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Effects of menstrual history on bone mineral density of female college gymnasts

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**EFFECTS OF MENSTRUAL HISTORY ON BONE MINERAL DENSITY
OF FEMALE COLLEGE GYMNASTS**

A Thesis

Presented to

The Faculty of the Department of Human Performance

San Jose State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts

by

Hawley Almstedt

August, 2001

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ABSTRACT

EFFECTS OF MENSTRUAL HISTORY ON BONE MINERAL DENSITY OF FEMALE COLLEGE GYMNASTS

by Hawley Almstedt

Bone mineral density is related to the amount of estrogen in the body and therefore, the number of menstrual cycles experienced by women. Many women who exercise intensely show changes in their menstrual cycle and may experience amenorrhea. This study examined the bone mineral density, measured via DEXA scans, and menstrual history, collected by questionnaire, of 15 female college gymnasts. Using a median split, a two way ANOVA showed significant ($p < 0.05$) differences in bone mineral density between athletes who had been menstruating 6 years or less ($n=8$) and athletes who had been menstruating for over 6 years ($n=7$). Fat mass, lean body mass, and years of gymnastics training were correlated with bone density at several regions of the body. The null hypothesis that menstrual history of female college gymnasts would not affect bone mineral density was rejected.

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Chapter 1

INTRODUCTION

Osteoporosis affects about 28 million Americans, 80% of which are women (National Osteoporosis Foundation, 2001). Along with cardiovascular disease and breast cancer, osteoporosis is one of the most serious diseases affecting women today.

According to McBean, Forgac, and Finn (1994), this disease leads to over 1.5 million fractures each year and incurs an annual medical cost of \$10 billion in the United States.

Prevention of osteoporosis lies in developing a high peak bone mass. Bone mass is developed from childhood and continues increasing until it reaches a peak somewhere between the ages of 30 and 35 years (McBean et al., 1994).

Peak bone mass is the major determinant of bone mass later in life. Individuals with a low peak bone mass have a greater risk of developing osteoporosis as they age. Exercising, at any age, is an important determinant of bone mass and decreases the risk of osteoporosis. Research has shown that between the ages of 10 years and 14 years, participation in sports and weight-bearing activities such as baseball, basketball, gymnastics, tennis, track, and soccer are especially beneficial in increasing peak bone mass (Slemenda, Miller, Hui, Reister, & Johnson, 1991). In persons who have already reached their peak bone mass, exercise may not increase bone mass, but it may help prevent loss (Taxel, 1998). Exercise also improves strength, stability, and balance to help reduce the risk of falls, which may lead to osteoporotic fractures (Taxel, 1998).

Research shows that bone mineral density is directly proportional to the number of menstrual cycles experienced by women (Drinkwater, Bruemner, & Chestnut, 1990).

Many women who exercise intensely or compete at an elite level of sport show alterations in their menstrual cycle and may experience amenorrhea (Nattiv, Agostini, Drinkwater, & Yeager, 1994). Particularly at risk are girls and women who participate in sports that emphasize low body weight or particular body shapes such as distance running, diving, figure skating, and gymnastics (Beals, Brey, & Gonyou, 1999).

Amenorrhea is a condition characterized by lack of menstruation and, therefore, low levels of circulating estrogen and progesterone. Estrogen, mechanical stress, and nutrition have a complex relationship in remodeling of bone tissue. A poor diet, absence of estrogen, and lack of mechanical stress can have a negative effect on bone growth (Snow-Harter, 1994). The exact mechanisms behind this phenomenon are unknown and still being investigated.

Rencken, Chestnut, and Drinkwater (1996) compared bone density at eight sites in 29 amenorrheic and 20 eumenorrheic athletes, most of whom were recreational runners. The average bone density for the amenorrheic athletes was significantly lower at all sites except the fibula. Seven of the amenorrheic women had bone density measures at the hip or spine characteristic of osteoporosis. Other studies indicate that college-aged gymnasts, despite a high prevalence of disordered eating and menstrual problems, have higher bone density than controls (Lindholm, Hagenfeldt, & Ringertz, 1995; Nichols et al., 1994).

Amenorrhea has also been associated with an increased risk of musculoskeletal injuries. In one study, female athletes of a university athletic department answered questionnaires concerning their exercise and menstrual history (Lloyd et al., 1986).

Researchers also reviewed medical records of the athletes. Lloyd et al. found that 24% of the women with irregular or absent menstrual cycles had incurred fractures compared to 9% of women with regular cycles. Thus, in addition to potential effects on bone mineral content, training-related menstrual irregularities may place young women at greater risk for musculoskeletal injuries.

Statement of Problem

The purpose of this study was to explore the following question.

1. How will menstrual history affect bone mineral densities in female collegiate gymnasts?

Null Hypothesis

The following null hypothesis was tested:

1. Menstrual history of female collegiate gymnasts will not affect bone mineral density.

Supplementary Research Questions

In addition, relationships between menstrual history, bone mineral density, training patterns, and body composition in female college gymnasts were examined. Oral contraceptive use involving estrogen supplementation was also examined.

Limitations

Limitations inherent in this investigation included the following:

1. A nonrandom sample was used which limits the generalizability of the results to those individuals who match the characteristics of the participants in this investigation.
2. A questionnaire was used to collect data concerning menstrual history and incidence of previous injury. The reliability of these data was dependent upon the participants' honesty and ability to recall the past.
3. Participants of this study may have been taking oral contraceptives or supplementing with estrogen, which would affect menstrual history and the outcome of the bone density measurements.
4. There was no measurement of circulating estrogen levels in the blood. It was assumed that menstrual status was directly related to estrogen concentrations in the body.
5. The DEXA software identified five ethnicity categories for persons being scanned. Therefore, participants were sorted according to ethnicities used in the software program: Asian, Black, Hispanic, White, and Other.

Delimitations

The delimitations placed on this study were:

1. This study was limited to female collegiate gymnasts who compete at the NCAA Division I level. Assumptions made from these conclusions will only apply to the specific population being examined.
2. The participants of this study were volunteers. Volunteers may differ in characteristics and training than gymnasts who did not volunteer.

3. Participants had the ability to compete at the NCAA Division I level. Perhaps some women have the ability to compete in gymnastics in college because they naturally have high bone density.
4. Nutritional status, calcium in the diet, and calorie intake and output all have a relationship with bone mineral density and menstrual status; however, these variables were not examined in this study.

Assumptions

1. It was assumed that all participants were honest and accurate about the information they provided on the questionnaire.
2. It was assumed that the frequency, intensity, and hours of training were similar for the athletes participating in this study.

Definition of Terms

Amenorrhea. Amenorrhea is commonly defined in the literature as experiencing less than three menstrual cycles in the last year or none in the last 6 months (Drinkwater, et al., 1990; Myburgh, Hutchins, Fataar, Hough, & Noakes, 1990; Nelson et al., 1986). For the purposes of this study, amenorrhea was defined as three or fewer menstrual cycles in the previous year, as reported on the Medical History and Menstrual Status Questionnaire.

Oligomenorrhea. Oligomenorrhea was defined in a previous study as experiencing between four and nine menstrual cycles in the previous year (Myburgh,

Hutchins et al., 1990). For the purposes of this study, women were characterized as oligomenorrheic if they experienced between four and nine menstrual cycles in the last year, as reported on the Medical History and Menstrual Status Questionnaire.

Eumenorrhea. Eumenorrhea was considered, in the literature, as normal menstrual cycling, or between 10 and 13 menstrual cycles in the last year (Myburgh, Hutchins et al., 1990; Nelson et al., 1986; Rencken et al., 1996). In this study, eumenorrhea was defined as 10 to 13 cycles in the previous year, as reported on the Medical History and Menstrual Status Questionnaire.

Injury. For the purposes of this study, injury was limited to any type of fracture diagnosed by a physician, as reported on the Medical History and Menstrual Status Questionnaire.

Menstrual History. For this study, menstrual history was defined by the number of years of menstruation, as reported on the Medical History and Menstrual Status Questionnaire.

Importance of Study

The relationships between intense exercise, menstrual irregularities, and bone mineral density in premenopausal women are paradoxical. Weight-bearing exercise and resistance training contribute to bone health in young adults and increase bone density. However, high levels of activity may contribute to amenorrhea and the absence of estrogen, which have negative effects on bone mineral density. Further study is needed to elucidate whether the bone-building effects of exercise are compromised in young

women who experience training-related menstrual irregularities. This question is particularly relevant because bone mineral content increases during adolescence, with peak bone mass generally occurring during early adulthood, prior to the age of 30 years (Recker et al., 1992). Thus, it is important to evaluate the effects of intense training, which may be associated with menstrual irregularities, on bone mineral density in young women.

Many researchers have examined the phenomenon of amenorrhea and low bone mineral density in runners and endurance athletes (Barrow & Saha, 1988; Marcus et al., 1985; Nelson et al., 1986). In addition, the bone mineral density of gymnasts has been compared with that of runners, swimmers, and controls (Robinson, Snow-Harter, Taaffe et al., 1995; Snow, Rosen, & Robinson, 2000; Taaffe et al., 1995). However, there has been a limited amount of research concerning menstrual status and bone mineral density in gymnasts, especially considering that gymnastics is a sport which may have a high prevalence of amenorrhea. Gymnasts have a high risk of developing amenorrhea because the sport emphasizes low body weight and lean physiques (Nattiv et al., 1994). Research up to this point has not examined the prevalence of amenorrhea in collegiate gymnasts. While research has explored common gymnastics injuries, no one has examined the effect of menstrual status on injuries in gymnasts.

A Medical History and Menstrual Status Questionnaire (Appendix A) was used to collect data regarding menstrual status, training patterns, use of birth control, and injuries. Dual-energy x-ray absorptiometry (DEXA) scans were performed to determine bone mineral density and body composition in female college gymnasts.

Chapter 2

REVIEW OF LITERATURE

Bone health is affected by many factors including genetics, hormonal levels, exercise habits, and diet. Achieving a large peak bone mass at a young age is proposed to help prevent osteoporosis and bone fractures in the aging adult years. One way to increase bone mass in young adults is participating in weight-bearing exercise (McArdle, Katch, & Katch, 1996). Therefore, high levels of weight-bearing exercise are beneficial and should be encouraged in young women. However, many women who exercise intensely show alterations in their menstrual cycle and may experience amenorrhea. Amenorrhea is the absence of menstruation, characterized by low levels of estrogen circulating throughout the body. Circulating estrogen has a complex relationship with calcium metabolism and, therefore, affects bone composition.

Osteoporosis and Exercise

Osteoporosis is a disease characterized by weakening bones leading to such fragility that risk of fractures is evident and increases with age. Along with cardiovascular disease and breast cancer, osteoporosis is one of the most serious diseases affecting women today. According to McBean et al. (1994), this disease leads to over 1.5 million fractures each year and incurs an annual medical cost of \$10 billion in the United States.

Many factors may put women at risk for developing osteoporosis. Nonmodifiable factors are postmenopausal status, age, ethnicity, and genetics. Modifiable factors

include physical activity, calcium intake, cigarette smoking, alcohol, and caffeine consumption (Thomas, 1997). Prevention of osteoporosis lies in developing a high peak bone mass between the ages of 30 and 35 (McBean et al., 1994). The exact age at which peak bone mass is achieved is often debated in the literature. Some researchers have found peak bone mass to be reached in the early twenties, while other researchers have found bone mass to still be accruing in the third decade of life (Birge & Dalsky, 1989; Recker et al., 1992). At whatever age peak bone mass is achieved, this is essentially the strongest bones will be for the rest of life. From this point on bone density slowly decreases, and large decreases are seen in postmenopausal women. Therefore, peak bone mass is the major determinant of bone mass later in life. Individuals with a low peak bone mass have a greater risk of developing osteoporosis as they age.

Exercising, at any age, is an important determinant of bone mass and decreases the risk of osteoporosis. At younger ages, participation in sports and weight-bearing activities such as baseball, basketball, gymnastics, tennis, track, and soccer are especially beneficial in increasing peak bone mass (Slemenda et al., 1991). In a longitudinal study of 81 females, Lloyd et al. (2000) found that the difference of physical activity between sedentary teenagers and teenagers who exercised almost daily was related to significant increases in hip bone mineral density. The participants in this study were measured for bone mineral density by dual energy radiograph absorptiometry at age 12 and again at age 18. There was no relationship between calcium intake over these 6 years and bone density. The exercising teenagers had a hip bone density 0.05 g/cm^2 higher than the

sedentary participants. In a previous study, Riggs and Melton (1992) identified that a small increase of 0.05 g/cm^2 represented a 50% reduction in osteoporotic fracture risk.

Recker et al. (1992) also found increases in bone density for women between the ages of 18 and 26 years to be associated with exercise. In a longitudinal study of 156 women, increases in bone density were found in the forearm, lumbar spine, and whole body over a 3 year period. Increases at the lumbar spine decreased with age, but increased with physical activity and calcium intake.

In persons who have already reached their peak bone mass, exercise may not increase bone mass, but it can help prevent loss (Taxel, 1998). Exercise also improves strength, stability, and balance to help reduce the risk of falls, which may lead to osteoporotic fractures (Taxel, 1998). A very dramatic example of the impact of exercise on bone mass can be seen in studies of bed rest immobilization. Schneider and McDonald (1984) found a 5% bone loss in the calcaneus after 1 month of bed rest.

In a review article, Birge and Dalsky (1989) attempted to answer some questions concerning exercise and osteoporosis. They concluded that the magnitude of stress on the body seems to be an important factor in strengthening the skeleton, more so than frequency of exercise. Therefore, weight-bearing exercise should be the main focus of an exercise program to help prevent osteoporosis. Also, the exercise should be site specific and intended for the area of the body where bone density is a concern. Exercising the legs may not improve bone density in the upper body. Thomas (1997) recommended that osteoporosis prevention in girls should begin during adolescence and continue throughout

their lifetime. Osteoporosis may even be considered a pediatric disease with a geriatric outcome.

Manifestations of Amenorrhea

Baer and Taper (1992) examined many characteristics of amenorrheic runners in an attempt to identify commonalities among the athletes. The participants, six amenorrheic and six eumenorrheic runners matched for age, weight, and body composition, completed questions regarding diet, training habits, and menstrual history. Compared to the eumenorrheic runners, the amenorrheic runners ran more miles per week and started training at an earlier age (at or before menarche). The amenorrheic and eumenorrheic athletes both consumed about the same number of calories, yet the amenorrheic group expended more energy through higher levels of exercise. This could be explained by a higher frequency or greater intensity of training. Therefore, despite the similar caloric intake, the energy deficit experienced by amenorrheic runners may have contributed to their menstrual status.

Drinkwater et al. (1990) also found amenorrheic runners to train harder, longer, and more days per week than eumenorrheic runners. Their research indicates that amenorrhea may be attributed to a negative calorie balance. In an examination of female athletes, Loucks and Heath (1994) reported that energy deficiencies, caused by a combination of poor diet and high levels of training, stifle reproductive function. The researchers suggested that exercise-induced amenorrhea may be prevented or corrected by increasing calorie consumption in the diet, without having to alter training habits.

Kaiserauer, Snyder, Sleeper, and Zierath (1989) attempted to identify factors associated with hormonal and metabolic changes seen in amenorrheic distance runners. In contrast to Baer and Taper (1992), Kaiserauer et al. found no difference between amenorrheic and eumenorrheic runners in the number of miles ran per week, body weight, percent fat, fat weight, lean body weight, or body mass index. The amenorrheic runners in this study ate less protein, fat, riboflavin, thiamin, calcium, and pantothenic acid than the regularly menstruating runners. Interestingly, the amenorrheic group was 25% vegetarian, and none of these athletes ate red meat. The researchers concluded that these low meat diets could explain the shortage of protein, fat, and riboflavin.

Sanborn, Albrecht, and Wagner (1987) found no difference in percent body fat between regularly and irregularly menstruating runners. Using hydrostatic weighing, the mean percent body fat for the amenorrheic and regularly menstruating runners was 17.4% and 17.7% respectively. The two groups had no significant differences in days trained each week, miles ran per week, years of training, height, weight, and age. The work of Nelson et al. (1986) complements that of Sanborn et al. (1987) in finding no differences in percent body fat between amenorrheic and eumenorrheic runners. However, research conducted by Myburgh, Bachrach, Lewis, Kent, and Marcus (1990) found significant differences in the percent body fat between regularly and irregularly menstruating female athletes.

In the work of Sanborn et al. (1987), the only significant difference between the two groups was the age of menarche. The amenorrheic runners had a later age of menarche by 1 year. Training before menarche was not the cause of this, as suggested by

Drinkwater et al. (1990), because only 3 of the 21 amenorrheic athletes began training before menarche. This suggests the possibility that women who have a late age of menarche may be predisposed to developing exercise-induced amenorrhea (Sanborn et al., 1987).

Frisch et al. (1981) examined the age of menarche and its relation to amenorrhea in collegiate athletes. The researchers proposed that women who train early in life, before the onset of menstruation, have a later age of menarche and an increased risk for developing amenorrhea. They also studied 21 college swimmers and 17 runners in relation to age of initiating training. Eighteen of the athletes who started training before menarche began menstruation around 15.1 years-of-age, and the 20 athletes who initiated training after menarche started menstruating around 12.8 years-of-age.

Frisch et al. (1981) concluded that each year of training before menarche delayed menstruation by 5 months. Training may delay menarche, but the difference in the age of onset may also be explained by the fact that women who began menstruating at age 12 did not have a chance to start training before that time. In the group of premenarche-trained athletes, 61% were irregular and 22% were amenorrheic (Frisch et al., 1981) while in the postmenarche-trained group, 60% of the women were regular and none were amenorrheic. The authors felt that the age of menarche could be related to the cause of amenorrhea in athletic women. Perhaps initiation of training is not related to age of menarche, and some women are predisposed to begin menstruating in the middle to late teens. According to the authors, these women may be prone to developing exercise-induced amenorrhea. Frisch et al. (1981) attempted to explain their findings by

suggesting that the metabolic and hormonal changes seen in amenorrheic athletes are the result of an increased lean mass to fat mass ratio.

While many studies examined physiological manifestations associated with amenorrhea, Loucks and Horvath (1984) attempted to identify psychological factors which contributed to amenorrheic status in college-aged runners. These researchers believed that the excessive psychological stress of training might contribute to the menstrual status of many athletes. In an attempt to quantify stress levels, the researchers used two psychological questionnaires, the Profile Of Mood States (POMS) and the State-Trait Anxiety Inventory (STAI). These questionnaires were completed before a submaximal run, after the run, and 1 week later. In comparing the results to normalized scores for undergraduate college women, the athletes deviated from the averages in a favorable manner. This indicates that the athletes had lower stress levels than the normalized values. Loucks and Horvath also found no difference in the values obtained for the amenorrheic runners versus the eumenorrheic runners. Despite these results, many experts have concluded that psychological stress may have an impact on menstrual status in athletes (Beals et al., 1999; Nattiv et al., 1994; Wolman, 1994).

Amenorrhea and Bone Mineral Density

Rencken et al. (1996) compared bone density at eight sites in amenorrheic and eumenorrheic athletes. Bone density was measured by DEXA at the lumbar vertebrae, hipbone, femur, tibia, and fibula. The 29 amenorrheic subjects had experienced less than two menstrual cycles in the previous year or none in the 6 months preceding this study.

The 20 eumenorrheic subjects experienced 12-13 cycles each year and had never gone more than 6 months without a cycle. Participants regularly exercised over 45 minutes a day, four days per week.

The average bone mineral density for the amenorrheic athletes was significantly lower at all of the sites except the fibula. Osteoporosis characterized bone mineral density measures at the hip or spine in 7 of the 29 amenorrheic women. Rencken et al. (1996) also found that body weight, in combination with months of amenorrhea and age of menarche, could predict the bone mineral density at the lumbar spine, femur, and tibia. Researchers concluded that weight-bearing exercise did not counteract the negative effects of low estrogen on bone mineral density.

Drinkwater et al. (1990) also studied the relationship between bone mineral density and menstrual status. In this study, the 97 participants completed questionnaires concerning their menstrual history and exercise habits. From these questionnaires, subjects were placed into one of three groups: eumenorrheic (10-13 cycles per year), oligomenorrheic (3-6 cycles per year), and amenorrheic (less than 2 cycles per year). Participants were excluded from the study if they were on birth control or if they did not exercise for at least 45 minutes, four days per week. Bone mineral density was measured at the lumbar vertebrae, femur, tibia, and fibula by dual-photon absorptiometry.

Drinkwater et al. (1990) found the amenorrheic group to have 17% lower bone density and the oligomenorrheic group to have 6% lower bone density than the eumenorrheic controls. The amenorrheic group had a significantly lower weight, later age of menarche, started training at an earlier age, and trained more frequently and longer

than the other two groups. These researchers also found significant bone loss in the lumbar vertebrae, but not at the peripheral sites tested. This study suggests that the trabecular bone of the vertebrae may be more susceptible to mineral loss in the absence of estrogen (Drinkwater et al., 1990).

According to Snow-Harter (1994), the skeleton is composed of two types of bone, cortical and trabecular. Trabecular bone makes up 70% of the axial skeleton and is characterized by a porous, honeycomb structure. According to Wolman (1994), trabecular bone can be found in the spine, proximal femur, and distal radius. Cortical bone makes up 80% of the entire skeletal mass and is characterized by tightly compacted plates. Snow-Harter (1994) indicates that remodeling activity is more common in trabecular bone because the red and yellow marrows abundant there are sources of bone-reabsorbing cells. Therefore, it is likely that bone loss occurs earliest in the trabecular bone of the spine and hip, and later in the cortical bone of the arms and legs.

Drinkwater, Bruemner, and Chestnut (1987) examined bone density at four sites in 74 athletic women using single and dual photon absorptiometry. After completing questionnaires, the participants were placed into groups according to their menstrual history. Of the 74 participants, 24% menstruated regularly, 12% were oligomenorrheic, and 64% were considered amenorrheic because they experienced at least 6 months without menstruation. There were significant differences in bone density of the athletes at the spine, but not at the two sites in the femur or radius. At the lumbar vertebrae, the bone mineral density measured 1.30 g/cm^2 , 1.18 g/cm^2 , and 1.02 g/cm^2 for the eumenorrheic, oligomenorrheic, and amenorrheic groups respectively. Drinkwater et al.

(1987) concluded that prior episodes of oligomenorrhea and amenorrhea have residual effects on the density of the lumbar spine.

Marcus et al. (1985) also found differences in the bone density of amenorrheic and eumenorrheic women in trabecular bone, but not at cortical bone sites. Marcus et al. measured the bone density of elite distance runners by computed tomography and photon absorptiometry at the lumbar spine and radius. Forearm mineral density was normal in both amenorrheic and eumenorrheic athletes compared to age-matched sedentary controls. It is interesting that the researchers chose to measure the density of the radius, a nonweight-bearing bone in runners. Perhaps the results may have been different if the cortical site chosen was a weight-bearing bone during running.

Results of Cann, Cavanaugh, Schnurpfel, and Martin (1988) complement those of Drinkwater et al. (1987, 1990). Cann et al. found that trabecular bone density in the spine was correlated to menstrual history. The bone density of 208 women was measured by computed tomography. This study did not examine other sites including cortical bone. Cann et al. (1988) concluded that untreated amenorrhea of 3 years in active women leads to trabecular bone loss.

In a previous study conducted by Cann, Martin, Genant, and Jaffe (1984) amenorrheic women were analyzed for bone density. Cann et al. measured bone density at the lumbar spine and radius by computed tomography. Bone mass in the appendicular cortical bone was only slightly lower than that of age-matched controls. The spinal trabecular bone densities measured were 20% to 30% lower than controls. However, this

study may not completely relate to previous studies because researchers did not target women experiencing exercise-induced amenorrhea.

Myburgh, Bachrach et al. (1990) studied differences in bone mineral densities of amenorrheic and eumenorrheic women with similar body weights. In contrast to Drinkwater et al. (1987, 1990), Myburgh, Bachrach et al. (1990) found lower bone mineral densities at appendicular sites containing cortical bone. This study examined bone mineral density in the lumbar spine, proximal femur, whole arm, whole leg, and femur shaft by DEXA. Twelve eumenorrheic athletes were compared to nine amenorrheic athletes with similar age, height, and weight; therefore, differences in bone mineral density could not be attributed to differences in body weight as Drinkwater et al. (1990) suggested. Myburgh, Bachrach et al. (1990) suggested that trabecular bone and cortical bone are susceptible to mineral loss in the absence of estrogen. This implies that weight-bearing activity does not protect cortical bone of the legs and arms from demineralization as Drinkwater et al. (1990) hinted.

Lloyd, Myers, Buchanan, and Demers (1988) found significant differences between women who menstruated regularly and those who did not. Researchers interviewed female collegiate athletes concerning their menstrual history and calculated the number of menses missed since menarche. Bone density of the first three lumbar vertebrae was measured by quantitative, single-energy computed tomography. Ten moderately oligomenorrheic athletes, missing fewer than 50% of their menses, had 88% of the bone density of the eumenorrheic athletes who had 10-13 cycles per year. The severely amenorrheic athletes, missing more than 50% of their cycles but still having

three menses per year, had only 69% of the density measured in the eumenorrheic women. The major conclusions of these studies concerning bone mineral density in amenorrheic athletes are summarized in Table 1.

Bone Mineral Density and Gymnastics

Many studies have investigated the effects of gymnastics training on bone mineral density. However, most of these investigations have been published as abstracts, providing a minimal amount of information in this area. Seven complete studies were published and will be discussed here. Nine abstracts concerning gymnastics and bone mineral density will also be discussed. The conclusions from these studies can be found in Table 2.

Nichols et al. (1994) examined the effect of a 6-month gymnastics season on bone mineral density. Bone scans were compared before and after a 27-week period for 11 eumenorrheic gymnasts and 11 sedentary controls. Amenorrheic gymnasts were excluded from the study, but those taking birth control pills were permitted to participate. In the preseason bone scan, the gymnasts measured significantly greater bone density than the controls. The training period after the initial bone scan averaged 4 hours per day, 5 days per week and included weight-training, running, stretching, and formal gymnastics workouts. After the 27-week training period, the gymnasts showed significant increases in bone density at the lumbar spine and small, nonsignificant increases at the femoral neck. Sedentary controls showed no changes in bone mineral density at either site.

Table 1

Summary of Conclusions from Studies Examining Bone Mineral Density (BMD) in Amenorrheic Athletes

Authors	Participants	Methods of Measurement	Major Conclusions
Cann et al. (1984)	Active & inactive women	Computed tomography	Amenorrhea is associated with decreased spinal bone mass.
Cann et al. (1988)	Female runners	Computed tomography	Amenorrhea may lead to irreversible trabecular bone loss.
Drinkwater et al. (1987)	Female athletes	Single and dual photon absorptiometry	Irregular menstruation has residual effects on lumbar BMD.
Drinkwater et al. (1990)	Young athletes	Computed tomography	Lack of menstruation results in an irreversible loss of vertebral BMD.
Lloyd et al. (1988)	Collegiate athletes	Computed tomography	Irregularly menstruating athletes demonstrate lower BMD than controls.
Marcus et al. (1985)	Elite distance runners	Computed tomography & photon absorptiometry	Trabecular bone mass is lower in amenorrheic athletes. Cortical bone seems unaffected by amenorrhea.
Myburgh, Bachrach et al. (1990)	Active women	DEXA	Amenorrheic women have lower BMD at cortical & trabecular sites.
Myburgh, Hutchins et al. (1990)	Athletes with stress fractures	DEXA	Athletes with stress fractures have greater menstrual irregularities & lower BMD at cortical and trabecular sites.
Nelson et al. (1986)	Runners	Dual photon absorptiometry	Trabecular bone is more susceptible than cortical bone to losses in the absence of estrogen.

Snow, Williams, LaRiviere, Fuchs, and Robinson (in press) conducted a similar study in which they followed gymnasts' bone density over 2 seasons and 24 months. Snow et al. attempted to determine whether bone density in elite female gymnasts increases during the competitive season and decreases in the off-season. The nine Division I college gymnasts were tested via a DEXA scan at baseline, 8 months, 12 months, 20 months, and 24 months. The increments between scans coincided with the end of the competitive season (at 8 and 20 months) and the end of the off-season (at baseline, 12, and 24 months). The gymnasts were all members of the same team and followed very similar training patterns of 20 hours gymnastics training each week. During the off-season, the athletes did not participate in gymnastics but did perform aerobics, weightlifting, and running about 3 hours per week.

Six of the gymnasts were eumenorrheic, 2 oligomenorrheic, and 1 was amenorrheic. The one amenorrheic gymnast showed different patterns in bone mineral density measurements than the other 8 gymnasts; therefore, her results were not included in the analysis. The oligomenorrheic gymnasts showed no differences in patterns when compared to eumenorrheic athletes. Snow et al. (in press) observed an overall 2.1% increase in the whole body density and a gain of 4.3% in the spine density after 24 months. Snow et al. also observed a decrease in bone density after the 4 month off-season in the whole body, hip, and spine. Because of the variation in results for the amenorrheic gymnast, Snow et al. suggested that future studies should investigate amenorrheic gymnasts to assess the prolonged effects of low estrogen on bone remodeling in young adult females.

Robinson, Snow-Harter, Taaffe et al. (1995) compared the bone mineral density and menstrual status of 20 runners, 21 gymnasts, and 19 controls, all between the ages of 17 and 27. The gymnasts had a later age of menarche (16.2 years-of-age) when compared to runners (14.4 years-of-age) and controls (13 years-of-age). Gymnasts also exhibited a 19% prevalence of oligomenorrhea and 28% prevalence of amenorrhea while the runners displayed only 15% prevalence for both conditions. The controls used in this study were completely eumenorrheic. Gymnasts were found to have higher bone mineral density than runners at all sites measured. The gymnasts showed higher densities than controls at the hip. The whole body and lumbar spine measurements did not differ between gymnasts and controls. The runners exhibited the lowest bone density of all three groups. Researchers concluded that forces created through running are less than those found in gymnastics training, and that exercise-induced menstrual irregularities may not always be associated with low bone mass.

Taaffe et al. (1995) compared bone densities of eumenorrheic college gymnasts, swimmers, and sedentary controls. Bone mineral density for the lumbar spine, hip neck, hip trochanter, and whole body was assessed using a DEXA scan. In addition, Taaffe et al. included a subregion analysis of the whole body scan, evaluating the arms, ribs, thoracic spine, lumbar spine, pelvis, and legs. The three groups differed in bone mineral density at the hip neck and trochanter with the gymnasts having the greatest values, followed by controls and swimmers respectively. Arm and leg bone mineral densities were greater for the gymnasts in comparison with swimmers and controls. Taaffe et al. concluded that high impact loading experienced by these eumenorrheic gymnasts had an

osteogenic stimulus and that nonweight-bearing training including forceful muscle contractions does not provide benefits to the skeleton.

Lindholm et al. (1995) examined the bone mineral content of young, female, former gymnasts. This study compared 19 former elite gymnasts with 21 age-matched controls. The former gymnasts were active in the sport during their prepubertal and pubertal years, but participated in the study when they reached the age of 19-23 years. Researchers found no difference in bone mineral content between the gymnasts and the controls. Investigators concluded that in the years prior to the study, the gymnasts gradually decreased their athletic activity and showed fewer menstrual disturbances. During this period, the athletes may have compensated for previous low estrogen status. Additionally, the high-impact, weight-bearing activity of gymnastics may have helped to maintain strong bones, despite the absence of estrogen. If the athletes had been menstruating regularly during their participation in gymnastics, the benefits of weight-bearing exercise on bone content did not linger after decreasing activity. Also, 14 of the 19 former gymnasts participating in this study had used birth control pills, 7 of them for over 1 year.

An additional study investigated the effect of past gymnastics participation on adult bone mass. Kirchner, Lewis, and O'Connor (1996) compared 18 former college gymnasts with 15 age-matched controls. All of the participants (aged in their forties) were eumenorrheic at the time of the study; however, 28% of the former gymnasts reported having an absence of menstrual cycles for more than 3 months compared to only 7% of the controls. The former gymnasts showed significantly greater bone mineral

density at six of the eight sites measured. Researchers concluded that there might be a residual effect of gymnastics training on bone mass that carries into adult life. The menstrual status of the former gymnasts at the time of competition was not assessed. The investigators indicated that a more in-depth assessment of menstrual history as well as a greater number of participants may have provided better insight into the relationship between former amenorrheic status and adult bone mass.

Cassell et al. (1993) explored whether muscle strain affects bone mineral density independent of activity and fat-free mass in children. This study compared 25 gymnasts, 21 swimmers, and 10 controls all between the ages of 7 and 10. Researchers measured peak torque at the shoulder and hip, and measured bone mineral density using a DEXA scan. After adjusting for weight, the researchers found bone mineral density to be associated with fat-free mass but not peak muscle torque. The bone mineral density of gymnasts was higher than swimmers and controls even after adjusting for weight, lean body mass, and peak torque. Cassell et al. (1993) concluded that the force on the bones of gymnasts, demanded by the activity itself, increases bone mass independent of lean body mass and body weight.

Kirchner, Lewis, and O'Connor (1994) compared bone mineral density, dietary intake, and menstrual status of 25 female collegiate gymnasts and 25 controls matched for age, weight, and height. Bone mineral density, measured by a DEXA scan, was significantly higher in the gymnasts at the proximal femur, lumbar spine, and whole body. Both groups were found to have calcium and calorie intakes below the recommended daily allowances. The gymnasts expended more energy and consumed

fewer calories than controls. There was a moderate negative correlation between calcium intake and lumbar spine bone mineral density in gymnasts. The gymnasts had a later age of menarche and a greater incidence of menstrual irregularities than controls.

Researchers concluded that bone mineral density in gymnasts was greater than controls regardless of insufficient calcium in the diet and menstrual irregularities.

Robinson, Snow-Harter, Gillis, and Shaw (1993) found very similar results in their examination of menstrual status and bone mineral density in 12 gymnasts, 20 runners, and 19 controls. In contrast to Kirchner et al. (1994), this study included highly competitive runners as well as gymnasts and controls. This study showed that gymnasts had higher bone mineral density than runners despite similar incidence of menstrual irregularities in the two groups. The runners had lower bone density at the spine and femur when compared to gymnasts and controls.

In a recent study, Snow et al. (2000) examined the relationship between insulin-like growth factor I (IGF-I), lean mass, and bone mass in runners, gymnasts, and controls. It is speculated that IGF-I plays a role in the mechanism by which bone responds to exercise. IGF-I is an anabolic peptide, formed in response to growth hormone, which may mediate muscle-bone interactions. As previous researchers have detected, Snow et al. (2000) found gymnasts to have significantly greater bone mass at the hip neck, hip trochanter, lumbar spine, and whole body than either runners or controls. IGF-I was significantly higher in gymnasts than runners. Bone mineral density and IGF-I values were also correlated with lean mass. These results imply that IGF-I may mediate

relationships between bone and lean mass, and that IGF-I can be used to predict hip neck bone density.

Two abstracts published data concerning bone mineral density changes in gymnasts and runners over an 8 month training period (Robinson, Snow-Harter, Gillis, & Shaw, 1994; Robinson, Snow-Harter, & Shaw, 1995). The 1994 study concluded that impact forces of gymnastics training increased bone mass, although forces from running did not alter bone mass. However, gymnasts with menstrual irregularities had no change in bone mass after 8 months of training. The 1995 study had similar conclusions except that some runners lost bone mass from baseline to 8 months. Robinson, Snow-Harter, and Shaw (1995) theorized that gymnastics training appears to be more helpful in building bone mass when compared with the training patterns of runners.

Blimkie, Dyson, Webber, and Adachi (1995) investigated the theory that young women with stronger bones excel in gymnastics and reach higher competitive levels in the sport than athletes with weaker bones. Blimkie et al. examined this theory by comparing 9 mother/gymnast pairs with 7 mother/control pairs. There were no significant differences in bone mineral density between the mother/gymnast pairs and the mother/control pairs. There were also no significant differences between the mothers of gymnasts and the mothers of controls; however, the gymnasts had significantly higher bone mineral density at the distal radius than controls. Researchers concluded that the increases in bone mineral density found in the young athletes are adaptations to gymnastics training and not inherent differences in persons successful in gymnastics.

Two abstracts published in 1995 provided data concerning gymnastics training and bone density in prepubescent gymnasts. Dyson, Blimkie, Webber, and Adachi (1995) compared 9 elite gymnasts with 10 controls, all between the ages of 8 and 11. These results suggested that gymnastics participation prior to puberty has beneficial outcomes in bone health. Padro, Eisenman, Sands, Beveridge, and Chan (1995) studied 13 prepubescent female gymnasts and 13 controls. The participants were matched for weight, height, and prepubescent stage. The gymnasts showed significantly greater bone density at the lumbar spine and tibia. Padro et al. (1995) concluded that the sport of gymnastics might have specific beneficial effects on the trabecular bone mass of the axial skeleton in children.

Fuchs and Snow (1998) performed a longitudinal case study of an amenorrheic gymnast. The 22 year-old participant competed in 4 years of Division I college gymnastics. She exhibited low calcium intakes, no fractures, and no family history of osteoporosis. Five months after the end of her college gymnastics career, a DEXA scan indicated a significant loss of bone mass at the femoral neck and lumbar spine. Compared to a scan performed while the athlete was participating in gymnastics, the percent change was -0.88% at the femoral neck and -1.3% at the lumbar spine. Whole body bone mineral density remained 5% above normal values. Fuchs and Snow (1998) concluded that amenorrheic women participating in high impact activities may curb excessive bone loss; however, the consequences of detraining calls for further investigation.

Table 2

Summary of Conclusions from Studies Examining Bone Mineral Density (BMD) in Gymnasts

Authors	Participants	Major Conclusions
Blimkie et al. (1995)	Mother/gymnast pairs, & mother/control pairs	Greater BMD at the distal radius is an adaptation of gymnastics training & is not related to maternal BMD.
Cassell et al. (1993)	Gymnasts, swimmers, & controls	Higher bone mass in gymnasts is likely due to strain on the skeleton during the activity and is not related to body weight or lean mass.
Dyson et al. (1995)	Prepubescent gymnasts & controls	Gymnasts have higher whole body and radius BMD than controls. No differences in BMD were found at the hip or spine.
Fuchs & Snow (1998)	Case study of 1 gymnast	Participation in the high impact activities of gymnastics may delay bone loss in amenorrheic women. Further study of detraining effects is needed.
Kirchner et al. (1994)	Gymnasts and controls	BMD in gymnasts is greater than controls despite menstrual irregularities and a low calcium intake.
Kirchner et al. (1996)	Former college gymnasts & controls	Greater BMD in former gymnasts suggests that training may have a residual effect which carries into adult life.
Lindholm et al. (1995)	Former elite gymnasts & controls	There is no difference in BMD between controls and former gymnasts 5 to 10 years after participation in the sport.
Nichols et al. (1994)	Gymnasts & controls	Regularly menstruating gymnasts showed increases in BMD over a 5 month training period.

table continues

Authors	Participants	Major Conclusions
Padro et al. (1995)	Prepubescent gymnasts & controls	Gymnasts have higher BMD than controls at the lumbar spine and tibia, but not at the radius. Gymnastics training may have a greater influence on the density of trabecular bone.
Robinson et al. (1993)	Gymnasts, runners, & controls	Gymnasts have higher BMD than runners despite similar incidence of menstrual irregularities and a later age of menarche.
Robinson et al. (1994)	Gymnasts, runners, & controls	Increases in femur BMD were seen in regularly menstruating gymnasts after 9 months of gymnastics training. Irregular athletes did not show improvements.
Robinson, Snow-Harter, & Shaw (1995)	Gymnasts & controls	After 8 months of training, gymnasts showed greater increases in axial BMD than runners even though a similar prevalence of menstrual irregularities was seen.
Robinson, Snow-Harter, Taaffe et al. (1995)	Gymnasts, swimmers, & controls	Gymnasts have greater hip BMD than runners and controls despite menstrual irregularities and a later age of menarche. Gymnastics appears to have bone building effects which may counteract a low estrogen status.
Snow et al. (2000)	Gymnasts, runners, & controls	Hip BMD is greater in gymnasts than runners and controls. IGF-I levels are higher in gymnasts than runners and may mediate relationships between bone and lean mass.
Snow et al. (in press)	Gymnasts	Gymnasts exhibit a pattern of increases in BMD with use (during season) and decreases in BMD with disuse (off-season) in a 24 month period.
Taaffe et al. (1995)	Gymnasts, swimmers, & controls	Gymnastics training may provide a bone-building stimulus not present in the training activities of swimming.

Risk of Injury

Along with having detrimental effects on bone, amenorrhea has been associated with an increased risk for musculoskeletal injuries. Myburgh, Hutchins et al. (1990) compared 25 female athletes with stress fractures with 25 athletes with no history of bone injury. The athletes were matched for age, weight, height, and exercise history. Bone mineral density, measured by DEXA, showed significantly lower densities at the spine and femur in the athletes with fractures. Myburgh, Hutchins et al. concluded that athletes with similar training habits but lower calcium intake, lower oral contraceptive use, lower bone density, and current menstrual irregularity were more likely to incur stress fractures.

Barrow and Saha (1988) examined differences in 241 collegiate athletes with and without stress fractures. They found women with regular menstrual cycles had a 20% lower incidence of stress fractures than very irregular women. Researchers concluded that stress fractures were associated with irregular menstruation, the incidence of fractures decreased with the increased length of oral contraceptive use, and there was a strong association between eating disorders and irregular menstruation.

Lloyd et al. (1986) found similar results in their retrospective study of 100 female runners. Women who had incurred a stress fracture during their training program were more likely to have absent or irregular menses. These athletes were also likely to have been running for more years and less likely to have used oral contraceptives than women without injury.

Preventing Bone Loss Due to Amenorrhea

Many researchers have proposed different methods of reversing bone loss due to amenorrhea. These methods include estrogen replacement therapy, reduced exercise intensity, weight gain, and increasing calorie and calcium intake. Hormonal contraceptives usually contain estrogen and progesterone. Taking oral contraceptives or using other hormonal birth control measures is similar to supplementing a woman's body with estrogen (Jonnavithula, Watten, Fox, & Lazaro, 1993). In amenorrheic women, this could help prevent bone demineralization by artificially supplying the body with the hormone it does not make on its own (Cumming, 1996).

Cumming (1996) compared changes in bone density of amenorrheic women who began hormone replacement therapy with those who refused treatment. Vertebral bone density increased 8% and femur bone density increased 4% in previously amenorrheic women who supplemented with estrogen for 24 to 30 months. The two groups had no significant differences in bone density at baseline testing. The group who refused therapy and continued their amenorrheic status showed a small decrease in bone mineral density of less than 2.5% at each site. This research suggests that hormone replacement therapy can help prevent bone loss as a result of amenorrhea and may even help reverse previous bone loss. This study also indicates that lack of treatment can lead to further bone loss.

Research conducted by Jonnavithula et al. (1993) found increases in bone density of the spine, wrist, and metatarsals in amenorrheic dancers with small weight gain when retested 2 years later. Jonnavithula et al. found a 9.6% increase in spine bone mineral density of amenorrheic dancers who gained less than 5% of their body weight, despite the

However, despite gains, the average bone densities were still significantly lower than normal controls after the weight gain.

Another possible mechanism for preventing bone loss due to amenorrhea is decreasing the training load. Lindberg, Powell, Hunt, Ducey, and Wade (1987) found an increase in bone mineral density in response to reduced exercise in amenorrheic runners after 15 months. These runners decreased their running distance by 43%, resulting in an increase in body weight of 5% and resumption of regular menstruation. Despite renewal of menses and an increase in circulating estrogen, research suggests that long periods of hypoestrogenemia has permanent effects on peak bone mass. Drinkwater, Nilson, Ott, and Chestnut (1986) examined bone mineral density of amenorrheic runners after resumption of menses. Even though there were significant increases in bone mass over a 15-month period, the gains did not reach levels of age-matched controls. Jonnavithula et al. (1993) found similar differences between amenorrheic dancers who regained menses for 2 years and sedentary controls.

Reversibility of bone loss among athletes who may have menstrual cycle irregularities is not well studied. Although it is commonly recommended to amenorrheic athletes to produce normal estrogen levels by using hormone replacements or altering the diet or training patterns, this has not been proven to reverse previous bone loss. A few researchers (Drinkwater et al., 1986; Jonnavithula et al., 1993; Lindberg et al., 1987) have seen improvements in bone density with resumption of menses, but it is still inconclusive as to whether these improvements will reach levels high enough to show no differences between persons who experienced a hypoestrogen status and those who did

not. In conclusion, bone loss due to amenorrhea may not be completely permanent, but it may not be completely reversible either.

Common Injuries in Gymnastics

Lowry and Leveau (1982) examined the number and types of injuries which occur to gymnastics competitors and noncompetitors in a retrospective study of private clubs. Researchers received completed questionnaires from 14 gymnastics clubs, composed of 4,215 participants, 3,412 of which were females. Injury was defined as any condition that limited participation for one class period or one practice and may have required treatment. Among the 307 female competitors, 206 experienced injuries during a 10 month season. Of the 3,042 female noncompetitors, 128 experienced injuries. Fractures were the fifth most common injury in both the competitor and noncompetitor groups, ranking behind contusions, strains, sprains, and inflammations. In the competitor group, 8% of the injuries were fractures while among the noncompetitors, only 3% of the injuries were fractures. It is evident that injury rates are high in gymnastics, especially for the competitive levels. Interestingly, only 1 of the 398 male participants in this study incurred a fracture over the 10 month season.

Pettrone and Ricciardelli (1987) completed a prospective analysis of club level gymnastics injuries over one season (a 7 month period). Fifteen clubs in Virginia participated in the study by completing questionnaires concerning skill level, student-instructor ratio, safety equipment, conditioning, and warm-up exercises. Each gymnast who was injured also completed a questionnaire providing information on the type of

injury, duration of nonparticipation, setting (practice or competition), and event on which the injury occurred. Pettrone and Ricciardelli (1987) found 5 injuries per 100 gymnasts at the competitive level. Fractures were the second most common injury, following sprains. However, fractures were the most common injury experienced during dismounts. Researchers also concluded that injury risk was greater in low-weight gymnasts.

Caine, Cochrane, Caine, and Zemper (1989) also performed a prospective study of gymnastics injuries examining 50 highly competitive young females over a 1 year period. An injury was defined as any condition resulting in the gymnast missing a part of a workout or competitive event. A total of 60 injuries occurred over the 1 year period; 38 of these injuries required consulting a physician. Fractures were the fifth most common injury ranking behind nonspecific injuries, sprains, strains, and inflammation.

Conclusion

Many factors affect the onset of exercise-induced amenorrhea including diet, training program, age of menarche, body weight, and body composition (Baer & Taper, 1992; Kaiserauer et al., 1989). Much of the research aimed at identifying a cause of amenorrhea is equivocal and contradictory. Some research suggests that body composition and mass may contribute to the disorder (Drinkwater et al., 1990) while other research hints that negative energy balance, training habits, and a later age of menarche may cause the problem (Frisch et al., 1981). A combination of these factors

may contribute to the onset of amenorrhea. As suggested by Frisch et al. (1981), women with a later age of menarche are predisposed to exercise-induced amenorrhea.

Evidence shows that there are correlations between amenorrhea, low levels of estrogen, and decreased bone mineral density (Drinkwater et al., 1990). Early research found a decrease in bone density at trabecular sites such as the vertebral column (Drinkwater et al., 1987; Marcus et al., 1985). Current research suggests that bone loss also occurs in cortical bone of the limbs (Myburgh, Bachrach et al., 1990). Contradictions in these findings may be a result of differences in the method of measuring bone density.

The dual-photon absorptiometry and the computed tomography methods of measuring bone mineral density may not be as accurate as measurements determined by DEXA. Dual-energy x-ray absorptiometry is believed to show greater precision and utilizes sophisticated software which allows for assessment of many sites at one time (Rencken et al., 1996). The difference in methods of measuring bone density may account for the contrasting results between Drinkwater et al. (1987, 1990) and Myburgh, Bachrach et al. (1990) in analysis of cortical bone sites. Drinkwater et al. (1987, 1990), using dual-photon absorptiometry, found no difference between cortical bone density of regular and irregular menstruating women, while Myburgh, Bachrach et al. (1990), using DEXA, found differences. Much of the early research which used computed tomography may not be as reliable as research that utilized DEXA.

In spite of participation in weight-bearing activity, some female athletes may have bones characteristic of postmenopausal osteoporosis (Rencken et al., 1996). These very

weak bones are susceptible to stress fractures as pointed out by Myburgh, Hutchins et al. (1990). Under normal conditions, weight-bearing activity helps build strong bones, especially during the young adult years when women obtain peak bone mass (McArdle et al., 1996). In the absence of menstruation, estrogen is unavailable to interact in bone metabolism.

Many young women today are becoming increasingly active during the years they should be building a large peak bone mass. If a teenager experiences exercise-induced amenorrhea, it is likely she will never reach the bone mass of her menstruating peers. It seems the bone loss experienced with exercise-induced amenorrhea is not completely reversible with the resumption of menses (Drinkwater et al., 1986). Therefore, it is advisable to manipulate body weight, diet, and training habits to induce menstruation and prevent bone loss.

Athletes are often unwilling to gain weight or reduce training, and may not place importance on the long-term consequences of exercise-induced amenorrhea. If an athlete is unwilling to make small changes in her lifestyle and resume menses, hormone replacement therapy may be advisable (Cumming, 1996). Perhaps after an amenorrheic athlete incurs a stress fracture, she may be willing to comply with recommendations concerning her menstrual status (Lloyd et al., 1986). However, it is likely that a considerable amount of time may have passed between the onset of amenorrhea and musculoskeletal injury. It may be too late to repair bone loss at this point, but prevention of further loss would be better than no therapy at all (Drinkwater et al., 1987). Athletic women need to realize that amenorrhea is not a benign phenomenon, but has dangerous

effects on bone health. Athletic trainers, coaches, dieticians, doctors, and parents need to be aware of the dangers of amenorrhea so they may properly advise their athletes.

Chapter 3

METHODS

This investigation focused on menstrual status and its relation to bone mineral density in female collegiate gymnasts. The methods chapter is subdivided into participants, instrumentation, procedures, research design, and statistical analysis.

Participants

A nonrandom method of participant selection was used for this investigation involving female collegiate gymnasts competing at the National Collegiate Athletic Association (NCAA) Division I level. A Medical History and Menstrual Status Questionnaire (Appendix A) was used to rule out any participants who had bone disease or were currently pregnant. Fifteen participants, aged 18-23 years, were recruited from an NCAA Division I gymnastics team. After approval from the San Jose State University Human Subjects Institutional Review Board, the head coach of the women's gymnastics team was asked for permission to approach the athletes for possible recruitment. Volunteers were informed of the small amount of risk associated with each DEXA scan.

Athletes participating at this level of competition are accomplished gymnasts who have trained in the sport for many years prior to enrolling in college. The participants in this study were all members of the same team; therefore, they had similar gymnastics training patterns for at least the past 9 months. In addition, the gymnasts answered questions regarding their exercise habits outside of gymnastics. Participants read and signed an informed consent (Appendix B) before beginning the study.

Instrumentation

Menstrual history and previous number of fractures were assessed using the Medical History and Menstrual Status Questionnaire (Appendix A), which is similar to those used previously (Bennell et al., 1996; Nichols et al., 1994). Participants were questioned concerning the number of menses in the previous year, age of menarche, pregnancy, length of menstruation, and use of hormonal contraceptives. The number of previous fracture injuries, the athlete's age at which they occurred, and the location on the body of the injury were also recorded. Injuries referred to any fracture diagnosed by a physician.

Bone mineral content was measured by a DEXA scan (QDR-100W, Hologic Inc.). The DEXA machine is accepted widely as being very precise, consistent, and safe. The method is simple and noninvasive, and the participants are exposed to only a small amount of radiation. According to Snow-Harter (1994), the DEXA scan is currently the most accurate method of measuring bone mineral density. A review article discussing the measurement of bone mineral density using the Hologic QDR-100W, found the precision coefficient of variation to be between 0.4% and 1.0% (Cole, 1992). The results using this instrument are highly reproducible according to Wolman (1994). The DEXA machine was calibrated using a spine phantom before each collection of data. The bone density of the spine phantom was determined in its first use in 1987, and the measurements are currently within valid ranges 14 years later.

The DEXA scan emits x-rays at two energy levels, separating bone tissue from soft tissue. The amount of radiation participants are exposed to is about 3% the level of a

chest x-ray, which is 5 mrem per scan (Snow-Harter, 1994). This can be compared to a full dental radiograph, which emits 300 mrem. The DEXA machine was used to measure bone density of the proximal femur, whole body, and forearm. The whole body scan also provided results concerning body composition.

Procedures

Each participant individually made an appointment for the bone scan. At this point, participants were asked if they had a bone disease and were not included in the study if they did. At this time, the participants were also asked if they were pregnant. Pregnant athletes were not included in this study. No athletes were excluded as a result of these criteria. Two days before the appointment, the athletes received written directions to the lab and instructions on the type of clothing appropriate for the scans. On the day of the measurement, the participant reported to the Musculoskeletal Research Lab at the Veterans Administration Hospital of Menlo Park, in comfortable clothing without metal buttons, zippers, or clasps. The purpose of the study was explained thoroughly and all questions were answered. Participants were informed of the small radiation exposure from the DEXA scan, and the informed consent was administered. Participants were again asked if there was any chance they were pregnant and were excluded from the study if the answer was yes.

In order to provide anonymous results, the participants were asked to draw a piece of paper with a number on it. The participants were told they had to remember their number in order to receive their results. They were given the questionnaire and

instructed to answer every question as accurately as possible, and were told to ask for help if they did not understand something on the form. Participants wrote their randomly chosen number on their questionnaire. The questionnaire also asked if participants had been diagnosed with a bone disease. After the questionnaire was completed, the athlete's height was measured using a wall stadiometer. The primary researcher measured and recorded height and weight measurements for all participants. Body weight was then measured using a beam scale. The height and weight scales were calibrated weekly using a standard meter stick and standard weight plates, respectively.

Participants were asked to remove all metal jewelry before the scan and were checked for any metal clothing. The DEXA scan was administered according to the manufacturer's protocol, after calibration using the phantom scan. The primary researcher, who had been trained by a certified DEXA technician, administered all scans and analyses. The certified DEXA technician was present during all data collection and analyses. The athlete lay supine on the table while the researcher positioned her leg for the left hip scan. The left leg was abducted and medially rotated before being strapped into the positioning device provided by the manufacturer. The scan was positioned to begin at the greater trochanter of the left hip. The participant was told to lie very still during the scan, as any movement would alter the results. After the hip scan, participants were encouraged to use the restroom or get a drink of water before the whole body scan.

The athlete was then repositioned on the table for the whole body scan. For this scan, the athlete lay supine on the table with the palms down. The researcher positioned the athlete down the center of the table, taping the feet together to ensure that her body

would remain centered and still. The researcher also taped the participant's hands and fingers to the table to help prevent movement. Before the scan began, the researcher placed the tissue bar on the table, parallel to the bottom of the foot, and next to the right leg of the participant. The tissue bar allowed for comparisons between the density of the bar and the densities of the different body tissues. The whole body scan began at the head and continued toward the feet.

Once the whole body scan was complete, the researcher assisted the athlete in removing the tape. The athlete was allowed to stand up and stretch before being asked to sit in the chair provided with her left side toward the DEXA machine. The forearm length was measured and recorded on the questionnaire to be used during analysis of the results. A foam block of the size indicated by the DEXA manufacturer was placed on the table. The athlete placed her left arm on the table, touching the outside of the forearm to the foam block. The athlete was asked to make a loose fist, and the scan was positioned to begin 15 cm up the arm measured from midway between distal ulna and distal radius. One pound weight straps were placed on the fist and the elbow to help reduce movement.

Participants' data were saved in the computer under their participant numbers and were analyzed after completion of all bone scans for the 15 participants. Once analysis was finished, the results of the scans were printed and sealed in envelopes with the participants' numbers on the front. An explanation of the results was included in the envelopes, which were placed on a table in the gym during a postseason practice. The athletes were allowed to pick up the envelope with their participant number to receive

their results. The results were listed and compared to norms established for their age group.

Supplementary Variables

Supplementary variables were also collected via the questionnaire. Age of menarche, years of training, body weight, body composition, number of previous fractures, location of fractures, hours of training per week, and estrogen supplementation were all variables examined in relation to menstrual status and bone mineral density.

Research Design

The independent variable was menstrual status. The participants were placed into two groups, using a median split, according to the number of years they had been menstruating. The dependent variable was bone mineral density at various sites.

Analysis of Data

All data collected from the questionnaire and DEXA scans were input into the SPSS statistical analysis program. Descriptive statistics were calculated for all quantitative variables. To enable comparisons between bone segments and sites, Z scores were calculated. A two-way ANOVA was used to determine statistical difference between the two groups divided by years of menstruation and Z scores for the 24 bone sites measured. First, the independent variable, menstrual status, was entered as a between subject variable, and the second variable, bone sites (as Z scores), was entered as

a repeated measure. Also, a two-way ANOVA was used to examine differences in bone mineral density between gymnasts taking oral contraceptives containing estrogen and those who were not. Estrogen supplementation served as the between subject variable, and bone sites (as Z scores) served as the repeated measure in this analysis. Pearson correlations were calculated to determine the relationships between years of gymnastics, number of menstrual cycles in the previous year, body composition, and the 24 bone mineral density measurements.

Chapter 4

RESULTS

Fifteen NCAA Division I gymnasts participated in this study. The athletes completed a questionnaire concerning menstrual history, exercise habits, use of oral contraceptives, and previous injuries. Three DEXA scans were performed to measure bone mineral density of the whole-body, hip, and forearm. Twenty-four bone mineral density data points were obtained by performing these three scans. Descriptive results for the participants can be found in Table 3. The participants were an average age of 20.1 ± 1.3 years. Their average body weight was 57.5 ± 7 kg, and the mean height for the group was 159.6 ± 6.6 cm. The athletes had been participating in gymnastics for an average of 14.4 ± 4 years. The athletes exercised an average of 21.6 hours per week ± 2 hours, while a majority of those hours, 19.3 ± 1.4 , were spent training gymnastics. In the past year, the gymnasts menstruated anywhere from 0 to 12 times, with an average of 10.3 ± 3.5 cycles per year. Eleven of the 15 athletes had previously taken birth control, and seven were currently taking an oral contraceptives containing estrogen. The team was composed mostly of white gymnasts ($n = 12$); however, there was one member from each of the Asian, Black, and Hispanic ethnicities.

Thirteen of the 15 gymnasts reported having at least one fracture, and one gymnast reported eight. The average percent body fat determined by the whole body DEXA scan was $18.3\% \pm 3.1\%$, while the average lean body mass was 46.9 ± 5.3 kg.

Table 3

Descriptive Results

	Minimum	Maximum	M	SD
Age	18	23	20.1	1.3
Body weight (kg)	46.5	71.0	57.5	7.0
Height (cm)	148.6	170.2	159.6	6.6
Years of gymnastics training	7	18	14.4	4.0
Hrs gymnastics/week	15	20	19.3	1.4
Hrs exercise/week	20	26	21.6	2.0
Years of menstruation	0	9.1	5.7	2.3
Menstrual cycles in last year	0	12	10.3	3.5
Fractures	0	8.0	2.0	2.0
Percent body fat	13.7	23.7	18.3	3.1
Lean body mass (kg)	38.3	55.0	46.9	5.3

The average whole body total bone mineral density was $1.14 \pm 0.049 \text{ g/cm}^2$. The average bone mineral density measurement for the total hip was $1.11 \pm 0.092 \text{ g/cm}^2$. The average radius and ulna total bone mineral densities were $0.628 \pm 0.04 \text{ g/cm}^2$ and $0.584 \pm 0.033 \text{ g/cm}^2$ respectively. Bone mineral density measurements for all 24 sites or body segments can be found in Table 4.

Using a median split, the 15 participants were divided into two groups based on their menstrual history (MH). Athletes who had been menstruating for 6 years or less were placed in the short menstrual history group (SMH), while athletes who had been menstruating for longer than 6 years were placed in the long menstrual history group (LMH). The seven athletes in the SMH group averaged 4.2 years of menstruation while the eight athletes in the LMH group averaged 7.3 years of menstruation. The groups were very similar in age (SMH 19.9 ± 1.6 years, LMH 20.4 ± 0.8 years) number of menstrual cycles in the previous year (SMH 9.8 ± 4.2 , LMH 11.0 ± 2.7), and exercise training hours (SMH 20.9 ± 1.6 , LMH 22.4 ± 2.2). The average body weight for SMH (56.0 kg) was slightly less than LMH (59.3 kg); however, LMH (161.2 cm) was somewhat shorter than SMH (157.7 cm). SMH averaged 45.8 kg lean body mass and 10.2 kg fat, while LMH averaged 48.2 kg lean body mass and 11.1 kg fat mass. The group of gymnasts that had been menstruating for more than 6 years had been training in gymnastics for a mean of 16.2 years compared to 12.8 years for the group menstruating for 6 years or less.

Bone mineral density measurements for all 24 body segments or sites were converted into Z scores to enable comparisons between sites and to generate a composite

Table 4

Mean Bone Mineral Density at Various Sites

Site	M BMD (g/cm ²)	SD
Whole Body		
Total	1.137	0.049
Head	1.848	0.173
Right arm	0.903	0.037
Left arm	0.905	0.040
Right ribs	0.713	0.041
Left ribs	0.727	0.034
Thoracic spine	0.983	0.088
Lumbar spine	1.226	0.116
Pelvis	1.199	0.092
Right leg	1.221	0.065
Left leg	1.199	0.059
Hip		
Total	1.111	0.092
Neck	1.058	0.111
Trochanter	0.888	0.096
Intertrochanter	1.259	0.116
Ward's	1.022	0.157

table continues

Site	<u>M</u> BMD (g/cm ²)	SD
Radius		
Total	0.628	0.040
Ultradistal	0.547	0.051
Mid	0.638	0.045
First 1/3	0.694	0.045
Ulna		
Total	0.584	0.033
Ultradistal	0.422	0.042
Mid	0.586	0.036
First 1/3	0.714	0.038

Note. BMD = bone mineral density

Ultradistal refers to the furthest region of the forearm bones, closest to the wrist

Mid refers to the middle region of the forearm bones

First 1/3 refers to the region of the forearm bones closest to the elbow joint

score. Collapsed over the 24 sites, those in the group menstruating for 6 years or less had significantly lower bone density ($Z = -0.315 \pm 0.953$) than those in the group who had been menstruating over 6 years ($Z = 0.360 \pm 0.914$), $F(1,13) = 4.72$, $p < 0.05$, $\eta^2 = 0.27$. Results for the two-way ANOVA can be found in Table 5.

Results from the Medical History and Menstrual Status Questionnaire indicated that seven of the participants were currently taking an oral contraceptive prescription containing estrogen. Four gymnasts were not currently taking oral contraceptives and had never previously. Based on these data, the participants were divided into groups based on estrogen supplementation. Four gymnasts were excluded from the analysis, one because she was on a progesterone only contraceptive, and two others because they were currently not taking oral contraceptives but had previously. A fourth gymnast contradicted herself on the questionnaire, making it difficult to determine whether she was or was not taking oral contraceptives. Bone mineral density measurements (as Z scores) of the seven athletes who were currently taking oral contraceptives containing estrogen were compared with the four athletes who had never taken oral contraceptives. Although some differences in bone density between these two groups were evident, a two-way ANOVA did not show these differences to be significant.

Pearson correlation coefficients were calculated to examine relationships between bone mineral density measurements, years of gymnastics training, menstrual cycles in the previous 12 months, fat mass, and lean body mass. Lean body mass was correlated with whole body total bone mineral density ($r = 0.62$; $p < 0.05$). Thirty-eight percent of the

Table 5

Source Table for the 2 (Menstrual History) x 24 (Sites) ANOVA with Repeated Measures on Sites

Source	SS	Df	MS	F
Years menstruation	40.8	1	40.8	4.72*
Error	112.42	13	8.65	
Bone sites	0.007	1	0.007	0.003
Years menstruation x bone sites	1.67	1	1.67	0.630
Error	34.35	13	2.64	

* $p < 0.05$

variance in whole body total bone mineral density can be explained by lean body mass ($r^2=0.38$).

Significant correlations were also found between lean body mass and the bone mineral density measurements of the left ($r = 0.70$; $p < 0.01$) and right ($r = 0.56$; $p < 0.05$) legs from the whole body DEXA scan. Lean body mass accounted for 49% and 31% of the variance in left and right leg bone mineral densities, respectively. Significant correlations between left and right rib bone mineral densities and years of gymnastics training were also found ($r = 0.59$; $p < 0.05$ and $r = 0.52$; $p < 0.05$). The correlation matrix can be found in Appendix C.

In conclusion, using a median split to divide participants by years of menstruation, a two-way ANOVA showed that athletes who had been menstruating 6 years or less had significantly lower bone mineral density than athletes menstruating over 6 years ($p < 0.05$). There were no significant differences in bone mineral density between athletes taking oral contraceptives containing estrogen ($n=7$) and those not taking oral contraceptives ($n=4$). Significant correlations were found between lean body mass and whole body total and leg bone mineral densities. Arm and left leg bone mineral densities were correlated with fat mass. Also, years of gymnastics training was correlated with rib bone mineral densities.

Chapter 5

DISCUSSION

The purpose of this study was to explore whether differences existed in bone mineral density measurements in female college gymnasts who varied in menstrual history. A second purpose was to determine what relationships, if any, existed between menstrual status, bone mineral density, training patterns, oral contraceptive usage, and body composition in female college gymnasts. Bone mineral density measurements collected via DEXA scans and information collected using the Medical History and Menstrual Status Questionnaire (Appendix A) allowed for comparisons between these variables. A two-way ANOVA found a significant ($p \leq 0.05$) difference in total bone mineral density between the gymnasts who had been menstruating for more than 6 years and those who had been menstruating for 6 years or less. Therefore, the null hypothesis that menstrual history of female collegiate gymnasts would not affect bone mineral density was rejected.

Some of the descriptive characteristics among the athletes participating in this study varied greatly among the group. The lightest gymnast weighed 46.5 kg while the heaviest gymnasts weighed 71.0 kg. This is a difference of almost 25 kg body weight within the group. One of the gymnasts participating in this study actually began gymnastics training at 1.5 years-of-age. Two of the participants, 19 and 21 years-of-age, had been training in gymnastics for 18 years. For these two participants, 86% to 95% of the years of their life had included gymnastics activities. The age of menarche within the group varied from 11.9 years-of-age to 21.5 years-of-age. There was almost a 10 year

difference in the onset of menstruation within this group. The group averaged two fractures each; while two athletes had never experienced a fracture injury, one gymnast had experienced eight. The average percent body fat for the group was 18.3%, while the difference from highest to lowest percent body fat was 10%.

One limitation inherent to this investigation is that there was no measurement of circulating estrogen levels in the blood. It is implied that menstrual status, measured by years of menstruation, is directly related to estrogen concentrations in the body. Athletes who have been menstruating for more years are assumed to have healthier levels of estrogen than athletes who have been menstruating for fewer years. Information concerning eating habits and specific calcium intake was not collected or analyzed. Some researchers (Baer & Taper, 1992; Kaiserauer et al., 1989; Loucks & Heath, 1994) suggested that differences in eating habits such as calorie and calcium intakes could explain variance in bone mineral density. In this study, three of the participants indicated that they regularly took a calcium supplement, and six of the athletes regularly took a multivitamin supplement containing calcium.

The questionnaire indicated that training hours and patterns were very similar for the 15 participants. Therefore, it is unlikely that differences in training patterns could explain discrepancies in bone mineral density. There is always some error introduced into the analysis when using a questionnaire to collect data. It might be difficult for some athletes to remember their menstrual cycle patterns in the previous year. Also, some athletes may feel uncomfortable answering questions concerning their menstrual status and may have difficulty answering the questions.

In comparing bone mineral density measurements with those previously collected for sedentary controls by other researchers, the gymnasts seem to have superior bone health. Displayed in Table 6 are the bone mineral density values found for controls in other studies and for the gymnasts in this study. Gymnasts in the present study had greater bone mineral density than sedentary controls at eight of the nine comparable sites used by Robinson, Snow-Harter, Taaffe et al. (1995), Snow et al. (2000), and Taaffe et al. (1995). It seems from these results and the results of others that the weight-bearing activities of gymnastics place additional demands on bones, increasing their mass.

Robinson, Snow-Harter, Taaffe et al. (1995), Snow et al. (2000), and Taaffe et al. (1995) also examined gymnasts and runners or swimmers whose bone mineral density values are shown in Table 7. Runners seem to have lower bone density than gymnasts, which supports the view that gymnastics training places unusually high loads on the bones, contributing to greater mass. In the study of Robinson, Snow-Harter, Taaffe et al. (1995), many of the runners and gymnasts exhibited menstrual irregularities and a later age of menarche when compared with controls. Of the 21 gymnasts participating, 6 were amenorrheic and 4 oligomenorrheic while of the 20 runners, only 3 were amenorrheic and 3 oligomenorrheic. The gymnasts in this study had a significantly ($p < 0.01$) later age of menarche (16.2 ± 1.7 years) than the runners (14.4 ± 1.7 years) and controls (13.0 ± 1.2 years).

Robinson, Snow-Harter, Taaffe et al. (1995) concluded that gymnastics training seems to have bone building effects which may counteract low estrogen status. Snow et al. (2000) agreed with Robinson, Snow-Harter, Taaffe et al. (1995) in their conclusion

Table 6

Bone Mineral Density Comparisons with Sedentary Controls

Bone sites and subregions	Present study n=15	Robinson et al. ^a (1995) n=20	Controls	
			Snow et al. (2000) n=13	Taaffe et al. (1995) n=19
Hip				
Neck	1.058 ± 0.111	0.974 + 0.11	0.969 + 0.115	0.974 + 0.105
Trochanter	0.888 ± 0.096		0.779 + 0.088	0.784 + 0.097
Whole body				
Total	1.137 ± 0.049	1.092 + 0.06	1.093 ± 0.069	1.092 + 0.064
Arms	0.904 ± 0.038			0.837 + 0.064
Ribs	0.720 ± 0.038			0.837 + 0.053
Thoracic spine	0.983 ± 0.088			0.683 + 0.036
Lumbar spine	1.226 ± 0.116			1.060 + 0.110
Pelvis	1.199 ± 0.092			1.074 + 0.084
Legs	1.210 ± 0.062			1.146 + 0.087

Note. Results are listed in g/cm²

^aRobinson, Snow-Harter, Taaffe et al.

that despite menstrual irregularities and a later age of menarche, gymnasts seem to have greater bone mineral density than runners and controls. Taaffe et al. (1995) concluded that gymnastics training provides a bone-building stimulus absent in the nonweight-bearing activities of swimming. Therefore, the conclusion that the high impact loading of gymnastics training could build greater bone density seems logical.

Comparisons of this study with the gymnasts of Robinson, Snow-Harter, Taaffe et al. (1995), Snow et al. (2000), and Taaffe et al. (1995) show similarly high bone mineral density measurements. Slight differences in results between these four studies could be explained by differences in methodology.

Snow et al. (in press) recently examined gymnasts over the course of a 2 year training period. Researchers found gymnasts to increase bone density during the competitive season when training intensity was high and impact loading was at its peak. The gymnasts' bone density decreased after a 4 month off-season of nongymnastics

training. The bone mineral density of the gymnasts participating in the present study was analyzed during the last few weeks of their competitive season. Perhaps the variation in bone density over the course of a training season could explain the slightly higher values of these gymnasts when compared to others. Maybe the other researchers collected data in the off-season or at the initiation of season, which is likely because participants would not be busy at these times. Robinson, Snow-Harter, Taaffe et al., Snow et al., and Taaffe et al. did not specify what time of the season the data were collected.

Another reason for the small differences in bone mineral density values could be

Table 7

Bone Mineral Density Comparisons with Previously Studied Gymnasts, Runners, and Swimmers

	Present study n=15	Gymnasts			Runners		
		Robinson et al. (1995) n=21	Snow et al. (2000) n=10	Taaffe et al. (1995) n=13	Robinson et al. (1995) n=20	Snow et al. (2000) n=13	Swimmers Taaffe et al. (1995) n=26
Hip							
Neck	1.058 ± 0.111	1.086 ± 0.12	1.103 ± 0.087	1.117 ± 0.110	0.882 ± 0.11	0.876 ± 0.112	0.875 ± 0.105
Trochanter	0.888 ± 0.096		0.876 ± 0.074	0.898 ± 0.130		0.739 ± 0.113	0.748 ± 0.085
Whole body							
Total	1.137 ± 0.049	1.110 ± 0.08	1.097 ± 0.062	1.127 ± 0.092	1.043 ± 0.06	1.030 ± 0.060	1.076 ± 0.066
Arms	0.904 ± 0.038			0.900 ± 0.062			0.843 ± 0.036
Ribs	0.720 ± 0.038			0.711 ± 0.059			0.676 ± 0.035
T spine	0.983 ± 0.088			0.958 ± 0.126			0.896 ± 0.094
L spine	1.226 ± 0.116			1.213 ± 0.163			1.096 ± 0.101
Pelvis	1.199 ± 0.092			1.181 ± 0.134			1.065 ± 0.080
Legs	1.210 ± 0.062			1.204 ± 0.095			1.115 ± 0.084

Note. Results are listed in g/cm²; T = Thoracic; L = Lumbar

* Robinson, Snow-Harter, Taaffe et al.

explained by the use of oral contraceptives containing estrogen. It is commonly accepted that birth control pills containing estrogen can affect bone metabolism. At the present time, oral contraceptive use by young women seems very common. In this study, 9 of the 15 gymnasts were currently or had previously taken birth control. Many of the previous studies of bone mineral density in gymnasts did not include participants taking oral contraceptives. The unusually high number of gymnasts on oral contraceptives in this group justifies an analysis between the athletes currently taking birth control containing estrogen and those who were not. The gymnasts participating in the studies of Robinson, Snow-Harter, and Taaffe et al. (1995), Snow et al. (2000), and Taaffe et al. (1995) had never taken oral contraceptive medication. Perhaps the estrogen supplemented in birth control prescriptions improves bone mass and explains the slightly higher whole body total and subregion bone density in this study when compared with others.

Pearson correlation calculations showed many variables to be related (Appendix C). Lean body mass was significantly correlated with bone mineral density at three different sites or regions. Fat mass was correlated with bone mineral density at four different sites or regions. Generally, the more lean body mass and the more fat mass a person has, the more that person weighs. The more a person weighs, the more stress is placed on the bones, especially during activity. Heavier persons could have an advantage over lighter persons in that the skeleton may respond to the additional weight placed on the bones by increasing mass.

The number of menstrual cycles in the previous 12 months was not significantly correlated with any of the bone mineral density values. However, three of the whole

body scan subregions were correlated with an $r > 0.40$, including the head, left ribs, and thoracic spine. Interestingly 11% of the variance ($r = 0.33$, $p > 0.05$) in the number of menstrual cycles in the previous year can be explained by fat mass. This supports the idea that menstrual irregularities may be associated with low percent body fat. Years of gymnastics training was significantly ($p < 0.05$) correlated with the whole body subregion analysis of the left and right ribs. The significance of this information calls for further investigation. This study would be greatly enhanced with the involvement of more participants. It would also significantly contribute to the literature if these same athletes could be retested again in 5 to 10 years to determine whether the bone mass accrued through gymnastics training remains with them after they no longer participate in the sport.

In her book, Little girls in pretty boxes: The making and breaking of elite gymnasts and figure skaters, Joan Ryan (1995) described the athletic amenorrhea common in these two sports. Ryan explains,

[the athletes] starve themselves...starving shuts down the menstrual cycle-the starving body knows it cannot support a fetus-and thus blocks the onset of puberty. It's a dangerous strategy to save a career. If a girl isn't menstruating, she isn't producing estrogen. Without estrogen, her bones weaken. She risks stunting her growth. She risks premature osteoporosis. She risks fractures in all bones, including her vertebrae, and she risks curvature of the spine. (p. 9)

From the results of this study, it seems that Ryan has somewhat exaggerated the amenorrheic situation of many gymnasts. These results indicate that gymnasts have some

protection against the detrimental effects of low estrogen, possibly because the impact loading patterns of gymnastics have been found to increase bone mass, even in the hip and spine. Ryan speaks of elite gymnasts and figure skaters in her book. While the NCAA Division I gymnasts participating in this study are not elite gymnasts striving to become Olympians, they are athletes who have greatly excelled at the sport. Perhaps the small differences in training between elite and accomplished gymnasts can account for Ryan's description of osteoporotic, prepubescent athletes. A question that still needs to be answered is whether the benefits in accruing bone mass due to the impact loads of gymnastics training outweigh the detriments of low estrogen. At the current time, these 15 collegiate gymnasts appear to be very healthy, but it is unknown how menstrual irregularities will affect bone mass once they have retired from the sport.

Conclusion

In conclusion, the null hypothesis that menstrual history of female collegiate gymnasts would not affect bone mineral density was rejected. There seems to be a difference in the bone mineral density of NCAA Division I female college gymnasts which depends on menstrual history. Women who begin menstruating at a younger age are exposed to healthier levels of estrogen and, therefore, have greater bone mass. However, athletes who supplemented with estrogen as a result of oral contraceptive use did not show greater bone mass than those who did not take oral contraceptives. Fat mass, lean body mass, and years of gymnastics training were correlated with the bone density of some regions of the body.

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APPENDIX A

Medical History and Menstrual Status Questionnaire

1. Today's Date _____
2. Date of Birth _____
3. Body Weight _____ (to be measured by researcher)
4. Height _____ (to be measured by researcher)
5. What is your ethnicity? (Please Choose One)
 - ☐ Asian ☐ White
 - ☐ Black ☐ Other
 - ☐ Hispanic
6. Are you currently taking any prescription medication? (including birth control)

Y N

 - 6a. If yes, name of prescription and reason for taking.

 - 6b. If yes, for how long?
7. Are you currently taking any nonprescription medication, over-the-counter drugs, or self-prescribed medication? (including anti-inflammatories or daily vitamins)

Y N

7a. If yes, name of medication(s) and reason(s) for taking.

7b. If yes, how long have you been taking this medication?

8. Describe any recent (in the past 12 months) medical illnesses, hospitalizations, medical problems, or surgeries you have had.

9. Do you have any metal implants in your body? (for example, surgically implanted screws or staples) If yes, please identify location.

10. Have you ever been diagnosed with a bone disease? **If yes, please inform the researcher for exclusion from the study.**

Y N

11. Have any of your blood relatives (include grandparents, parents, brothers, and sisters) been diagnosed with osteoporosis or bone disease?

Y N

11a. If yes, who, at what age, and where is the osteoporosis located?

12. Are you currently pregnant? **If yes, please inform researcher for exclusion from the study.**

Y N

12a. Is there any possibility that you are currently pregnant? **If yes, please inform the researcher for exclusion from the study.**

Y N

13. At what age did you begin gymnastics training?

Years ____ Months ____

14. How many hours do you train gymnastics each week?

15. Do you exercise outside of gymnastics practice?

Y N

15a. If yes, how many hours?

15b. If yes, what type of exercise(s)? (Please describe activity, for example aerobics, cycling, etc.)

16. Have you begun menstruating?

Y N

16a. If yes, at what age did you have your first period?

Years _____ Months _____

17. In the past six months, how many times did you have your period?

18. In the past year, how many times did you have your period? (once a month, once every two months, etc.)

18a. How many days does your period typically last?

19. Have you used a hormonal birth control in the last year? (Including the pill, Norplant, etc.)

Y N

19a. Are you currently using a hormonal birth control?

Y N

19b. How long have you been using this product? Or how long did you use this product?

Years _____ Months _____

20. Have you taken hormones in the last year for any other reason?

Y N

20a. If yes, for how long?

Years _____ Months _____

21. Have you been pregnant in the last 12 months?

Y N

22. Compared to other times, how much overall stress have you experienced during the last year?

- ☐ More stress than usual
- ☐ About the same amount of stress as usual
- ☐ Less stress than usual

23. Has a doctor ever diagnosed you as having a broken bone? This includes stress fractures, hairline fractures, and any other fractures.

Y N

23a. If yes, how many times?

23b. If yes, where on your body was (were) the broken bone(s) and at what age did the fracture occur? Please name all fractures **locations** and **age** (in years and months) that they occurred. Please specify whether the injury occurred during season, off-season (summer), or pre-season (fall).

24. Are you currently recovering from a fracture injury?

Y N

24a. If yes, where on your body is the fracture and when did the injury occur? (ie: what is the length of your rehabilitation?)

25. Please specify which events you trained in the most recent season (for example, all-around, vault and floor, or bars only)

26. Have you ever had a DEXA scan before?

Y N

26a. If yes, at what age?

Years _____ Months _____

26b. What were the results of your DEXA scan?

APPENDIX B

Informed Consent

I, _____ volunteer to participate in the research project entitled, Effects of Menstrual Status on Bone Mineral Density of Female College Gymnasts. The study will be conducted at the Musculoskeletal Research Lab at the VA Hospital of Menlo Park under the direction of Hawley C. Almstedt.

The procedures have been explained to me and I understand them. They are as follows: the purpose of this study is to determine how menstrual status affects bone mineral density in female collegiate gymnasts. The tasks involve completing a medical history and menstrual status questionnaire and performing a dual energy x-ray absorptiometry (DEXA) bone scan. The DEXA bone scan has a small amount of risk associated with the process. The scan emits radiation equivalent to approximately 3% of a chest x-ray. The procedures will include a one hour session.

I will benefit by participation in this study by receiving information concerning my body composition and bone mineral density.

All the data collected from participation in this study may be used for scientific purposes, including publication and presentation at professional conventions and events.

I understand I will not be compensated for my participation in this study. No service of any kind, to which I am otherwise entitled, will be lost or jeopardized if I choose not to participate in this study. My participation is voluntary and I may withdraw from the study at any time without prejudice to my relations with the Department of

Human Performance, San Jose State University, the principal investigator, or their associates.

I understand that this consent may be withdrawn at any time without penalty. I have been given the right to ask questions, and my questions, if any, have been answered to my satisfaction. I understand the data will be reported in group form, and individual data will remain confidential. I understand that I will receive a signed and dated copy of the consent form.

Participant's Signature

Date

Investigator's Signature

Date

APPENDIX C
Pearson Correlation Results

	Years gym training	Menstrual cycles/year	Fat mass (kg)	Lean body mass (kg)
Years gym training				
Menst cycles/year	0.36			
Fat mass	0.14	0.33		
Lean body mass	0.23	0.27	0.52*	
WB Total	0.37	0.35	0.47	0.62*
WB Head	0.48	0.49	0.44	0.32
WB Left Arm	0.10	0.11	0.60*	0.50
WB Right Arm	0.09	0.23	0.61*	0.35
WB Left Ribs	0.59*	0.43	0.39	0.43
WB Right Ribs	0.52*	0.34	0.20	0.48
WB Thoracic Spine	0.50	0.42	0.51	0.39
WB Lumbar Spine	0.50	0.17	0.06	0.36
WB Pelvis	0.44	0.25	0.29	0.42
WB Left Leg	-0.11	0.14	0.59*	0.70**
WB Right Leg	-0.18	-0.15	0.31	0.56*
Hip Neck	0.03	-0.11	-0.03	0.11
Hip Trochanter	-0.05	-0.14	-0.03	0.13
Hip Intertrochanter	0.21	0.06	0.18	0.22
Hip Ward's	-0.54	-0.19	-0.27	-0.21
Hip Total	0.10	-0.06	0.13	0.16
Radius Ultradistal	0.27	0.28	0.48	0.38
Radius Mid	-0.18	-0.12	0.34	0.27
Radius First 1/3	-0.02	-0.14	0.32	0.28
Radius Total	0.03	0.02	0.45	0.37
Ulna Ultradistal	0.01	0.09	0.09	0.04
Ulna Mid	-0.15	-0.13	0.24	0.35
Ulna First 1/3	-0.28	-0.42	0.19	0.42

Note. * $p < 0.05$; ** $p < 0.01$; $n = 15$; WB refers to the whole body DEXA scan; Ultradiſtal

refers to the furthest region of the forearm bones, closest to the wrist; Mid refers to the

middle region of the forearm bones; First 1/3 refers to the region of the forearm bones

closest to the elbow joint.

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APPENDIX D

Human Subjects-Institutional Review Board Approval Letter

TO: Hawley Almstead
909B El Lisa Drive
San Jose, CA 95123

FROM: Nabil Ibrahim,
AVP, Graduate Studies & Research

DATE: February 19, 2001

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Bone Mineral Density, Menstrual Status, and Previous Incidence of Injury in Female Collegiate Gymnasts."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information. This approval is in effect for one-year and data collection beyond February 19, 2002 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at
(408) 924-2480.

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