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ESTUDO LONGITUDINAL DE FATORES QUE AFETAM O RISCO DE FRATURA POR ESTRESSE EM DUAS POPULAÇÕES DE COLEGIAIS DO SEXO FEMININO

LONGITUDINAL STUDY OF FACTORS AFFECTING STRESS FRACTURE RISK IN TWO DISTINCT COLLEGE FEMALE POPULATIONS

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RESUMO

Objetivos: As fraturas por estresse causam significante morbidade em mulheres. Diferenças no nível de atividades, valores hormonais e densidade mineral óssea (BMD) afetam diferentemente as taxas de fraturas por estresse. Os autores hipotetizaram que mulheres de um Colégio militar terão maior nível de atividade do que mulheres em colégios com um ambiente mais flexível, que correlacionará com mudanças nos valores hormonais, menor (BMD) e mais fraturas por estresse.

Método: Nesse estudo prospectivo comparativo, 63 mulheres de duas Instituições (The Citadel: The Military College Of South Carolina And The College Of Cherleston) relataram detalhadamente suas atividades, dieta e lesões através de um questionário e tiveram sua BMB e os valores hormonais séricos medidos num intervalo de 06 meses, por um período de 2 anos; 38 sujeitos completaram o estudo. A análise estatística examinou diferenças e mudanças ao longo do tempo entre as duas amostras.

Resultados: Uma fratura por estresse ocorreu em cada Instituição. As mulheres do Citadel tiveram maiores níveis de atividade, que as mulheres do College of Charleston no longo do estudo. As mulheres do Citadel tiveram menor nível de hormônio folículo estimulante, maior 17 Beta-Estradiol aos 24 meses e maior BMD na extremidade proximal femoral aos 18 meses da investigação ($p < 0,05$).

Conclusões: Os valores séricos hormonais podem ser um indicador mais sensível de resposta ao nível da atividade física que o BMD dentro da amostra e duração deste estudo. Outros estudos são necessários para definir esta complexa interrelação.

Palavras chaves: Fratura por estresse; Fator de risco; Mulheres; BMD.

ABSTRACT

Objectives: Stress fractures cause significant morbidity in females. Differences in activity levels, hormone values, and bone mineral density (BMD) affect different rates of stress fracture. The authors hypothesized that females at a military college will have greater activity levels than females in a flexible college environment, which will correlate with greater changes in hormone values, lower BMD, and more stress fractures.

Methods: In this prospective comparative study 63 females from two institutions (The Citadel: The Military College of South Carolina and the College of Charleston) self-reported on a detailed activity, diet, and injury questionnaire and had BMD and serum hormone values measured at 6-month intervals for a two year period; 38 completed the study. Statistical analysis was designed to examine differences and changes over time between the two samples.

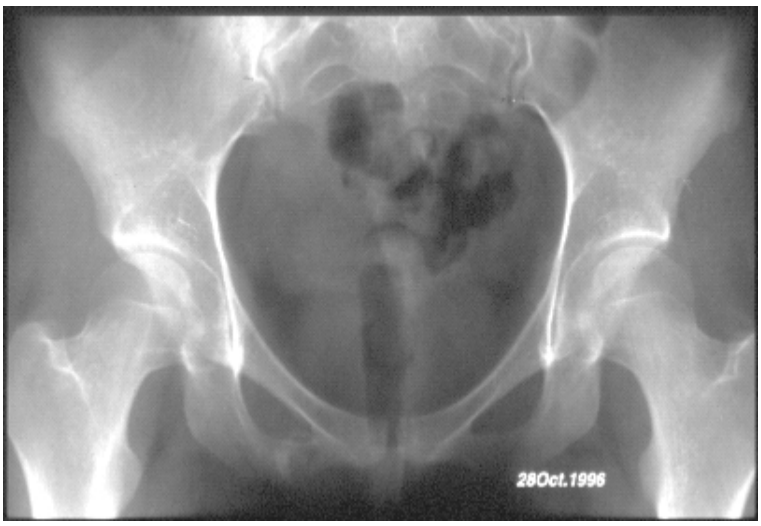
Results: One stress fracture occurred in each institution. Citadel females had higher activity levels than females at the College of Charleston throughout the study. Citadel females had lower follicle stimulating hormone levels at 24 months, greater 17 beta-estradiol at 24 months, and greater proximal femoral BMD at eighteen months ($p < .05$). **Conclusions**: Serum hormone values may be a more sensitive indicator of responses to activity level than BMD within the subject selection and duration of this study. Further studies are necessary to fully define this complicated interrelationship.

Keywords: Stress fracture, risk factors, females, BMD.

Running Head: Female Stress Fracture Risks.

FIGURE 1

AP pelvis radiograph showing a healing stress fracture of the right inferior pubic ramus.



Introduction

Stress fracture results from multiple repetitive sub-threshold loads upon normal bone, which overwhelms the body's ability to repair the microtrauma. *The time frame for stress fracture may be short due to a bolus of intense activity or may occur over a prolonged period of time and therefore be considered chronic in nature.* Stress fractures are overuse injuries which can occur in bone through increased repetition (fatigue fractures) or as a result of weakened bone (insufficiency fractures). Endurance athletes (Ardevol and Henriquez, 2002, Barrow and Saha, 1988, Milgrom et al., 2003), military recruits (Freidel et al., 1997, Protzmann, 1979, Protzmann and Griffis, 1977, Williams, 2002) and women are at particularly high risk (Fines and Stacy, 2002, Oza and Elgazzar, 2003, Verma and Sherman, 2001, Warren et al., 2002).Other factors shown to increase stress fracture risk include Caucasian race, menstrual irregularities, hormonal abnormalities, low bone mineral density (BMD), excessive training or abrupt increases in training, and abnormalities in lower extremity alignment (Beck el al., 1996, Bennell et al., 1998, Bijur et al., 1997, Brudvig et al., 1983, Huang et al., 1999, Ilahi and Kohl, 1998).

Originally described by Breithaupt, a Prussian military surgeon (Breithaupt, 1855), research into causes of stress fracture originally focused on military populations (Gefen, 2002, Ross and Allsopp, 2003), but has recently expanded to include endurance athletes and female populations (Barfield et al., 2003, Jones et al., 2002, McBryde and Barfield, 2002, Peiro et al., 2003). Integration of females into male training regimens has also been *associated* as a cause of the increased rate of stress fractures seen in women in military training programs. *The standard stride length for male Army recruits is 76 cm. Because female stride length is typically shorter, over striding to stay in step may contribute to the documented increased risk of pubic ramus stress fracture* (Hill et al., 1996). In 1976, female cadets were first admitted to the Unites States Military Academy at West Point. These female cadets suffered ten times the number of stress fractures of their male counterparts (Protzman, 1979, Protzman and Griffis, 1977). The first female cadet was admitted to The Citadel (The Military College of South Carolina) in 1995. She resigned within one month. In 1996, four females were admitted, two of whom resigned within four months due in part to pelvic stress fractures (**Figure 1.)** The current study was initiated to identify modifiable factors that might place females in a military college at higher risk for stress fracture than their counterparts in a traditional college environment by prospectively measuring variables known to correlate with increased stress fracture risk. We hypothesized that Citadel females would be more active and that this activity would create a measurable cascade of endocrine changes that would negatively affect BMD, in turn increasing stress fracture risk and subsequent bony injury.

Methods

This study was initiated in August 1998 and was completed in May 2000. Following approval of the study by the Institutional Review Boards of the sponsoring institutions, sixty-three female volunteers were enrolled; 42 at The Citadel (Cit) and 21 at the College of Charleston (CofC). The mean age of the subjects was Cit-18.8 years; CofC 20.6 years. All subjects were active undergraduates and the only exclusionary criterion was pregnancy. Subjects were recruited through written and oral announcements in physical education classes at the two institutions. BMD testing and blood draws were conducted through the General Clinical Research Center (GCRC) at Medical University of South Carolina (MUSC). A pregnancy test was executed at baseline and at each six-month interval through the study prior to blood draws and BMD testing. *All testing of subjects was conducted between 12:00-4:00 pm., therefore reducing the risk of pulsatile hormone variations between the two samples.* All participants received $50 in compensation at each time of blood draws and BMD testing. All testing was conducted during the proliferatory phase (5-7 days following the menstrual cycle) of the menstrual cycle. This is the period of time during the female cycle when hormones are least likely to fluctuate. Thirty-eight completed the entire two-year course of the study. Twenty-seven females from Cit completed the study and eleven from CofC completed the study. All participants self-reported on a detailed questionnaire prior to the start of the study that reflected baseline values in the variables tested. The questionnaire was an instrument devised specifically for study participants. They reported again at three-month intervals for two years. Information in the questionnaire included demographics, menstrual history during the period of the study (age of menarche was not assessed), history of eating disorders or prior stress fractures, estimated calcium intake, including supplementation, and activity level (number of days running per week, miles run/week, and days of weight lifting/week.). Oral or other contraceptive use was not quantified. Activities other than those identified above were not quantified during the study period. Physical activity in the three months prior to enrollment in the study was assessed as a baseline measurement. A random sample of subjects in both groups reported on food intake through a standardized GCRC Dietary Calcium Source Questionnaire. From the questionnaire, based on serving size, we were able to estimate calcium intake in terms of mg Ca/Day.

In addition, serum hormone values were measured at baseline and at six-month intervals for two years. Blood tests included 17- beta estradiol (EST), follicle stimulating hormone (FSH), luteinizing hormone (LH), and sex-hormone binding globulin (SHBG.) All serum hormone values were measured during the proliferative phase of the menstrual cycle to minimize the confounding effects of cyclic hormone level fluctuations. Assay kits for FSH, LH and 17 betaestradiol were purchased from Bayer, and the direct chemiluminescent signals were measured using the ADVIA Centaur System (Bayer).

The luteinizing hormone (LH) assay is a two-site sandwich immunoassay using direct chemiluminometric technology, which uses constant amounts of two antibodies that have specificity for the intact LH molecule. The first antibody, in the Lite Reagent, is a monoclonal mouse anti- LH antibody labeled with acridinium ester. The second antibody, in the Solid Phase, is a monoclonal mouse anti-LH antibody, which is covalently coupled to paramagnetic particles. Serum is collected from serum separate tube and used for the assay. The system automatically performs the following steps:

- dispenses 50ul of serum sample into a cuvette.
- dispenses 100ul of Lite Reagent and incubates for 5.0 minutes at 37°C
- separates, aspirates, and washes the cuvettes with reagent water
- dispenses 300ul each of Acid Reagent and Base Reagent to initiate the chemiluminescent reaction.

A direct relationship exists between the amount of LH present in the patient sample and the amount of relative light units (RLUs) detected by the system.

Follicle-Stimulating Hormone (FSH) utilizes the assay is the same two-site sandwich immunoassay described above.

17 betaestradiol are assays in a competitive immunoassay using direct chemiluminescent technology, that derives its name from the coupling of the estradiol immunogen at the specificity-enhancing sixth position, allowing for the production of a highly specific antibody. This 17b-estradiol-6-antibody allows the ADVIA Centaur Estradiol-6 assay to be used across a wide range of applications. Estradiol in the patient sample competes with acridinium ester-labeled estradiol in the Lite Reagent for a limited amount of rabbit anti-estradiol antibody in the Antibody Reagent. Rabbit anti-estradiol is captured by mouse anti-rabbit IgG, which is coupled to pragmagnetic particles in the Solid Phase. Serum is collected from serum separate tube and used for the assay.

The system automatically performs the following steps:

- dispenses 50ul of sample and 50ul of Antibody Reagent into a cuvette and incubates for 5.5 minutes at 37°C
- dispenses 50ul of Lite Reagent and 250ul of Solid Phase and incubates for 5.0 minutes at 37°C
- separates, aspirates, and washes the cuvettes with reagent water
- dispenses 300ul each of Acid Reagent and Base Reagent to initiate the chemiluminescent reaction

A inverse relationship exists between the amount of estradiol present in the patient sample and the amount of relative light units (RLUs) detected by the system.

Sex hormone binding globulin (SHBG) was assayed at Esoterix Inc (Calabasas Hills, CA). The monoclonal antibody made for human SHBG is coated onto plastic beads. The sample and SHBG monoclonal antibody is incubated overnight with the antibody coated bead. SHBG is the sample or standard form. The bead-antibody-SHBG-antibody sandwiches, attaching a label to the beads. The beads are washed to remove unbound label and counted for the SHBG score.

Measurements of BMD were taken at four locations in the left hip and four lumbar vertebral levels using dual energy x-ray absorptiometry (DEXA) (Hologic 1000, Waltham, MA) by a single technician. These sites were chosen for their high metabolic activity (Nevill et al., 2003; Nutil et al., 1993). Bone mineral density (BMD) was measured at six-month intervals for two years at the time of the blood draw. During the second 12-months of the study, body composition was also measured using DEXA at the time of the BMD measurements. DEXA provides one of the most accurate and reproducible measurements of body composition in addition to measuring BMD. Body composition compartments measured with the DEXA included each arm and leg, trunk and head. The coefficient of variation, which is a generic indicator of the population variance was $<1.0\%$, indicating small variability between measurements.

Comparisons between the 2 groups at any specific time point were made using t-tests. Statistical analyses across multiple time points were performed using repeated measures generalized estimating equations (Diggle et al., 1994) to account for the fact that subjects' measures over time were not independent from one another, and an auto-regressive (type 1) covariance structure was used. This structure assumes that measures from successive time points are

TABLE 1

SUBJECT DEMOGRAPHICS

College	Age	Height (cm)	Body Mass (kg)	BMI
The Citadel	18.8 years	162.3	61.7	22.2
College of Charleston	20.6 years	167.2	64.4	22.4
p values	0.001	0.54	0.79	0.93

TABLE 2

SERUM HORMONE VALUES

College	FSH	LH	Estradiol	SHBG
The Citadel	4.38 MIU/mL	4.44 MIU/mL	56.71 pg/mL	76.43 μg/mL
College of Charleston	5.16 MIU/mL	6.53 MIU/mL	61.95 pg/mL	84.6 μg/mL
p values	0.24	0.02	0.63	0.84

TABLE 3

BODY FAT AND BMD VALUES

College	% Body Fat	Lumbar BMD	Hip BMD
The Citadel	24.8%	1.05 g/cm^2	1.02 g/cm^2
College of Charleston	28.8%	1.03 g/cm^2	0.96 g/cm^2
p value	0.02	0.79	0.08

TABLE 4

SUBJECT DEMOGRAPHIC

VARIABLE	The Citadel	College of Charleston
LH Baseline	4.44 (4.34) MIU/mL	6.53 (4.04) MIU/mL
FSH 6-Months	4.42 (1.56) MIU/mL	5.22 (1.47) MIU/mL
FSH 24-Months	4.06 (1.71) MIU/mL	5.92 (2.14) MIU/mL

TABLE 5

SUBJECT DEMOGRAPHICS

VARIABLE	The Citadel	College of Charleston
Est 12-Months	66.17 (52.4) pg/mL	45.5 (23.16) pg/mL
Est 18-Months	85.76 (75.5) pg/mL	53.0 (48.7) pg/mL
Est 24-Months	101.04 (114.46) pg/mL	43.2 (39.2) pg/mL

FIGURE 2

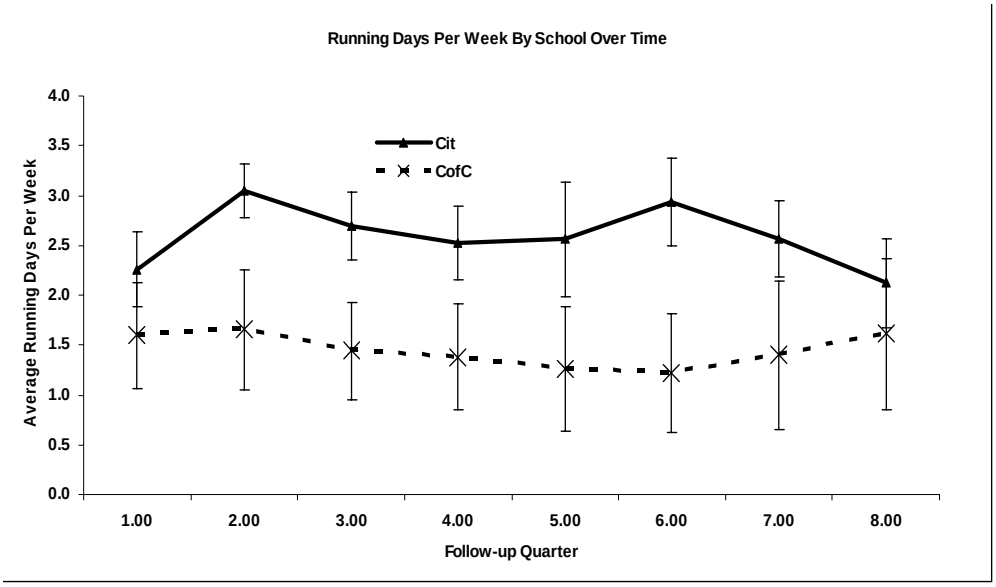


FIGURE 3

FIGURE 5

LUMBAR SPINE PMD

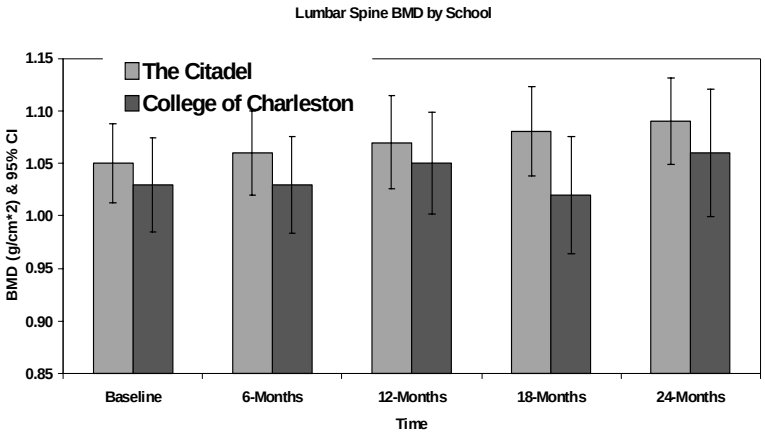
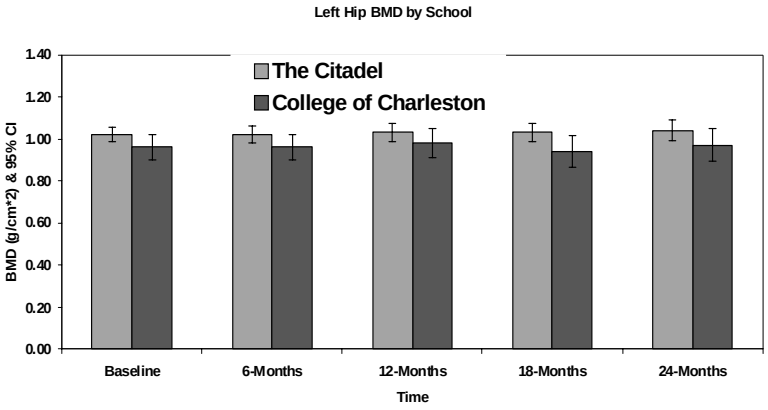


FIGURE 6

LEFT HIP PMD



more strongly correlated than measures from distant time points..

Our hypotheses were that:

- Citadel females would be more active in the variables measured
- BMD would be lower in Citadel females compared with CofC females because of the intensity of physical activity
- The serum values measured would negatively affect BMD among Citadel females, lowering the total BMD.

Results

There were no statistical differences between the groups with regard to height, body mass or BMI. The study population from The Citadel was significantly ($p < 0.001$) younger than that from the College of Charleston. See Table 1 for baseline values and p values.

Tables 2 and 3 show the baseline variables measured with z scores and p values.

There were significant differences between the two groups with respect to LH and % body fat.

As displayed in **Figure 2** Cit females ran significantly more days/week ($p < 0.001$) than CofC females at each time point, with peaks at quarters two and six, which corresponded to the initiation of school for freshmen and sophomore years. In both schools the number of running days/week declined between the first and second years of the study, although the differences were not statistically

significant (Cit fresh 2.76 days/wk; Cit sophomores 2.54 days/wk/ CofC freshmen 1.49 days/wk; CofC sophomores 1.41 days/wk). Across all eight time points Cit females had greater numbers of running miles/ week ($p = 0.03$) compared with CofC as displayed in **Figure 3** with peaks at quarters two and six. **Figure 4** shows that Cit females weight trained more days/week through the first six quarters, although the there were no differences.. Cit freshmen weight trained 1.33 days/ wk compared with 1.18 days/wk for CofC freshmen. Cit sophomores weight trained 1.37 days/wk compared with 1.4 days/wk for CofC sophomores.

Statistically significant differences were found between the two groups for two different hormone values. FSH was significantly decreased in Cit cadets at 24-months ($p = 0.008$) where the average value was 4.06 MIU/ml vs. 5.92 MIU/ml in CofC females. Differences in FSH were noted at 6 months ($p = 0.07$), but was not significant.. LH showed differences at baseline, but did not achieve statistical significance ($p = 0.07$). Values showing trends towards statistical significance are shown in table 4.

At 24-months, EST levels were higher in Cit females (101.4 pg/ml vs. 42.3 pg/ml in CofC females $p = 0.03$.) EST differences were seen at 12 ($p = 0.07$) and 18 months ($p = 0.09$), however statistical significance was not achieved. **Table 5** shows the means and standard deviations for EST by group across time.

When the EST/SHBG ratio was examined, at each 6-month time interval after baseline, Cit had higher ratios. Differences were not statistically different.

Females did not present any unusual menstrual disturbances and contraceptive use was not assessed.

BMD values at all time points and locations measured were higher for Citadel females than for their College of Charleston counterparts, although these values were not statistically significant at each time point. **Figures 5 and 6** (95% CI) show BMD measurements for the two groups from baseline to 24-months. Lumbar BMD (LBMD) at baseline was not statistically different ($p < 0.56$). At 18 months LBMD showed a mild trend Cit-1.08 g/cm^2; CofC-1.02 g/cm^2 ($p = 0.11$). Hip BMD (HBMD) at baseline was statistically different Cit-1.02; CofC 0.96 g/cm^2 ($p < 0.05$). HBMD continued to be statistically different at 18 months (Cit-1.04 g/cm^2; CofC-0.94 g/ cm^2 ($p = 0.02$). At the hip, differences occurred at 6-months ($p = 0.07$) and 24-months ($p = 0.11$), but statistical significance was not seen.

Body composition differences were statistically different ($p < 0.02$). Cit females had a mean 24.8% body fat. CofC females had a mean of 28.8% body fat. Four females in each group had BMI values below 19 kg/m^2.

Random sampling of levels of calcium intake from individuals within the two groups led to average calcium levels which were below the USRDA (1200 mg/day) for each group. Average daily calcium intake in Cit females was 762 mg/day and was 800 mg/day in females at CofC.

One stress fracture occurred at each institution. The stress fractures were diagnosed and recorded by the sports medicine physicians at each institution who were not members of the research unit conducting the project. Radiographic follow-up and bone scans may have been part of the standard of care for the two females, but the researchers in this study were not privy to that information.

DISCUSSION

The goals of our study were to examine variables we believed, based on our observations and a review of the literature, that could place females in a military college at higher risk for stress fracture when compared to counterparts in a more traditional college environment. We prospectively measuring variables known to correlate with increased stress fracture risk. We hypothesized that Citadel females would be more active and that this activity would create a measurable cascade of changes that would negatively affect BMD, in turn increasing stress fracture risk and subsequent bony injury.

The results of our study support our hypothesis that females at Cit were more active in running and weight training compared with CofC females, although differences between freshmen and second year students were not statistically significant. Although age was statistically different the authors do not believe age differences affected the variables measured. The differences in activity levels were statistically significant for running, but not for weight training. Despite these differences and a history of significant stress fracture rates at Cit, during the period of our study, no significant increase in these rates was observed. The year prior to the initiation of data collection two of the four female freshman cadets resigned with inferior pubic rami stress fractures. Potential reasons for the limited number of stress fractures seen during the study period include relatively small sample sizes and a likely increase in physical training prior to arriving at The Citadel by the incoming female freshman class in 1998. The number of athletes in the study was not quantified, however it should be noted that in both samples there were females who participated on the respect sport teams and the percentages in each group were similar. A study published in 1997 compared male and female cadets at the US Military Academy at West Point during their 6-week basic training period prior to the initiation of classes found that women had 2.5

times the rate of hospitalization compared with men and suffered significantly more stress reactions and stress fractures compared with men. Fifteen percent of the women had one or more stress fractures or reactions, while 2.3% of men have similar injury patterns (Bijur et al., 1997). The rate of subject attrition decreased the power of our study, however it was not exceptionally high for a prospective study of this length. Approximately 64% of the subjects from Cit completed the study while 52% of the CofC subjects completed the study. As far we the researchers know, no subject dropped from the study due to injury, other than the two with stress fractures. The majority of subjects in both groups dropped from the study because they dropped out of college for a variety of reasons. These factors combined with a more reasonable level of physical expectation by the leadership at The Citadel as a result of the previous year's fractures may have decreased the number of stress fractures.

Citadel females had leaner body composition measures, which may have contributed to some of the serum variable differences.

It is both puzzling and difficult to interpret why LH showed a trend at baseline with Cit being lower than CofC. One possible complicating factor for serum hormone measurement in this study, or any study involving women, is the cyclic nature of the release of these molecules. Although every attempt possible was made to measure values at the same time during the menstrual cycle, differences in several days can make a large difference in values.

Despite these difficulties, several observations regarding the results obtained deserve attention. Statistically lower estrogen values were seen in CofC C females at 24 months with similar trends towards lower values at 12 and 18 months. Between 40-50 pg/ml of estrogen are considered necessary to prevent BMD loss, and College of Charleston females were below this level. This combined with a lower EST/SHBG ratio may have contributed to lower BMD at the lumbar spine and left hip among CofC subjects compared with Cit. Higher ratios of EST/SHBG are indicative of more EST availability for metabolic work. Pooled Pearson correlation of hormone changes yielded limited value to our findings.

When EST levels are low, LH release is accelerated to increase estrogen production, thereby increasing bone metabolism through an increase in circulating endogenous estradiol levels.. Among our subjects the baseline EST level was lower among Cit subjects (56.17 pg/mL) compared with CofC subjects (61.95 pg/mL). High activity levels, seen in the Cit subjects prior to the start of the study (late summer), in preparation for the beginning of the "fourth class system (plebe system)" could have signaled the pituitary gland to increase LH production, but this was not seen in our study group. The FSH values at 6-months and 24-months were both at the low end of the normal range (3-20 MIU/mL) in both groups. Typically leaner more active females have higher FSH levels, although since both groups in our study were at the low end of normal, the statistical differences may have been a function of different numbers in each group and that the groups were more homogeneous than hypothesized in the genesis of the study. We chose not to select study participants based on activity levels. We therefore, included both varsity athletes and relatively sedentary individuals from each institution. This may have resulted in decreased differences between the groups.

Baseline BMD at the left hip showed statistical differences ($p < 0.05$) and at each serial point other than 12-months there was a trend or statistical difference. Unfortunately, the authors do not have BMD data on the two females who resigned the year before this study was initiated, however it is clear from the values seen in the Cit females (Lumbar BMD-1.05 g/cm^2; Hip BMD-1.02 g/cm^2)at the start of the study that they had higher BMD values than CofC females (Lumbar BMD-1.03 g/cm^2; Hip BMD- 0.96 g/cm^2)which likely created a prophylactic effect. These greater values may be a function of a higher number of participants at Cit or it may have been due to increased training prior to starting the fall semester**.** At each time point across the 24-months Cit females had higher BMD than CofC females. Each group had average BMD values that fell within their age-adjusted normal ranges. At the left hip CofC females never reached 1.0 g/cm^2. In addition to the possible reasons for the minimal detected differences noted above, it has recently been suggested that small changes in bone volume and geometry stimulated by exercise that are only minimally detectable by DEXA if at all, can yield measurable protective effects on bone (Rubin et al., 2001, Rubin and Lanyon, 1984, Schaffler et al., 1990, Turner and Robling, 2003). One explanation is that small levels of localized bone formation on medial and lateral cortices where bone stress and strain is greatest bolster the bony geometry, thereby decreasing fracture risk. Further, bone cells are sensitive to fluid shear stress and respond by elevating intracellular calcium, and paracrine/autocrine secretion of growth factors leading to bone matrix protein stimulaton. The fact that Cit females were optimally dynamically active may have contributed to findings of greater BMD at each time point. This could explain the finding that the group with the significantly higher running level in fact had higher BMD at all points measured.

Both schools were low in calcium intake. Cit was at 762 mg/day. CofC was at 800 mg/day. The RDA for calcium intake, through food intake and supplements is 1200 mg/day. Despite these

deficiencies, lack of calcium intake did not seriously affect BMD in either group. This may be due to underreported intake of foods and/or supplements in each group. Alternatively, low calcium intake, when combined with appropriate amounts of exercise when combined with a multitude of other variables among these subjects may not have adversely affected BMD and stress fracture rates in this sample.

At the time we initiated our study Hill and colleagues published a paper in *JBJS* (Hill et al., 1996) reporting 11/12 pubic ramus stress fractures in females when integrated in military training with males. Their rationale was that women were overstriding to stay in step with the men while in formation, thereby increasing the eccentric muscle stress on the inferior pubic ramus by the adductors. The two females who resigned at Cit in 1997, the year prior to initiation of the current study, had stress fractures in the same bony location.

Based on our study sample Cit females have kept their activity level appropriate to maintain optimal hormone concentrations in the variables we examined and these levels have led to BMD levels consistent with healthy active lifestyle. We had one stress fracture in each group.

CONCLUSIONS

The findings of the present study demonstrate the complex interactions between activity level, serum hormone values, dietary intake, and bone mineral density. *The training volume among Cit subjects was not great enough in magnitude to result in the stress fracture incidence that we had anticipated. The differences between the groups was also not great enough to result in significant BMD differences, and among the Cit subjects the training load appeared to be prophalytic for BMD increases.* We anticipate that the long-term information obtained from this study will contribute to an understanding of and, therefore the prevention of repetitive stress bony injuries in females. Larger studies with more varied study populations may be necessary to further delineate these interactions.

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