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Menstrual irregularity and stress fractures in collegiate female distance runners*

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ABSTRACT

From 240 questionnaires, we investigated the prevalence of stress fractures in competitive collegiate female long distance runners and its relationship to menstrual history. The runners were divided into three groups according to their menstrual history: very irregular 69/240 (0 to 5 menses/year), irregular 51/240 (6 to 9 menses/year), and regular 120/240 (10 to 13 menses/year). Stress fractures occurred in 49% of the very irregular runners, 39% of the irregular runners, and 29% of the regular runners. The majority of the stress fractures occurred in the tibia. Runners who had never used oral contraceptives were over twice as likely to have had a stress fracture when compared with runners who had used oral contraceptives for more than 1 year. These data suggest that female distance runners who have a history of irregular or absent menses and who have never used oral contraceptives may be at an increased risk for developing a stress fracture. When amenorrheal runners were separated from the very irregular group, an alarming trend was noted in eating behavior disorders. Forty-seven percent of the amenorrheal group, 20% of the one to five menses/year group, 10% of the irregular group, and 7% of the regular group admitted to an eating behavior disorder.

The growing interest of women in athletics is evident from their increased participation in collegiate track. The number of women's collegiate track programs has grown from 402 in 1976 to 822 in 1986, and it was only in 1982 that the National Collegiate Athletic Association held its first track and field championships for women. Because of the short time that a large number of young women have been involved in strenuous athletics, the volume of literature concerning their medical complications has been limited until now.

Exercise-induced amenorrhea has recently received much attention following reports that young women with this complication have a decreased bone mineral density.[5,8,11,25,30,36] The realization that physical training is associated with menstrual irregularity has stimulated a search for the cause of this disorder. Although the exact etiology of these menstrual changes has not been elucidated, excessive body weight loss, low body fatness, stress, and amount of training have all been suggested, as well as hormonal causes of a hypothalamic-pituitary origin.

Documentation on stress fractures, unlike that for exercise-induced menstrual irregularities, dates back to 1855 when the Prussian military physician Breithaupt[3] made the original description. Until the 1970s, much of the literature concerned stress fractures in military recruits exposed to distinct stresses; these stress fractures have a different distribution than those sustained by runners. Stress fractures comprise a substantial percentage of injuries to runners in general[21,33,34] especially to women.[20,22,35]

Clinically, a fatigue stress fracture is a partial or complete fracture of bone caused by its inability to withstand nonacute macrotraumatic stress applied in a rhythmic, repeated submaximal manner.[10,33] It is a process in which remodeling predominates over repair. An insufficiency stress fracture, on the other hand, occurs from normal stress on a bone with decreased fracture resistance caused by various predisposing conditions (e.g., osteoporosis).[10,19]

The peak incidence of stress fractures occurs between the ages of 18 to 25 during the transformation of circumferential lamellar bone to osteonal bone.[53] A stress fracture occurring during this time can be disastrous to the runner vying for an athletic scholarship or preparing for a major competition, as the treatment for these injuries is generally rest or reduction of running to a level below that which causes symptoms.[10] The duration of interruption in training varies ac-

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cording to the individual runner and the particular bone involved.

Amenorrheal runners, because they are hypoestrogenic similar to postmenopausal osteoporotic women, may be at an increased risk for developing stress fractures. It is the purpose of this study to determine the prevalence of stress fractures and its relationship to menstrual history in a large sample of collegiate female distance runners.

METHODS

During April 1987, 1,000 questionnaires, each containing 37 questions, were mailed to 116 collegiate women's track coaches throughout the United States with instructions to distribute to all female distance runners (800 meters and longer). The questionnaire covered running, menstrual, contraceptive, and stress fracture history, as well as physical characteristics and eating behavior. Stress fracture was defined as a running-related injury diagnosed by a physician using radiograph or bone scan.

We received responses from 241 runners from 30 states. The data received from each runner were assigned to one of three groups according to the runner's menstrual history since menarche: very irregular (0 to 5 menses/year), irregular (6 to 9 menses/year), and regular (10 to 13 menses/year). During analysis, statistically significant data on amenorrheal runners (0 menses/year) were separated from the very irregular group.

Means of data were compared by analysis of variance. Chi-square was used in analysis of 2 percentages, and modified according to Fleiss for comparing greater than 2 percentages.

It should be kept in mind that the results from this study were obtained from a survey and were subject to sampling and nonsampling errors. Sampling errors occur because the whole population is not included, whereas nonsampling errors result from respondent's interpreting questions differently, not providing correct information, mistakes in data analysis, and other similar errors. To reduce the errors, we tried to obtain a large sample from a cross-section of the United States. In the beginning, we also sent out a pilot questionnaire to a small group that was to improve clarity and remove ambiguities in the final questionnaire. Several additional questions were added to the questionnaire as a result of this pretesting. In addition, in order to minimize nonresponse, we included addressed and stamped envelopes for return of the questionnaire and offered each respondent the results of the research, if she so desired. We would like to point out that since the mean age of our sample is 20 years, a respondent's historical recall should be accurate given the relatively short time involved. We also contacted several respondents for clarification and additional information.

RESULTS

Fifty percent of the respondents had a history of menstrual irregularities. Table 1 shows that the very irregular runners tended to weigh less and run more miles per week than both the irregular and regular runners. Regular runners had a significantly younger age of menarche than either the irregular or very irregular groups, but all three groups were above the national mean of 12.9 ± 1.2 years.[16] The very irregular group contained three runners aged 19 to 20 who had not achieved menarche; therefore, no menarchial age was included for them. An examination of the relationship between menarche and onset of training shows that the very irregular runners began training significantly earlier than the regular group, although the mean onset of training for all three groups (Fig. 1) was before menarche. The three runners who had not achieved menarche are not included in the statistical analysis; their mean age of onset of training was 10.67 years. The three groups were similar with respect to other physical characteristics and training regimens, including best race performances, except the very irregular runners, who had significantly faster 10,000 meter times when compared with the regular runners.

TABLE 1
Physical characteristics and training regimens of runners according to menstrual history

	Menstrual history		
	Very irregular (N = 69)	Irregular (N = 51)	Regular (N = 120)
Age (yr)	20.2 ± 1.9	20.2 ± 1.4	20.3 ± 2.2
Weight (lb)	113.4 ± 9.9[a]	119.3 ± 10.0	118.5 ± 11.8
Height (inches)	65.1 ± 2.3	65.6 ± 2.4	65.3 ± 2.5
Age menarche (yr)	14.7 ± 1.9[b]	14.3 ± 1.6	13.6 ± 1.6[a]
Training			
Days/wk	6.6 ± 0.5	6.6 ± 0.4	6.5 ± 0.6
Miles/wk	47.9 ± 11.6[a]	42.1 ± 12.0	41.2 ± 11.3
Pace (min/mile)	7.2 ± 0.5	7.3 ± 0.05	7.2 ± 2.4
Years running	7.0 ± 2.7	6.7 ± 2.6	7.2 ± 2.4
Best performances (min)			
Mile	5.02 ± 0.21	5.01 ± 0.24	5.14 ± 0.27
800 m	2.23 ± 0.09	2.25 ± 0.08	2.25 ± 0.10
1,500 m	4.63 ± 0.22	4.72 ± 0.23	4.67 ± 0.20
3,000 m	10.09 ± 0.63	10.16 ± 0.50	10.25 ± 0.66
5,000 m	17.70 ± 1.20	17.78 ± 0.97	18.13 ± 0.95
10,000 m	36.78 ± 1.76[c]	36.79 ± 2.25	38.44 ± 2.67

[a] $P < 0.05$.
[b] Three subjects had not achieved menarche and were not included.
[c] Significantly different from regular group (P = 0.04).

Thirty-seven percent of all subjects had sustained at least one stress fracture since beginning their running career, Caucasians having the highest frequency (39%) and blacks the lowest (17%) (Table 2). However, the differences between these percentages by race are not statistically significant, mainly because the black group contained only 12 runners (Table 2).

Figure 2 gives the prevalence of stress fractures in the runners according to menstrual history. The regular group, with 29% (35/120) prevalence, had a significantly lower percentage than both the irregular 39% (20/51) and very irregular 49% (34/69) groups ($P < 0.05$). When runners with abnormal menstrual history (0 to 9 menses/year) versus a normal menstrual history (10 to 13 menses/year) are compared, an even more significant difference is noted (P =

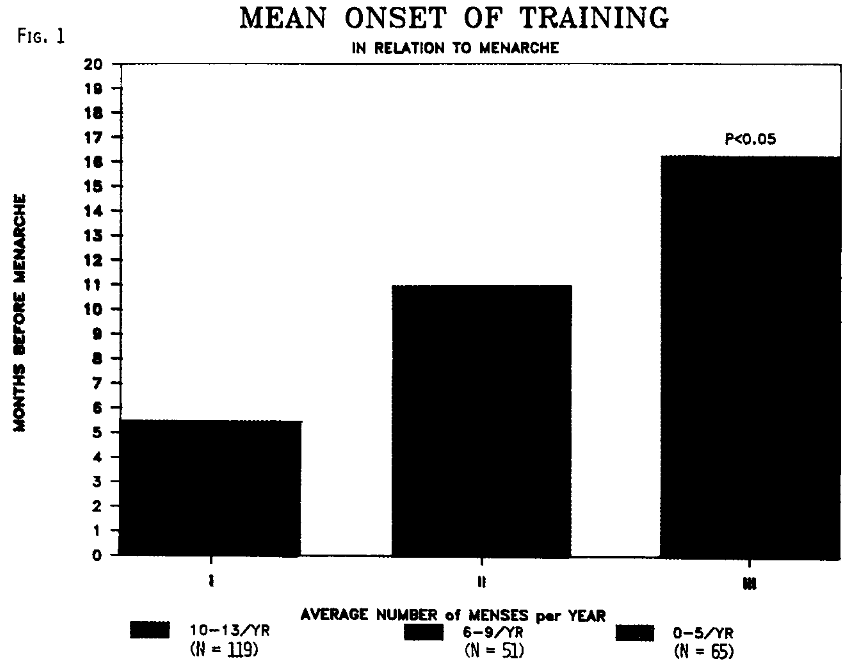

Figure 1. Mean onset of training for regular, irregular, very irregular menstrual groups.

TABLE 2
Stress fracture prevalence according to race

Subject group	No.	% With stress fractures
All	240	37
Caucasians	220	39
Blacks	12	17
Others	8	38

0.007). Tables 3 and 4 show that, in addition to having had more stress fractures, runners with menstrual irregularities had more multiple stress fractures. This trend is most evident when amenorrheal runners are compared with the other three groups ($P < 0.05$). Table 4 shows that the amenorrheal group was the only one to have a runner who had six stress fractures and that out of 120 regular runners, none had more than three stress fractures. There was no difference in frequency of soft tissue injury among the four groups. Of the non-stress fracture injuries, shin splints (posterior tibial tendinitis and periostitis) and sprained ankles were the most common complaints.

Women who had used oral contraceptives for at least 1 year and runners who had never used oral contraceptives were analyzed for stress fracture frequency over the previous 2 years. Runners using oral contraceptives had significantly fewer stress fractures than nonusers (12% versus 29%), as shown in Figure 3.

Table 5 and Figure 4 show the anatomical sites of the distribution of stress fractures. The tibia (63%) was by far the most common site of injury. This is in agreement with most other surveys of stress fractures in runners.[32,33,37,47,48]

Finally, a striking relationship appears to exist between menstrual irregularity and prevalence of eating behavior disorders. Figure 5 shows that 47% of the amenorrheal runners had a history of eating behavior disorders such as anorexia and bulimia.

DISCUSSION

The results of our study are consistent with recent information concerning the effect of strenuous exercise on the menstrual cycle.[9,41] Exercise-induced oligomenorrhea and amenorrhea are common among female distance runners, and our finding that 50% of the runners reported having a history of menstrual irregularities accords with the results of other studies.[12,43] However, not all 120 runners with menstrual irregularities in our study were assuredly athletically induced as 23 had eating disorders. In addition, an equal number of cyclic runners, who may have been susceptible to menstrual irregularities, were using oral contraceptives. Prevalence rates from studies on amenorrhea vary according to the criteria used in classifying a runner's menstrual disruption as amenorrheal and with the particular group surveyed. Young competitive athletes have a higher incidence than older recreational joggers. Our sample of collegiate runners had a much higher prevalence that that in the general population of college students.[2,49]

We found menstrual irregularities to be associated with low body weight and high training mileage. Feicht et al.,[12] studying a similar sample of college track and cross country runners, reported that body weight did not appear to affect menstrual function but that training mileage and intensity could be an associated cause of menstrual dysfunction. Carlberg et al.,[6] using members of collegiate varsity track teams, and Lutter and Cushman,[29] using female marathon runners,

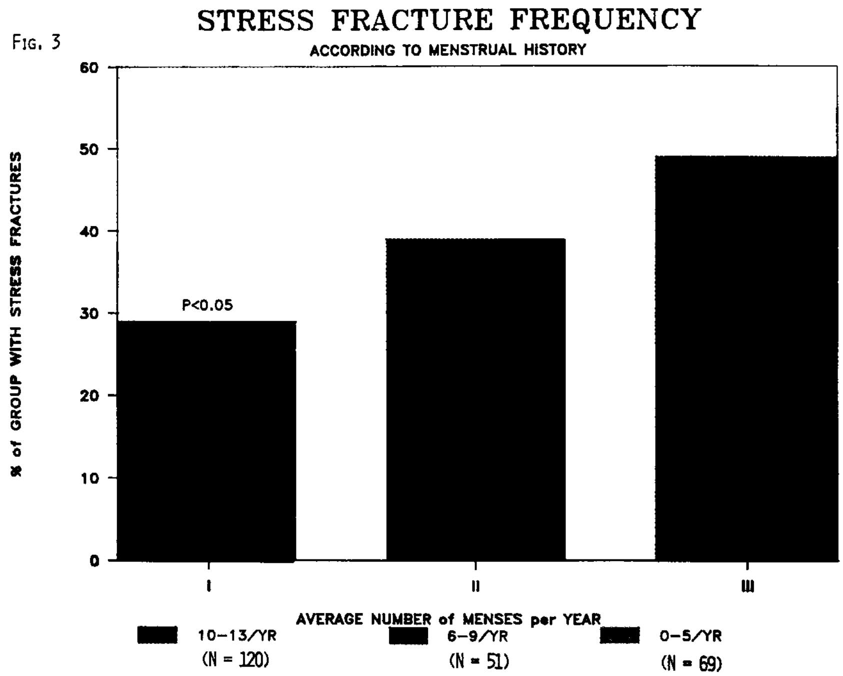

Figure 2. Prevalence of stress fractures according to menstrual history.

TABLE 3
Total no. of stress fractures per person according to menstrual history

Group	Ratio
Amenorreic	22/19 = 1.16[a]
1-5 Menses/yr	35/50 = 0.70
Irregular	32/51 = 0.63
Regular	54/120 = 0.45

[a] $P < 0.05$.

TABLE 4
No. of stress fractures in each athlete (%)

Group	1	2	3	4	5	6
Amenorrheic	60	10	10		10	10
1-5 Menses/yr	71	21	4		4	
Irregular	65	15	15	5		
Regular	60	26	14			

both reported that low body weight and high mileage may contribute to disrupted menstrual function in certain individuals with oligomenorrhea and amenorrhea. In the present study, the irregular runners actually weighed more than the regular ones; some runners with very high mileage and low body weight were regular and some runners with normal body weight and moderate training mileage were amenorrheal. Although we did not examine fat mass, other studies[11,13,26,28,30,38,42] have shown that a critical fat mass, as suggested by Frisch and McArthur,[15] is an unreliable indicator of menstrual function as well.

Frisch et al.[14] and Warren[51] proposed that women who initiate training before menarche may have delayed menarche and be at increased risk for secondary amenorrhea. Marcus et al.[30] supported this hypothesis. They found that amenorrheal runners initiated training within 1 year of menarche, whereas the cyclic women began training approximately 5 years later. In our study, all three groups of runners averaged onset of training before menarche, but the very irregular runners started significantly ($P < 0.05$) earlier (16 months before menarche) than the regular runners (6 months before menarche). We suggest that not only does premenarchal training increase the risk of delayed menarche and subsequent secondary amenorrhea, but that this risk increases with earlier premenarchal training.

The overall prevalence of stress fractures in our study was 37%, a high percentage for an approximately 7 year period of running. We suspected this number to be even higher due to competitive training in the group sampled, increased use of bone scan as a more sensitive diagnostic tool, sampling and nonsampling errors, and female-dependent anthropometric variations in gait.[46] Women in the military have been reported to have as high as 10 times the incidence of stress fractures as men in the same training environment.[4,39,44] Hulkko and Orava,[20] Kannus et al.,[22] and Michelli[35] found that women sustained a higher rate of stress fractures than men in association with running. Markey[31] suggested that, because they are shorter than men, women are overstressed at equal distances. In the present study, we found no difference in frequency of stress fractures related to difference in height; within our group of runners, those with and without stress fractures were nearly identical in height.

In a study of 295 military trainees, Brudvig et al.[4] reported a much lower incidence of stress fractures in black women than in Caucasians. Black women are also less susceptible to osteoporosis than Caucasian women, and this may be related to a greater bone mass in black populations.[7] We found that Caucasians had over twice as many stress frac-

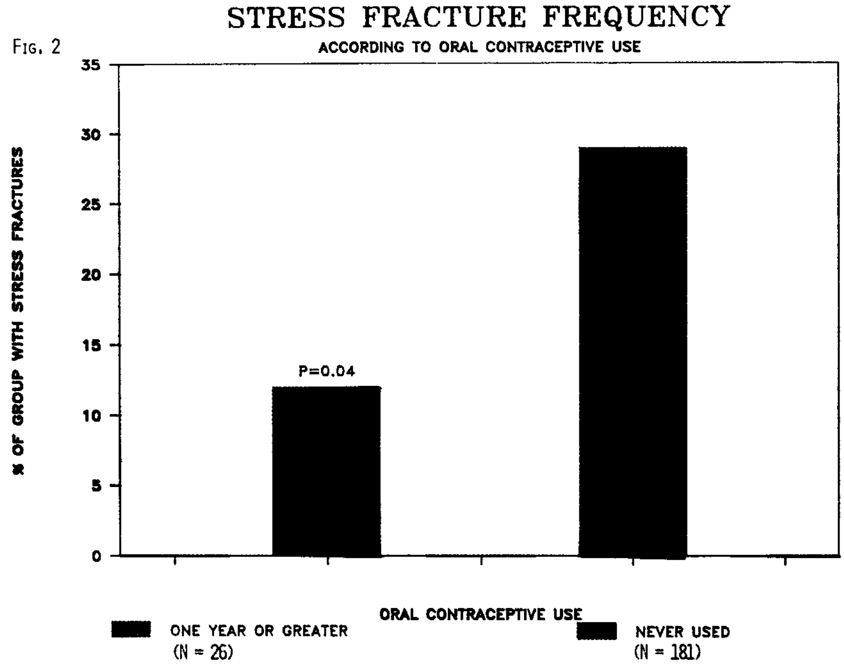

Figure 3. Effect of oral contraceptive use on stress fracture frequency.

TABLE 5
Distribution of stress fractures[a]

Tibia (63%)	
Proximal	25%
Mid	28%
Distal	48%
Metatarsals (21%)	
Second	52%
Third	24%
Fourth	14%
First	10%
Fibula (9%)	
Distal	100%
Femur (4%)	
Calcaneous	
Pelvis	<4%
Tarsal	

[a] The exact location in every bone was not specified for each stress fracture.

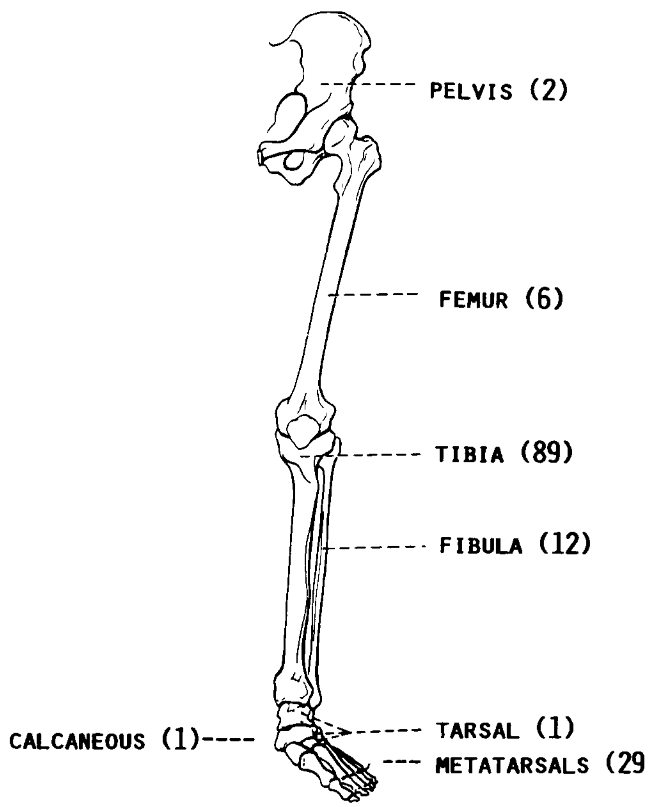

Figure 4. Distribution of stress fractures by anatomical sites.

tures as blacks. Unfortunately, only 12 blacks were surveyed, so these results are not statistically significant.

Hypoestrogenic amenorrhea is associated with decreased bone density. The increase in stress fracture frequency correlated with increasing menstrual irregularity suggests that relatively small changes in menstrual regularity affect the maintenance of bone composition through a decrease in estrogen. Several studies using small populations of runners have noted a high frequency of stress fractures in amenorrheal runners when compared with eumenorrheal runners.[25,30] Similar findings were reported by Warren et al.[52] for a group of ballet dancers. Our study suggests that, in addition to amenorrhea, a sustained history of oligomenorrhea may also predispose to subsequent stress fractures. A recent study by Lloyd and associates[27] is consistent with our findings. They compared cyclic collegiate athletes with ath-

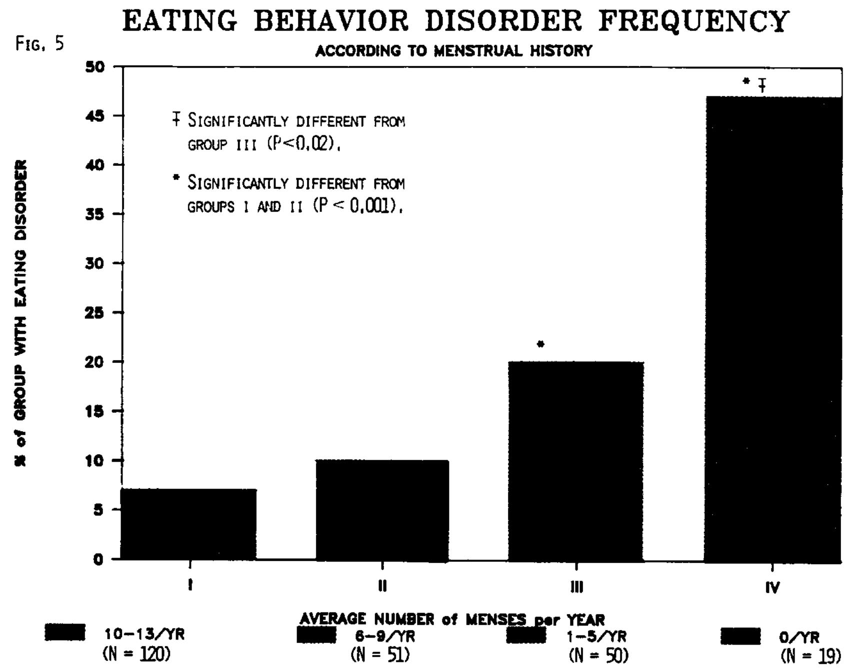

Figure 5. Effect of eating behavior disorders and menstrual irregularity.

letes whose menstrual history was either irregular or absent and found nearly four times the frequency of stress fractures in the irregular or amenorrheal women.

One particular amenorrheal runner in our survey who has sustained six stress fractures (one for every year of training) expressed great distress at her situation and questioned what she should do. Our results suggest that estrogen, through the use of oral contraceptives, may be a protection against stress fractures. More detailed studies in this area are needed. It is interesting to question the mechanism of the decreased bone mineral content in these hypoestrogenic athletes found in other studies when one considers that postmenopausal women with lower levels of estrogen have reported increases in bone mineral density with exercise.[1,23,24,45]

It should be noted that the alarmingly high prevalence of eating behavior disorders in the present study was obtained by simply asking respondents whether or not they had a problem. Although Diagnostic and Statistical Manual of Mental Disorders-III criteria for evaluation were not met, a number of runners described in detail their problem or the care they received. One athlete, without any problems, supplied the following information, "I have been involved with distance running for 8 years and see a lot of female athletes with eating disorders and excess injury, particularly stress fractures. These girls seem to be obsessed with their weight both by running a lot (over 50 miles per week) and not eating." In a recent psychiatric study, Gadpaille et al.[17] found 8 of 13 amenorrheic runners interviewed to have eating disorders. The incidence of bulimia in groups of college aged females has been studied, with percentages varying from 4% to 13%.[40] The incidence of anorexia has been surveyed in professional ballet dancers, and results range from 5% to 20%, depending on the competitiveness of the company.[50] Because of the significance of our findings, we encourage more valid studies of eating behavior in competitive female distance runners, possibly using the eating attitude test, or EAT-26, a 26-item test used as an objective measure of the symptoms of anorexia nervosa.[18]

Amenorrheal runners who have an eating disorder may be at even greater risk for stress fractures. Markey[31] suggests that persons with nutritional deficiencies may not have the building blocks for the osteoblast to create new bone. In our study, six of nine runners who were amenorrheal and admitted to an eating disorder had stress fractures. Of the 26 runners who had used oral contraceptives for over 1 year, 2 had eating disorders and 1 of those 2 had a stress fracture.

We believe that the disorder of oligomenorrhea in young women will become more and more prevalent as more and more young women become involved in athletics. We suggest that the physician and the female runner should be aware of the following risk factors associated with stress fractures:

1) Training errors: increasing mileage too rapidly.

2) Surface and topography: running on poor surfaces or too much hill running.

3) Poor physical fitness: training resumed after significant inactivity or injury.

4) Biomechanical factors: pronated feet, forefoot varus, subtalar varus, tibial varus, and leg length discrepancies.

5) Running gait: altered through muscular fatigue or minor injury.

6) Poor shoes.

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DISCUSSION

Herbert A. Haupt, MD, *St. Louis, Missouri:* The authors are to be commended for an excellent presentation of information on an area that we all need to know more about, the problems associated uniquely with the female athlete. However, as we evaluate this paper it is very important to always keep in mind that this is a questionnaire study and is contingent upon 241 responses to 1,000 questionnaires sent out. Some bias in the data must be assumed. The athletes who have an interest or concern in the subject of a questionnaire are more likely to respond to that questionnaire. This may explain the relatively high incidence of stress fractures in their whole study population at 37%.

Beyond this, there are some very salient points that should be emphasized. These are the strong association of stress fractures in female runners who have irregular menstruation. Secondly, the rate of stress fractures may be lessened in these athletes if they have taken birth control pills for more than 1 year. Thirdly, there appears to be a strong association of eating disorders in female runners with irregular menses. And finally, premenarche training is associated with later irregular menstruation in the female athlete.

I have only one question for the authors, and that is whether they noticed any change in the menstrual cycles of these athletes when they decreased the training intensity or discontinued training all together.

Authors' Reply: No, we have not followed up this study group, although we can do this in the future. Previous studies have associated an increase in weight and a decrease in training mileage with a resumption of menses.

As the actual number of athletes in each of the 116 collegiate women's track programs was not known to us, we included 10 questionnaires in most of our mailing to these coaches. Some of these programs had less than 10 athletes; thus, all 10 questionnaires were not distributed. Some other coaches informed us later that the questionnaires were not distributed as most of the athletes had already left the campus on summer vacation. This suggests that the actual response rate was much higher than 24% (241 out of 1,000 originally mailed).