Stress Fractures of the Pelvis in Female Navy Recruits: An Analysis of Possible Mechanisms of Injury

Guarantor: Edward W. Kelly, MD
Contributors: Edward W. Kelly, MD*; LCDR Scott R. Jonson, MSC USN†; Mark E. Cohen, PhD; CDR Richard Shaffer, MSC USN§

The purpose of our study was to investigate possible risk factors and mechanisms for the development of pelvic stress fractures in female Navy recruits. We used a case-control retrospective study of female Navy recruits undergoing basic military training. We compared anthropometric and activity data between recruits with pelvic stress fractures (N = 25) and female recruits who completed training without injury (N = 61). Recruits developing pelvic stress fractures were significantly (p < 0.05) shorter and lighter and were more frequently Asian or Hispanic than recruits without stress fractures. In addition, recruits with pelvic stress fractures reported marching in the back of their training division, were road guards, and felt that their stride was too long during training activities more often than recruits without injury. Self-reported fitness, activities before recruit training, or a history of amenorrhea was not found to be associated with the development of a pelvic stress fracture in our population.

Methods

Subjects
Volunteer subjects in this study were 86 healthy female recruits, aged 17 to 34 years, undergoing basic military training at the Naval Recruit Training Center, Great Lakes, Illinois, during the period March 1, 1995, through April 1, 1996. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures in females were diagnosed with pelvic stress fractures, whereas the female rate was 1 in 367. As a result of the prolonged healing time and the increased rate of pelvic stress fractures in our female recruits, we chose to investigate possible risk factors for pelvic stress fractures in this population. Because military training is a very uniform experience, we believed that there was something intrinsically different about the recruits who developed the pelvic stress fractures compared with females who completed recruit training without injury. We hypothesized that the female recruits who developed pelvic stress fractures were shorter and had identifiable risk factors for low bone density compared with those without injury.

Methods

Subjects
Volunteer subjects in this study were 86 healthy female recruits, aged 17 to 34 years, undergoing basic military training at the Naval Recruit Training Center, Great Lakes, Illinois, during the period March 1, 1995, through April 1, 1996. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures in females were diagnosed with pelvic stress fractures, whereas the female rate was 1 in 367. As a result of the prolonged healing time and the increased rate of pelvic stress fractures in our female recruits, we chose to investigate possible risk factors for pelvic stress fractures in this population. Because military training is a very uniform experience, we believed that there was something intrinsically different about the recruits who developed the pelvic stress fractures compared with females who completed recruit training without injury. We hypothesized that the female recruits who developed pelvic stress fractures were shorter and had identifiable risk factors for low bone density compared with those without injury.

In similar activities,28-30 The proposed reasons for the gender disparity include females' lower bone density, poor musculoskeletal fitness, wider pelvic girdle, and shorter legs compared with males.4,28,29,31 During our study, only 1 of more than 10,000 male recruits was diagnosed with a pelvic stress fracture, whereas the female rate was 1 in 367.

As a result of the prolonged healing time and the increased rate of pelvic stress fractures in our female recruits, we chose to investigate possible risk factors for pelvic stress fractures in this population. Because military training is a very uniform experience, we believed that there was something intrinsically different about the recruits who developed the pelvic stress fractures compared with females who completed recruit training without injury. We hypothesized that the female recruits who developed pelvic stress fractures were shorter and had identifiable risk factors for low bone density compared with those without injury.

Methods

Subjects
Volunteer subjects in this study were 86 healthy female recruits, aged 17 to 34 years, undergoing basic military training at the Naval Recruit Training Center, Great Lakes, Illinois, during the period March 1, 1995, through April 1, 1996. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures in females were diagnosed with pelvic stress fractures, whereas the female rate was 1 in 367. As a result of the prolonged healing time and the increased rate of pelvic stress fractures in our female recruits, we chose to investigate possible risk factors for pelvic stress fractures in this population. Because military training is a very uniform experience, we believed that there was something intrinsically different about the recruits who developed the pelvic stress fractures compared with females who completed recruit training without injury. We hypothesized that the female recruits who developed pelvic stress fractures were shorter and had identifiable risk factors for low bone density compared with those without injury.

Methods

Subjects
Volunteer subjects in this study were 86 healthy female recruits, aged 17 to 34 years, undergoing basic military training at the Naval Recruit Training Center, Great Lakes, Illinois, during the period March 1, 1995, through April 1, 1996. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures in females were diagnosed with pelvic stress fractures, whereas the female rate was 1 in 367. As a result of the prolonged healing time and the increased rate of pelvic stress fractures in our female recruits, we chose to investigate possible risk factors for pelvic stress fractures in this population. Because military training is a very uniform experience, we believed that there was something intrinsically different about the recruits who developed the pelvic stress fractures compared with females who completed recruit training without injury. We hypothesized that the female recruits who developed pelvic stress fractures were shorter and had identifiable risk factors for low bone density compared with those without injury.

Methods

Subjects
Volunteer subjects in this study were 86 healthy female recruits, aged 17 to 34 years, undergoing basic military training at the Naval Recruit Training Center, Great Lakes, Illinois, during the period March 1, 1995, through April 1, 1996. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures in females were diagnosed with pelvic stress fractures, whereas the female rate was 1 in 367. As a result of the prolonged healing time and the increased rate of pelvic stress fractures in our female recruits, we chose to investigate possible risk factors for pelvic stress fractures in this population. Because military training is a very uniform experience, we believed that there was something intrinsically different about the recruits who developed the pelvic stress fractures compared with females who completed recruit training without injury. We hypothesized that the female recruits who developed pelvic stress fractures were shorter and had identifiable risk factors for low bone density compared with those without injury.

Methods

Subjects
Volunteer subjects in this study were 86 healthy female recruits, aged 17 to 34 years, undergoing basic military training at the Naval Recruit Training Center, Great Lakes, Illinois, during the period March 1, 1995, through April 1, 1996. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures were studied in females exclusively because the incidence of pelvic stress fractures in females was significantly higher than in males during the study period, 181:1 for males and 181:61 for females. Stress fractures in females were diagnosed with pelvic stress fractures, whereas the female rate was 1 in 367. As a result of the prolonged healing time and the increased rate of pelvic stress fractures in our female recruits, we chose to investigate possible risk factors for pelvic stress fractures in this population. Because military training is a very uniform experience, we believed that there was something intrinsically different about the recruits who developed the pelvic stress fractures compared with females who completed recruit training without injury. We hypothesized that the female recruits who developed pelvic stress fractures were shorter and had identifiable risk factors for low bone density compared with those without injury.
Stress Fractures of the Pelvis in Female Navy Recruits

At the time of diagnosis, subjects completed a 21-question survey to record their age, height, weight, and known risk factors for low bone density. Questions assessed the subjects' smoking history and history of prolonged amenorrhea (6 consecutive months or more without a period). Body mass index was calculated as kg/m². Each subject's self-perceived fitness was assessed using questions modified from the study of Washburn et al.32 The subjects were asked, "Rate your physical fitness compared with others of your same age and sex," "How many times a week did you run more than 1 mile during the 2 months before recruit training?" and "In your leisure activities, how often do you work up a good sweat?" For statistical purposes, the subjects were divided into two groups—"fit" or "unfit"—based on their answers to each of the three fitness questions. Subjects were considered unfit if they stated that they were in "good, fair, or poor" condition, exercised fewer than three times per week, and "rarely worked up a good sweat" while exercising.

Additionally, subjects answered questions about activities they participated in during recruit training, including "How frequently were you a road guard?" and "Where did you march in the division?" Finally, subjects were asked about the length of their stride while marching and running in formation: "Was your stride too long, too short, or comfortable?"

Stress fracture diagnoses were based on the subject's subjective complaint of atraumatic, insidious onset of pain and tenderness consistent with positive radiographic findings (periostal elevation, sclerosis, or fracture line) on plain film or bone scintigraphy (local area of increased uptake). All stress fracture subjects were evaluated in the Naval Hospital's Musculoskeletal Clinic. All radiographic findings were interpreted by the Naval Hospital's staff radiologists. Control subjects had their medical records reviewed to ensure that they had not been seen for a musculoskeletal injury during recruit training.

Data Analysis

The survey results were subjected to univariate analysis using the Tukey range, Kruskal-Wallis, or χ² test as appropriate. p values < 0.05 were considered significant. Analysis was done using StatXact.

Results

Descriptive statistics for both groups are shown in Table I. Table II summarizes the questionnaire results for the same groups. The fitness questions are represented by the percentage of subjects responding with answers that would indicate that they were in the unfit category or "average or below average" fitness as described by Washburn et al.32 In comparing the two groups, subjects developing pelvic stress fractures were on average shorter, lighter, and less often Asian or Hispanic, but less often African American, than the control group. In addition, subjects with pelvic stress fractures marched in the rear of their training divisions, served as road guards, and felt that their stride was too long while marching and running more frequently than those subjects without injuries. Self-reported good to poor fitness and a history of prolonged amenorrhea were not found to be associated with the development of a pelvic stress fracture.

Discussion

Pelvic stress fractures were first described in military recruits as early as 1937,23,33-35 each report citing only a few isolated cases. More recently, Meurman29 and Ozburn and Nichols30 reported multiple cases of pelvic stress fractures in military recruits. Pelvic stress fractures have also been reported in civilian athletes, most often affecting long-distance runners29,32,34,36-38 and fencers.39

The cause of a pelvic stress fracture has been attributed to the pull of the adductor muscles on the narrow pubic rami.23,28,36 The muscular pull theory is supported by the fact that stress fractures of the pelvis most frequently occur at the ischium (Fig. 1), which is the narrowest area of the pubic bone (Fig. 2) as well as the site for the origin of the adductor magnus.40 During the normal gait cycle, the medial portion of the adductor magnus acts with the other adductor muscles to flex the hip, whereas its lateral fibers act with the hamstrings to extend the hip.23,40 Selakovich and Love proposed that it was the interplay between the adductor muscles, which originate medially on the pubic rami, and the hamstrings, which originate laterally, acting as antagonists during gait, that create a shear stress at the narrow ischium and produce a fracture.34

The results from our study clearly support this hypothesized mechanism. Those females who developed stress fractures of the pelvis tended to be shorter than average, marched at the rear of the training division, were frequently road guards, and complained the most of having to overstride while marching. These findings fit into a consistent explanatory framework for pelvic stress fractures driven by height and the assignment of individuals, by height, into marching formations. Short recruits are assigned to the rear of marching formations. Here, these short individuals are required to overstride to keep pace with the taller formation leaders. When the short individuals are forced to take "giant steps" and overstride, the accumulation of the large shear and/or tensile stresses placed on the pubic rami by the adductors and hamstrings is amplified.

Military Medicine, Vol. 165. February 2000
Ozburn and Nichols noted that many of the female Army recruits suffering pelvic stress fractures were short and also marched at the back of the company. The recruits commented on having to "run or take giant steps to keep up" with the taller males at the front of their training division. Hill and colleagues were able to eliminate the occurrence of pelvic stress fractures in female British Army recruits by decreasing the stride length of a marching training regiment to 27 inches from the standard 30-inch pace. In another study, Reinker and Ozburn were able to decrease the incidence of all stress fractures in a female Army trainee population from 12% to 1.5% by switching the marching order from progressively shorter to progressively taller. Our study is the first we have identified that demonstrates statistically that the combination of being short and marching at the rear of a tall-to-short aligned division significantly contributes to the development of pelvic stress fractures in female recruits.

Other authors have noted a similar relationship between shorter female height and injury rates among military recruits. Giladi et al. and Finestone et al. suggested that it is the short, narrow bones that are at risk for stress fracture. Barrow and Saha, however, found no relationship between height and stress fracture risk among female athletes. In an

---

**TABLE II**

**QUESTIONNAIRE RESULTS BY GROUP**

<table>
<thead>
<tr>
<th>Group 1 (Pelvic Fractures)</th>
<th>Group 2 (No Injuries)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N = 25)</td>
<td>(N = 61)</td>
<td></td>
</tr>
<tr>
<td><strong>Self-reported fitness</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects stated that they were in good, fair, or poor condition at the start of recruit training</td>
<td>80</td>
<td>69</td>
</tr>
<tr>
<td>Subjects reported exercising less than three times per week before recruit training</td>
<td>64</td>
<td>67</td>
</tr>
<tr>
<td>Subjects stated that they &quot;rarely worked up a good sweat&quot; while exercising</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td><strong>Low bone density risk factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent who have ever smoked</td>
<td>16</td>
<td>33</td>
</tr>
<tr>
<td>Smoker pack years</td>
<td>0.8 (2.3)</td>
<td>1.23 (2.9)</td>
</tr>
<tr>
<td>Subjects reported a family history of osteoporosis</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Subjects reported a history of significant amenorrhea</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td><strong>Activities at recruit training</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects reported being a road guard &quot;frequently or almost every day&quot;</td>
<td>72</td>
<td>26</td>
</tr>
<tr>
<td>Subjects reported marching at the back of the formation</td>
<td>84</td>
<td>36</td>
</tr>
<tr>
<td>Subjects felt that their stride was &quot;too long&quot; while running</td>
<td>29</td>
<td>12</td>
</tr>
<tr>
<td>Marching</td>
<td>75</td>
<td>38</td>
</tr>
</tbody>
</table>

Data are percentages or means (SD).

*P < 0.001.

*P < 0.01.
African-American race against stress fractures may be attributable to the findings. We believe that short stature is not an independent risk factor for stress fracture in general may be explained by our findings. We believe that short stature is not an independent risk factor for pelvic stress fractures when individuals are allowed to walk, march, or run at their natural pace and stride. This is the case, for example, with athletes who run at a natural stride length. Short stature does become a risk for pelvic stress fractures, however, when an individual is forced to "overstride," such as when marching in a formation of recruits aligned from tall to short.

In our study population, 20% of the control subjects in group 2 were African American, whereas less than 4% of the subjects who developed pelvic stress fractures were African American. A low rate of stress fractures in African-American subjects has been reported by several other investigators in both military and athletic populations. The apparent protective factor of African-American race against stress fractures may be attributed to the demonstrably higher bone density of African-American individuals compared with whites, Asians, and Hispanics. The majority of the women developing pelvic stress fractures in the present study were Asian (24%), Hispanic (32%), or white (36%). The increased proportion of Hispanic and Asian females in the pelvic stress fracture group may be attributable to the shorter-than-average height in these ethnic populations or to differences in anthropometric factors, such as pelvic bone geometry or body mass index. To the best of our knowledge, no other published reports demonstrate a similar predilection of pelvic stress fractures in Asian or Hispanic individuals. Further research is needed in this area.

Increasing age, cigarette smoking, and extremes of body mass have all been demonstrated in other studies to be predictive for the development of overuse injuries, stress fractures in particular. These variables, as well as other predictors for low bone density, such as prolonged exercise-induced amenorrhea and poor fitness, did not appear to increase the risk for stress fractures in our population. The lack of a correlation between factors predictive of low bone density and the development of pelvic stress fractures indicates that the main risk factor for such injuries in our population is activity related rather than an intrinsic lack of fitness.

The relatively small number of subjects in each group limited our study. Our study was also limited by data collected retrospectively through a survey. We relied on self-reported heights and weight for subjects in both groups, which may have been inaccurate. Because the survey was conducted at the time of the injury and the activity a recruit is exposed to during training is fairly uniform, we are confident of the reliability of the participants' answers. We did not make radiographs or bone scans of individuals in the control group that might have identified asymptomatic stress fractures. We do not feel that this is relevant, however, because the goal of our study was to identify risk factors for subjects with symptomatic stress fractures. In addition, we did not perform specific quantitative measures of bone density, bone morphology, or skeletal alignments, which would give more specific information. Nonetheless, we feel that our findings shed light on the mechanism of injury for pelvic stress fractures and open the door to further research in this area.

In June 1996, several changes were made in an attempt to decrease these injuries in our training population. By having the shortest individuals in a division march in front, prohibiting the road guards from running, and rotating the road guard position on a daily basis, the overall stress fracture rate in our female recruits decreased from 3.5% to 1.3%. During this same period, the pelvic stress fracture rate decreased by more than 80%. These results support our conclusions that overstriding is the major source of stress for pelvic stress fractures in female Navy recruits.

Conclusions

Our study supports the theory that stress fractures at different anatomic sites may result from different mechanisms. The most significant risk factor in our population for the development of a pelvic stress fracture is the combination of being short and marching at the rear of an integrated training division. The overstriding was easily altered, decreasing the incidence of all stress fractures in our female recruits. The association between Asian or Hispanic race and the development of pelvic stress fractures is likely related to the shorter average height in these individuals, but this may require further review.

References


Military Medicine, Vol. 165, February 2000