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The Effects of Menstrual Irregularities on Bone Density in Elite Female Gymnasts

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Abstract

Background: Elite gymnastics is a popular sport with intense physical demands. Healthcare providers may be concerned that elite gymnasts often begin training at an early age, which places stress on young girls at a critical time in their development. Elite gymnasts are also thought to be at greater risk of developing components of the female athlete triad, including amenorrhea, due to the desire to maintain a thin and muscular physique. However, studies have shown that gymnasts tend to have higher bone mineral density despite having a higher incidence of menstrual irregularities.

Methods: An exhaustive literature search of MedLine, CINAHL, Web of Science, CommonKnowledge and Google Scholar was conducted. Keywords were "Amenorrhea" and "Bone density" and "Female gymnasts". Eligibility criteria were broad with no limitation of the age of the gymnasts. Male gymnasts were excluded. Data quality was assessed using the GRADE system.

Results: Three studies were included in the systematic review. Wulff Helge and Kanstrop found more cases of menstrual irregularities but higher bone mineral density in gymnasts. Correlative statistics showed no correlation between the menstrual irregularities and BMD. Robinson et al reported greater BMD in gymnasts over runners regardless of menstrual status. Correlative statistics found no correlation between current menstrual status and history of menstrual irregularities, and BMD in gymnasts. Ducher et al found higher bone measurements in gymnasts with normal menses when compared to gymnasts with menstrual irregularities and controls.

Conclusion: This review showed conflicting results with two studies showing a positive benefit of intense gymnastics on bone density. One study showed no benefit. Based on results, no definitive conclusion can be drawn and further studies are needed. Larger longitudinal studies with consistent bone density measurement methods would be beneficial and would increase the statistical power of results.

Keywords: "Amenorrhea" and "Bone density" and "Female gymnasts"

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Biography

[Information redacted for privacy]

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BMD……………………………………………………………Bone mineral density
DEXA...Dual energy x-ray absorptiometry
BMC………………………………………………………….Bone mineral content
ToA……………………………………………………………………Total bone area
ToD……………………………………………………….. …Total volumetric density
TrD………………………………………………….. …Trabecular volumetric density
BSI……………………………………………………..………Bone strength index
CoD……………………………………………………..Cortical volumetric density
SSI……………………………………………………………..Stress-strain index
BMAD…………………………………………………..Bone mineral apparent density

The Effect of Menstrual Irregularities on Bone Density in Elite Female Gymnasts

BACKGROUND

Gymnastics has become a popular activity for boys and girls of all ages. In fact, the number of competitive gymnasts in 2007 topped 90,000 according to USA Gymnastics statistics.[1] Gymnastics is an intense sport once participants reach a competitive level. It is not uncommon for practice hours to reach upwards of 20 hours a week and it is an extremely high-impact strenuous activity with intense physical demands. Traditionally, the sport of gymnastics has been defined by the artistic gymnastics discipline. Artistic gymnastics consist of the most commonly known of the gymnastics events: floor exercise, uneven bars, balance beam and vault. However, with the evolution of gymnastics, came a new discipline: rhythmic gymnastics. Rhythmic gymnastics is a sport that combines elements of ballet, gymnastics, dance and the use of multiple apparatus.

Of concern to healthcare providers is the fact that elite gymnasts often begin training at an early age, many by the age of ten.[2] This places a great deal of stress on young girls at a critical time of physiological and psychological development.[2] In fact, almost half of the skeletal mass accumulation is obtained from the age of 10-20 years old. Additionally, calcium accumulation triples during an adolescent's pubertal growth spurt, which most often occurs during the second decade of life.[3]

Another concern is that gymnastics is a sport that places emphasis on athletes maintaining a thin and muscular physique. Many believe this places gymnasts at risk for developing components of the female athlete triad, which is characterized by disordered eating, menstrual irregularities and osteoporosis.[4] Taaffe et al[5] conducted a study in 1997 evaluating bone density in elite athletes and found that 31% of gymnasts participating in the study reported menstrual irregularities. Menstrual irregularities, such as amenorrhea, in athletes are associated with hypoestrogenism and bone loss.[6] Christo et al[7] studied amenorrhea in adolescent athletes and found that bone density measurements were lower in athletes with amenorrhea compared to athletes with normal menses. This decrease in bone density can lead to osteoporosis resulting in an increased risk of fractures later in life.[3]

Although gymnasts have an increased risk of developing different components of the female athlete triad, a few studies[7,8] have shown the opposite to be true. Surprisingly, gymnasts, when compared to other elite athletes and controls, actually have an increased bone density despite their propensity towards conditions that would tend to decrease it. One study in particular conducted by Cynthia Cassell et al[8] evaluated bone density in elite seven to nine year old gymnasts as compared to elite swimmers and non-athletes and found that gymnasts had a greater bone density values. The authors propose that the increase in bone density might be due to the high-impact weight-bearing physical training of the gymnasts, as the bone density measurement in swimmers, whose activity is more non-weight bearing, was similar to non-athlete controls.[8] Similar results were found in a study of bone density of female gymnasts, runners, swimmers and non-athlete controls conducted by Taaffe et al[5]. When compared to runners, gymnasts had greater baseline bone density, even when results were adjusted for differences in bone size and body weight. Additionally, when compared with swimmers and non-athlete controls, gymnasts displayed greater bone density measurements at the femoral neck, and when measurements were adjusted for body weight, gymnasts had greater bone density measurements of the whole body, femoral neck and lumbar spine than swimmers. Not only were the baseline measurements of bone density greater in gymnasts when compared to swimmers and controls, but the changes in bone density were greater over time in gymnasts (2.8% change +/- 2.4%). Taafee et al[5] also eludes to the fact that the high-impact bone loading, with forces at the hip as high as 10-12 times body weight, found in gymnastics training may very well be the reason for the higher bone density measurements in female gymnasts and is more willing to make the connection between increased bone density and gymnastics than is Cassell et al[8], who noted that there may be bias present in the results. Cassell et al[8] suggest that "there may be a selection bias in the body type of young girls who choose to participate in different sports. Smaller girls may be more likely to participate in gymnastics, while girls who have a higher percent body fat may be more likely to swim owing to…a greater success in this sport." [8]

With the findings of increased bone density in gymnasts as a result of high-impact bone loading activity as well an increased incidence of menstrual irregularities, do the positive effects of gymnastics outweigh the negative effects of menstrual irregularities in these gymnasts? The purpose of this paper is to provide a systematic review of studies that have evaluated this particular question of interest to healthcare providers that may care for this unique and challenging patient population.

METHODS

An extensive literature search was conducted for all studies evaluating menstrual status and bone density in female gymnasts. The MedLine, CINAHL, Web of Science and CommonKnowledge databases were accessed through the Pacific University library website. In addition, a limited, yet detailed search was conducted through Google

Scholar. Keywords used for searches conducted in MedLine, CINAHL and Common Knowledge were “Amenorrhea” and “Bone density” and “Female gymnasts”. Search terms used in Web of Science were limited to “Female gymnasts”. However, a refined search was conducted using the Web of Science category entitled, “Endocrinology Metabolism”.

Eligibility criteria for the systematic review were broad and only excluded male gymnasts. The search was limited to English, free full text articles. However, there were no limitations on age of the gymnasts. Data quality of the three studies included in the systematic review was assessed using the GRADE system.

RESULTS

Searches of these databases resulted in a total of 20 articles for review. Of those, only one study was selected for the systematic review.   Initial literature searches of Google Scholar resulted in over 1,000 articles. As a result, the search of Google Scholar was further limited to studies conducted after 1995. This limited the number of articles to slightly over 700 articles. Two hundred titles were reviewed and an additional two studies were selected to include in the review.   A total of three cross-sectional studies were selected for inclusion. Table 1 provides a summary of the studies included in the systematic review.

Wulff Helge and Kanstrop[9] conducted a Danish study in 2000 that evaluated the relationships between bone mineral density (BMD), maximal muscle strength and the concentration of sex hormones in elite female gymnasts. The study participants included 17 healthy females ranging in age from 15 to 20 years old. The study groups consisted of 11 elite gymnasts composed of six artistic and five rhythmic gymnasts from the Danish national gymnastics teams. The gymnasts trained an average of 15 hours per week. The control group consisted of six non-athlete controls whose physical activity consisted of walking or bicycling less than four hours per week and one compulsory physical education class. Information on physical activity, sports injuries as well as menstrual status was collected by self report in a survey conducted by the authors.[9]

Other study methods, including bone density, was measured in the whole body, lumbar spine, proximal femur and distal radius via dual-energy x-ray absorptiometry (DEXA) and body composition was measured via whole body scan. Sex hormone concentration was measured via blood sampling from three consecutive menstrual cycles and maximal muscle strength was measured as peak torque in trunk flexion and extension and right and left knee extension.[9]

Wulff Helge and Kanstrup[9] found that the artistic gymnasts were much leaner than controls despite having the same weight. The body fat percentage of the artistic gymnasts was 36% lower than the rhythmic gymnasts and greater than 50% lower than the control group. Menstrual status was also included in the general characteristics of the study. The artistic gymnasts group had more cases of menstrual irregularities with two participants with oligomenorrhea and three with amenorrhea. The results of the rhythmic gymnasts group were identical to that of the controls with only one participant from each group with oligomenorrhea.[9]

Bone mineral density (BMD) was found to be greater in the artistic gymnasts group than controls in the lumbar spine, proximal femur and the right and left distal radius. In addition, BMD was also greater in the rhythmic gymnasts group than controls in all sites except the distal radius. When a comparison was made between the artistic and rhythmic gymnasts, differences were only found in the BMD of the right and left radius. The BMD of the artistic gymnasts' right radius was 30% higher and 50% higher on the left.[9]

Correlative statistics conducted by Wulff Helge and Kanstrup[9] included correlation of BMD to body fat, menstrual history, sex hormone concentration and to maximal muscle strength. In regards to menstrual history, there was a positive correlation found in all study groups between the age at menarche and BMD (r = 0.55-0.75). There was no correlation between the history of menstrual irregularities and BMD in the artistic gymnast group. There appears to be a greater correlation between BMD and sex hormone concentration. For example, the authors found a strong positive correlation between the level of serum progesterone in the follicular phase of the menstrual cycle and the BMD at the whole body (r=0.93), the proximal femur (r=0.92) and in the lumbar spine (r=0.89) in the artistic gymnasts group. There were also positive correlations between sex hormone concentration and BMD in the rhythmic gymnasts group, but the correlations were not as strong. The strongest correlations in this study were the correlation between maximal muscle strength in trunk flexion and extension and BMD (r=0.74-0.96). This strong positive correlation was only present in the gymnasts group and not the controls. Wulff Helge and Kanstrup[9] conclude with, "It is apparent from our results that, in spite of oligomenorrhea or amenorrhea, it is possible for female gymnasts to maintain a BMD that is correlated to maximal muscle strength and within normal range or even higher than in a normal population."[9]

Robinson et al[10] investigated bone mass and bone density and menstrual irregularities in gymnasts and runners compared to non-athletes. The study was conducted in Eugene, Oregon and included 60 healthy, non-smoking women between the ages of 17 and 27 years old. The group of runners that participated in the study was 20 women that were middle and long-distance runners. The gymnast group consisted of 21 competitive college gymnasts with 12 from the Oregon State University women's gymnastics team and nine from the Stanford women's team. The control group consisted of 19 women whose physical activity was limited to less than three hours per week by self report.[10]

Study methods included a health questionnaire that collected information about the study participant's health history, exercise level, menstrual status and diet. Bone density measurements were obtained via DEXA from the whole body, proximal femur and the lumbar spine. Bone mineral apparent density (BMAD) was calculated for the lumbar spine and femoral neck to adjust for differences in bone size among the study groups. Body fat and lean mass percentages were obtained using whole body scan. Data on maximal oxygen consumption, muscle strength and nutrient intake was also collected.[10]

Menstrual status as self reported on the study participants' health questionnaire was evaluated and showed that the gymnasts group underwent menarche at a much older age than runners and controls. For instance, the mean age for menarche in the gymnasts group was 16.2 compared to 14.4 for the runners and 13.0 for the controls. In addition, there was a greater prevalence of menstrual irregularities in the gymnasts group with 19% with oligomenorrhea and almost 30% with amenorrhea compared to 15% in the runners and no cases of menstrual irregularities in the control group.[10]

When comparing bone mineral density and menstrual status among the gymnasts and runners, there were no great differences between the two groups. However, when comparing the athletes with normal menses versus the athletes with menstrual irregularities there was a trend, although, not statistically significant, for the athletes with normal menses to have greater bone density than those with menstrual irregularities. For example, the whole body BMD for the gymnasts with normal menses was 1.132 +/- 0.09 compared to the BMD for those gymnasts with oligo- or amenorrhea at 1.085 +/- 0.06. When BMD was evaluated with current menstrual status and menstrual history over the last year, there was a significant difference in the BMD of the gymnasts group in the femoral neck ($p=0.0001$) and lumbar spine ($p < 0.001$) even with current menstrual irregularities and a history of oligo- or amenorrhea. [10]

BMD regardless of menstrual status was found to be higher in gymnasts compared to runners and controls in the femoral neck (1.110 +/- 0.08 vs. 1.043 +/- 0.06 vs. 1.092 +/- 0.06). In addition, BMD was found to be higher in the lumbar spine and whole body for the gymnasts group when compared to the runners. When BMAD was calculated to adjust for bone size differences, the gymnasts were once again found to have significantly higher BMD in the femoral neck and lumbar spine compared to both runners and the control group. The BMAD for the femoral neck was 0.470 +/- 0.05 in the gymnasts, 0.358 +/- 0.05 for the runners and 0.413 +/- 0.06 in the control group. Also, when the BMD was determine relative to body weight, the gymnasts continued to maintain a greater BMD in the femoral neck and lumbar spine compared to both runners and controls.[10]

When correlative statistics were conducted using regression analyses, there was found to be no correlation between current menstrual status and history of menstrual irregularities, and BMD in the gymnasts group. The only positive correlations were found in the runners. The authors felt that there were no correlations between menstrual status and BMD due to low statistical power in the gymnast group.[10]

Robinson et al also[10] concludes that "our results demonstrate that gymnasts have higher bone density than do runners and control women, despite a similar prevalence of oligo-and amenorrhea."[10] Specifically, gymnasts had higher bone density at all sites (whole body, lumbar spine, and proximal femur) than runners. Gymnasts were also found to have higher bone density in the femoral neck when compared to non-athlete controls. The authors propose that it is the strong muscular contractions and forces on the lumbar spine that exceed 10-12 times body weight that stimulate bone growth in elite gymnasts resulting in a higher bone mineral density. This increase in BMD was not found in the runners and it is believed that this is due to the fact that long distance running results in repetitive, lower impact bone-loading activity that has forces on the lumbar spine at only 2-5 times body weight and the forces on the lumbar spine and other specific regions of bone are not strong enough to result in increased bone growth.[10]

The authors also hypothesize that the gymnasts were able to maintain a higher BMD despite a greater prevalence of menstrual irregularities because the high impact forces from gymnastics were "able to override the resorptive effects of low reproductive hormones."[10] It is proposed that there is a theoretical "set point" for bone growth that is controlled by mechanical forces and estrogen concentration. Increased mechanical forces and a higher concentration of estrogen will lower the set point at which bone growth is stimulated. In gymnasts with amenorrhea, the decreased concentration should result in a higher set point for bone growth. However, the results of this study demonstrate that the high impact bone-loading activity of gymnastics overcome the higher set point expected with menstrual irregularities. [10]

Ducher et al[6] conducted a study in Australia that investigated the impact of menstrual history on the exercise-induced benefits of gymnastics in retired elite artistic gymnasts. Study participants included 55 women between the ages of 17-44 years of age. The gymnasts group consisted of 25 retired gymnasts who had competed in high-level gymnastics for at least four years during their childhood and adolescence trained for at least 15 hours per week and had been retired from gymnastics for at least three years. The control group consisted of 30 women whose physical activity was limited to two hours or less a week of physical activity during their child and adulthood.[6]

Like the two previous studies, study participants completed a questionnaire requesting information on menstrual history and age at menarche. From that questionnaire, the gymnast group was further divided into two groups: those with a history of amenorrhea and those who have never had a history of amenorrhea.[6]

Ducher et al[6] collected information on bone mineral content (BMC), total bone area (ToA) and total volumetric density (ToD). Additional bone parameters included in this study trabecular volumetric density (TrD), bone strength index (BSI), cortical volumetric density (CoD), stress-strain index (SSI), cortical thickness, muscle and fat area, spinal BMC, and bone mineral apparent density (BMAD). Most of the bone parameters were measured using peripheral quantitative computed tomography. Measurement sites included the distal epiphyses and shafts of the radius and tibia.

However, dual-energy x-ray absorptiometry (DXA) was used to measure spinal BMC and BMAD. DXA was also used to determine whole body composition.[6]

This study also found that menstrual irregularities were more common among the gymnasts than the controls with over half of the gymnasts reporting a history of amenorrhea compared to only 13% of controls. However, the four controls that had a history of amenorrhea were excluded from analysis.[6]

When comparing bone parameters between the gymnasts with a history of amenorrhea and the control group, there was no significant difference detected for the following measurements: BMC, BMAD at the lumbar spine, TrD and BSI at the radius and tibia, and cortical area at the proximal radius. However, when comparing the gymnasts with no history of amenorrhea to controls, there was a significant difference with the gymnasts having a higher trabecular volumetric density and bone strength index ($p < 0.05$). In addition, cortical thickness was found to be lower in the gymnasts with amenorrhea compared to controls ($p < 0.01$). However, this difference was not found when comparing the gymnasts with normal menses to controls.[6]

In addition, there were significant differences in trabecular density, bone strength index and spinal BMAD between the gymnasts with amenorrhea and those with normal menses ($p < 0.05$). These indices were found to be greater in the gymnasts with normal menses. However, total area of the distal radius was greater in the gymnasts with amenorrhea when compared to gymnasts with normal menses and controls.[6]

Correlative statistics were conducted for various bone parameters and age at menarche. In all groups there was a positive correlation between age at menarche and bone mineral content ($r=0.39$) and total bone area ($r=0.60$) at the distal radius and with total bone area at the proximal radius. However, there was a negative correlation between age at menarche and cortical density and cortical thickness (r=-0.50 and -0.39).[6]

The authors discuss the results of their study and state that "…gymnasts displayed greater bone mass and size…when compared to non-active age-matched women…However, the gymnasts who experiences either primary or secondary amenorrhea did not show any benefits in trabecular volumetric bone density and bone strength at the distal radius and tibia, as well as lumbar spine BMC…and BMAD over controls."[6] The authors also discuss findings of previous studies that report a positive association between late menarche and endocortical diameter and a negative association between later menarche and cortical area and cortical thickness suggesting "the puberty-associated rise in estrogens is thought to favor endocortical apposition and limit periosteal expansion, known as 'estrogen-driven packing of bone."[6] The authors suggest that gymnasts with menstrual irregularities, such as amenorrhea, do not have the benefit of "estrogen-driven packing of bone" that occurs in puberty and thus compensate for decreased cortical thickness by having larger, less dense bones.[6]

DISCUSSION

Artistic gymnastics has proven to be a very beneficial activity for increasing bone density in elite gymnasts. In addition, it is evident that elite gymnasts tend to have a higher prevalence of menstrual irregularities, which is known to lead to decreased bone density and a greater risk of osteoporosis and fracture later in life. What is more controversial and debatable is if the negative impact of menstrual irregularities on bone density outweighs the positive effects. This systematic review focused on studies that have addressed this clinical question. Two studies[9,10] showed that the presence of menstrual irregularities did not negate the positive effects of gymnastics and that the gymnasts have higher bone density than controls despite having oligo- or amenorrhea. The remaining study[6] did not show any benefit on bone density and found that the bone density of those gymnasts with a history of menstrual irregularities was similar to that of non-athlete controls.

Limitations of Study

There were a number of limitations for all three studies. First, they are all cross-sectional observational studies, which are inherently considered to be of low quality. In addition, this type of clinical question does not allow for randomization of study subjects. This too leads to a downgrade in study quality. The three studies in the review also have very small study populations, with the largest study having only 60 participants. This tends to result in weak statistical power and difficulty in difficulty in making strong conclusions.

Another limitation of the three studies is the method by which menstrual status was collected. It was reported in all three studies that menstrual status was collected by self-report on a health questionnaire. This lends itself to a great deal of subjectability and may lead to an underestimation of the true prevalence of menstrual irregularities. For example, an elite gymnast may be more likely to report a normal menses rather than reveal the true clinical picture.

The methods by which bone density was measured in the three studies also tend to limit results. Wulff Helge and Kanstrup[9] and Robinson et al[10] used DEXA to measure bone density of various sites in their studies. However, Ducher et al[6] used pQCT to measure a number of detailed bone parameters, including cortical thickness and the bone strength index, while DEXA was limited to measurements of only the bone mineral apparent density (BMAD) and bone density of the lumbar spine. These more detailed methods of measurement may allow for a more in-depth analysis of bone health.

Data analysis methods also threaten the quality of the three studies. For example, all of the studies use standard mean and standard error in the data analysis. This does not allow for prediction of harm and limits the extent to which results can be applied in clinical practice.

While there are similar limitations among the three studies, there are also limitations that are unique to each study. For instance, Wulff Helge and Kanstrup[9] do not provide an adjustment or correction in the statistical analysis for the dramatic differences in the percent of lean body mass and percent body fat among the artistic gymnasts and controls. For example, the percent body for the artistic gymnasts group was 14.1% compared to 30.1% in the control group. This is statistically significant ($p < 0.001$) and would likely lead to an underestimation of BMD. Unlike this study, the studies conducted by Robinson et al[10] and Ducher et al[6] take steps to adjust for differences in the study populations. For instance, Robinson et al[10] provided measurements of BMD relative to body weight and BMAD to adjust for differences in bone size. Ducher et al[6] also adjusted for bone size by calculating BMAD. Bone parameters were also calculated by Ducher et al[6] adjusting for differences in height.

There are limitations in the recruitment process for the studies conducted by Wulff Helge and Kanstrup[9] and Ducher et al.[6] Elite gymnasts were recruited to the study conducted by Wulff and Helge[9] from the Danish national artistic and rhythmic gymnastics teams while gymnast participants in the Ducher et al[6] study were recruited from the Australian gymnastics team. Limiting study participant selection to only one team in each study may lead to selection bias and thus limiting results. Robinson et al[10] recruit gymnasts from the Oregon State University and Stanford University teams and allow for a more diverse study population.

CONCLUSION

In conclusion, three studies evaluating menstrual irregularities and bone density in female gymnasts were included in this systematic review. Two studies[9,10] show that the negative effects of menstrual irregularities, such as oligo- or amenorrhea, do not outweigh the positive skeletal benefits of gymnastics. One study[6] showed no benefit. As a result of this review, no clear conclusion can be drawn and it is clear that further studies are required to fully evaluate this topic. Larger studies would be beneficial and would increase the statistical power of the results. Further research should also consider a true longitudinal study that follows young girls beginning their gymnastics career through retirement to determine if the skeletal benefits of gymnastics are carried throughout their lives. In addition, further studies should consider how bone parameters are measured to ensure the most useful and consistent results.

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Table 1. Characteristics of Reviewed Studies

Summary of Findings **Quality Assessment**

Study	Design	Screening Group	Control Group	Age range	Outcomes	Sampling	Sampling process	Menstrual Status data collection methods	Adjustment for confounders	Data analysis	Overall study quality
Wulff Helge and Kanstrup[9]	Cross-sectional observational study	11 gymnasts (six artistic and five rhythmic)	6 non-athletes	15-20 years	BMD of whole body, proximal femur and lumbar spine Maximal muscle strength Serum estrogen and progesterone levels	Appropriate	Possibly limited due to recruitment from only one team	Self-report via questionnaire	None	Limits applicability due to use of SM/SE	Very low
Robinson et al[10]	Cross-sectional observational study	21 gymnasts	20 middle and long-distance runners	17-27 years	BMD of whole body, proximal femur and lumbar spine Aerobic capacity and muscle strength Nutrient intake	Appropriate	More diverse population (recruitment from multiple university teams)	Self-report via questionnaire	BMAD calculated to adjust for bone size BMD calculations adjusted for body weight	Limits applicability due to use of SM/SE	Very low
Ducher et al[6]	Cross-sectional observational study	25 retired artistic gymnasts	30 non-athletes	17-44 years	-Bone mineral content -Bone area and volume -Trabecular density -Bone strength -Cortical area and thickness -Medullary area -Cortical density -Spinal BMC -BMAD	Appropriate	Possibly limited due to recruitment from only one team	Self-report via questionnaire	Calculations of all bone parameters were conducted to adjust for height BMAD was calculated to adjust for bone size	Limits applicability due to use of SM/SE	Low