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Vitamin D Status and Bone Mineral Density in Female Collegiate Dancers and Cheerleaders

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Abstract: Bone mineral density reflects an athlete's cumulative history of energy availability, physical activity, and menstrual status, as well as nutritional and environmental factors. Although sports with high-impact loading are associated with higher bone mineral density than low-impact or non-impact sports, confounding variables are differences in the athletes' body size and sport-specific training. The purpose of this study was to determine if bone mineral density (BMD) and vitamin D status are different between two groups of female collegiate athletes who have comparable body size/weight requirements, but who engage in qualitatively different training regimens. Full body, spine and dual femur BMD was assessed by dual energy X-ray absorptiometry (DXA) in members of a university pep-dance team (n = 10) or cheer team (n = 9), ages 18-22. Plasma vitamin D status was assessed by ELIZA. There was no significant difference between the groups for total body BMD (1.23 g/cm^2 dance vs 1.22 g/cm^2 cheer, P = 0.70), spine BMD (1.39 g/cm^2 dance vs 1.36 g/cm^2 cheer, P = 0.72) or dual femur BMD (1.20 g/cm^2 dance vs 1.11 g/cm^2, P = 0.23). Insufficient serum vitamin D status (20-32 ng/mL) was found in 74% of the athletes (27 ± 4 ng/mL, dance and 25 ± 8 ng/mL, cheer). In addition, estimated daily vitamin D and calcium intakes were less than the RDA for both dancers and cheerleaders. Despite nutritional insufficiencies, BMD was not significantly different between the low-impact activity pep dance team and high-impact activity cheer team, suggesting that the type of physical activity was not as important for BMD in these athletes as participating in 20+ hours a week of physical activity, which could have counteracted the negative effects of the nutrient insufficiencies on their bone health.

Key words: Female athletes, physical activity, nutritional status.

1. Introduction

Osteoporosis is a skeletal disorder characterized by low bone mass and compromised bone strength predisposing individuals to an increased risk of fracture [1]. Regular exercise in children and adults has shown positive outcomes for bone health and the prevention of osteoporosis [2, 3]. Specifically, individuals who regularly engage in weight bearing activity such as running, jumping, and strength training have greater bone mineral density (BMD) compared with sedentary individuals [3-6] as a result of the mechanical forces imposed by the activity. Physical activity can also increase muscular strength and stability, which can help decrease the chances of falling or subsequent fracturing of bone [3].

Athletes in particular have shown the effect that years of physical activity and mechanical loading can have on bone. Athletes participating in weight bearing sports typically have 5%-15% greater total body BMD when compared to non-athletes [3, 6-8]. However, it has yet to be determined if any one sport or type of athletic activity is more beneficial or osteogenic than another. In general, research has shown that sports that have a repeated occurrence of high impact movements, such as gymnastics, volleyball, basketball, and track & field jumping events, have a greater effect on BMD when compared with sports with little or no impact such as cycling, water polo, and swimming [5-7, 9-12]. Often missing from comparisons of BMD in various sports is consideration of confounding factors such as body weight, training history, injury, menstrual status, dietary intake, or sunlight exposure [13].

The purpose of this study was to determine if bone mineral density and nutritional factors in bone health are different in two groups of female athletes (pep

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dancers and cheerleaders) who have comparable body size/weight requirements, but who engage in qualitatively different training regimens. Cheerleaders perform high-impact gymnastics based movements, while pep dancers perform routines based on low-impact hip hop and ballet dance movements. Although the National Collegiate Athletic Association (NCAA) does not recognize dancing and cheerleading as sports [14], research has shown that both activities require similar physical demands as other collegiate sports based on the results of various fitness tests [15, 16]. Participants in both cheer and dance have also shown a high prevalence of disordered eating and pressure to be thin when compared with other sports [17], as well as high prevalence of vitamin D insufficiency [18-20], which could potentially have detrimental effects on their bone health.

2. Methods

2.1 Subjects and Design

Forty female collegiate members of the University of Nevada, Las Vegas NCAA division I university dance team or cheerleading team, between the ages of 18-25, were recruited from summer tryout camps for this study. Women who did not participate on either dance or cheer team the previous year were excluded (n = 21). Members of the dance (n = 10) and cheer (n = 9) teams were measured in the pre-season, immediately following team tryouts. Subjects were in the same phase of training and self-reported menstrual cycles. Characteristics of the participants are summarized in Table 1. The University Institutional Review Board reviewed and approved the study protocol, and all study participants gave written informed consent.

2.2 Bone Mineral Density and Body Composition

Data collected on subjects included age (yrs), race, height (cm), weight (kg), body composition, and bone mineral density. Height (Health-O-Meter Professional, height rod) and weight (Tanita BWB-600 scale, Tanita Corp of America, Arlington Heights, IL) were measured prior to DXA scan. Total body bone mineral density (BMD), dual femur BMD, lumbar spine BMD, and body composition were determined using dual energy x-ray absorptiometry (DXA) with a Lunar Densitometer DPX-L (Prodigy, GE Lunar Corp, Madison, WI). Scans were conducted by investigators trained and certified in DXA use. Subjects were positioned on their backs with arms straight at their sides, palms facing down. BMD was expressed as grams per centimeter squared (gm/cm^2).

2.3 Vitamin D

Blood samples (600 μL) were collected via finger stick, and were centrifuged at 3000 RPM for 20 min at 4°C. Duplicate samples of plasma (20 μL) were stored at -80 ℃ until all samples were collected for subsequent analysis. 25(OH) vitamin D was determined by ELISA (Eagle Biosciences, INC, Nashua, NH). The intra-assay coefficient of variation (CV) was 4.9% at 10.8 ng/mL, 6.9% at 24.6 ng/mL, and 3.2% at 64.1 ng/mL. The inter- assay CV was 7.8% at 16.6 ng/mL, 7.0% at 43.5 ng/mL, and 8.6% at 67.8 ng/mL.

2.4 Calcium and Vitamin D Food Intake and Sunlight Exposure Questionnaires

The subjects completed a questionnaire to estimate average daily calcium and vitamin D intake [19]. Subjects were asked how often on a daily and weekly

Table 1 Participant characteristics.

	Dance (n = 10)	Cheer (n = 9)	P values
Age	20.5 ± 1.35	19.8 ± 0.44	P = 0.07
Height (cm)	163 ± 4.0	162 ± 4.0	P = 0.27
Weight (kg)	60.75 ± 7.03	59.11 ± 6.39	P = 0.30
BMI	22.88 ± 2.32	22.57 ± 2.53	P = 0.39

Values are mean ± standard deviation; (P > 0.05).

basis they consumed vitamin D containing foods. Specific food choices included milk (whole, skim, 1%, 2%, chocolate), soy or rice milk, vitamin D fortified cereal, calcium fortified orange juice, eggs, fatty fish, yogurt, cheese, cottage cheese, or ice cream [19, 20]. The calcium and vitamin D content of each food was obtained from the USDA National Nutrient Data Base for Standard Reference [21] and from Chen et al. [22], and from selected food labels. These values were multiplied by the self-reported daily and weekly intake of each food and averaged to get an estimated total daily intake for calcium and vitamin D expressed as mg and IU respectively. In addition, subjects completed a questionnaire to determine how much leisure time was spent outside in the sun, the frequency and SPF of sunscreen used if any, and the typical clothing worn when outdoors [19].

2.5 Statistical Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences for Windows analysis software (PASW Statistics Version 20.0, SPSS Inc., Chicago, IL). Differences between variables were determined by two sample t-tests assuming equal variances. Significance was accepted at the $P \leq 0.05$ level.

3. Results

There was no significant difference between the dance team and cheer team total body BMD (1.23 ± 0.09 vs 1.22 ± 0.09 g/cm^2 for dance and cheer respectively, $P = 0.70$), for spine BMD (1.39 ± 0.16 vs 1.36 ± 0.16 g/cm^2 for dance and cheer, $P = 0.72$) or dual femur BMD (1.20 ± 0.14 vs 1.11 ± 0.16g/cm^2 for dance and cheer, $P = 0.23$) (Fig. 1).

Plasma vitamin D (25(OH) D) concentration was not different between the dance and cheer teams (27.45 ± 4.26 vs 24.59 ± 7.61 ng/mL for dance and cheer respectively, $P = 0.32$) (Table 2). However, only 5 of the 19 athletes had sufficient vitamin D status (25(OH) D > 30 ng/mL). Serum vitamin D status was found to be insufficient (20-30 ng/mL) [23] in 7 of 10 dance team members (25.0 ± 1.9 ng/mL) and in 7 of 9 cheer team members (21.0 ± 2.7 ng/mL). Among those deemed to have insufficient vitamin D, members of the cheer team had significantly lower vitamin D than members of the dance team ($P = 0.003$). Overall, there was no significant difference between the dance

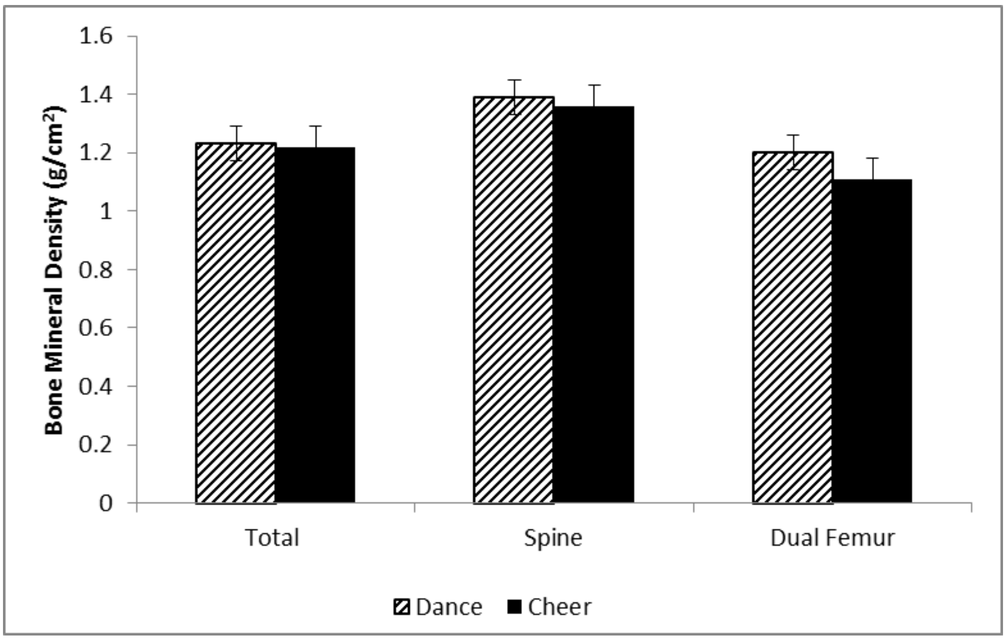

Fig. 1 Total body, spine, and dual femur bone mineral density was not significantly different between the dance team, and the cheer team (*P* > 0.05).

Table 2 Vitamin D status and estimated dietary intake.

	Dance (n = 10)	Cheer (n = 9)
Plasma Vitamin D (ng/mL)	27.45 ± 4.26	24.59 ± 7.61
Daily Vitamin D Intake (IU)	255.9 ± 335.07	228.22 ± 144.86
Daily Calcium Intake (mg)	503.6 ± 723.55	531.33 ± 236.22

Values are mean ± standard deviation; ($P > 0.05$).

and cheer teams for estimated daily vitamin D intake (Table 2). Estimated daily vitamin D intake was 256 ± 335 IU for the dance team and 228 ± 145 IU for the cheer team ($P = 0.82$); only 2 of the 19 athletes had estimated intakes above the RDA of 600 IU per day [24]. Estimated sunlight exposure was similar between the two teams, and confirmed that both teams can be classified as indoor sports, as practices and performances outside are very infrequent.

There was no significant difference between the dance and cheer teams for estimated daily calcium intake (Table 2). Daily calcium intake was 504 ± 723 mg for dance and 531 ± 236 mg for cheer ($P = 0.91$); only 4 of the 19 athletes had an estimated daily calcium intake near to or above the RDA of 1,000mg/day [24]. The questionnaires also revealed that none of the 19 athletes were taking a multivitamin or any calcium supplements. A majority of athletes (7 of 10 dance and 7 of 9 cheer) self-reported that they considered themselves to have a normal menstrual cycle.

4. Discussion

Athletes who regularly engage in weight bearing activity such as running, jumping, and strength training have greater bone mineral density compared with athletes engaged in non-weight bearing sports or sedentary individuals [2, 4]. Mechanical forces during weight bearing activity come from both ground-reaction forces and muscle-joint forces putting strain on bone tissue, which has osteogenic effects [25]. Thus, mechanical loading by activity specific or body mass related impact forces should have a discernable effect on bone mineral density.

The main finding in this study was that there were no differences in total bone mineral density, lumbar spine bone mineral density or dual-femur bone mineral density between pep dancers and cheerleaders, despite differences in their specific training regimens. General conditioning for both teams consists of running two miles per day, five days per week. Although not mandated, they also attend a local cross-fit gym for additional training. The teams practice separately for approximately twenty hours per week. During practice, the cheer team performs high impact, gymnastics based movements, where both feet are off the ground at the same time. The cheer athletes perform tumbling routines, throws and catches, as well as numerous jumps. Ground-reaction forces for these activities range anywhere from 10-18 times body weight [26, 27]. In contrast, the pep dancers perform low impact movements where at least one foot at a time is always on the ground. Their routines are based around ballet movements, contemporary dance, and hip hop dance sequences. Small vertical jumps performed by the dance team have ground force reactions of 1.5-3 times body weight [26]. Thus, these results suggest that for athletes in dance and cheer differences in mechanical loading were not as important determinants of BMD as the volume of time spent being physically active.

Physical activity is known to be a factor in promoting bone formation and moderate levels of physical activity, as little as twice per week, have been shown to reduce the risk of fractures [2]. Athletes, regardless of sport, have higher bone mineral density than non-athletes [3, 6-8], and BMD is higher in athletes engaged in high impact sports such as basketball and volleyball than in athletes in low-impact or non-impact sports such as swimming, water polo, and distance running [5-7, 9-12]. Although sports with high-impact loading are associated with higher bone mineral density than low-impact or non-impact sports, confounding variables are differences in the athletes' body size and sport-specific training [11, 13]. The fact that higher bone mineral density relative to non-athletes has been found in athletes engaged in low-impact sports suggests that total time spent in physical activity is an important determinant of bone health [7]. Collegiate athletes typically train in excess of 20 hours per week. The strongest predictor of bone strength index in a comparison of middle distance runners with age-matched controls was hours per week of physical activity [28]. The results of the current study were somewhat surprising as it was expected that the high-impact training program would lead to higher BMD in the cheerleaders. However, given similar body mass and percent body fat in the dancers and cheerleaders, the similar time spent weekly in training appears to have mitigated the differences in impact loading on BMD. Further support for this comes from the finding that BMD did not differ between dancers and cheerleaders at any of the sites measured. Previous studies have shown a sport specific response to loading patterns in bone mineral density [6, 9, 11, 29]. Team female team handball players had higher forearm BMD, considered to be a weight-bearing site in this sport, than female soccer players [29]. Similarly, lower leg bone strength index was not different in female water polo players compared with controls, while bone strength index at the distal radius was 32% greater in water polo players than in controls [6]. While high-impact loading sports produce the greatest gains in BMD [11], the effect of time spent in physical activity on bone health should not be discounted.

Bone mineral density reflects an athlete's cumulative history of energy availability, physical activity, and menstrual status, as well as nutritional and environmental factors such as vitamin D and calcium, and sunlight exposure. Vitamin D is unique in that it can be obtained both from the diet and by sunlight exposure [22, 30, 31]. However, food sources of vitamin D are limited to a few foods such as oily fish [22] and selected fortified foods [22, 30, 32]. Consequently, circulating vitamin D is primarily derived from sunlight exposure rather than diet [30, 31]. Vitamin D insufficiency varies seasonally in athletes, with the greatest prevalence in indoor sport athletes from northern latitudes (> 35-37°) during the winter [19, 29, 33]. However, vitamin D insufficiency has also been reported in athletes from sunny, lower latitudes who conscientiously use sunblock and clothing to minimize sun exposure [19, 29].

Both dance and cheer teams had low dietary calcium and vitamin D intake, and serum vitamin D levels. Only 26% of the athletes studied (5 of 19) had a circulating 25 (OH) D concentration greater than 32 ng/ml. Conversely, two athletes were vitamin D deficient (25(OH) D less than 20 ng/ml). This was unexpected given that Las Vegas is at 36° North latitude and experiences 300 days of sunshine per year. However, these athletes were well informed on the risks of sun exposure and self-reported following best practices recommendations to minimize sunlight exposure as well as training indoors. On the other hand, estimated dietary vitamin D intake was 256 ± 335 IU for the dance team and 228 ± 145 IU for the cheer team, which is lower than the RDA, but consistent with vitamin D intakes from food sources reported for collegiate athletes [19]. In addition, estimated daily calcium intake was 50% of the RDA. Although there is some evidence that a daily multivitamin supplement may help maintain vitamin D status [19], none of the cheer and dance athletes reported daily multivitamin use. Despite these nutritional deficiencies, bone mineral density in the cheer and dance athletes was 7% greater than in non-athletes matched for age, height, and weight (unpublished data) consistent with the results of previous studies indicating that athletes typically have

5%-15% higher BMD than non-athletes [3, 6-8]. These results suggest that the volume of physical activity performed by the cheer and dance athletes could have counteracted the negative effects of these nutrient insufficiencies on their bone health.

5. Conclusion

In conclusion, despite differences in training regimens, bone mineral density was not significantly different between the low-impact activity pep dance team and the high-impact activity cheer team at any site measured, suggesting that the volume of weight-bearing activity from participating in 20+ hours a week of physical activity compensated for the insufficiencies in vitamin D and may be more important than mechanical loading for gains in bone mineral density in these athletes.

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