Bone Mineral Density Differences Across Female Olympic Lifters, Power Lifters, and Soccer Players

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Abstract

Jeon, W, Harrison, JM, Stanforth, PR, and Griffin, L. Bone mineral density differences across female Olympic lifters, power lifters, and soccer players. *J Strength Cond Res* 35(3): 638–643, 2021—Athletic training improves bone mineral density (BMD) through repeated mechanical loading. The location, intensity, and direction of applied mechanical pressure play an important role in determining BMD, making some sports more advantageous at improving BMD at specific regions. Thirty-seven (10 power lifters [PL], 8 Olympic lifters [OL], 8 soccer players [SP], and 11 recreationally active [RA]) women participated in a cross-sectional study. We measured lumbar spine (L1-L4), femoral neck, total-body BMD, and overall body composition (total fat mass, lean mass, percent body fat) with dual-energy x-ray absorptiometry. All athletic groups had greater total BMD than RA ($p = 0.01$ [PL]; $p < 0.001$ [OL]; $p = 0.01$ [SP]). Olympic lifters had the highest total BMD than all other athletic groups. Olympic lifters had the significantly greater total BMD than PL ($p = 0.018$), but there was no difference in total BMD between PL and SP. As compared with RA, OL showed greater BMD at both the total lumbar spine ($p = 0.002$) and the femoral neck ($p = 0.007$), whereas PL showed greater BMD only for the total lumbar spine ($p = 0.019$) and SP showed greater BMD only for the femoral neck ($p = 0.002$). Olympic-style lifting includes both high-impact and odd-impact loading modalities that are associated with the highest BMD at both the lumbar spine and femoral neck.

Key Words: DXA, Olympic lifting, power lifting, recreationally active, soccer

Introduction

Osteoporotic and stress fractures are a major public health concern that cause substantial clinical and economic burdens to society (22). Age and sex are the greatest known risk factors for developing osteoporosis and bone fractures (4). Bone fractures are more common in women than in men because of differences in bone mass and geometry (3). Reduced estrogen levels in women post menopause cause loss of trabecular bone (38), increasing the risk of bone fractures.

The single most important predictor of bone fractures is bone mineral density (BMD) (7). For example, lumbar spine BMD is useful in the prediction of spine fractures, whereas BMD measured at the proximal femur provides more accurate prediction of overall osteoporotic fracture of the spine and hip (29). The annual incidence rate of hip fractures and subsequent mortality among people aged 65 years and older in the United States is increasing as a result of the high risk of falling and prevalence of osteoporosis in the older population (5). By the year 2025, osteoporosis is projected to account for 3 million fractures and a corresponding $25.3 billion in annual costs in the United States. (1). Therefore, regular exercise targeting sites vulnerable to fracture is recommended to improve BMD and prevent the risk of fracture (26).

Increases in physical activity positively affects bone health for individuals of all ages. In particular, high-impact (exercises that put stress on weight-bearing joints, e.g., Olympic lifting, power lifting, and sports that involve jumping) and odd-impact (exercises that incorporate motions in many direction, influencing the entire circumference of bones, e.g., soccer, racquet games, and step aerobics) loading exercises are superior to low-impact exercises such as yoga and pilates for improving BMD (35,39). This is because loading-induced strains of high- and odd-impact exercises promote bone formation and help prevent bone resorption during bone remodeling (12).

Weightlifters have greater BMD at most skeletal sites than athletes in different sports, such as orienteering, cycling, and cross-country skiing (24). For example, significantly greater BMD at the lumbar spine, dual femur, and total body were observed in female individuals who engaged in competitive lifting for more than 30 years compared with their age- and gender-matched groups (44). There are 2 well-known forms of lifting style: Olympic weightlifting (clean and jerk, and snatch) and power lifting (squat, deadlift, and bench press). Both male and female Olympic lifters (OL) have greater total BMD of the lumbar spine and femoral neck BMD than recreationally active controls (13,36); however, male power lifters (PL) have greater BMD only in the lumbar spine compared with recreationally active controls, but no difference was found at the femoral neck (42). There are no differences in either the lumbar spine or the femoral neck BMD in female PL compared with controls (35).

Resistance training is effective for increasing BMD at the lumbar spine and enhances the development of peak bone mass in premenopausal women (17,31,35). Weight-bearing exercises may also have important benefits for postmenoposal women, preventing further bone loss. Although the effect of high-impact loading on increasing BMD of postmenopausal women is impaired by estrogen deficiency (28), von Stengel et al. found that BMD of the lumbar spine in postmenopausal women was improved to a greater extent when performing weightlifting training with greater acceleration and velocity (43). Thus, Olympic lifting could potentially be a good training method for both pre- and

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postmenopausal woman to increase lumbar spine and femoral neck BMD and prevent fractures because the clean and jerk and the snatch techniques require a greater velocity with acceleration (odd-impact), weight-bearing (high-impact), and high magnitude of loading at the hip and lumbar region (20).

To our knowledge, no studies have compared the effect of the 2 different types of weightlifting, Olympic lifting and power lifting, on lumbar spine and femoral neck BMD in one study. In addition, although the effect of odd-impact loading forces of soccer on femoral neck BMD in female athletes is well known (35), very little is known about the influence of odd-impact loading forces of weightlifting exercises on femoral neck BMD. Thus, the aim of this study was to investigate the influence of high-impact or odd-impact loading sports on total-body, lumbar spine, and femoral neck BMD to determine which sport (Olympic lifting, power lifting, or soccer) is most highly associated with high BMD at the lumbar spine and femoral neck compared with recreationally active (RA) women. We hypothesized that Olympic-style lifters and PL have a greater lumbar spine BMD compared with soccer players (SP) because both lifting sports require high-impact mechanical loading at the lumbar spine. We hypothesized that OL and PL have a greater lumbar spine BMD compared with SP and that OL would have a greater BMD at the femoral neck than PL because Olympic lifts require includes accelerating movements with rapid changes of direction from the sagittal plane (anterior-posterior) to frontal plane (vertical).

Method

Experimental Approach to the Problem

A between-group (cross-sectional) design was used to examine site-specific BMD differences across female athletes. We measured lumbar spine, femoral neck, and total-body BMD and overall body composition. BMD (in g·cm−2) was measured by a dual-energy x-ray absorptiometry (DXA). Three scans were performed for each subject for the total body, femoral neck, and lumbar spine (L1–L4). For the femoral neck measurement, the subject's dominant hip was scanned (35). Body mass and height were also measured to the nearest 0.1 kg and 0.5 cm, respectively. Body mass index (BMI) was calculated as body mass divided by height squared (kg·m−2). Body composition including lean mass (kg), fat mass (kg), and percent body fat (%kg) was measured by a DXA with a GE Lunar iDXA (GE Healthcare, Chicago, IL with enCoreTM Software version 15).

Subjects

Thirty-seven healthy, premenopausal, women (The age range was 18–50 (mean: 24.5, SD 7.9); 8 OL, 10 PL, 8 SP, and 11 RA females, 24.5 ± 7.9 years; mean ± SD) participated in this study. The RA group had no prior experience in any high-impact or odd-impact sports, either competitively or for more than 6 months from the age of 14 years to the present. All women were amateur competitive athletes, and they were recruited through local gyms and athletic clubs, as well as through exercise classes offered at The University of Texas at Austin. All athletes had at least 9 months of training experience in their specific sport. Recreationally active had no training set plan for their workouts, and intensities varied from week to week. In average, OL and PL performed weight training 3 times per week with their intensity at 80% of their 1 repetition maximum with 4–6 reps per set. Soccer players participated in team practice 3–4 times per week for 2–3 hours per day during their in-season training and had at least 1 game per week.

All subjects were healthy and without any preexisting conditions that would inhibit them from exercise or affect their BMD negatively. Any subjects who reported taking medication with side effects known to affect BMD or who may have been pregnant were excluded from the study. Anyone with amenorrhea or on birth control hormone medication or using anabolic steroids were also excluded. All procedures were approved by The University of Texas at Austin's Institutional Review Board and were in accord with the Helsinki Declaration of 1975. All subjects were informed of all testing procedures and signed a written informed consent form before participation.

Procedures

After the consent form was signed and a health questionnaire was completed, the subjects' body mass and heights were measured. Subjects were positioned for each scan type according to the standard DXA positioning protocol of the guidelines by the manufacture. Data from body composition (bone and tissue) provided BMD values for lumbar spine, femoral neck and total body, and tissue composition (lean mass, fat mass, and percent body fat) for each subject were obtained.

Statistical Analyses

A 1-way analysis of variance was used to compare body composition (total fat mass, nonbone lean mass, and percent fat). A 2-way mixed-model (groups × BMD) analysis of covariance was used to compare BMD value (total body, femoral neck, and lumbar spine) differences. Body mass, height, and BMI were used as covariates because each of these variables has a positive correlation to BMD independently (19,25). A Tukey's test was used for post hoc analysis. SPSS 22.0 (SPSS Inc., Chicago, IL) was used for all statistical analysis with an alpha level of significance of $p \leq 0.05$ set a priori. All data are presented as a mean ± *SD*.

Results

Athletic Characteristics

Table 1 shows the characteristics of the 4 groups. Despite differences in age and height ($p < 0.01$), there were no differences in body mass, fat mass, and BMI among all groups. There was no difference in percent body fat among the 3 athletic groups, and all athletic groups had a lower-percent body fat and higher lean mass (fat-free mass) than RA (Table 1). Soccer players reported the greatest number of years of sport-specific training since the age of 14 years. There was no significant difference in years of training between OL and PL. All BMD data are displayed in Table 2.

Bone Mineral Density at Different Skeletal Sites

There was a main effect of skeletal site on BMD value ($F = 60.97$; effect size [partial eta squared] = 0.64). The lumbar spine showed the highest BMD (1.27 ± 0.14; 95% confidence interval [CI], lower bound = 1.24, upper bound = 1.32; $p < 0.01$), followed by total BMD (1.18 ± 0.11; 95% CI, lower bound = 1.17, upper

Table 1
Characteristics of the athletic groups and the control group (mean ± *SD*).*

	Recreationally active ($n = 11$)	Power lifter ($n = 10$)	Olympic lifter ($n = 8$)	Soccer player ($n = 8$)	p (F)
Age (y)	22.09 ± 4.48§	23.70 ± 5.60§	33.13 ± 11.12†‡‖	20.25 ± 3.01§	0.002 (6.312)
Height (cm)	158.31 ± 4.51§‖	161.06 ± 5.53‖	165.71 ± 4.97†	170.04 ± 5.37†‡	< 0.01 (9.452)
Weight (kg)	58.96 ± 10.96	68.58 ± 32.74	69.75 ± 13.31	65.10 ± 8.19	0.607 (0.620)
Body fat (%)	35.07 ± 6.03‡§‖	26.63 ± 3.89†	26.63 ± 4.21†	27.01 ± 3.10†	< 0.01 (8.535)
Fat mass (kg)	20.36 ± 6.58	15.50 ± 4.09	18.24 ± 6.06	16.93 ± 3.47	0.213 (1.581)
Lean mass (kg)	36.50 ± 5.50‡§‖	42.16 ± 5.35†§	49.15 ± 7.95†‡	45.58 ± 5.36†	< 0.01 (7.844)
Body mass index (kg·m^{-2})	23.38 ± 3.91	22.95 ± 2.77	25.28 ± 3.76	22.44 ± 2.11	0.337 (1.168)
Sport-specific training since age 14 (y)	0 ± 0§‖	2.38 ± 1.27†‖	3.91 ± 2.93†‖	8.25 ± 3.01†‡§	< 0.01 (26.041)

*N = total subjects of each group; F = F-Ratio; PL = power lifters; OL = Olympic lifters; SP = soccer players; RA = recreationally active.
†Significantly different than RA ($p < 0.05$).
‡Significantly different than PL ($p < 0.05$).
§Significantly different than OL ($p < 0.05$).
‖Significantly different than SP ($p < 0.05$).

bound = 1.22; $p < 0.01$), and the lowest BMD was observed at the femoral neck (1.08 ± 0.14; 95% CI, lower bound = 1.05, upper bound = 1.13; $p < 0.01$).

Total Bone Mineral Density

All 3 athletic groups had greater total BMD than RA (RA: 95% CI lower bound = 1.02, upper bound = 1.12; PL: 95% CI, lower bound = 1.15, upper bound = 1.24, p = 0.01; OL: 95% CI, lower bound = 1.23, upper bound = 1.34; $p < 0.001$; SP: 95% CI, lower bound = 1.14, upper bound = 1.30; p = 0.01)) and OL had greater total BMD than PL (p = 0.018; F = 9.99; effect size [partial eta squared] = 0.60).

Lumbar Spine

Although there were no significant differences in total lumbar spine BMD (L1-L4) across the 3 athletic groups, OL (95% CI, lower bound = 1.26, upper bound = 1.45) and PL (95% CI, lower bound = 1.22, upper bound = 1.38) had significantly greater total lumbar spine BMD than RA (95% CI, lower bound = 1.07, upper bound = 1.25; p = 0.007 [OL] and p = 0.019 [PL], respectively; F = 2.86; effect size [partial eta squared] = 0.36).

For individual lumbar vertebra, OL and PL had greater BMD of lumbar vertebrae 2 (L2: OL [95% CI, lower bound = 1.24, upper bound = 1.44] and PL [95% CI, lower bound = 1.20, upper bound = 1.38]; p = 0.018 and p = 0.046, respectively) than RA (95% CI, lower bound = 1.06, upper bound = 1.26; F = 2.20; effect size [partial eta squared] = 0.30).

Olympic lifters and PL also had greater BMD of lumbar vertebrae 3 (L3: OL [95% CI, lower bound = 1.32, upper bound = 1.52] and PL [95% CI, lower bound = 1.28, upper bound = 1.45]; p = 0.012 and p = 0.041, respectively) than RA (95% CI, lower bound = 1.15, upper bound = 1.33; F = 2.57; effect size [partial eta squared] = 0.34).

At the lumbar vertebrae 4, all 3 athletic groups had significantly greater BMD than RA (95% CI, lower bound = 1.03, upper bound = 1.23; L4: OL [95% CI, lower bound = 1.28, upper bound = 1.49], PL [95% CI, lower bound = 1.23, upper bound = 1.41], and SP [95% CI, lower bound = 1.20, upper bound = 1.46]; p = 0.002, p = 0.005, and p = 0.031, respectively; F = 3.24; effect size [partial eta squared] = 0.39).

Femoral Neck

Olympic lifters (95% CI, lower bound = 1.05, upper bound = 1.22) and SP (95% CI, lower bound = 1.13, upper bound = 1.31) had significantly greater BMD at the femoral neck than RA (95% CI, lower bound = 0.88, upper bound = 1.04; p = 0.012 [OL] and p = 0.002 [SP], respectively; F = 5.43; effect size [partial eta squared] = 0.40). However, there was no significant difference between PL (95% CI, lower bound = 1.00, upper bound = 1.15) and RA. Soccer players had significantly greater femoral neck BMD than PL (p = 0.035) but not OL.

Table 2
Total and Site-Specific Bone Mineral Density of each sport group (mean ± *SD*).*†

Bone mineral density, g·cm^{-2}	Recreationally active	Power lifter	Olympic lifter	Soccer player
L1	1.101 ± 0.092	1.195 ± 0.156	1.263 ± 0.112	1.205 ± 0.165
L2	1.162 ± 0.081§‖	1.285 ± 0.167‡	1.363 ± 0.101‡	1.300 ± 0.165
L3	1.238 ± 0.097§‖	1.361 ± 0.122‡	1.447 ± 0.110‡	1.374 ± 0.172
L4	1.146 ± 0.091§‖¶	1.325 ± 0.142‡	1.401 ± 0.148‡	1.303 ± 0.166‡
Total lumbar spine	1.163 ± 0.081§‖	1.296 ± 0.131‡	1.373 ± 0.110‡	1.299 ± 0.161
Femoral neck	0.971 ± 0.987‖¶	1.075 ± 0.158	1.127 ± 0.089‡	1.212 ± 0.096‡§
Total BMD	1.071 ± 0.066§‖¶	1.191 ± 0.081‡	1.306 ± 0.078‡§	1.233 ± 0.067‡

*BMD = bone mineral density; PL = power lifters; OL = Olympic lifters; SP = soccer players; RA = recreationally active; BMI = body mass index.
†L1—L4 (lumbar spine segment 1—4), *SD*. All statistically significant difference include covariates (mass, height, and BMI) adjustment.
‡Significantly different than RA ($p < 0.05$).
§Significantly different than PL ($p < 0.05$).
‖Significantly different than OL ($p < 0.05$).
¶Significantly different than SP ($p < 0.05$).

Discussion

To our knowledge, this is the first study to directly compare BMD between Olympic style lifters and PL. Our findings showed that OL had the highest total BMD with greater regional BMD at both the total lumbar spine and femoral neck compared with RA.

We found that weight lifting groups (PL and OL) had greater lumbar spine BMD compared with RA. In accordance with our finding, previous studies have reported that increased mechanical loading through resistance training and high-impact weight-bearing exercises increases BMD at the lumbar spine. For example, a study on the effects of types of training found that lumbar spine BMD was significantly increased in both weight trainers (1.2 ± 1.8%) and runners (1.3 ± 1.6%) compared with a control group by 8-month training (40). Heinonen et al. (18) showed that among squash players, aerobic dancers, and speed skaters, only squash players had a significantly greater BMD value (13.8%) at the lumbar spine than a sedentary control group. Compared with non–weight-bearing exercise, addition of weight-bearing exercise to medical treatment increases BMD of the lumbar spine and femoral neck in older adults with osteoporosis (40).

Olympic lifting technique requires complex movement skills. Not only it is a high-impact loading modality needed but also it requires performing 2 ballistic lifts overhead known as the "clean and jerk" and the "snatch." The "clean" is a very fast and powerful lift and a quick entry into a front squat position requiring extension of the ankles, knees, and hip joints in a very short period. The "jerk" is the returning to a standing position very quickly from the front squat position. During the jerk, the lifter drives the lead foot forward rapidly while resisting a heavy weight-bearing load on the lead foot explosively (similar to single leg vertical jumping), to accelerate the barbell upward before coming to a full standing position. Similar to the "jerk," the "snatch" also involves multijoint explosive movements for lifting the bar above the head, and kinetic features of the "snatch" (maximal force and power) is similar to the squatting vertical jump (11,33).

Thus, Olympic-style lifts could be considered as an exercise that has the high-impact (high-intensity weight-bearing) with odd-impact (accelerating and decelerating forward and backward) loading modalities and high-magnitude loading (weight loading requiring very high muscle force production). Unlike Olympic-style lifts, power lifting is the sport of maximal strength that primarily involves relatively slow high-impact or high-magnitude loadings during the squat, bench press, and deadlift (15).

We found that Olympic-style lifters have a higher BMD of the femoral neck without a significant difference from SP. Compared with RA, both OL and SP groups had significantly greater femoral neck BMD, whereas no significant difference was observed in PL. Soccer and squash includes accelerating and decelerating movements along with rapid changes in direction. The continuous transverse and torsional loads during soccer and squash, odd-impact loading, improve the femoral neck BMD (8,18,32). Similar to the specific characteristics of the odd-impact sports, "the speed of execution" is very important for the success of Olympic lifts because the time required for vertically directing overhead movement during Olympic lifting is very short. If the pathway of lifting the barbells is not correct or the 3 joints of the leg (the ankle, knee, and hip) are not extended sequentially during the clean and jerk or the snatch drive, the lift will fail. On the other hand, power lifting exercises can be performed at a slower speed than Olympic lifts because they allow time for adjustments in the initial position at the beginning phase of the lift (37).

Previous studies have shown that although power lifting improves lumbar spine and total-body BMD, it has not shown a significant impact on femoral neck BMD (16,35,42). Our findings support these findings, showing that there was no difference in femoral neck BMD between the PL and RA groups, whereas OL showed a significantly greater femoral neck BMD compared with the RA. This suggests that the high-impact of the power lifts alone does not provide a benefit on the femoral neck BMD, whereas the additional mechanical loading characteristic of the Olympic lifts (the odd and high impacts) could provide advantages to improve the BMD and strength of the femoral neck as well as of the lumbar spine.

Osteoporosis is a bone disease associated with low BMD and mainly occurs in older women with decreased estrogen levels after menopause (30). Skeletal muscle mass and muscular strength also weaken with age and sarcopenia in skeletal muscle is predominant among individuals with low BMD (9,21). For these reasons, older woman often experience bone loss, muscle weakness, and poor balance control that contribute to the increase risk of falls and fractures.

Regular weight-bearing exercise during youth leads to substantial benefits in bone mass improvement and helps to provide lifelong fracture protection (41). Postmenopausal athletes with a lifetime history of weight-bearing activities had higher BMD compared with sedentary controls of similar age. The improved bone structural properties through mechanical loading exercise from a young age, including young adulthood, seems to result in a greater BMD and reduce the number of fractures and bone loss because of aging (2,23). Thus, regular weight-bearing exercises in early adulthood may have a benefit in preventing further bone loss and improving strength, coordination, and balance. Our findings suggest that Olympic style lifts could be used as effective weight-bearing exercise because Olympic lifting involves high-impact loading and odd-impact loading, which contribute to continuous BMD gains.

Several studies have shown that training with loads corresponding to 80–100% of 1 repetition maximum (high-intensity strength training) is most effective for increasing maximal dynamic strength because this training regimen seems to recruit muscle fibers and produce additional neural adaptations maximally (10,27). In addition, previous study showed that high-intensity strength training exercises are an effective method to preserve BMD at the femoral neck and lumbar spine while improving muscle mass, strength, and balance in postmenopausal women (34). However, the risk associated with high-intensity resistance training in older adults is not well understood and may be greater than for lower-intensity training.

Bemben et al. (6) found that both low intensity with a high-repetition and high intensity with a low-repetition resistance trainings were effective in improving muscle strength and size if the volume of work are similar to each other. Therefore, Olympic lifting with appropriate training adjustments according to the individual's functional abilities from adolescence and adulthood might be the ideal resistance training that contributes to improving muscular strength and the BMD of the lumbar spine, femoral neck, and total body, and it could be a preventive strategy against bone fragility and fractures in old age.

Generic differences may also contribute to the differences in BMD across the groups (14). Thus, we cannot exclude the possibility that individuals who had genetically high BMD could have been more likely participated in Olympic lifting or power lifting. This study is also limited by our inability to control the activity level of subjects in RA. However, we believe that our results provide new insights on the positive influence of Olympic lifting training for improvement in BMD at the lumbar spine and femoral neck.

Practical Applications

Olympic lifting includes high- and odd-impact loading modalities that improve the femoral neck and lumbar spine BMD. The results of the current study have shown that OL have significantly greater BMD at the lumbar spine and femoral neck than RA subjects (control group), whereas there was no significant difference between PL and control group. In addition, total BMD was significantly greater in OL than PL. Our findings provide valuable information for coaches and practitioners to design resistance training programs. Olympic weightlifting training from young age could provide long-term effects on improving BMD at the lumbar spine and femoral neck and prevent age-related fractures in later life.

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