EFFECT OF RETIREMENT FROM WOMEN'S GYMNASTICS ON BONE MINERAL DENSITY, MENSTRUAL PATTERNS, DIETARY INTAKE, BODY COMPOSITION, BODY IMAGE, AND EATING ATTITUDES

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DEDICATION

This thesis is dedicated to my friends, family, and in loving memory of my father, Wendell Hinton. I especially want to say thank you Mom for always supporting me while I completed this at my own pace. I know I would not be where I am today without the emotional support of my family and friends. So it is with sincere gratitude that I dedicate this thesis to them.

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The purpose of this study was to examine gymnastics on bone mineral density (BMD), menstrual function, diet, body composition, body image, and eating attitudes after retirement from the sport comparing gymnasts with a control group. Bone mineral density was determined at lumbar (L2-L4), femoral neck (neck), Ward's area (Ward's), greater trochanter, and total body sites using dual energy X-ray absorptiometry (Lunar, DPX). Initially, gymnasts had significantly greater neck, Ward's, and greater trochanter BMD than controls ($p < .05$). Current data show gymnasts have significantly greater neck and Ward's BMD than controls ($p < .05$). Overall, significant declines in L2-L4, neck, Ward's, and greater trochanter BMD were found for gymnasts and significant declines for neck were found for controls ($p < .05$). Ex-gymnasts had significantly lower leg fat tissue than controls ($p = .014$). No significant differences were found for any nutritional variable or

exercise. It was concluded gymnasts continue to have greater BMD than controls despite decreased exercise.

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CHAPTER I

INTRODUCTION TO THE STUDY

Although there are many benefits of participating in sports, the potential long-term health consequences of participation in college athletics are poorly understood. Many female athletes, gymnasts in particular, feel that to succeed in their sport, they must maintain a low body weight and a low percentage of body fat (Rosen & Hough, 1988). In order to do so, many athletes restrict their food intake (O'Connor, Lewis, & Kirchner, 1995). This restriction could set the stage for disordered eating behaviors (Harris & Greco, 1990) which may put the athlete at risk for two other associated disorders, amenorrhea (less than 4 cycles/year as defined by Feicht, Johnson, Martin, Sparks, & Wagner, 1978) and osteoporosis. This array of disorders which includes, disordered eating, amenorrhea, and osteoporosis, is defined as the female athlete triad (Yeager, Agostini, Nattiv, & Drinkwater, 1993).

Bone mass development is influenced by several factors including genetics, which appears to be the major factor in bone mass development (Pollitzer & Anderson, 1989), hormonal status, exercise, and nutrition. Disordered eating (anorexia nervosa or bulimia nervosa) leads to poor nutrition which compromises development of peak bone mass (Robinson et al., 1995). Although the age at which peak bone mass is achieved has not been established, experts hypothesize that the maximization of bone density in the first two decades of life is important in preventing osteoporosis (Johnston, Hui, & Wiske, 1981). However, Recker et al. (1992) and Silverberg & Lindsay (1987) believe that peak bone mass is achieved by females during the third decade of life.

Hormonal status, namely estrogen deficiency, has also been targeted as one of the most significant factors influencing the development of bone mass (Drinkwater, Nilson, Ott, & Chesnut, 1986). Although weight-bearing exercise has been reported to enhance bone density, athletes with menstrual dysfunction do not seem to benefit from this enhancement (Howat, Carbo, Mills, & Wozniak, 1989). Also, the age at menarche is frequently delayed in athletes who begin intensive training prior to menarche in comparison with the mean age of American girls (Claessens et al., 1992). Therefore, menstrual dysfunction and delayed menarche may lower bone density in spite of activity.

Food restriction, when paired with vigorous physical activity, may contribute to decreased circulating estrogen concentration (Wilmore, Wambsgans, & Brenner, 1992) that could lead to decreased bone mineral density (Drinkwater et al., 1984). Bone mineral density is influenced by menstrual history in which amenorrheic (less than 4 cycles/year) athletes have been found to have decreased vertebral bone density when compared to a matched group of eumenorrheic ($\geq$ 10 cycles/year) athletes (Feicht, Johnson, Martin, Spartks, & Wagner, 1978).

The density of bone is positively related to physical activity, with significantly higher bone mineral content seen in women who maintain an active lifestyle, particularly during their premenopausal years (Dalsky, 1990; Stillman, Lohman, Slaughter, & Massey, 1986). However, there are contributing factors to osteoporosis in postmenopausal women, such as a lifetime pattern of inactivity (Silverberg & Lindsay, 1987).

Gymnastics is a weight-bearing sport which demands a lean body. Gymnasts feel pressure to maintain a self-perceived "optimum" low body weight and percent body fat in order to maximize strength to body weight ratio (Benardot & Czerwinski, 1991). Consequently, in order to obtain / maintain this low weight and percent body fat, some may overtrain or restrict their food intake that may ultimately lead to decreased bone mass (Kirchner, Lewis, & O'Connor, 1995; Rosen & Hough, 1988). Bone development is dependent on adequate calcium intake (Kanders & Lindsay, 1985), among other nutrients. However, many athletes, gymnasts in particular, consume less than the recommended 1200 mg of calcium per day (Kirchner, Lewis, & O'Connor, 1996; National Research Council, 1989). The average consumption for calcium in former gymnasts, according to

Kirchner, Lewis, & O'Connor was 669 mg/day. Therefore, gymnasts are at risk for osteoporosis through two potential avenues: decreased calcium intake and estrogen deficiency (amenorrhea).

Statement of the Problem

The purpose of this study was to examine the effect of competitive gymnastics on bone mineral density, menstrual function, dietary practices, body composition, body image, and eating attitudes at least one year after retirement from the sport.

The participants, ex-gymnasts ($\underline{n} = 11$) and controls ($\underline{n} = 7$), were selected due to their prior involvement in other studies. Athlete participants were ex-gymnasts from Texas Woman's University in Denton and have not been involved in competitive gymnastics for at least one year. Bone density and body composition were measured by dual energy X-ray absorptiometry (DXA) (DPX, Lunar, Madison, WI). A medical and lifestyle history questionnaire including the Eating Attitudes Test (Garner & Garfinkel, 1979) and the Contour Drawing Rating Scale (Thompson & Gray, 1995) were administered and a 3-day dietary record was kept by each participant for nutritional analysis.

Descriptive statistics were calculated to determine the range, mean, and standard deviation on all variables measured. A Pearson product-moment correlation was performed to determine any significant correlation between diet, bone mineral density, lean tissue mass, fat mass, and demographic data. Those variables with a significant correlation were then used in the stepwise multiple regression analysis. Repeated measures analysis of variance (ANOVA) was performed to determine any significant differences within groups over time (BMDP2V) as well as between groups at the same time (BMDP 7D). Stepwise multiple regression analysis (BMDP2R) was done to determine if a significant relationship existed between bone mineral density, muscle mass, and weight.

Definitions and / or Explanation of Terms

Amenorrhea. Absence or suppression of menstruation; normal before puberty, after menopause, and during pregnancy and lactation (Taber, 1989). In keeping with the comparison study, a participant was considered amenorrheic if she had less than four menses during the past year (Feicht, Johnson, Martin, Sparks, & Wagner, 1978).

Body Composition. A method of describing the composition of the body based on fat weight, lean tissue weight, water weight, and bone weight (Arnheim & Prentice, 1997).

Bone Mineral Density. Relative amount of bone mineral per measured bone width with values expressed as g/cm^2 (Snow-Harter & Marcus, 1991).

Control. Women who had participated in various research studies performed one to four years earlier in which they had a DXA bone scan were selected.

Cortical Bone. Compact bone that comprises the outer wall of bones and the shafts of the long bones of the appendicular skeleton (Clarkson & Haymes, 1995).

Dual Energy X-Ray Absorptiometry. (DXA). A method using a dual energy X-ray beam for measuring bone mineral density and body composition. A person lies recumbent on the scanning table while a detector records transmission from an X-ray source located under the table (Snow-Harter & Marcus, 1991).

Eumenorrhea. Ten or more menstrual cycles per year (Robinson et al., 1995).

Fat Mass. The amount of fat in the body as expressed in kilograms (kg).

Female Athlete Triad. Interrelated disorders in female athletes consisting of disordered eating, amenorrhea, and osteoporosis (Yeager, Agostini, Nattiv, & Drinkwater, 1993).

Gymnast. For this study, the gymnasts used were former members (at least 1 year post competition) of the varsity gymnastics team at Texas Woman's University, a member of NCAA Division II. Most of the gymnasts participated in the comparison study in 1992 (Nichols et al., 1994).

Lean Body Mass. The weight of the body minus the fat content.

Oligomenorrhea. Scanty or infrequent menstrual flow (Taber 1988); three to six cycles per year at intervals greater than 36 days (Drinkwater, Bruemner & Chesnut, 1990;

Robinson et al., 1995).

Osteopenia. Low bone mass; BMD more than 1 standard deviation (SD) below but less than 2.5 SD below the young adult mean value (Kanis, Melton, Christiansen, Johnston, & Khaltaev, 1994).

Osteoporosis. A condition in which low bone mass and microarchitectural deterioration of bone tissue lead to increased bone fragility and a consequent increase in fracture risk (Christiansen, 1995); BMD more than 2.5 SD below the young adult mean value (Kanis, Melton, Christiansen, Johnston, & Khaltaev, 1994).

Percent Body Fat. The proportion of the total body weight that is fat tissue expressed as a percentage. It is determined by dividing the fat weight obtained using DXA by total body weight.

Retirement. A point of transition from an activity in which there has been a commitment of time and energy and a role identification (Baillie, 1993).

Total Body Weight. The gravitational force exerted on an object (Taber, 1989); the actual weight of the body in kilograms as measured on a beam scale.

Trabecular Bone. Also known as "spongy bone"; forms the internal cavity of the bone and is mainly found in the axial skeleton (vertebra) and the distal ends of long bones (Clarkson & Haymes, 1995).

Hypotheses

The following primary hypotheses were examined at the .05 level of significance:

1. There will be no significant differences in bone mineral density, caloric intake, menstrual patterns, body composition, body image, and eating attitudes when comparing the results of gymnasts from a previous study at which time they were in competitive gymnastics and this study in which they have been retired for at least one year.

2. There will be no significant differences in bone mineral density, caloric intake, menstrual patterns, body composition, body image, and eating attitudes when comparing retired gymnasts with controls for the initial or current study.

The following specific hypotheses were examined at the .05 level of significance:

1. There will be no significant predictors between total kilocalories, carbohydrate, protein, fat, calcium, vitamin D, iron, phosphorus, weight, and muscle mass and bone mineral density (L2-L4, femoral neck, Ward's area, greater trochanter and total body).

2. There will be no significant differences in dietary intake when comparing data for gymnasts versus controls from the initial or current study.

3. There will be no significant differences in body image, as assessed by the Contour Drawing Rating Scale, between gymnasts and controls.

4. There will be no significant differences in the Eating Attitudes Test between gymnasts and controls.

5. There will be no significant differences in any physiological variables for gymnasts versus controls for the initial or current study.

Limitations of the Study

The study was subject to the following limitations:

1. The degree to which the participants followed directions.

2. The ability of the researcher and the qualified technicians to accurately measure and record the variables tested.

3. The validity and reliability of the programs, methods, and equations used for determining bone mineral density, percent body fat, menstrual patterns, and dietary composition.

Significance

There is evidence that during the college years, low-body-weight female athletes are at increased risk for premature bone loss and osteoporosis (Wilmore et al., 1992). It is not known, however, what happens to bone mass once competitive sport, in this case gymnastics, is discontinued, especially if aberrant eating habits and menstrual irregularities continue into the later adult years.

Many studies have examined parts of, or all of the female athlete triad which is defined as interrelated disorders of disordered eating, amenorrhea, and osteoporosis (Yeager, Agostini, Nattiv, & Drinkwater, 1993). A number of investigators have reported reduced bone mineral density in athletes with menstrual disturbances (Drinkwater et al., 1984), including gymnasts (Howat et al., 1989). Decreased levels of estrogen have been documented in athletic, menopausal, and anorexic women (Drinkwater et al.; Marcus, Cann, & Madvig, 1985; Rigotti, Nussbaum, Herzog, & Neer, 1984). Preoccupation with weight and food restriction could lead to disordered eating behavior (Sundgot-Borgen, 1994), that, along with intense physical training, may contribute to menstrual disturbances (Wilmore et al., 1992). In addition, poor intakes of dietary calcium, that can accompany food restriction, may compromise long-term bone health (Kanders, Dempster, & Lindsay, 1988).

Gymnasts begin high-intensity training during childhood and continue this level of training throughout their competitive careers (Kirchner et al., 1995). Most gymnasts train and compete during the years associated with peak bone mass accumulation (Matkovic, Fontana, Tominac, Goel, & Chesnut, 1990). Therefore, the purpose of this study was to determine if retirement from competitive college gymnastics affects bone mineral density, dietary habits, lifestyle factors, menstruation, body composition, body image, or eating attitudes after at least one year of not competing.

CHAPTER II

REVIEW OF THE LITERATURE

The potential long-term health consequences of participation in college sports, specifically gymnastics, are poorly understood. Thousands of athletes across the country end their competitive collegiate sports career each semester because of graduation or retirement from sport. Most are bid a fond farewell and have only their memories and past accomplishments to remember their career. Upon cessation of their competitive career, many student-athletes are left with numerous hours each week that were once filled with training, practice, or competitions. Many retired college athletes receive no information on the possible changes their bodies will go through in the upcoming months and years.

The purpose of this study was to examine the effect of competitive gymnastics on bone mineral density, menstrual function, dietary practices, body composition, lifestyle factors, body image, and eating attitudes at least one year after retirement from the sport. For discussion of the related literature, bone mineral density was used as the primary topic with each of the previously mentioned variables. Also, assessment tools for the different variables will be discussed as well as pertinent information regarding bone. Order of discussion is as follows: a) Assessment Tools, b) Bone Remodeling, c) Measurements of Bone, d) Bone Mineral Density, e) Menstrual Irregularity / Hormonal Status and Bone Mineral Density, f) Exercise and Bone Mineral Density, g) Dietary Intake and Bone Mineral Density, h) Body Composition, and i) Body Image.

Assessment Tools

The preferred tool for assessment of bone mineral density for this study was dual energy X-ray absorptiometry (DXA) that uses a dual energy X-ray beam. This method was chosen to replicate a 1992 comparison study and also because DXA measurements of bone mineral density are more precise and accurate and scanning time is considerably less when compared to dual photon absorptiometry (DPA) (Snow-Harter & Marcus, 1991). Radiation exposure from DXA is approximately 5 millirem versus 10 millirem from DPA. Precision error is also lower with DXA when compared to DPA (<1.0% vs. about 2.5%, respectively). Mineral densities are reported as grams of mineral per square centimeter of bone area (Snow-Harter & Marcus).

Dietary intake was determined by Nutritionist IV version 4.0 (N^2 Computing, San Bruno, CA), a computer program designed to compute the approximate caloric intake, as well as percent fat, protein and carbohydrate from an individual's diet. Each participant kept a three-day food record in which they recorded what they ate and drank for three days, including two weekdays and one weekend day.

Body composition was also measured. When the participant was scanned for total body bone mineral density, body composition was also obtained. Finally, a lifestyle / medical history questionnaire was given to each participant. This questionnaire gave insight to each participant's family history, menstrual history, dietary intake, current activity level, oral contraceptive use, the presence of diseases and use of medications that might affect bone density, and lifestyle factors such as smoking and alcohol consumption.

The Eating Attitudes Test (EAT) (Garner & Garfinkle, 1979) was also administered in conjunction with the questionnaire. This test was used to assess seven areas symptomatic of eating disorders and consists of 40 objective statements presented in a 6-point, forced-choice, self-report format. Garner and Garfinkle validated EAT using 2 groups of female anorexia nervosa patients (n = 32 and 33) and female control subjects (n = 34 and 59). Total EAT score was significantly correlated with criterion group ($r = 0.87$, $p < 0.001$), suggesting a high level of concurrent validity.

Also administered with the lifestyle / medical history questionnaire was the Contour Drawing Rating Scale, a body-image assessment tool (Thompson & Gray, 1995). This tool was selected because sets of contour drawings and silhouettes of incremental sizes are the most popular tools for assessing this subjective element of body-image disturbance (Thompson & Altabe, 1991). The Contour Drawing Rating Scale has a reliability coefficient within the acceptable range, $r = 0.78$, and is highly significant ($p < .0005$). Validity of the scale for assessing perceived body size was examined by the degree of correspondence between an individual's reported weight and current self ratings. Contour drawing selections were strongly correlated with reported weight, $r = .71$, $p < .0005$ ($n = 32$).

Bone Remodeling

The skeleton is comprised of two compartments, peripheral and central. The peripheral skeleton constitutes 80% of skeletal mass and is composed mainly of compact plates which are organized about central nutrient canals. The central skeleton, 70% of which is composed of trabecular, or cancellous bone, is the second compartment (Silverberg & Lindsay, 1987).

Trabecular and cortical are the two main types of bone tissue. Trabecular bone is found at the ends of long bones. It consists of a honeycomb shape of trabeculae which are filled with marrow and fat. The shafts of long bones consist entirely of cortical bone that encloses the central marrow cavity (Silverberg & Linsday, 1987).

The mechanisms by which bone responds to functional loading are poorly understood. However, bone does adapt to stress or lack of stress by forming or losing tissue. This process is controlled through remodeling, a continuous cycle of destruction and renewal of bone. Remodeling is performed by individual bone remodeling units comprised of bone-resorbing osteoclasts and bone-forming osteoblasts. Net gain occurs when osteoblastic activity exceeds osteoclastic resorption; net loss occurs when resorption is greater than formation. Osteoclastic activity removes the damaged material so that osteoblasts can deposit matrix and mineral along the paths of supposed stress. As long as damage is gradual, bone mass increases. With an increased rate of damage however, bone formation may not keep up with accumulation of fatigue damage, and fracture may result. The remodeling process takes approximately 14-18 weeks to complete (Silverberg & Lindsay, 1987).

Measurements of Bone

Several noninvasive methods for measuring bone mass have been used in research. Single and dual photon absorptiometry (SPA and DPA), dual energy X-ray absorptiometry (DXA), and quantitative computed tomography (QCT) are among the most common. These measurements result from the absorption (attenuation) by bone of a collimated radiation beam. Single and dual photon absorptiometry measure density of bone using a radionuclide, and QCT and DXA measure bone density using X-rays (Snow-Harter & Marcus, 1991).

Single photon absorptiometry is based on the attenuation of a collimated photon beam (usually iodine-125) by bone and is best suited for regions of the body where variations of soft tissue composition is minimal. Dual photon absorptiometry uses isotopes that emit photons at two energy levels and is used mainly for measurement of the lumbar spine and proximal femur. Dual energy X-ray absorptiometry uses a dual energy X-ray beam. Quantitative computed tomography, also a noninvasive technique, makes it possible to measure pure trabecular bone. This technique requires the participant to lie on a scanning table above a phantom of known densities. The bone area measured is then analyzed against the phantom.

Bone Mineral Density

The most common bone disorder in the United States, osteoporosis is defined as "a disease characterized by low bone mass and microarchitectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk" (Consensus development conference, 1994). An estimated 26 million white women are at risk of bone fracture due to low bone mass or osteoporosis; men and non-white women are not included so this estimate is lower than the actual number of individuals at risk (Melton, 1995). In the United States, approximately 16.8 million (54%) postmenopausal white women have osteopenia and another 9.4 million (30%) have osteoporosis (Melton).

Riggs and associates (1986) report that bone loss associated with osteoporosis may begin as early as age 30 even though the condition is most commonly associated with post-menopausal females. The age at which peak bone mass is achieved has not been established. Some experts hypothesize that the maximization of bone density in the first two decades of life is important in preventing osteoporosis (Johnston, Hui, & Wiske, 1981) while others believe that peak bone mass is achieved by females during the third decade of life (Recker et al., 1992). It is suggested that linear bone growth is completed during the second decade; however, bone mass continues to increase during the third decade. Recker et al. estimate from longitudinal data that bone density in the forearm bones and lumbar vertebrae reaches its peak from 28.3 to 29.5 years. Increased risk for osteoporosis and associated fractures can result from low bone mass, poor bone architecture, and fatigue damage (Heaney, 1991).

Genetic endowment probably determines the upper level of achievable bone density (Smith, Nance, Won Kang, Christian, & Johnston, 1973) but other known factors contributing to variability in bone mass are hormonal status, physical activity, and diet. Genetics has been reported to explain 80% of differences in bone mass (Kelly, Eisman, & Sambrook, 1990).

Riggs et al. (1986) concluded that vertebral bone loss probably begins before menopause and continues into old age (postmenopausally) with a trend toward midlife acceleration. If this is true, high bone density that gymnasts achieve should help protect them against this accelerated loss during midlife.

Menstrual Irregularity / Hormonal Status and Bone Mineral Density

Many factors, including menstrual history, significantly influence bone mineral density (BMD). Vertebral BMD in amenorrheic athletes has been found to be lower than a matched group of eumenorrheic athletes (Drinkwater et al., 1984; Wilmore Wambsgans, & Brenner, 1992). A low estrogen state has also been associated with decreased bone mineral density in studies with amenorrheic athletes (Drinkwater et al.). Estrogen is an important factor to consider when discussing bone mineral density because it is believed that estrogen has a direct effect on bone (Eriksen et al., 1988). Estrogen is the major hormone responsible for the maintenance of bone mass and it acts directly on human bone cells through an estrogen receptor-mediated mechanism (Eriksen et al.).

Drinkwater et al., (1984) studied bone mineral content in a group of 14 amenorrheic (no more than one menstrual cycle in the previous 12 months) runners (n = 11) and crew members (n = 3) and 14 eumenorrheic athletes (runners n = 11, crew members n = 3). Subjects were chosen according to sport, age, weight, height, and the frequency and duration of daily training sessions. The only marked difference between the groups regarding athletic history was that the miles run per week were significantly higher for the amenorrheic versus eumenorrheic athletes. Single photon absorptiometry (Norland-Cameron 178) was used to measure bone mineral content of the radius of the nondominant arm (one tenth and one fifth site). Bone mineral content and density of the spine (L1-L4) were determined with dual photon absorptiometry. No significant difference was apparent at the two sites on the radius between the two groups. However, when compared to the eumenorrheic group, the amenorrheic runners had significantly lower BMD in the lumbar spine (1.30 vs. 1.12 g/cm^2; respectively). Both the amenorrheic and eumenorrheic groups exceeded the current recommended dietary allowance for calcium (800 mg) per day resulting in no significant difference.

Drinkwater et al. (1984) concluded that exercise did not protect amenorrheic athletes from vertebral bone loss in the absence of estrogen. However, the researchers felt that there were not sufficient data to make firm conclusions concerning the effects of exercise and estrogen on cortical and trabecular bone.

A follow-up study was pursued after seven of the athletes in the previously discussed article reported resumption of their menses (Drinkwater, Nilson, Ott, & Chesnut, 1986). These athletes showed significant increases over a 15.5 month period in their lumbar bone mineral density even though their values were still significantly less than the eumenorrheic athletes. The two athletes who remained amenorrheic exhibited further decreases in bone mineral density.

Fehling, Alekel, Clasey, Rector, and Stillman (1995) report that gymnasts have higher bone mineral density than other athletes despite having higher or the same incidence of menstrual irregularity. Fehling et al. reported that the lumbar spine, femoral neck, Ward's triangle, and total body BMD of gymnasts was higher than swimmers and controls even though the gymnast group included 10 subjects with oligomenorrhea (4-8 cycles/year) or amenorrhea (0-3 cycles/year) and the swimmers and controls had none. In this study, the prevalence of oligo/amenorrhea did not appear to negatively influence BMD of gymnasts.

In a recent study, Robinson et al. (1995) concluded that gymnasts have higher bone mass than runners despite similar prevalence of amenorrhea and oligomenorrhea. Twenty competitive middle- and long-distance runners (800 m to marathon), 21 competitive collegiate gymnasts, and 19 sedentary controls were assessed. Bone mineral density of lumbar spine (L2-L4), proximal femur, and whole body were measured by dual energy X-ray absorptiometry (QDR-1000/W, Hologic Inc., Waltham, MA). Self-reporting was used to determine menstrual status for each participant. Participants were categorized as amenorrheic (0-2 cycles/year, none within the past 6 months), oligomenorrheic (3-6 cycles/year with more than 36 days between cycles), or eumenorrheic (10 or more cycles per year) and number of cycles since menarche was taken into account.

Gymnasts reported a significantly later menarche age (16.2 years) compared with runners (14.4 years) and controls (13.0 years). Oligo- and amenorrhea was noted for 47% of gymnasts and 30% of runners. Four gymnasts were oligomenorrheic; 6 were amenorrheic with four having primary amenorrhea. Eleven gymnasts were eumenorrheic and regularly menstruating for at least the past two years, but five had regular cycles since menarche and the remaining six were oligomenorrheic for 1-4 years before becoming eumenorrheic. Regarding the runners, 3 were oligomenorrheic, 3 amenorrheic, and 15 eumenorrheic. The eumenorrheic runners had menstruated regularly for at least the past 1.5 years, and 6 had been taking oral contraceptives for at least a year. Two of these six runners were oligomenorrheic before taking oral contraceptives; six had regular menstrual cycles since menarche. All 19 control participants were eumenorrheic and had menstruated normally for at least 3 years; most of them had menstruated normally since menarche.

Lumbar spine BMD was significantly greater in both gymnasts and controls when compared to runners (1.17 and 1.11 vs. 0.98 g/cm^2, respectively). Gymnasts exhibited significantly greater femoral neck BMD (1.09 g/cm^2) than controls and runners (0.97 and 0.88 g/cm^2, respectively). Both gymnasts and controls had significantly higher whole body

BMD compared to runners (1.11 and 1.09 vs. 1.04 g/cm^2, respectively). Dietary calcium intake (food sources only) was not significantly different among groups and all groups were below the Recommended Dietary Allowance of 1200 mg/day for young women.

Robinson et al. (1995) recognize that more long-term studies are needed, but this study provides strong evidence that skeletal loading patterns of gymnasts have powerful osteogenic effects. The possible decreased bone density experienced by exercise-induced oligo- and amenorrhea are probably counterbalanced by the gymnasts skeletal loading patterns.

Drinkwater, Bruemner, and Chesnut (1990) studied the relationship between prior menstrual irregularities and current menstrual status to bone density. Ninety-seven active women (age 18 to 38 years) who exercised regularly for at least 45 min, 4 days per week were studied. Bone mass was measured with dual photon absorptiometry (Series 84, Ohio Nuclear, Cleveland, Ohio) at five sites: (1) lumbar vertebrae (L1-L4), (2) femoral neck, (3) femoral shaft, (4) 6.4 cm below the midpoint of the tibia, and (5) parallel portion of the fibula. Bone mass of two radial sites (one tenth and one fifth of the length of the forearm) was measured with single photon absorptiometry (Norland-Cameron Bone Analyzer, Model 178).

The women were divided into three categories dependent upon their current menstrual status. Regular status was defined as 10 to 13 periods per year, oligomenorrhea (occasional irregularities) was defined as 3 to 6 periods per year with more than 36 days between periods, or amenorrhea (no regular cycles) meaning no more than 2 periods per year or no period during the last 6 months.

A significant difference was found in vertebral bone mineral density between each group. Women who always had regular menstrual cycles had significantly higher vertebral bone mineral density than those with occasional irregularities and those who never had regular menstrual cycles (1.27 vs. 1.18 and 1.05 g/cm^2; respectively). The researchers found body weight to be a significant predictor variable for bone density at all five sites. The amenorrheic women weighed less (49.6 vs. 60.0 kg body weight, respectively), were younger (25.2 vs. 30.0 years, respectively), began serious training at an earlier age (17.8 vs. 23.4 years, respectively), and had a later menarche (15.9 vs. 12.9 years, respectively) than the women who always had regular menstrual cycles. Drinkwater, Breumner, and Chesnut (1990) concluded that a decrease of vertebral bone density is likely to accompany extended periods of oligomenorrhea/amenorrhea and that women with low body weight are more at risk.

Exercise and Bone Mineral Density

Physical activity plays an important role in bone health. Density of bone is related positively to physical activity, with significantly higher bone mineral content seen in women who maintain an active lifestyle, particularly during their pre-menopausal years (Stillman, Lohman, Slaughter, & Massey, 1986). It appears that bone stress, such as that produced by impact with the ground or by weight-training, increases bone density. Conversely, there are known causes of excessive rates of bone mineral loss. Immobilization, such as extended bed rest, results in osteopenia from disuse. A second cause of rapid bone mineral loss is weightlessness such as experienced by astronauts in space (Vogel & Whittle, 1976).

Although there seem to be factors (e.g. nutritional status, menstrual patterns) that could hinder the bone mineral density of gymnasts (Risser et al., 1990), there are several reports of higher bone mass in gymnasts and other athletes involved in high-impact weight-bearing sports vs. non-weight-bearing sports such as swimming (Grimston, Willows, & Hanley, 1993; Heinrich et al., 1990). Grimston and associates found that children (aged between 10 and 16 years) involved in weight-bearing sports (running, gymnastics, tumbling, and dance) had significantly greater femoral neck bone mineral density (0.78 ± 0.02 g/cm^2) than those involved in non-weight-bearing sports (swimming) (0.72 ± 0.02 g/cm^2). Children involved in weight-bearing sports also had a tendency for greater lumbar spine (L2-L4) bone mineral density than those involved in non-weight-bearing sports (0.70 ± 0.03 g/cm^2 vs 0.66 ± 0.03 g/cm^2, respectively).

Most studies done to determine if exercise had a positive effect on bone mineral density are cross-sectional studies that compare athletes and sedentary controls. Risser et al. (1990) studied bone mineral density of the lumbar spine and calcaneus in volleyball players, basketball players, swimmers, and non-athletes. Twenty-nine female varsity athletes and 13 non-athletes were used. Dual photon densitometry (Lunar DP3) was used to measure the lumbar spine densities at L2-L4; the calcaneus bone mineral densities were determined using a single photon densitometer (Osteon, Inc.).

Swimmers had significantly lower bone mineral density in the lumbar spine (1.05 g/cm^2) when compared to volleyball and basketball players as well as controls (1.31, 1.26, and 1.18 g/cm^2; respectively). Both volleyball and basketball players had greater bone mineral density in the calcaneus than swimmers and controls (0.530, 0.564, 0.375, and 0.438 g/cm^2; respectively). These data supported the concept that athletes in sports that involve running and jumping have higher bone density in the lumbar spine and lower extremities than non-athletes. However, because of small sample size, the selected group studied may not be typical of the general population of athletes and non-athletes. Also, because of the cross-sectional design of the study, the investigators stated they could not determine if differences in bone measurements were caused by differences in exercise type and intensity.

Heinrich et al. (1990) used dual photon absorptiometry (Lunar DP3) to study bone mineral density in a group of 40 female athletes. The group included women who performed predominantly weight lifting resistance exercise (11 body builders) and non-resistance endurance exercise (13 swimmers, 5 collegiate runners, and 11 recreational runners) and inactive nonathletes (18 controls). The athletes averaged 5.7 years of training and worked out an average of 6 days per week.

Body builders were found to have higher bone mineral density than swimmers, runners, and inactive group at all four sites of the appendicular and axial skeleton. Lumbar vertebrae (L2-L4) bone mineral density of body builders (1.40 g/cm^2) was consistently greater than that of swimmers (1.31 g/cm^2), collegiate runners (1.28 g/cm^2), recreational runners (1.30 g/cm^2), and controls (1.25 g/cm^2). Body builders also had significantly greater bone density at Ward's triangle than swimmers, collegiate runners, recreational runners, and controls (1.06 vs. 0.86, 0.89, 0.85, 0.86 g/cm^2; respectively). Bone mineral density at the femoral neck was also greater in body builders when compared to swimmers, collegiate runners, recreational runners, and controls (1.09 vs. 0.97, 1.03, 0.95, 0.95 g/cm^2; respectively). Heinrich et al. (1990) suggest that weight training may provide a greater stimulus for increasing bone mineral density than swimming, running, or being sedentary.

Kirchner, Lewis, and O'Connor (1996) used dual-energy X-ray absorptiometry (Hologic, QDR 1000W) to determine bone mineral density of former female college gymnasts and age-, height-, and weight-matched controls. Both former gymnasts and controls were between the ages of 29 and 45 years. Former gymnasts had started participation in the sport at an average age of 11 years, had competed for approximately 7 years with about 3 of those years competing in National Collegiate Athletic Association college or club levels. Authors did not indicate what level each gymnast had trained or how long gymnasts had been out of formal competition. Percent body fat was measured by DXA during the total body scan; energy expenditure was determined from standardized 7-day recall questionnaire for estimates of current activity, activity during the college years, and activity over the last 10 years. The Eating Disorders Inventory Symptom Checklist was used to collect data on current menstrual function and menstrual history.

Bone densities of former gymnasts were significantly higher ($\underline{p} < 0.001$) than those of the controls at all sites measured, including lumbar spine (L1-L4) (1.176 ± 0.028 vs. 1.010 ± 0.022 g/cm^2), femoral neck (0.996 ± 0.026 vs. 0.844 ± 0.028 g/cm^2), Ward's triangle (0.863 ± 0.032 vs. 0.709 ± 0.027 g/cm^2), and whole body (1.165 ± 0.013 vs. 1.073 ± 0.016 g/cm^2). Former gymnasts were also found to have a lower percent body fat

(23.9 $\pm$ 1.0 vs. 28.8 $\pm$ 1.6%) and expend more energy on a daily basis (2,614 $\pm$ 170 vs. 2,151 $\pm$ 93 kcal) than controls.

Kirchner, Lewis, and O'Connor (1996) offer several possible explanations for higher bone mineral density in former gymnasts. First, there may be a residual effect of gymnastics participation on bone mass that carries on into later decades of life, years after gymnastics participation has ended. Second, level or intensity of training during college and/or postcollege of former gymnasts was higher than their respective controls and may contribute to higher bone mineral density measurements. Another possible explanation is that gymnasts may have been more active during childhood and overall lifetime than controls. Lastly, genetics has been reported to explain 80% of differences in bone mass (Kelly, Eisman, & Sambrook, 1990); thus another possibility is that former gymnasts were inclined genetically to have higher bone density before their participation in gymnastics.

Jacobson, Beaver, Grubb, Taft, and Talmage (1984) evaluated effect of exercise on bone density in female college athletes (age = 18-22 years) and older athletic women (age = 22-70 years). Collegiate athletes consisted of 11 varsity tennis and 23 varsity swimming team members. The older athletic group was composed of 86 women who exercised at least three hours per week, 8 or more months of the year, for a minimum of 3 years. The control group consisted of randomly selected age-matched women with no history of significant exercise. Controls were selected for both collegiate athletes ($\underline{n} = 46$) and older athletic women ($\underline{n} = 67$). Bone mineral density of lumbar spine was measured by dual photon densitometry (Lunar, Madison, WI); single photon densitometry (Norland-Cameron, 278A) was used to assess bone mineral density of two radial sites (midshaft and 5 mm separation site).

For intercollegiate athletes, both groups had significantly higher bone mineral density at two radial sites but only tennis players had higher lumbar spine density when compared to controls. Older athletic women had higher bone density values for all measurements when compared to their age matched controls but not all comparisons, such as lumbar vertebrae density, were significantly different. When older women were divided into three age groups (20-40, 40-55, and 55-70), athletic women over the age of 55 showed greater difference in bone mineral density when compared to their age-matched controls versus the other athletic groups and their age-matched controls. For example, distal radial bone density and mid radial bone density were .975 vs. .790 g/cm^2 and .890 vs. .769 g/cm^2 for athletic women versus controls, respectively. Lumbar vertebrae density was higher in athletic women age 55-75 years versus controls (1.341 $\pm$ 83 vs. 1.195 $\pm$ 42 g/cm^2) but the difference was not significant.

Jacobson, Beaver, Grubb, Taft, and Talmage (1984) found that women who exercise regularly and intensely, such as intercollegiate athletes, have increased bone mass in both compact and trabecular areas. The researchers suggest that exercise appears to have a beneficial effect on skeletal health and that tennis appears to maintain bone mass better than swimming.

Stillman, Lohman, Slaughter, and Massey (1986) studied the relationship of bone mineral content and levels of physical activity in 83 healthy females (age 30 to 85 years). Participants were divided into three physical activity groups: low ($\underline{n} = 19$), moderate ($\underline{n} = 36$), or high ($\underline{n} = 28$). This division was based on a written activity profile questionnaire that was completed by each participant. The questionnaire inquired about the amount of physical activity performed in home life, employment, and past and present recreational and athletic pursuits. Single photon absorptiometry (Norland-Cameron Bone Mineral Analyzer, Madison, WI) was used to determine bone mineral density of the midshaft radius.

The high activity group was found to have significantly greater bone mineral density when compared to either the moderate or low activity group (0.857 vs. 0.759 and 0.745 g/cm^2; respectively). However, when the women were divided into either a premenopausal ($N = 51$) or postmenopausal ($N = 30$) group, only the high activity group of premenopausal women showed a greater bone mineral density when compared to the other activity groups. Physical activity was positively related to bone density, with significantly higher radial bone mineral density seen in pre-menopausal women who remained active versus low or moderately active women.

Dook, James, Henderson, and Price (1997) measured bone mineral density and body composition in mature (42 - 50 years), eumenorrheic female athletes involved in nonimpact, medium impact, or high impact sports versus non-athletes. Participants were divided into four groups based upon involvement in their sport. Netball / basketball players were designated as the "high" impact group, runners and field hockey players were designated as "medium" impact, swimmers were placed in the "non" impact group and there was a nonsport control group designated as "con". Athletes in the various sports had long-term (>20 years) histories of significant training and performance.

Dual energy x-ray absorptiometry (Hologic QDR 2000, Hologic, Inc., Waltham, MA) was used to assess bone mineral density (g/cm^2), total body fat (kg), and total lean mass (kg). A goniometer was used to assess isometric muscle strength of the dominant arm flexors and leg extensors. Daily calcium intake was estimated by an adapted food frequency questionnaire.

Groups were not significantly different regarding age, height, weight, or calcium intake. Lean mass was corrected for its association with body height. No differences were found between exercising groups in fat mass or corrected lean mass, however, all exercising groups had significantly higher corrected lean mass than the control group ($p < .05$). There were significant between-group differences in BMD at all sites ($p < .001$) and all exercising groups had higher arm BMD than the control group ($p < .05$). Height, corrected lean mass, and leg extensor strength correlated significantly with BMD at all sites. The high impact group had significantly higher whole body BMD than the non-impact group and both impact groups were greater than the non-impact group in regional leg BMD. Dook, James, Henderson, and Price (1997) concluded that females who participate regularly in the premenopausal years in high impact physical activity tend to have higher bone mineral density than nonathletic controls.

Nichols et al. (1994) compared bone mineral density of 11 female, eumenorrheic intercollegiate gymnasts after 27 weeks of gymnastics training with that of 11 sedentary, eumenorrheic females (less than 3 hr of any exercise each week). The gymnasts trained an average of 20 hr each week by weight training, running, stretching, and formal gymnastics training. Dual energy x-ray absorptiometry (Lunar DPX, Madison, WI) was used to measure bone mineral density of lumbar spine (L2-L4), right proximal femur (femoral neck, Ward's triangle, and greater trochanter), and total body.

Preseason bone mineral density of gymnasts was significantly greater than controls at both lumbar spine (1.328 vs. 1.225 g/cm^2; respectively) and femoral neck (1.193 vs. 1.079 g/cm^2; respectively). After 27 weeks of training, lumbar bone density increased significantly (0.017 g/cm^2) for gymnasts, but the increase for femoral neck density (0.017 g/cm^2) was not significant compared to controls. Controls showed no changes at either site for mean bone mineral density. Investigators concluded that without negative factors, such as amenorrhea, gymnastics training seems to be beneficial in increasing bone mineral density.

Dietary Intake and Bone Mineral Density

When discussing dietary intake of female athletes, one of the most important nutrients to analyze is calcium. Calcium is the mineral found in the largest quantity in the body, averaging 1.5% - 2% of body weight. Approximately 60% of the weight of mature bone is mineral, mainly in the form of calcium phosphate, and 99% of the calcium in the body is in bone (Peacock, 1991) . This makes calcium an essential nutrient for healthy bone development. Although calcium can be reutilized by tissues, it cannot be manufactured (Peacock). The only source of calcium available to the body is that obtained from the diet with dairy products being the primary supplier. However, the exact role of calcium in maintaining bone mass is unclear.

Kanders and Lindsay (1985) studied the effects of calcium intake and physical activity on vertebral bone density. A group of 60 Caucasian women, 24-35 years of age, completed a questionnaire regarding their daily physical activity and calcium intake. Although 17 of the women reported using calcium supplements, the contribution to the total calcium intake from the supplements was relatively small. Participants were divided into either a high calcium intake (755 mg/day or above) or low calcium intake (less than 755 mg/day) group and an active (high exercise, 500 kcal/day energy expenditure or greater) or non-active (low exercise, less than 500 kcal/day energy expenditure) group. Energy expenditure was determined when each participant completed an activity questionnaire/interview. Dual photon absorptiometry was used to determine vertebral bone density.

Women in the high calcium intake group had significantly higher bone mineral density than those in the low calcium intake group. Results for the exercise groups were similar; bone mineral density of the high exercise group was significantly greater than that of the low exercise group. Furthermore, the combination of high calcium intake and high exercise had the greatest impact on vertebral bone density as this group had the largest bone mass when compared to the low calcium, low exercise group. A low calcium intake plus exercise seemed to have little effect on bone density whereas a high calcium intake, regardless of exercise level, appeared beneficial to bone density. Therefore, the authors concluded that for the benefits of exercise to be expressed, a high calcium intake appears necessary.

Halioua and Anderson (1989) studied the effect of lifetime calcium intake and physical activity on bone mineral density in women 20-50 years of age (n = 181). Three groups were formed based on daily calcium intake information (current, past, and lifetime calcium intake) from a quantitative food frequency questionnaire: low (< 500 mg/day), intermediate (≥ 500 mg/day and < 800 mg/day), and high (≥ 800 mg/day). The questionnaire was also used to determine current and past physical activity. Again, the women were classified as either being sedentary (< 2 hr/week of exercise), moderately active (neither sedentary nor active), or active (> 45 minutes of exercise at least 4 times per week). Bone mineral density was measured at the 5-mm site and two-thirds site in the nondominant forearm with single photon absorptiometry (Norland-Cameron, Madison, WI) .

Significantly greater bone mineral density at both sites measured was reported in women with intermediate or high lifetime calcium intakes when compared to the low intake group. The physically active group also had significantly higher bone mineral density than the sedentary group.

To control for the effect of genetics, Johnston et al. (1992) studied bone mineral density in 70 pairs of identical twins (male and female) over a 3 year period. One twin in each pair received 1000 mg of calcium citrate malate each day (calcium intake = 1612 mg/day) and the other a placebo (calcium intake = 908 mg/day). Prepubertal twins (22 pair) who received calcium had significantly greater gains in BMD of the radius and lumbar vertebrae than controls. No significant differences in BMD of pubertal and postpubertal twins were found between calcium supplemented and placebo twins. There was no significant difference in the physical activity levels of the twins who received the calcium supplement and those who received the placebo. The results of this study suggest that extra calcium in the diet is more beneficial to achieving peak bone mass prior to puberty.

With calcium being such an important factor in bone development, the effect of the overall diet should be considered. It has been argued that low-body weight athletes such as gymnasts, are under social pressure to excel in their sport and therefore attempt to improve their performance by restricting their food intake to obtain or maintain a self-perceived "optimum" body weight (Loosli, Benson, Gillien, & Bourdet, 1986). This argument is supported by reports suggesting that gymnasts have a high prevalence of symptoms related to disordered eating behavior (Harris & Greco, 1990; O'Connor, Lewis, & Kirchner, 1995; Rosen & Hough, 1988). Furthermore, a number of health problems such as amenorrhea and loss of bone mass, are known to be associated with eating disturbances in female athletes (Leon, 1991).

Rosen and Hough (1988) studied the pathogenic weight control behaviors of 42 female collegiate gymnasts, ages 17 to 22 years, from five teams. Pathogenic weight control behaviors were defined as self-induced vomiting, fluid restriction, fasting, and/or the use of diet pills, diuretics, and laxatives. All gymnasts were dieting actively and 26 of the 42 were using at least one form of pathogenic weight control. The most frequently used methods were self-induced vomiting, the use of diet pills, and fasting. Furthermore, 28 of the 42 were told they were too heavy by their coaches that resulted in pathogenic weight control methods. Harris and Greco (1990) did not find results similar to those of Rosen and Hough. The gymnasts in the Harris and Greco study ranged in age from 17 to 23 years and were comprised of three high school seniors, 23 competitive collegiate gymnasts, one college graduate gymnast, and one not in college or competing. Although these gymnasts had a preoccupation with weight that might be considered excessive, they did not use dangerous forms of weight control behavior as frequently as the gymnasts studied by Rosen and Hough.

Loosli, Benson, Gillien, and Bourdet (1986) evaluated the quality of diet and knowledge of nutrition in a group of 97 competitive female gymnasts aged 11 to 17 who practiced at least nine hours each week. The level of each gymnast was not reported. Each gymnast kept a three-day food record and height, weight, and menstrual cycles were recorded. The gymnasts reported an average of 1,838 kcal per day whereas the recommended energy intake for girls of their age and height is approximately 2,100 kcal per day. In addition, 40% of the gymnasts reported to consume less than two thirds of the recommended dietary allowance for calcium (1200mg/day). Each gymnast also completed a questionnaire designed to determine her knowledge of nutrition. The responses on the questionnaire revealed that the gymnasts knew little about dietary carbohydrate as an energy source; 53% did not know what a complex carbohydrate was.

Although it has been reported that gymnasts use pathogenic weight control methods and have a tendency to engage in poor dietary practices, both of which negatively affect bone mineral density, there is still much evidence that gymnasts have high bone mineral density, as was previously discussed. Kirchner, Lewis, and O'Connor (1995), in a previously reviewed study, observed high BMD in gymnasts despite their having inadequate calcium intakes and a high prevalence of menstrual irregularity. Both gymnasts and controls in their study reported consuming less than two-thirds (683 $\pm$ 57 mg vs. 752 $\pm$ 63 mg, respectively) of the 1200 mg/day RDA for calcium (National Research Council, 1989).

Nichols et al. (1994), in a previously discussed article, examined the effects of 27 weeks of gymnastics training on bone mineral density, body composition, and diet. Gymnasts and controls had similar intakes for total kilocalories and calcium, however, calcium was lower than the recommended daily allowance of 1200 mg (National Research Council, 1989). Despite the low calcium intake, gymnasts still reported greater lumbar spine and bone mineral density than controls when measured at preseason (1.328 vs. 1.225 g/cm^2; respectively).

DiMarco et al. (1992) initiated and evaluated a multidisciplinary nutrition support program for intercollegiate women gymnasts at Texas Woman's University, Denton, Texas. Changes in body composition and nutrient intake were evaluated over four months during which time the gymnasts were counseled weekly on nutrition related topics. Fifteen varsity gymnasts participated in this study. Gymnasts trained 5 days per week, 4 hr each day. Training consisted of weight lifting 3 days/week, aerobic activity (running, swimming, aerobic dance, stair climbing, or bicycling), stretching, and formal gymnastics training.

Diet records were collected pre-, mid-, peak, and post season and evaluated for total kilocalories, protein, fat, carbohydrate, vitamins A, B complex, C and D, iron and calcium. Height, weight, and percent body fat were measured pre- and peak season. Body fat was determined by three site skinfold test using Lange skinfold calipers.

Average daily energy intake was 2121.9 kcal/day pre-season, which is below the Recommended Dietary Allowance of 2,200 kcal/day (RDA; National Research Council, 1989) and decreased to 1505.2 kcal/day post season. Total intake for protein and fat (percentages and average grams/day) were within the suggested values for athletes as well as some micronutrients (Vitamins D, C, B complex). Average calcium intake was below the 1,200 mg/day RDA. Each nutrient measured decreased from pre-season to post season even though some of the decreases were not significant. There was a significant decrease in body fat percent from pre-season to peak season (15.4 vs. 14.5%, respectively) and a non-significant increase in weight (119.6 vs. 120.6 lb, respectively). This indicates that the gymnasts gained fat free weight (lean muscle) throughout the training period.

<u>Body Composition</u>

Gymnasts participate in a sport that places a premium on having a low body weight and being lean secondary to the fact that evaluation of the physique is an integral component in judging performance. It is a difficult sport in which form and appearance are paramount, and demands for suppleness contrast with those for strength. Leanness is considered an essential requisite of gymnasts; therefore, the girls who engage in this sport tend to have a lower percentage of body fat than that of other athletes (Johnson, Nebelsick-Gullett, Thorland, & Housh, 1989; Reggiani, Arras, Trabacca, Senarega, & Chiodini, 1989).

Reggiani, Arras, Trabacca, Senarega, and Chiodini (1989) investigated the nutritional status and body composition of 26 female gymnasts who trained an average of 12.4 hours each week for at least 6 years. Nutritional status was determined by assessing a detailed weekly diary of all foods and drinks consumed. Body composition was determined with a bioelectrical impedance plethysmograph (BIA-103, RJL).

Calcium intake of the gymnasts was only 539 mg per day which is well below the recommended dietary allowance (RDA) of 1200 mg (National Research Council, 1989). Daily caloric intake was 25% lower than the recommended 2070 kcal/day for the same aged girls. However, their caloric intake was within normal ranges when compared to caloric intake per kilogram of body weight. Their caloric intake was probably not adequate based on caloric expenditure because of the amount of hours spent training each week. Percent body fat, although low, was found to be in keeping with that of athletes in other sports.

Johnson, Nebelsick-Gullett, Thorland, and Housh (1989) studied the effect of a competitive season on the body composition of 56 collegiate female athletes from five sports (swimming, track, volleyball, gymnastics, and basketball). Hydrostatic weighing was used pre- and post-season to determine body density, relative fat, fat-weight, and fat-free weight. Postseason values determined that gymnasts and track athletes had significantly lower body fat then basketball, volleyball, and swimming (14.5 and 14.32% vs. 20.36, 20.86, and 22.24%; respectively). Gymnasts decreased percent body fat significantly across the season from 18.83% at preseason to 14.50% at postseason. The authors suggest consistent monitoring of percent body fat throughout the season to insure good health and proper nutrition practices from the athletes.

Body Image

Body image has not yet been defined absolutely. McCrea, Summerfield, and Rosen (1982) defined body image as "the subjective evaluation of one's own body and the associated feelings and attitudes" while Cash (1990) referred to it as " the view from inside". Much of the research with body image has focused on participants' satisfaction ratings with various body parts and a number of measures for the assessment of body-size dissatisfaction have been developed in recent years (Berscheid, Walster, & Bohrnstedt, 1973; Butters & Cash, 1987; Garner, Olmstead, & Polivy, 1983). Body image is of increasing interest because its relationship with percent body fat and disordered eating. Also of growing interest is studying body image differences between athletes and nonathletes.

Huddy, Nieman, and Johnson (1993) investigated the relationship of percent body fat and body image among male college varsity athletes and nonathletes. Participants were 45 male students ranging in age from 18 to 27 years and were divided into three groups. Group 1 consisted of 15 sedentary students, group 2 was 15 varsity football players, and group 3 consisted of 15 varsity athletes from the university swimming team. A 20-item questionnaire, developed by the principal investigator of the study, was used to measure body image. Percent body fat was obtained by measuring skinfolds of the chest, abdomen, and thigh and using the formula of Brozek, Grande, Anderson, and Keys (1963). Scores obtained were correlated to estimate the relationship between body image and adiposity.

Researchers found a significant difference in percent body fat between swimmers (11.7% $\pm$ 1.7) and nonathletic subjects (17.7% $\pm$ 6.5) but not between nonathletes and football players (15.1% $\pm$ 4.9). On the other hand, nonathletes were found to have a relationship between percent body fat and specific attitudes about body image ($r = -.76$). Athletes, on average, showed somewhat higher body-image scores than nonathletic students. Researchers conclude that body image as measured in this study was inversely related to percent body fat among college men, especially among students not engaged in varsity sports.

Hallinan, Pierce, Evans, DeGrenier, and Andres (1991) examined the relationship between sex and perception of body image among athletes and nonathletes. Participants were 58 male athletes, 36 male nonathletes, 56 female nonathletes and 65 female athletes ranging in age from 17 to 30 years. To assess body image, participants were presented with a nine-figure silhouette scale which represents a monotonic increase in percent size from the first to the ninth silhouette. Participants were to rate their current figure and what they would perceive as an ideal figure.

For men, *t*-tests showed no significant differences based upon athletic participation, and both athletes and nonathletes were satisfied with their own body. For female nonathletes, the current figure was noted as larger than the ideal figure ($p < .001$). For female athletes, the mean ratings for current and ideal figures were also significantly different ($p < .001$). However, mean ratings for athlete/nonathlete comparisons for both current and ideal figure were not significantly different for either men or women. Results of the study indicate that the majority of female students overestimate their body shapes and idealize a thinner image. Furthermore, formal athletic participation has no significant effect upon this perception.

In order to analyze body esteem of female collegiate athletes, DiNucci, Finkenberg, McCune, S., McCune, E., and Mayo (1994) administered three subscales of the Body Esteem Scale (Sexual Attractiveness, Weight Concern, and Physical Condition) to 31 female student-athletes from three sports (basketball, n = 9; volleyball, n = 10; softball, n = 12). Participants were members of Division I intercollegiate athletics teams and each team was either nationally ranked (top 20) or was a conference champion. A control group of 34 women who did not participate in athletics was also administered the scale.

On Weight Concern, the mean of the control group (26.5) was significantly lower ($p < .05$) than those of the athletic groups (volleyball = 35.7, basketball = 35.8, softball = 37.3). For Physical Condition, the control group mean (31.0) was significantly lower ($p < .05$) than that of the basketball group (37.0). No other comparisons among the groups were significant. Each athletic group had significantly higher mean scores on Weight Concern than the control group of nonathletes, indicating that the athletes had more positive feelings about their body weight and functions. Basketball players had significantly higher Physical Condition scores, indicating they had higher positive feelings about their physical condition than did the control group of nonathletes, although no significant differences were found between the teams.

Summary

While it is likely that the type of physical training in which competitive gymnasts engage provides a high mechanical stimulus to bone mineralization, a high percentage of these athletes may also engage in behaviors that would theoretically have a negative influence on bone mineral density. Gymnasts feel pressure to maintain a self-perceived "optimum" low body weight and percent body fat in order to maximize strength to body weight ratio (Benardot & Czerwinski, 1991). In order to obtain / maintain this weight and percent body fat, many restrict their food intake which could lead to other health concerns. Poor intake of dietary calcium, which can accompany food restriction, may compromise long-term bone health. In addition, preoccupation with weight and food restriction could lead to disordered eating behavior, which, along with vigorous physical activity, may contribute to menstrual disturbances.

CHAPTER III

METHOD

The overall purpose of this study was to examine the effect of competitive gymnasts versus controls on bone mineral density, menstrual function, dietary practices, body composition, body image, and eating attitudes at least one year after retirement from the sport. The procedures for this study are presented in this chapter under the following headings: a) Participants, b) Instruments, c) Procedures, and d) Design and Analysis.

Participants

Participants from previous studies were the selected population. All athlete participants were ex-gymnasts from Texas Woman's University and have not been involved in competitive collegiate gymnastics for at least one year. A control sample was selected as well, based on the criteria that tests used in this study had been previously performed on them. All participants were caucasian and free from any disorder known to effect bone metabolism. Initial measurement dates vary for each participant but range from August 21, 1991 to January 12, 1996. At least one year separates all participants initial and current scan.

The sampling design used was purposive or criterion based, the criteria being that each participant had to be either a member of the varsity gymnastics team that was involved in the previous study, or have had data collected previously. The athlete participants, ages ranging from 21 years to 26 years, were members of the varsity gymnastics team (n = 11) at Texas Woman's University.

Control participants (n = 7) were selected based on prior involvement in studies that examined bone mineral density. Ages for controls ranged from 21 years to 31 years, and they were similar to the gymnasts in height, weight, and age.

Instruments

Bone density and body composition were measured by a dual energy X-ray absorptiometer (DXA) (DPX, Lunar, Madison, WI). Scans for the determination of bone mineral density of the lumbar spine (L2-L4), the right femur, and the total body were taken. These specific areas were chosen to replicate the previous study. Total body scans were taken to determine bone mineral density, muscle mass, and percent body fat.

Dietary information was evaluated using the Nutritionist IV version 4.0 (N^2 Computing, San Bruno, CA) software program from each participant's 3-day food record. A medical / lifestyle history questionnaire similar to that of the previous study was administered and completed at the time of the bone scans. Also completed (used in the current study only) was the Contour Drawing Rating Scale (Thompson & Gray, 1995) and the Eating Attitudes Test (Garner & Garfinkel, 1979). The Contour Drawing Rating Scale was chosen because of high reliability when compared to other silhouette rating scales. This particular type of test was selected because sets of contour drawings and silhouettes of incremental sizes are the most popular tools for assessing this subjective element of body-image disturbance (Thompson & Altabe, 1991).

The Eating Attitudes Test was chosen because the test demonstrates a high degree of internal reliability, despite the relatively small number of questions. This test had also been previously used with some of the athletes involved in this study.

Procedures

The participants were all informed of the purpose and procedures of the study and each provided written consent before any data collection was done. The university's Human Subjects Review Committee approved the study. The consent form and a copy of the university's approval are found in Appendix A.

Participants were asked to wear lightweight clothing with no metal zippers or buttons for the bone mineral density measurements. For the lumbar scan, the participant was supine on a padded table with her legs positioned on a support block so that the thighs were at a 60 to 90 degree angle. The participant, still in the supine position, but without the support block, had her right leg slightly rotated inward for the femoral scan. Total body scans were done with the participant lying supine and flat on the padded table.

Body composition (muscle mass and percent body fat) was determined from the total body scans performed on the DXA using analysis software provided by Lunar Corporation (Version 3.61). By defining different regions of the body with cut lines used in the analysis program, regional values for muscle mass were determined. After the technician had appropriate positions of the cut lines, muscle mass, fat mass, and bone mineral content were computed for total body and each region.

A medical and lifestyle history questionnaire was administered at the time of the bone scans to determine menstrual history, physical activity, and current dietary practices. This questionnaire contained questions similar to those asked at the initial study as well as more in-depth questions. A copy of the questionnaire is found in Appendix B.

All participants completed the Contour Drawing Rating Scale (Thompson & Gray, 1995), a subjective test used to assess body image, and the Eating Attitudes Test (Garner & Garfinkel, 1979), a 40 question forced-choice test used to assess for disordered eating. For the Contour Drawing Rating Scale, participants selected the silhouette figure they perceived themselves to look most like. The Contour Drawing Rating Scale was scored by giving a numeric score to each silhouette (1-9) and taking the mean score for each group.

For the Eating Attitudes Test, participants answered all 40 questions as honestly as possible. For statistical analysis of the Eating Attitudes Test, each extreme response in the 'anorexic' direction was scored as worth 3 points, while the adjacent alternatives were weighted as 2 points and 1 point respectively (Garner & Garfinkel, 1979). Confidentiality was insured at all times.

Each participant also completed a 3-day dietary record including two week days and one weekend day. Each participant was contacted by phone at which time each aspect of the study was explained and an appointment for data collection was set. On the day of data collection, each participant was instructed how to keep a 3-day food record by a Registered Dietitian. Also provided with these instructions was a stamped envelope addressed to the researcher. Participants were asked to mail food records when completed. Once the 3-day records were returned, they were computer-analyzed using the Nutritionist IV version 4.0 dietary program. From the analysis, the following daily dietary information was obtained: a) total kilocalories, b) grams of carbohydrate, fat and protein, c) percent of total kilocalories from carbohydrate, fat and protein, d) milligrams of calcium, iron, and phosphorus, and e) micrograms of vitamin D.

When participants were involved in college gymnastics, they had a rigorous training schedule that consumed much of their time. They were involved in 144 days of practice throughout the school year and the team competed in approximately 13 meets each season. Each meet consisted of 4 separate events (vault, uneven parallel bars, balance beam, and floor exercise), and a gymnast may have participated in any number of the events at each meet. The athletic training program for the gymnasts involved weight training, running, stretching, and formal gymnastics training. They trained an average of 4 hr per day, 5 days per week. During the fall semester (preseason) weight training took place 3 days per week and lasted approximately 1 hr. All major muscle groups were trained with 2 sets of 14 different exercises using 8-10 repetitions per set. Other forms of strength training using movements which simulated gymnastics took place the other 2 days of the week. The rest of the practice time, the remaining three to four hours each day, was spent in formal gymnastics training. During the spring semester (competitive season), weight training was reduced to 2 days per week, number of exercises used was decreased to 10, and repetitions were increased to emphasize muscular endurance.

No data was available regarding previous exercise history for the control participants. However, current exercise regimens were assessed for both the gymnasts and controls from the lifestyle questionnaire. Both groups reported similar minutes / week of exercise.

Design and Analysis

This study was designed to determine the effects of college gymnastics on bone mineral density, menstrual cycle, dietary practices, body composition, and lifestyle factors at least one year after retirement from the sport. The data obtained from this study were compared to data obtained from previous studies using the same gymnasts while they were still competing. A control group was also assessed.

Descriptive statistics were calculated to determine the range, mean, and standard deviation on all variables measured. Assumptions which needed to be met for all analyses include normality, skewness, and kurtosis. A Pearson product-moment correlation was performed to determine any significant correlation between diet, bone mineral density, lean tissue mass, fat mass, and demographic data. Those variables with a significant correlation were then used in the stepwise multiple regression analysis. A 2x2 repeated measures analysis of variance (ANOVA) was performed to determine any significant differences both within the groups over time (BMDP2V) as well as between groups at the same time (BMDP7D). Interaction between groups was also examined to determine if changes over time were different between groups. Stepwise multiple regression analysis (BMDP2R) was done to determine if a significant relationship existed between bone mineral density, muscle mass, and weight. The data were analyzed using the Biomedical

Data Packages, Series P (BMDP) on the university's mainframe computer, the VAX 6330.

CHAPTER IV

PRESENTATION OF THE FINDINGS

The overall purpose of this study was to examine the effect of competitive gymnastics on bone mineral density, menstrual function, dietary practices, body composition, body image, and eating attitudes at least one year after retirement from the sport. Data collected while the gymnasts were in competition was compared to current data. Comparable control participants were also assessed.

Descriptive statistics were calculated as mean physiological and dietary data of participants. An independent t-test was computed as mean composite EAT score between gymnastics group and control group. Body image was analyzed as mean Contour Drawing Rating Scale score between gymnastics group and control group via Mann-Whitney U test. A Pearson Product Moment Correlation was performed to determine if a correlation existed between BMD, diet, lean tissue, fat tissue, and demographic data. No significant correlations including diet existed, therefore diet variables were not included in the stepwise regression analysis. Repeated measures analysis of variance was used to determine if differences existed in bone mineral density or muscle mass within each group over time. Stepwise multiple regression was used to determine if a relationship existed between bone mineral density, lean tissue mass, and weight. Assumptions which needed to be met for all analyses include normality, skewness, and kurtosis; all assumptions were met. This chapter will report the analyzed data in the following order: (a) Description of the Participants, and (b) Data Analysis.

Description of the Participants

Participants were 11 caucasian female ex-gymnasts from Texas Woman's University and 7 caucasian females used as controls, all of whom have initial and current data. The number of participants that participated in either the initial or current study varies depending on the variable tested, and is described when assessing that particular variable. Descriptive statistics of the participants age, height, weight, age of menarche, and percent body fat are displayed in Table 1. The controls were approximately 3 years older than the gymnasts. Height, weight, and age at menarche were similar between the two groups. Percent body fat of the gymnasts was lower than the controls, but the difference was not significant ($\underline{p} > .05$). Average number of menstrual cycles for the gymnasts was also calculated for each year in college. Gymnasts reported an average of 8 menstrual cycles during freshman year, 8 menstrual cycles for sophmore year, junior year was an average of 9 cycles, and senior year was an average of 10 cycles. Although her data did not significantly affect the group of gymnasts, one former gymnast participant was oligomenorrheic, defined as 3 to 6 cycles per year at intervals greater than 36 days (Drinkwater, Bruemner & Chesnut, 1990). Mean minutes of current exercise reported by each group was 223 minutes per week for the former gymnasts and 225 minutes per week for the control group.

Also of interest to the researcher was if the retired gymnasts were currently involved in gymnastics in any way. Six of the 11 retired gymnasts coach at private clubs an average of 20 hours per week.

Table 1

Physiological Data of Participants

Variable	Range	M	SD
Age (years)			
Gymnasts	5 (21-26)	24	1.8
Controls	10 (21-31)	27	3.4
Height (cm)			
Gymnasts	31 (142-173)	161.3	8.2
Controls	23 (157-180)	165.9	7.2

table continues

Variable	Range	M	SD
Weight (kg)			
Gymnasts	25.5 (42.73-68.18)	59.9	6.8
Controls	28.2 (41.82-70.0)	57.8	6.3
Menarche (years)			
Gymnasts	6 (12-18)	14.7	1.9
Controls	3 (12-15)	13.2	2.6
Body Fat (%)			
Gymnasts	16.8 (20.4-37.2)	23.0	2.2
Controls	16.9 (17.5-34.4)	29.5	3.1

Note. n = 11 (gymnasts), n = 7 (controls).

Nutritional information including vitamin and mineral supplements was analyzed by Nutritionist IV version 4.0 and is shown in Figure 1 (gymnasts) and Figure 2 (controls) (see Appendix D, Table 7 for mean values and standard deviation). Both initial (1 - 5 years

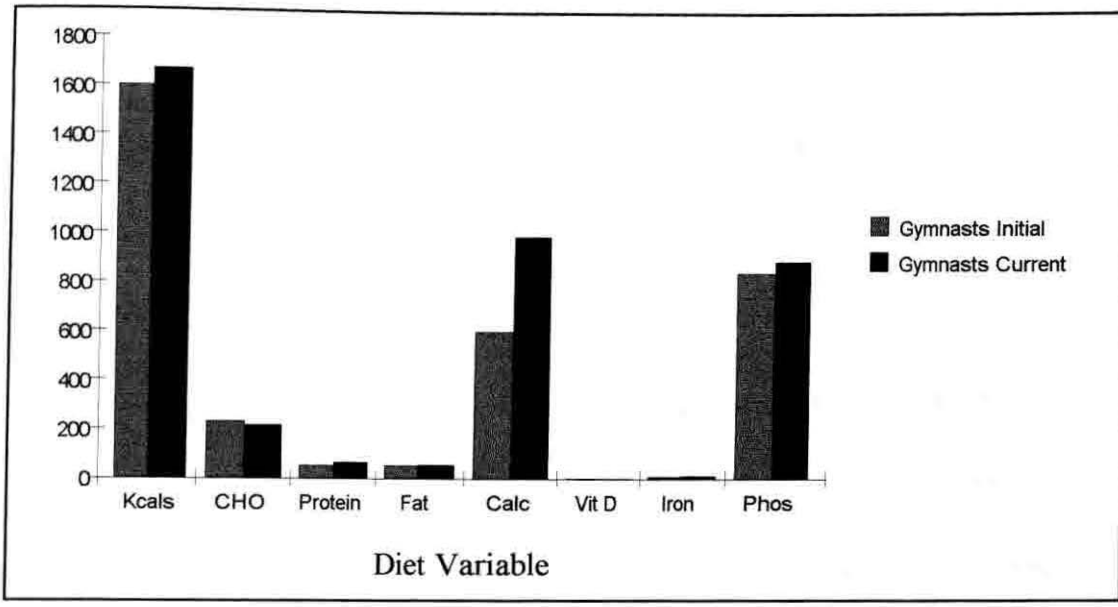

Figure 1. Average Daily Dietary Intake for Gymnasts Initial (n = 7) versus Current (n = 11) current. Kcals is kilocalories, CHO is carbohydrate (g), Protein is protein (g), Fat is fat (g), Calc is calcium (mg), Vit D is vitamin D (ug), Iron is iron (mg), Phos is phosphorus (mg).

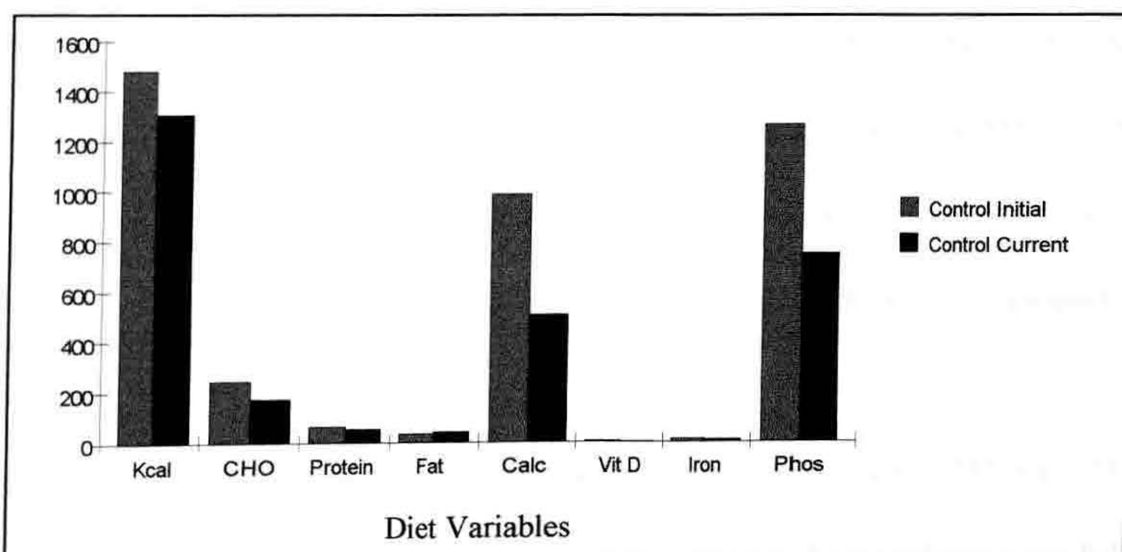

Figure 2. Average Daily Dietary Intake for Controls Initial (n = 3) versus Current (n = 7). Kcal is kilocalories, CHO is carbohydrate (g), Protein is protein (g), Fat is fat (g), Calc is calcium (mg), Vit D is vitamin D (ug), Iron is iron (mg), Phos is phosphorus (mg).

prior) and current information is presented. Initial diet data was available for 3 controls and 7 gymnasts; current diet data was available for 7 controls and 11 gymnasts. Initial data for gymnasts was collected prior to the beginning of their last competitive season. Average daily intakes for kilocalories, carbohydrates, protein, fat, calcium, vitamin D, iron and phosphorus were not significantly different between gymnasts and controls (p >.05).

The controls initial diet was comprised of 67% carbohydrates, 17.3% protein, and 20.7% fat whereas their current diet was comprised of 53.8% carbohydrates, 16.8% protein, and 29.6% fat. The gymnasts initial diet was comprised of 58.3% carbohydrates, 13.1% protein, and 30.4% fat; their current diet was comprised of 52.2% carbohydrates, 15.6% protein, and 29.6% fat. The larger variance seen between the controls initial and current diet versus the gymnasts could be a result of a small number of control participants for the initial diet (n = 3). No gymnast reported taking vitamin supplements for their initial diet and 4 reported taking vitamin supplements currently. One control reported taking a vitamin supplement during the initial diet and no controls reported taking a supplement currently.

The average intake of carbohydrates by adults in the United States in 1985 was 177 grams for females (USDA, 1987). Only the current intake for the control group was below this average by 1 gram. The Recommended Dietary Allowance (RDA) of protein by adults in the United States in 1985 was 46-50 grams per day. Both the gymnast group and the control group exceeded this requirement at the initial analysis and the current analysis. Fat intake is recommended not to exceed 30% of caloric intake per day. Initially, the gymnasts mean intake for fat was 30.4%; all other data show both groups to be under the recommended 30% intake.

The average bone mineral densities from the initial and current scans are provided in Figure 3 (gymnasts) and Figure 4 (controls) (see Appendix D, Table 8 for mean values and standard deviation). Bone mineral density for gymnasts for all sites decreased significantly from the initial study to the current study.

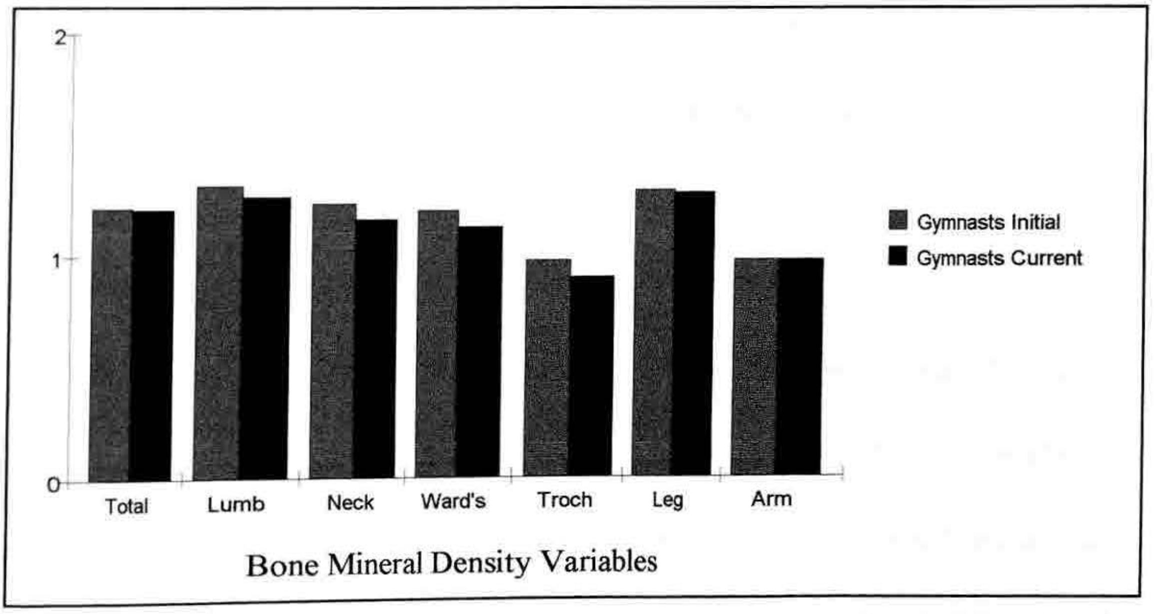

Figure 3. Bone Mineral Density Values for Gymnasts ($\underline{n}$ = 11) Initial versus Current. Total is total body BMD, Lumb is lumbar (L2-L4) BMD, Neck is femoral neck BMD, Ward's is Ward's area BMD, Troch is greater trochanter BMD.

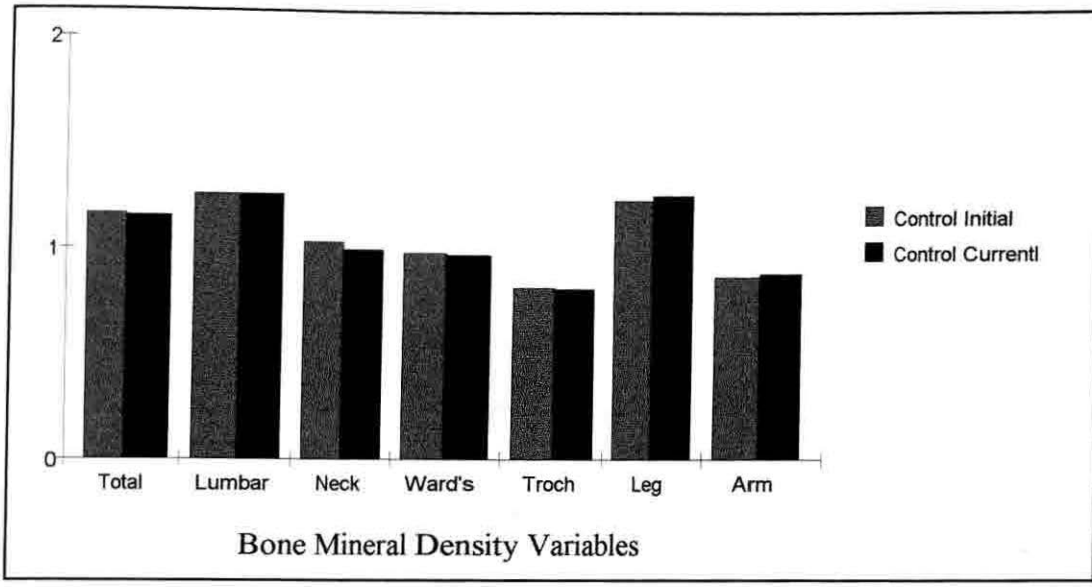

Figure 4. Bone Mineral Density Values for Controls (n = 7) Initial versus Final. Total is total body BMD, Lumb is lumbar (L2-L4) BMD, Neck is femoral neck BMD, Ward's is Ward's area BMD, Troch is greater trochanter BMD.

Bone mineral density for the control group decreased over time at all sites except leg and arm. Gymnasts initially had significantly greater femoral neck, Ward's area, and greater trochanter bone mineral density when compared to controls ($p < .05$). Figure 5 (gymnasts) and Figure 6 (controls) show values for total lean tissue mass, leg lean tissue mass, and arm lean tissue mass (see Appendix D, Table 8 for mean values and standard deviation). Gymnasts total lean tissue mass and arm lean tissue mass increased from the initial to the current study and controls arm lean tissue mass increased over time as well. Initial and current values for these body composition variables were not significantly different within each group ($p > .05$).

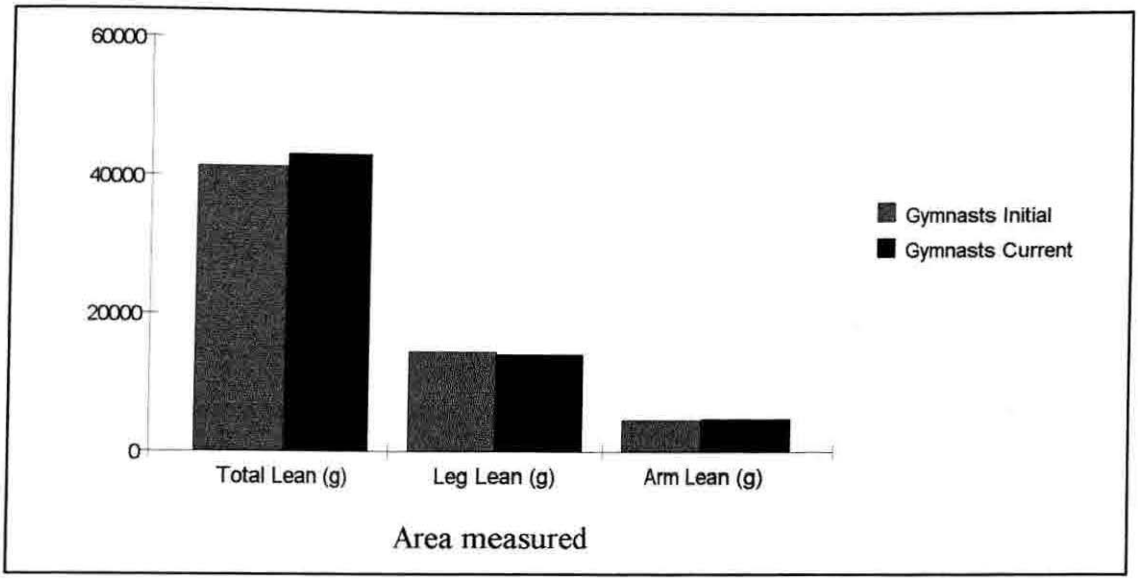

Figure 5. Lean Tissue Mass Values for Gymnasts ($\underline{n}$ = 11) Initial versus Current. Lean is lean tissue mass measured in grams.

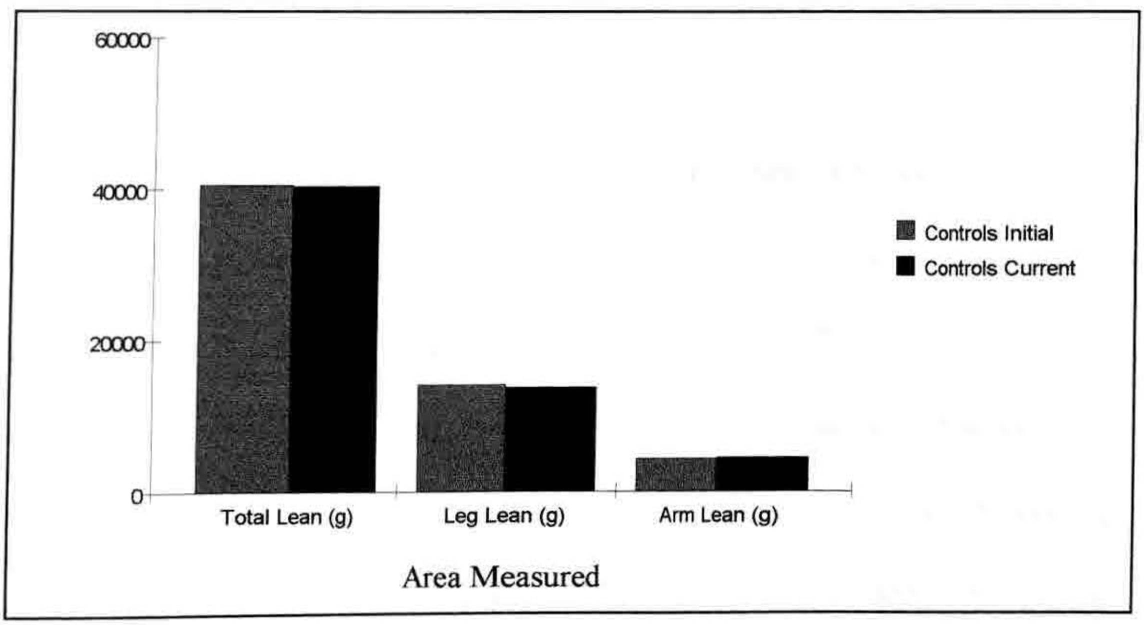

Figure 6. Lean Tissue Mass Values for Controls ($\underline{n}$ = 7) Initial versus Current. Lean is lean tissue mass measured in grams.

Data Analysis

A 2x2 repeated measures analysis of variance was done to determine if any significant differences existed in nutritional intake, bone mineral density, lean tissue mass, or fat mass between the gymnasts and controls over time. There were no significant differences in average daily intakes for gymnasts or controls regarding kilocalories, carbohydrate, protein, fat, calcium, vitamin D, iron and phosphorus between the initial and current dietary intakes ($p > .05$). There were no significant differences within groups or between groups at the same time or over time, regarding any diet variables ($p > .05$).

Results of the repeated measures analysis of variance for bone mineral density measurements are provided in Table 2. Overall, significant declines in lumbar (L2-L4), femoral neck, Ward's area, and greater trochanter bone mineral density (BMD) were found ($p < .05$). Interactions for each site were also significant indicating that gymnasts had a significantly greater loss of BMD than controls ($p < .05$). With simple effect analysis for each group, controls had a significant decline in BMD only at the femoral neck ($p = .040$) where gymnasts declines were significant for lumbar ($p = .0003$), femoral neck ($p = .0002$), Ward's area ($p = .0059$), and greater trochanter ($p = .0001$) BMD. However, the length of time between measurements of BMD for gymnasts was significantly greater than for controls. Therefore the rate of loss (slope) for each group was examined. No

Table 2

Repeated Measures ANOVA Summary Table for Bone Density Measurements

Variable	df	SS	MS	F	p
Total Body BMD					
Time	1	0.0000	0.0000	0.060	.814
Error	14	0.0045	0.0003		
Lumbar BMD					
Time	1	0.0088	0.0088	12.65	.002*
Error	17	0.0119	0.0007		
Neck BMD					
Time	1	0.0297	0.0297	35.90	.001*
Error	17	0.0140	0.0008		
Ward's Area BMD					
Time	1	0.0208	0.0208	6.420	.021*
Error	17	0.0551	0.0032		
Troch BMD					
Time	1	0.0201	0.0201	22.81	.001*
Error	17	0.0149	0.0008		

Note. $n = 11$ (gymnasts), $n = 8$ (controls). * Significance, $p < .05$. Data presented are for within groups. Bone Mineral Density is BMD.

significant differences in slope were found between groups, even when covaried on age.

Results of the repeated measures analysis of variance for lean tissue mass and fat mass are shown in Table 3. None of the lean tissue mass variables measured, total lean, leg lean, or arm lean, showed a statistically significant difference within groups over time ($p > .05$). Gymnasts showed significantly lower leg fat than the controls ($p = .014$). None of the other fat mass variables, arm fat or total fat, were significantly different within groups ($p > .05$).

Table 3

Repeated Measures ANOVA Summary Table for Lean Tissue Mass and Fat Mass

Variable	df	SS	MS	F	p
Total Lean Tissue					
Time	1	8907.62	8907.62	0.01	.931
Error	14	16047217.92	1146229.85		
Arm Lean Tissue					
Time	1	265823.12	265823.12	4.36	.055
Error	14	852662.74	60904.48		
Leg Lean Tissue					
Time	1	841578.44	841578.44	1.02	.328
Error	14	11495806.46	821129.03		

table continued

Variable	df	SS	MS	F	p
Total Fat Tissue					
Time	1	13819366.70	113819366.70	2.78	.117
Error	14	69591159.66	4971797.12		
Arm Fat Tissue					
Time	1	254670.35	254670.35	4.17	.060
Error	14	855120.29	61080.020		
Leg Fat Tissue					
Time	1	6010986.33	6010986.33	7.86	.014*
Error	14	10704021.38	764572.956		

Note. *Significance, $p < .05$. Data presented are for within groups.

One-way analysis of variance was also used to look at differences between groups. The results of this test are shown in Table 4 (initial data) and Table 5 (current data). Data for three controls were not available for any leg, arm, or total body computations. When analyzing this data, if a significant p value was found, Levene's test must have $p > .05$ for the variable to be significant. If Levene's was significant ($p < .05$), then either the Welch or Brown-Forsythe must have a significant p value in order for the variable to be considered significant. For all variables, gymnasts had greater bone mineral density than controls. However, not all sites measured were significantly greater ($p < .05$).

Table 4

One-Way ANOVA for Initial Bone Mineral Density

Variable	df	SS	MS	F	p
Total BMD					
Group	1	0.0083	0.0083	1.33	.269
Error	14	0.0872	0.0062		
Lumbar BMD					
Group	1	0.0133	0.0133	1.28	.274
Error	17	0.1775	0.0104		
Neck BMD					
Group	1	0.1826	0.1826	13.38	.002*
Error	17	0.2319	0.0136		
Ward BMD					
Group	1	0.2241	0.2241	9.060	.008*
Error	17	0.4205	0.0247		
Troc BMD					
Group	1	0.1228	0.1228	10.10	.005*
Error	17	0.2068	0.0122		

Note. *Significance $p < .05$. Bone Mineral Density is BMD. Control group $n = 5$, Gymnasts group $n = 11$.

Table 5

One-Way ANOVA for Current Bone Mineral Density

Variable	df	SS	MS	F	p
Total BMD					
Group	1	0.0198	0.0198	3.98	.062
Error	17	0.0846	0.0050		
Lumbar BMD					
Group	1	0.0005	0.0005	0.05	.829
Error	17	0.1799	0.0106		
Neck BMD					
Group	1	0.1322	0.1322	9.410	.007*
Error	17	0.2390	0.0141		
Ward BMD					
Group	1	0.1329	0.1329	5.670	.029*
Error	17	0.3986	0.0234		
Troch BMD					
Group	1	0.0452	0.0452	4.23	.055
Error	17	0.1815	0.0107		

Note. For the control group, $n = 7$ and for the gymnasts, $n = 11$. Data presented are for between groups. *Significance, $p < .05$.

Results of the stepwise multiple regression analyses are presented in Table 6. Significant predictors of bone mineral density include arm lean tissue mass (initial data collection), weight (current data collection), and total lean tissue mass (initial data collection). However, there were no significant predictors of change in bone mineral density ($p > .05$). No diet variables were assessed in the stepwise regression due to no significant correlation being found from the Pearson product-moment correlation analysis.

Table 6

Significant R^2 Values for Stepwise Multiple Regression Analysis

	Predictors		
Dependent Variable	Arm LTM 1	Weight 2	Total LTM 1
Total BMD 1	.60	---	---
Lumbar BMD 1	.27	---	---
Total BMD 2	---	.45	---
Leg BMD 2	---	.55	---
Lumbar BMD 2	---	.34	---
Neck BMD 1	---	---	.70
Leg BMD 1	---	---	.64

Note. --- Variable was not a significant predictor for that BMD site. 1 = data from initial study, 2 = data from current study.

An independent t-test was calculated via BMDP 3D to determine significant mean differences between scores on the Eating Attitudes Test between the gymnasts and controls. A Levene's test for probability was calculated because of unequal group sizes ($\underline{n}$ = 11, gymnasts; $\underline{n}$ = 7, controls). The variances were considered unequal because the $\underline{p}$ value for the Levene's test was $< .05$, therefore the separate $\underline{t}$ was reported. There was no significant difference between gymnasts and controls ($\underline{p}$ = .67).

The Contour Drawing Rating Scale (body image) was analyzed by the Mann-Whitney U test and tested via BMDP 3S. There was no significant difference between groups on perception of body image ($\underline{p}$ = .67).

CHAPTER V

DISCUSSION

The purpose of this study was twofold. The first purpose was to determine any significant differences in bone mineral density, menstrual function, dietary practices, body composition, body image, and eating attitudes for gymnasts during collegiate competition and then at least one year after retirement from the sport. A second purpose was to determine any significant differences between gymnasts and controls on the same variables, one to five years after initial assessment. The results are discussed in the following order: (a) Summary (b) Discussion, (c) Conclusion, and (d) Recommendations for Further Research.

Summary

Participants were 11 retired collegiate gymnasts from the Texas Woman's University gymnastics team and 7 non-athletic females (controls) who have participated in previous studies at the university. All participants were caucasian and free from any disorder known to affect bone metabolism. Initial measurement dates vary for each participant but range from August 21, 1991 to January 12, 1996. All initial measurements for the gymnasts were completed by September 6, 1994. Number of scans per year are as follows: 1991 - initial scan for 3 gymnasts; 1992 - initial scan for 3 gymnasts and 1 control; 1993 - initial scan for 2 gymnasts; 1994 - initial scan for 3 gymnasts; 1995 - initial scan for 4 controls; 1996 - initial scan for 2 controls and current scan for 2 gymnasts and 2 controls; 1997 - current scan for 9 gymnasts and 5 controls. All current measurements were taken between May 9, 1996 and March 9, 1997. At least one year separates all participants initial and current scans.

Bone mineral density and lean tissue mass were measured using dual energy X-ray absorptiometry (Lunar DPX) located in the Texas Woman's University Bone Laboratory. Body composition was determined using the Lunar DPX (version 3.61). A lifestyle questionnaire was completed by each participant as well as the Eating Attitudes Test (EAT) and a Contour Drawing Rating Scale. Participants also kept a 3-day diet record which they returned to the researcher via mail for analysis.

Descriptive statistics were calculated to determine the range, mean, and standard deviation on all variables measured. A Pearson product-moment correlation was performed to determine any significant correlation between diet, bone mineral density, lean tissue mass, fat mass, and demographic data. Variables with a significant correlation were then used in the stepwise multiple regression analysis. A 2x2 repeated measures analysis of variance (ANOVA) was performed to determine any significant differences both within the groups over time (BMDP2V) as well as between groups at the same time (BMDP7D). Stepwise multiple regression analysis (BMDP2R) was used to determine if a significant relationship existed between bone mineral density, muscle mass, and weight. No diet variables were analyzed in the stepwise regression due to no significant correlation being found from the Pearson product-moment correlation analysis.

Physiological variables were age, height, weight, menarche and percent body fat. Controls were slightly older than the gymnasts. Height and menarche were similar between the two groups. Average age of menarche for each group was considered normal (Taber, 1989). Menstrual status was not normal for all participants. One gymnast was oligomenorrheic for unknown reasons but did not influence the results. Percent body fat was not significantly different between the gymnasts and controls ($p > .05$).

Nutritional data were analyzed for mean daily intakes of kilocalories, carbohydrates, protein, fat, calcium, phosphorus, vitamin D, and iron. Average daily intakes of all nutrients were similar for both groups. Calcium intake for gymnasts and controls was lower than the Recommended Daily Allowance (National Research Council, 1989).

Bone mineral density was determined for total body, lumbar spine (L2-L4), femoral neck, Ward's area, and the greater trochanter. The initial scan revealed the gymnasts to have significantly higher bone mineral density than the control group for the femoral neck, Ward's area, and the greater trochanter ($p < .05$). The current scan revealed the gymnasts to have significantly higher bone mineral density than the control group in the femoral neck ($p = .007$) and Ward's area ($p = .029$). Total lean tissue mass, as determined by DXA, was not significantly different between the two groups in either the initial or the current measurement ($p > .05$).

The primary hypotheses that guided this investigation were tested at the .05 level of significance. The null hypotheses were:

1. There are no significant differences in bone mineral density, caloric intake, menstrual patterns, body composition, body image, and eating attitudes when comparing the results of gymnasts from a previous study at which time they were in competitive gymnastics and this study in which they have been retired for at least one year. Rejected.

2. There are no significant differences in bone mineral density, caloric intake, menstrual patterns, body composition, body image, and eating attitudes when comparing retired gymnasts with controls for the initial or current study. Rejected.

The following specific hypotheses were examined at the .05 level of significance:

1. There are no significant predictors between total kilocalories,

carbohydrate, protein, fat, calcium, vitamin D, iron, phosphorus, weight, and muscle mass and bone mineral density (L2-L4, femoral neck, Ward's area, greater trochanter and total body). Rejected.

2. There are no significant differences in dietary intake when comparing data for gymnasts versus controls from the initial or current study. Accepted.

3. There are no significant differences in body image, as assessed by the Contour Drawing Rating Scale, between gymnasts and controls. Accepted.

4. There are no significant differences in the Eating Attitudes Test between gymnasts and controls. Accepted.

5. There are no significant differences in any physiological variables for gymnasts versus controls for the initial or current study. Accepted.

Discussion

From the results of the current study, it is indicated that gymnasts, even after retirement from the sport, continue to have significantly higher bone mineral density for all measurements, lumbar spine, femoral neck, Ward's area, and greater trochanter, except total body ($p = .81$), than a group of controls. Lean tissue mass, neither initially ($p = .76$) nor currently ($p = .45$) was significantly higher than controls. No significant differences were found in percent body fat between gymnasts and controls initially or currently

(p = .14, p = .91, respectively). No significant correlations were determined regarding diet.

Bone mineral density was measured for total body, at the lumbar (L2-L4) vertebrae, femoral neck, Ward's area, and greater trochanter. The average value for total body bone mineral density of the gymnasts and controls were slightly higher (7.9% and 4.9%, respectively) than that of the United States population (M = 1.120 to 1.142 g/cm^2, standard deviation not reported) of similar ages (Lunar Corporation, 1990). The values for the lumbar bone mineral density of the gymnasts and controls were also slightly higher (6.6% and 5.7%, respectively) than that of the reference population (M = 1.188 to 1.207 g/cm^2) of similar ages. Both the gymnasts and controls had slightly higher (21.1% and 3.9%, respectively) bone mineral density for femoral neck than the reference population (M = 0.958-0.994 g/cm^2) of the same age. The average value for Ward's area bone mineral density of the gymnasts and controls was slightly higher (27.5% and 8.4%, respectively) than the reference population (M = 0.886 to 0.947 g/cm^2) of similar ages. The greater trochanter bone mineral density for the gymnasts and controls was also slightly higher (14.4% and 2.1%, respectivey) than that of the reference population (M = 0.787 to 0.798 g/cm^2) of similar ages.

The increased bone mineral density in gymnasts versus controls is in keeping with results from other studies which have reported higher bone mineral density in eumenorrheic athletes when compared to controls (Dook, James, Henderson, & Price, 1997; Heinrich et al., 1990; Howat, Carbo, Mills, & Wazniak, 1989; Kirchner, Lewis, and O'Connor, 1996; Nichols et al., 1994). Only one study to date has examined bone mineral density of former gymnasts. Kirchner, Lewis, and O'Connor (1996) examined bone mineral density of former female college gymnasts and age-, height-, and weight-matched controls. Using DXA (Hologic, QDR 1000W) they found significantly higher ($\underline{p} < 0.001$) bone mineral density at all sites measured, which include lumbar spine (L1-L4), femoral neck, Ward's area and whole body.

Several studies have examined bone mineral density in female collegiate gymnasts not yet retired. Howat, Carbo, Mills, and Wazniak (1989) examined the bone mineral density of female collegiate gymnasts versus controls. Using DPA they found regularly menstruating gymnasts to have significantly higher lumbar bone mineral density than controls (1.37 and 1.20 g/cm^2; respectively). This initial value was slightly higher than the initial value in this study, which could be because Howat, et al., reported values for L1-L4 vertebrae instead of L2-L4. Nichols et al. (1994) also examined bone mineral density among eumenorrheic collegiate gymnasts with that of sedentary, eumenorrheic females. Using DXA, they found preseason bone mineral density of gymnasts to be significantly greater than controls at both lumbar spine (1.328 vs. 1.225 g/cm^2; respectively) and femoral neck (1.193 vs. 1.079 g/cm^2; respectively). Initial data for this study report comparable findings to Nichols et al. for gymnasts and controls. For this study, bone mineral density at the lumbar spine was greater for gymnasts versus controls (1.319 vs. 1.265 g/cm^2; respectively) but not significantly (p = .274). Gymnasts were significantly greater at the femoral neck (p = .002; 1.240 vs. 1.040 g/cm^2; respectively), Ward's area (p = .008; 1.203 vs. 0.84 g/cm^2; respectively) and greater trochanter (p = .005; 0.980 vs. 0.820 g/cm^2; respectively).

Heinrich et al. (1990) used dual photon absorptiometry (Lunar DP3) to study bone mineral density in a group of various athletes and controls. Higher lumbar vertebrae (L2-L4) bone mineral density values were reported for a group of body builders, swimmers, collegiate runners, and recreational runners when compared to controls. Body builders also had greater bone density at Ward's area and femoral neck than the other athletes and controls. Femoral neck and Ward's area bone mineral densities were greater in the gymnasts in the current study when compared to the body builders. Lumbar spine bone mineral density, however, was greater in the body builders than the gymnasts. Different scanning devices were used (DPA vs. DXA) which could explain some of the difference. Controls in both studies had comparable bone mineral densities.

Bone mineral density was examined by Dook, James, Henderson, and Price (1997) for mature (42 - 50 years old) athletes in various impact-loading sports (basketball, netball, running, field hockey) versus non-athletic controls. Athletes had been involved in their sport for at least 20 years and all participants were eumenorrheic. Athletes in impact-loading sports had significantly higher total body ($p < .0001$) and regional leg ($p < .0001$) bone mineral density. Researchers concluded that females who participate regularly in the premenopausal years in high impact physical activity tend to have higher bone mineral density than nonathletic controls.

There are several possible explanations why former gymnasts have significantly higher bone mineral density than controls. First, there may be a residual effect of gymnastics participation on bone mass that carries on into later years of life. Studies have shown that sports involving jumping and running promote higher bone density in the lumbar spine (L2-L4) and lower extremities than other sports (Dook, James, Henderson, & Price, 1997; Grimston, Willows, & Hanley, 1993; Risser et al., 1990). Gymnasts increase their bone mineral density throughout most of their career due to intensity and type of training resulting in higher bone mineral density than controls (Nichols et al., 1994). This in turn means that when they retire from the sport, even though they probably lose at the same rate as the controls, they have more to lose.

Another possible explanation is that gymnasts may remain more physically active than controls after retirement from gymnastics therefore continually stimulating bone growth (Kirchner, Lewis, O'Connor, 1996). However, this study found no significant difference between minutes of exercise per week for gymnasts and controls (223.65 vs. 224.70 minutes / week; respectively). Estrogen has a great impact on bone mineral density, however, estrogen deficiency did not have a role in this study. Age at menarche was not significantly different between the two groups and is considered average. Lastly, former gymnasts may be more genetically inclined to have higher bone density before their participation in gymnastics; genetics has been reported to explain 80% of differences in bone mass (Kelly, Eisman, & Sambrook, 1990).

Lean tissue mass (muscle mass) for total body, leg, and arm remained similar for each group from the initial study to the current study. There were no significant differences between gymnasts or controls regarding lean tissue mass. Stepwise regression was used to determine any significant predictors of bone mineral density. Arm muscle mass (initial data), total muscle mass (initial data), and weight (current data) were found to be significant predictors of bone mineral density.

Dietary data were analyzed for mean kilocalories, carbohydrates, fat, protein, calcium, phosphorous, vitamin D, and iron. No significant differences were seen between the gymnastics group and the control group currently or within either group over time. These results do not correspond with those of Kirchner, Lewis, and O'Connor (1995) who found former gymnasts to have significantly lower kcal intakes than controls ($p < .05$). Gymnasts in the current study reported a higher intake of kcals than gymnasts reported in the Kirchner, Lewis, and O'Connor study (1670 ± 201.5 vs. 1381 ± 109; respectively). However, in a 1996 study, Kirchner, Lewis, and O'Connor found no significant difference between former gymnasts and controls for all nutrients reported.

Gymnasts mean average of kilocalories increased from the initial study to the current study and mean average kilocalories for the control group stayed the same. However, the number of initial diets calculated for the control group were only three, compared to eight for the current diet. The mean average for carbohydrates decreased for both groups from the initial study to the current study. Mean average for protein, calcium, vitamin D, phosphorus and iron increased for the gymnasts but decreased for the controls. Fat intake increased for both groups.

The recommended dietary allowance (RDA) of calcium and phosphorus for non-pregnant females 18 to 24 years old is 1200 mg of each per day (National Research Council, 1989). For 25 to 50 year old non-pregnant females, the RDA decreases to 800 mg of each per day. For the current study, the mean age for the gymnasts was 24.3 years with a mean calcium intake of 790.6 $\pm$ 124.3 mg per day and a mean phosphorus intake of 890.7 $\pm$ 165.2 mg per day, both of which are below RDA. Gymnasts were below the RDA for calcium and phosphorus initially as well (601.7 $\pm$ 210.4 mg and 845.1 $\pm$ 291.0 mg; respectively). The mean age for the controls in the current study was 27.6 years putting them in the lower RDA category. The control group was below the RDA with a mean calcium intake of 509.1 $\pm$ 226.3 mg per day and a mean phosphorus intake of 751.9 $\pm$ 209.1 mg per day. Data from the initial study indicate the control group to be above the RDA for both calcium and phosphorus (990.5 $\pm$ 856.3 mg and 1269 $\pm$ 80.6 mg, respectively). The recommended calcium to phosphorus ratio for optimum utilization of calcium by bone is 1:1 (National Research Council, 1989), however, phosphorus intake for both groups exceeded calcium intake. The calcium to phosphorus ratio for the gymnasts for this study was 1:1.1, and the ratio for the control group for this study was 1:1.5.

No significant differences were found between the gymnasts and controls regarding the Eating Attitudes Test or the Contour Drawing Rating Scale. These tests were not part of the initial assessment, therefore there is no comparison. Hallinan, Pierce, Evan, DeGrenier, and Andres (1991) found significant differences when comparing current image and ideal image between women athletes and nonathletes. Several studies have found that women express dissatisfaction with their physical size and image (DiNucci, Finkenburg, McCune, S., McCune, E., & Mayo, 1994; Huddy, Nieman, & Johnson, 1993). This study however, found no significant difference between former athletes and controls.

Conclusion

It can be concluded that, within the limits of this study, gymnasts continue to have significantly higher femoral neck, Ward's area, and greater trochanter bone mineral density than controls even after retirement from competitive gymnastics. This study also found initial total lean tissue mass, initial arm lean tissue mass, and current weight to be significant predictors of bone mineral density. However, no significant predictors of the change in bone mineral density were found.

Recommendations for Further Research

The following are recommendations for future studies:

1. Longitudinal studies on bone mineral density, lean tissue mass, and diet on various athletes after retirement from their sport.

2. Longitudinal bone mineral density studies designed to determine any significant differences between men and women after retirement from competitive sport.

3. Longitudinal studies assessing body image on male and female athletes

during college participation and after completion of college participation.

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Appendix A

Human Subjects Approval and Consent Form

TEXAS WOMAN'S UNIVERSITY

DENTON DALLAS HOUSTON

HUMAN SUBJECTS
REVIEW COMMITTEE
P.O. BOX 22939
Denton, TX 76204-0939
Phone: 817/898-3377

March 8, 1996

Johnna D. Hinton
214 Hickory Lane
Denton, TX 76205

Dear Johnna D. Hinton: [redacted]

Your study entitled "Post-competitive Lifestyle and It's Impact on Bone Density, Dietary Intake and Body Composition among Female Gymnasts" has been reviewed by a committee of the Human Subjects Review Committee and appears to meet our requirements in regard to protection of individuals' rights.

Be reminded that both the University and the Department of Health and Human Services (HHS) regulations typically require that agency approval letters and signatures indicating informed consent be obtained from all human subjects in your study. These are to be filed with the Human Subjects Review Committee. Any exception to this requirement is noted below. This approval is valid one year from the date of this letter. Furthermore, according to HHS regulations, another review by the Committee is required if your project changes.

Special provisions pertaining to your study are noted below:

____ The filing of signatures of subjects with the Human Subjects Review Committee is not required.

____ Other:

_X_ No special provisions apply.

Sincerely,

Chair
Human Subjects Review Committee - Denton

cc: Graduate School
Dr. Nancy DiMarco, Nutrition and Food Sciences
Dr. Betty Alford, Nutrition and Food Sciences

TEXAS WOMAN'S UNIVERSITY
DENTON / DALLAS / HOUSTON

HUMAN SUBJECTS
REVIEW COMMITTEE
P.O. Box 425619
Denton, TX 76204-3619
Phone: 817/898-3377
Fax: 817/898-3416

March 10, 1997

Ms. Johnna D. Hinton
214 Hickory Lane
Denton, TX 76205

Dear Ms. Hinton: [redacted]

The request for an extension of the approval for your study entitled "Post-competitive Lifestyle and It's Impact on Bone Density, Dietary Intake and Body Composition among Female Gymnasts" has been reviewed by a committee of the Human Subjects Review Committee and appears to meet our requirements in regard to protection of individuals' rights.

Be reminded that both the University and the Department of Health and Human Services (HHS) regulations typically require that agency approval letters and signatures indicating informed consent be obtained from all human subjects in your study. **These consent forms, agency approval letters, and an annual/final report are to be filed with the Human Subjects Review Committee at the completion of the study.**

This approval is valid one year from March 8, 1997. Furthermore, according to HHS regulations, another review by the Committee is required if your project changes. If you have any questions, please feel free to call the Human Subjects Review Committee at the phone number listed above.

Sincerely,

Chair
Human Subjects Review Committee

cc. Graduate School
Dr. Nancy DiMarco, Department of Nutrition & Food Sciences
Dr. Betty Alford, Department of Nutrition & Food Sciences

TEXAS WOMAN'S UNIVERSITY
SUBJECT CONSENT TO PARTICIPATE IN RESEARCH
Bone Density, Dietary Intake and
Body Composition among Former Female Gymnasts.

INVESTIGATOR: Johnna Hinton R.D., L.D. (817) 898-2644
Nancy DiMarco, PhD., R.D., L.D. (817) 898-2645

The goal and purpose of this research study is to examine bone density, dietary intake and body composition of former female collegiate gymnasts.. Subjects will be asked to fill out a three-day dietary recall form, an Eating Attitudes Test, and a medical and lifestyle questionnaire. Body composition will be measured with a five-site skinfold test (measuring each site a minimum of three times) in the TWU training room and bone mineral density will be measured using the lunar DPX dual energy x-ray absorptiometer which is located in the Bone Lab, Department of Nutrition and Food Sciences. All testing will be performed on the TWU - Denton campus and take approximately two hours.

Risks:
The only risk involved in this study is exposure to a minimal amount of radiation. The amount of radiation from the dual energy x-ray absorptiometry scans (less than 5 mR) are far less than the 100 mR of a chest x-ray and the 600 mR of a lumbar x-ray. The bone scan exposes a developing fetus to a small amount of radiation. If there is a chance that you are pregnant, you must have a pregnancy test before you can be cleared to have the bone density scan. Confidentiality will be ensured to all subjects. A coding system using numbers will be used to match all data and no names will be released in association with any information collected. A master list with names and codes will be kept locked at all times in the TWU Nutrition and Food Sciences Department. Information will be stored for five years and then destroyed by shredding.

Benefits:
Benefits, at no cost to the participant, as a result of participation in this study include: body composition analysis, bone mineral density analysis with recommendations to prevent osteoporosis later in life, nutrient analysis of diet, analysis of eating attitudes, and an abstract of the findings of the study.

We will try to prevent any problem that could happen because of this research. Please let us know at once if there is a problem and we will help you. You should understand, however, that TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

If you have any questions about the research or about your rights as a subject, we want you to ask us. Our phone number is at the top of this form. If you have questions later, or if you wish to report a problem, please call us or the Office of Research & Grants Administration at 817-898-3375.

Participation in this study is voluntary and I may withdraw at any time. Refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

An offer to answer all of my questions regarding the study has been made and I have been given a copy of the dated and signed consent form.

Subject's signature ________________________________ **Date** ___________________

Witness's signature ________________________________ **Date** ___________________

Appendix B

Medical and Lifestyle History Questionnaire

MEDICAL AND LIFESTYLE QUESTIONNAIRE

The purpose of this questionnaire is to gather information on your medical history and lifestyle. Please answer all questions to the best of your ability. At the time of your bone density test we will be able to answer any questions you may have and review your history with you. All information will be kept confidential.

Today's date ______________________ Age ____________________

Name ______________________ Home phone ________________

Address ______________________ Work phone ________________

____

Date of birth ______________________

I. **MEDICAL HISTORY**

1. What is the highest your adult ($\geq$ 18 yr) weight has ever been?
   _____Age ___
   What is the lowest your adult ($\geq$18 yr) weight has ever been?
   _____ Age_____

2. Do you have any current medical conditions? YES NO
   If yes, please list conditions.
   ____
   ____
   ____
   ____
   ____

3. Please list any medication you are currently taking, along with the dose and duration. Please include vitamin and mineral supplements.

Medication	Dose	For how long
______________	______________	______________
______________	______________	______________

III. MENSTRUAL/REPRODUCTIVE HISTORY

4. How old were you when you started menstruating? ____________

5. As a competitive gymnasts, did you have regular menstual cycles (regular = ≥10/yr)? YES NO
   If no, how many cycles per year did you have as a: Freshman ____ Sophmore ______ Junior ________ Senior________

6. Do you currently have regular cycles? YES NO
   If no, how many cycles per year do you have? ____________

7. Have you had times where you missed periods other than when you were pregnant or breast-feeding? YES NO
   If yes, at what age and for how long did you go without having a period?

Age	Number of months without period
____	____________
____	____________
____	____________
____	____________

8. Have you ever taken sex hormones? YES NO
   If yes, please indicate what kind, at what age, for how long and what dose.

Type	At what age	For how long	What dosage
Birth control pills	________	________	________
Estrogen/progesterone	________	________	________
Other___________	________	________	________

III. ORTHOPEDIC HISTORY

9. Have you ever been diagnosed with or experienced any of the following?

Low back pain	YES	NO
Rickets	YES	NO
Bone tenderness	YES	NO
Scoliosis	YES	NO

Osteomalacia YES NO
Osteoporosis YES NO
Osteopenia YES NO

If you answered "yes" to any of the above questions please explain.

____

____

10. Have you ever fractured or broken any bones? YES NO
    If yes, please list which bone(s) were broken, at what age, and the cause of the fracture(s).

Bone	Age	Cause
________	_____	____________________
________	_____	____________________
________	_____	____________________
________	_____	____________________

IV. FAMILY HISTORY

11. Has anyone in your family been diagnosed with osteoporosis?
    YES NO
    If yes, please indicate their relationship to you and age they were diagnosed.

Relationship to you	Age they were diagnosed
____________	________
____________	________
____________	________

12. Does anyone in your family have a history of breaking bones easily or with minor trauma? YES NO

    If yes, relationship to you, bone(s) they have broken, and what caused the break.

Relationship to you	Bone(s) broken	Cause of break
____________	_________	_________
____________	_________	_________
____________	_________	_________

V. DIET HISTORY

13. Are you on a special diet for any reason? YES NO
    If yes, what kind of diet are you on?
    ____

14. Do you eat/drink milk, yogurt or cheese? YES NO
    If yes, which foods, how much and how often?

Foods	How much	How often
______________________		____________
______________________		____________
______________________		____________
______________________		____________

15. Do you remember drinking milk as a child and teenager?
    YES NO
    If yes, how much?___________ how often?___________

VI. LIFESTYLE

16. Do you smoke? YES NO
    If yes, how much do you smoke per day? ____________________
    At what age did you start smoking? ________________________

17. If no, have you ever smoked? YES NO
    If yes, at what age did you start? ______________
    At what age did you stop? ____________________
    How much did you smoke per day? _____________

18. Do you drink alcohol? YES NO
    If yes, how much? __________________________
    and how often? ____________________________

19. Have you ever been confined to bed for a week or more?
    YES NO
    If yes, please indicate when and for how long.

Date	For how long
__________	______________________________
__________	______________________________

20. Do you currently exercise? YES NO
    If yes, please indicate what type of exercise you do, how often you do it, and for how long.

	How often	For how long
Walking	________	________
Jogging	________	________
Aerobics	________	________
Dancing	________	________
Tennis	________	________
Racquetball	________	________
Basketball	________	________
Volleyball	________	________
Weight Training	________	________
Gymnastics	________	________
Other ________	________	________
________	________	________
________	________	________

21. Would you describe your activity level as sedentary, somewhat active, active, or extremely active? ________________

22. Do you currently have any medical problems that limit your normal activity level? YES NO
    If yes, please explain. ________________________
    ____

23. Are you currently involved in gymnastics in any way? YES NO
    If yes, please explain how. ________________
    How many hours per week? ________________

THANK YOU FOR YOUR PARTICIPATION IN THIS RESEARCH PROJECT

Appendix C

Three Day Food Record

INSTRUCTIONS FOR RECORDING OF FOODS

Your diet records are a very important part of this research study. For our results to be reliable we need HONEST and ACCURATE diet records. You will record three days (2 weekdays and 1 weekend day), however, the days do not have to be consecutive. We ask that you not alter your eating habits during this crucial part of the study. It is important that your information be factual for our analysis and results to be valid. All information will be kept confidential. Thank you for your participation.

1. Please write down EVERYTHING you eat or drink for three consecutive days including any / all vitamin and mineral supplements.

2. Record BRAND NAMES (if known - i.e. Parkay margarine, Kellogg's Corn Flakes, Philadelphia Cream Cheese, etc.) and NAMES OF RESTAURANTS.

3. Specify METHODS OF PREPARATION. Example: whether meat is fried, broiled, baked, breaded, etc.

4. For foods PREPARED WITH FAT, specify fat used. Example: fried in margarine (with brand name).

5. FULLY DESCRIBE all foods, beverages, condiments, spreads, etc. (e.g., chicken thigh, skin not eaten; decaffeinated coffee; low calorie French dressing).

6. LIST INGREDIENTS for sandwiches and mixed dishes.

7. Record EXACT AMOUNTS. Specify weight, volume (e.g., household units such as cup, tsp., TB., fl oz.) or dimensions in inches.

8. Include ADDITIONS AT THE TABLE. Example: baked potato *with 1 Tb. butter*, coffee *with 1 tsp. sugar*. Record each addition on a separate line.

9. Describe all VITAMINS, MINERALS and other SUPPLEMENTS.

Food Record Data Collection Form

Please complete as accurately as possible using the examples provided as a guide. Use only 1 form per day. Do not put information pertaining to more than 1 day on the same form. **Record everything you consume for accuracy.**

Name: ______________________ Day number (circle): 1 2 3

AGE: __________ Date of recorded intake: ______________

FOOD	TYPE	PREPARATION	AMOUNT	TIME CONSUMED
Chicken	Breast	Fried	Half breast	12:30 PM
Milk	Whole	–	12-oz glass	3:00 PM
Broccoli	Fresh	Steamed	1 stalk	6:30 PM

Appendix D

Raw Data

Physiological Variables of Participants

#	% BF 1	% BF 2	age of menarche	currently on bc	months on bc	normal menses	minutes of exercise/wk
				Gymnasts			
101	23.5	31.9	16	no	***	yes	180
102	22.4	24.9	16	yes	21	yes	190
103	26.2	34.6	16	no	18	yes	195
104	19.0	20.7	18	yes	12	yes	420
105	21.9	21.3	16	no	0	yes	320
106	20.9	27.4	13	no	0	no	0
107	21.6	20.4	14	no	18	yes	0
108	23.1	28.2	12	no	12	yes	420
109	24.8	22.8	13	no	0	yes	330
110	25.7	37.2	16	no	0	yes	150
111	24.1	21.0	12	no	0	yes	220
				Controls			
112	19.2	17.8	13	no	60	yes	210
113	****	24.6	13	yes	48	yes	180
114	****	20.6	13	no	12	yes	210
115	28.3	29.5	15.5	yes	48	yes	510
116	33.9	31.8	13	yes	96	yes	235
117	37.5	34.4	12	yes	36	yes	135
118	28.4	34.4	13	yes	96	yes	250

Note. # = participant number; % BF 1 = percent body fat initial scan; % BF 2 = percent body fat current scan; currently on bc = currently taking birth control pills; months on bc = number of months total on birth control.

Average Daily Dietary Intake of Participants (Initial and Current)

#	Kcals1 Kcals2	CHO1 CHO2	Protein1 Protein2	Fat1 Fat2	Calcium1 Calcium2	Vit D1 VitD2	Iron1 Iron2	Pho1 Pho2
				Gymnasts				
101	889	143.7	26.5	24.8	316.2	0.0	5.7	339
	1956	230.3	73.8	62.3	797.5	0.5	10.6	847
102	-------	-------	------	------	-------	-----	------	----
*	2688	460.8	108.4	39.3	1986	16.0	27.6	1920
103	2172	315.7	101.9	62.7	873	2.3	15.8	1043
	-------	-------	-------	------	-------	------	------	----
104	-------	-------	-------	------	-------	------	------	----
	-------	-------	-------	------	-------	------	------	----
105	-------	-------	-------	------	-------	------	------	----
*	2179	394.1	67.4	29.8	1545	13.6	29.3	1268
106	1549	242.4	61.1	38.4	632.6	4.5	11.2	870
	1624	213.1	66.9	57.8	622.4	4.1	6.9	976
107	1789	211.6	52.3	83.7	955.2	4.6	10.8	1129
	1360	165.5	59.4	47.7	997.4	5.1	8.2	928
108	1545	221.4	50.1	51.9	623.5	1.7	11.1	692
	1768	231.1	56.9	54.3	817.2	1.2	9.3	610
109	1733	251.7	52.6	61.3	486.2	1.3	10.1	993
*	1577	254.9	75.7	29.9	792.3	8.7	29.7	1107
110	2091	325.1	66.5	61.8	596.3	3.5	11.9	1048
	1738	210.2	55.2	76.9	716.7	0.7	9.2	875

#	Kcals1 Kcals2	CHO1 CHO2	Protein1 Protein2	Fat1 Fat2	Calcium1 Calcium2	Vit D1 VitD2	Iron1 Iron2	Pho1 Pho2
111	-------	-------	------	------	------	-----	-----	----
*	1561	225.0	55.4	49.0	714.9	9.8	11.2	615
				Controls				
112	------	-------	-----	------	------	-----	-----	----
	1379	224.0	43.9	37.3	625.6	1.6	12.2	754
113	-------	--------	-----	------	------	-----	-----	----
	2164	263.3	84.5	90.4	1045	0.00	10.7	907
114	-------	--------	-----	------	------	-----	-----	----
	2215	225.0	93.9	105.9	953.4	4.4	15.9	1421
115	1928	342.0	77.0	42.0	1596	10.0	90.0	1326
*	1506	222.7	52.0	48.4	669.2	2.6	12.4	899
116	--------	--------	------	-------	------	------	------	----
	2880	385.5	92.9	105.4	1807	8.8	18.3	1821
117	1033	155.0	51.0	26.0	385.0	1.0	10.0	1212
	1109	129.5	58.9	37.6	349.1	1.9	9.3	604
118	2198	263.0	103.1	61.8	1482	-----	-----	----
	1081	101.9	44.9	42.7	213.3	0.0	3.9	266

Note. # = participant number; 1 = initial diet; 2 = current diet; * = values include supplements; --- = no data available for participant; Kcals = total kilocalories; CHO = grams of carbohydrates; Protein = grams of protein; Fat = grams of fat; Calcium = milligrams of calcium; Vit D = micrograms of Vitamin D; Iron = milligrams of iron; Pho = milligrams of phosphorus.

Physiological Variables of Participants

Participant #	Age 1 (years)	Age 2 (years)	Weight 1 (kilograms)	Weight 2 (kilograms)	Height 1 (centimeters)	Height 2 (centimeters)
101	21	25	58.2	57.7	157	157
102	20	23	65.5	62.3	165	165
103	20	24	68.2	68.2	168	168
104	20	22	64.6	64.6	173	173
105	18	21	63.2	64.6	170	170
106	21	26	40.0	42.7	142	142
107	21	25	60.9	60.9	165	165
108	21	26	50.0	55.0	157	157
109	18	23	56.8	58.6	160	160
110	21	26	55.9	64.6	160	160
111	19	22	57.3	60.0	155	157
112	29	31	55.9	55.5	173	170
113	26	27	60.0	60.5	163	165
114	29	30	42.3	41.8	155	157
115	24	25	56.8	56.8	160	160
116	26	27	68.6	65.9	180	180
117	19	21	63.6	70.0	168	165
118	25	30	56.4	59.1	157	157

Note. 1 = Initial scan; 2 = Current scan.

Bone Mineral Density Values of Participants

Participant #	Lumbar 1 Lumbar 2	Neck 1 Neck 2	Ward's 1 Ward's 2	Troch 1 Troch 2	Total 1 Total 2
101	1.431 1.403	1.256 1.151	1.251 1.155	0.963 0.873	1.236 1.218
102	1.252 1.206	1.177 1.155	1.232 1.194	0.962 0.904	1.206 1.199
103	1.346 1.277	1.309 1.272	1.228 1.194	1.015 0.984	1.282 1.272
104	1.315 1.287	1.382 1.327	1.301 1.301	1.121 1.030	1.321 1.291
105	1.327 1.296	1.369 1.280	1.376 1.357	1.052 0.990	1.223 1.223
106	1.201 1.093	0.989 0.908	0.940 0.856	0.751 0.655	1.043 1.055
107	1.403 1.394	1.290 1.259	1.274 1.228	0.914 0.913	1.288 1.262
108	1.182 1.096	1.129 1.045	0.992 0.928	0.924 0.826	1.143 1.151
109	1.228 1.201	1.100 0.985	0.939 0.797	0.839 0.756	1.118 1.106
110	1.331 1.277	1.296 1.151	1.418 1.174	1.137 0.964	1.214 1.232

table continued

Participant #	Lumbar 1 Lumbar 2	Neck 1 Neck 2	Ward's 1 Ward's 2	Troch 1 Troch 2	Total 1 Total 2
111	1.493 1.402	1.301 1.280	1.286 1.253	1.107 1.026	1.285 1.286
112	1.248 1.249	0.928 0.925	0.848 0.863	0.757 0.779	1.173 1.165
113	1.263 1.315	1.014 0.960	0.925 0.927	0.792 0.801	**** 1.155
114	1.057 1.102	0.880 0.897	0.834 0.945	0.676 0.673	**** 1.065
115	1.261 1.199	1.146 1.110	1.112 1.097	0.869 0.823	1.186 1.173
116	1.273 1.253	0.994 0.938	0.981 0.920	0.796 0.813	1.133 1.128
117	1.453 1.421	1.209 1.129	1.253 1.075	0.990 0.920	1.254 1.244
118	1.257 1.264	1.058 1.038	0.935 1.001	0.860 0.881	1.081 1.163

Note. Bone Mineral Density is BMD g/cm^2. 1 = Initial scan; 2 = Current scan. Lumbar is L2-L4, Neck is femoral neck BMD, Ward's is Ward's area BMD, Troch is greater trochanter BMD, Total is total body BMD. **** = no data available.

Lean Tissue Mass and Fat Mass Values of Participants

Participant #	Total Lean 1 Total Lean 2	Leg Lean 1 Leg Lean 2	Arm Lean 1 Arm Lean 2	Total Fat 1 Total Fat 2	Leg Fat 1 Leg Fat 2	Arm Fat 1 Arm Fat 2
101	39137 36656	14449 12631	4614 4376	13679 18439	5844 7248	1613 1923
102	42589 43861	14292 15403	4964 5037	14640 15477	6024 7158	1094 1149
103	44227 43577	14069 15213	5224 5279	17887 23603	6745 9812	1693 2358
104	48817 50879	16743 17224	6107 6771	12278 13348	5477 6213	884 1039
105	45257 47554	15055 16525	5416 6186	13834 13756	6481 6928	897 1292
106	30225 28604	10960 8995	3047 2987	8377 11710	4033 5311	762 995
107	44510 43061	16286 14997	4560 4613	13145 12453	5429 4372	1183 895
108	35410 36669	13054 12492	3263 4049	11553 15531	5052 6612	785 1178
109	41572 42392	16223 14865	4450 5015	14080 13383	6658 6764	1190 990
110	38450 37115	14860 12726	4113 4419	14366 24041	6739 10043	1357 2408

table continued

Participant #	Total Lean 1 Total Lean 2	Leg Lean 1 Leg Lean 2	Arm Lean 1 Arm Lean 2	Total Fat 1 Total Fat 2	Leg Fat 1 Leg Fat 2	Arm Fat 1 Arm Fat 2
111	44630 44933	14875 15479	5084 4810	13779 12619	5727 5928	1171 1059
112	42126 41720	14550 14401	3956 4026	10729 9867	5509 4854	727 605
113	***** 42181	***** 15728	**** 4722	***** 14861	**** 6950	**** 1544
114	***** 30169	***** 9470	**** 3471	***** 8596	**** 3794	**** 734
115	39438 38008	13009 12080	4332 4432	16096 16781	6831 7119	1431 1638
116	43061 43810	14969 15250	4973 4923	23249 20933	7882 9768	1588 1988
117	41123 42539	13694 14564	4806 5386	23839 24071	11079 11349	1553 1527
118	37038 36133	14124 12514	3494 3632	16025 20308	8732 10757	1128 1385

Note. Lean is Lean Tissue Mass (g), Fat is Fat Mass (g). 1 = Initial data, 2 = Current data.

Table 7

Average Daily Nutritional Intakes

Nutrient	Controls		Gymnasts	
	Initial (n = 3)	current (n = 7)	Initial (n = 7)	current (n = 11)
Kilocalories	1481	1308	1599	1670
±SD	632.9	281.1	401.4	201.5
Carbohydrates (g)	248	176	233	218
±SD	132.2	65.9	59.1	30.1
Protein (g)	64	55	52	65
±SD	18.4	4.9	13.8	8.8
Fat (g)	34	43	54	55
±SD	11.3	7.7	20.5	15.7
Calcium (mg)	991	509	602	991
±SD	856.3	226.3	210.4	124.3
Vitamin D (ug)	6	2	3	3
±SD	6.4	0.5	1.9	3.2
Iron (mg)	12	11	10	12
±SD	56.6	2.2	2.3	8.6
Phosphorus (mg)	1269	752	845	890
±SD	80.6	209.1	291.0	165.2

Note. Values included vitamin / mineral supplements added to diet.

Table 8

Bone Mineral Density and Lean Tissue Mass Values for Participants

	Controls[a]	Gymnasts
Variable	Initial current	Initial current
Total BMD (g/cm^2)	1.165 ± 0.064[b] 1.156 ± 0.054	1.214 ± 0.084 1.209 ± 0.076
Lumbar BMD (g/cm^2) (L2-L4)	1.259 ± 0.115 1.258 ± 0.098	1.319 ± 0.098 1.267 ± 0.110
Neck BMD (g/cm^2)	1.033 ± 0.116 0.999 ± 0.093	1.236 ± 0.122 1.165 ± 0.137
Ward's Area BMD (g/cm^2)	0.984 ± 0.150 0.975 ± 0.086	1.203 ± 0.169 1.131 ± 0.185
Troch BMD (g/cm^2)	0.820 ± 0.099 0.813 ± 0.079	0.980 ± 0.121 0.902 ± 0.118
Leg BMD (g/cm^2)	1.233 ± 0.078[b] 1.256 ± 0.041	1.294 ± 0.105 1.282 ± 0.088
Arm BMD (g/cm^2)	0.869 ± 0.083[b] 0.885 ± 0.049	0.979 ± 0.095 0.979 ± 0.076
Total lean (g)	40557.36 ± 2381.64[b] 40441.98 ± 3235.32	41347.61 ± 5234.18 43190.99 ± 6178.52

table continues

Variable	Controls[a]		Gymnasts	
	Initial current		Initial current	
Leg lean (g)	14069.18 13761.66	± 759.809[b] ± 1383.17	14624.04 14231.81	± 1626.34 ± 2331.75
Arm lean (g)	4312.18 4459.94	± 607.867[b] ± 665.449	4621.84 4867.35	± 902.533 ± 1014.67

Note. Mean ± SD. [a]Data for controls n = 7. [b]Initial data for controls n = 5. Data for gymnasts n = 11. Bone mineral density is BMD. Neck BMD is femoral neck area, Troch BMD is the greater trochanter. Lean is lean tissue mass. Total lean is lean tissue mass of total body, leg lean is lean tissue mass of legs, and arm lean is lean tissue mass of arms.