to the low demand training. In an *ex vivo* rat model, Moreno et al. (21) found that female rat bones have a lower resistance to fatigue than male rat bones in the absence of a physiological response such as muscle fatigue or osteogenic adaptation. If this is also true for humans, then the high stress fracture risk for the female Karakal recruits may be a function of the fact that female bone has different fatigue characteristics that male bone.

The female soldiers of Karakal did not sustain a statistically higher incidence of other overuse injuries, such as anterior knee pain, back pain, Achilles tendonitis, and ankle sprain than males who did the same training. However, there was a trend (P = 0.07) for more back pain among females. The lack of significant differences for these injuries may be because the relatively small number of male recruits in this study resulted in insufficient statistical power.

The current study indicates that in the low-intensity Karakal light infantry training, female lower extremity long bone had a much higher risk for stress fracture than male bone. This pattern was not seen for the other overuse injuries monitored in the study. The fact that the odds ratio for low BMI, the only risk factor for stress fractures identified in the study, was lower than 1.4 indicates that a factor not identified in this study is responsible for the high stress fracture risk in female Karakal recruits. There may be an intrinsic difference between the male and the female bone resistance to fatigue.

This study was supported by the US Department of Defense Bone Health and Military Medical Readiness Research Program.

The opinions and assertions in this article are those of the authors and do not necessarily represent official interpretation, policy, or views of the US Department of Defense or the Israeli Defense Forces.

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