Participation in High-Impact Sports Predicts Bone Mineral Density in Senior Olympic Athletes

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Participation in High-Impact Sports Predicts Bone Mineral Density in Senior Olympic Athletes

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Background: Loss of bone mineral density (BMD) and resultant fractures increase with age in both sexes. Participation in resistance or high-impact sports is a known contributor to bone health in young athletes; however, little is known about the effect of participation in impact sports on bone density as people age.

Hypothesis: To test the hypothesis that high-impact sport participation will predict BMD in senior athletes, this study evaluated 560 athletes during the 2005 National Senior Games (the Senior Olympics).

Study Design: Cross-sectional methods. The athletes completed a detailed health history questionnaire and underwent calcaneal quantitative ultrasound to measure BMD. Athletes were classified as participating in high impact sports (basketball, road race [running], track and field, triathalon, and volleyball) or non-high-impact sports. Stepwise linear regression was used to determine the influence of high-impact sports on BMD.

Results: On average, participants were 65.9 years old (range, 50 to 93). There were 298 women (53.2%) and 289 men (51.6%) who participated in high-impact sports. Average body mass index was 25.6 ± 3.9. The quantitative ultrasound-generated *T* scores, a quantitative measure of BMD, averaged 0.4 ± 1.3 and −0.1 ± 1.4 for the high-impact and non-high-impact groups, respectively. After age, sex, obesity, and use of osteoporosis medication were controlled, participation in high-impact sports was a significant predictor of BMD (R^2 change 3.2%, $P < .001$).

Conclusions: This study represents the largest sample of BMD data in senior athletes to date. Senior participation in high-impact sports positively influenced bone health, even in the oldest athletes.

Clinical Relevance: These data imply that high-impact exercise is a vital tool to maintain healthy BMD with active aging.

Keywords: high impact; bone mineral density; exercise; elderly

Osteoporosis, a disease seen frequently in the elderly, is characterized by reduced bone mineral density (BMD) and disrupted bone structure.[22] An estimated 10 million people in the United States have osteoporosis. Another 34 million are estimated to have low BMD, or osteopenia, which puts them at an increased risk to develop osteoporosis.[22] The reduced bone density characteristic of osteoporosis increases the risk of bone fracture. Fifty percent of women and 25% of men over the age of 50 will suffer a fracture related to osteoporosis in their lifetime, with hip fracture accounting for approximately 15% of those cases of osteoporosis-related fracture.[22]

Hip fractures are a leading cause of morbidity and mortality in the elderly population. A recent study conducted in Canada involving 3981 patients aged 60 years or older who were admitted for hip fracture found an in-hospital mortality rate of 6.3% and a 1-year mortality rate of 30.8%.[14] Hip fracture is also associated with significant financial expenditures. In the United States, the cost of care for patients with osteoporotic fractures—including hospital, nursing home, and outpatient services—was $18 billion in 2002, and it is rising.[22] In addition, there is significant evidence that treatments for osteoporosis, such as calcium supplementation and drugs (eg, bisphosphonate),

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are underused in the elderly population.[11,15,16] These findings suggest that if the affected population fully used treatment modalities, the costs would probably exceed \$18 billion. Furthermore, with an aging population, this number is almost certain to show a significant increase in the years to come.

Prevention of osteoporosis becomes a top priority when one considers the significant morbidity, mortality rates, and treatment costs associated with osteoporotic fracture. The US Department of Health and Human Services estimates that without a more effective prevention plan, 13.9 million people will have osteoporosis by 2020 and 47.5 million will have low bone density.[22]

Research has shown that BMD in athletes is significantly greater than it is in sedentary controls and that it is highest in athletes who participate in *high-impact exercise*, defined as activities involving running, jumping, and weight lifting.[2,24,25,28] Although previous studies have shown that some form of exercise is beneficial for maintaining bone mass and structure as one ages,[1,6,26] the specific effect of high-impact exercise has not yet been fully explored in aging populations. Senior athletes, as opposed to a sedentary elderly population, may provide the most accurate answers to these questions because disuse and chronic disease are less likely to confound data. This study recruited athletes involved in the 2005 Senior Olympics, thereby accruing, to our knowledge, the largest sample of BMD data in the elderly population to date. These data were used to compare the BMD of those involved in high- and low-impact exercise, to test the hypothesis that high-impact exercise has a positive effect on BMD in the elderly.

MATERIALS AND METHODS

In 2005, 10 400 athletes aged 50 to 103 years competed at the National Senior Games (the Senior Olympics) held in Pittsburgh, Pennsylvania, from June 3 to June 18. The Senior Olympics is an 18-sport competition for athletes aged 50 years or older; it is held on odd-numbered years. Athletes qualify for the Senior Olympics by winning their events in their individual states' senior games. The 18 sports in which the senior athletes compete during the games include archery, badminton, basketball, bowling, cycling, golf, horseshoes, race walking, racquetball, road race, shuffleboard, softball, swimming, table tennis, tennis, track and field, triathlon, and volleyball. Of these, basketball, road race, track and field, triathlon, and volleyball were considered *high impact* owing to the almost continuous running and jumping maneuvers involved with these sports. The other 13 were classified as *non-high-impact*.

All Senior Olympians received a Senior Athlete Health Registry Questionnaire with their registration materials. This survey was designed for this project, and it requested general information (gender, ethnicity, marital status, etc) as well as relevant medical history. From June 2 to June 13, 2005, all respondents were invited to participate in BMD testing via a calcaneal quantitative ultrasound of the heel of their dominant foot. *T* score data were generated by the quantitative ultrasound machine and recorded for each participant. Thus, the measured sample was purely a sample of convenience, and all data besides the quantitative ultrasound were self-reported. Dual-energy X-ray absorptiometry is still the gold standard for measurement of BMD, but this test usually requires evaluation in a radiologic facility. Studies have found the correlation of measurements taken with quantitative ultrasound to those of dual-energy X-ray absorptiometry to be as high as .86.[17] The survey and procedures for measurement of *T* score were approved by the university institutional review board.

DATA ANALYSIS

All *T* scores as well as survey data were entered into a computerized database. The type of sports in which the athletes participated was recoded as being either high impact or non-high-impact. Other potential predictors of BMD that were explored included age, sex, minority status, use of osteoporosis medications, and a history of doctor-diagnosed obesity.

Hierarchical linear regression was used to test the hypothesis that high-impact sports participation is associated with higher BMD, after controlling for other variables that may affect BMD. To accomplish this, BMD was regressed onto potentially confounding variables in the first step of the regression model—namely, age, sex, minority status, osteoporosis medication use, and history of doctor-diagnosed obesity. In the second step of the regression, participation in high-impact sports versus non-high-impact sports was entered into the model to determine whether this variable explained a significant amount of variance in the BMD scores after controlling for the potential confounding factors (ie, ΔR^2_{adj}, $P < .05$). All analyses were performed using SPSS 15.0 and the level of statistical significance was set to $P < .05$.

RESULTS

Of the 1408 Senior Olympians who returned the survey, 560 underwent BMD testing via the quantitative ultrasound machine. Statistical tests determined that those senior athletes included in the current analysis were largely comparable to the senior athletes who completed the senior games survey but did not have their BMD tested. Specifically, independent samples *t* tests indicated that no significant group differences in terms of age, $t(1397) = -1.76$, $P = .08$, weight, $t(1321) = 0.57$, $P = .57$, or body mass index, $t(1306) = 0.70$, $P = .87$. Chi-square tests found no significant group differences in terms of minority status, $\chi^2(1; n, 1392) = .40$, $P = .53$, gender, $\chi^2(1; n, 1400) = 1.81$, $P = .18$, or doctor-diagnosed obesity, $\chi^2(1; n, 1403) = .05$, $P = .82$. In comparison to seniors with survey data but no BMD data, participants in the current study were significantly less likely to be on osteoporosis medication, $\chi^2(1; n, 1321) = 5.07$, $P = .02$, and more likely to play high-impact sports, $\chi^2(1; n, 1403) = 4.24$, $P = .04$. However, the magnitude of the difference between participants with and without BMD data was relatively small for osteoporosis medication (6.3% versus 9.7%, respectively) and high-impact sports (48.5% versus 42.9%, respectively).

Table 1. Prevalence of sports participation for senior athletes.[a]

Sport	n	%
Archery	15	4.7
Badminton	26	4.7
Basketball[b]	149	26.7
Bowling	47	8.4
Cycling	41	7.3
Golf	13	2.3
Horseshoes	15	2.7
Race walk	17	3.0
Racquetball	17	3.0
Road race[b]	24	4.3
Shuffleboard	29	5.2
Softball	67	12.0
Swimming	28	5.0
Table tennis	20	3.6
Tennis	42	7.5
Track and field[b]	81	14.5
Triathlon[b]	15	2.7
Volleyball[b]	25	4.5

[a]n, 559. Overall, 102 athletes participated in more than 1 sport.
[b]High-impact sport.

The average age of the study participants was 65.9 years, with approximately half being women and approximately half participating in high-impact sports. Most were Caucasian. Table 1 shows the sports that were considered high impact, as well as an individual breakdown of senior athlete participation in each sport. Table 2 summarizes *T* score and survey data.

Table 3 presents correlations between the BMD *T* score and the primary study variables. In the first step of the model, results indicated that as an athlete ages, he or she tends to exhibit lower BMD. Lower BMD was also significantly associated with being female, being on osteoporosis medication, and having a history of doctor-diagnosed obesity. Being from a minority population was not associated with a significantly higher or lower BMD. Participation in high-impact sports was significantly associated with higher BMD.

Table 4 presents the results for combining these primary study variables into a regression analysis. Together, these 5 variables accounted for 15% of the variance in BMD scores. When high-impact sports participation was entered into the second step of the regression, it explained a significant amount of variation in BMD, above and beyond the 15% explained by the 5 potential confounding variables entered in Step 1 of the model. Specifically, participation in high-impact sports accounted for an additional 3% of the variance in BMD scores, with those individuals participating in high-impact sports having higher BMD. Thus, step 1 showed that 15% of the variance in BMD can be attributed to age, being from a minority population, being a woman, being on osteoporosis medication, and having doctor-diagnosed obesity, with all being associated with a negative influence on BMD (except being from a minority population). Although those 5 variables combined accounted for 15% of the variance in BMD, high-impact sports participation accounted for another 3% by itself.

DISCUSSION

This study supports previous research indicating a positive effect of high-impact sports on BMD in senior athletes. Regression analysis indicated that age, sex, minority status, osteoporosis medication, and doctor-diagnosed obesity accounted for just 15% of the variance in BMD of the sample. Participation in a high-impact sports accounted for another 3%. Thus, high-impact sports may have an effect on BMD that is similar to that of other, more recognized factors. Results of this study indicated that combining 5 factors thought to be involved in determining BMD accounted for 15% of the variance in BMD. Participation in high-impact sports was associated with a higher BMD, whereas a lower BMD was associated with increased age, being a woman, and having a physician's diagnosis of obesity.

From about the age of 40, men and women lose, on average, 0.5% of their bone mass each year.[21] Therefore, high-impact exercise could be a useful tool in lessening the loss of BMD in the elderly, which could improve the risk of fracture owing to a fall or other minimal trauma.[21] In addition, evidence suggests that high-impact exercise can reduce the risk of falling in the first place in older populations if that exercise includes balance, leg strength, flexibility, or endurance training.[4,8,10] Therefore, high-impact exercise may prove to be a valuable tool (in more than one way) in reducing the morbidity and mortality associated with hip fracture in the elderly.

The effects of estrogen on bone health are well known, given that withdrawal of estrogen during menopause is associated with a rapid bone loss.[21] However, evidence indicates that the rapid initial bone loss of menopause declines significantly over time. It seems that halting the rapid initial bone loss in perimenopausal women may be valuable as time goes on and the rate of bone loss declines. A study by Engelke et al demonstrated that high-impact exercise helped sustain bone mass in early postmenopausal women over a 3-year period.[6] So, high-impact sport may attenuate the rapid bone loss characteristic of the perimenopausal period. Furthermore, although postmenopausal women are largely considered to be out of the time frame when high-impact exercise is valuable for bone health,[9,12] there is accumulating research that supports

Table 2. *T* score and survey data in senior athletes.[a]

	n	Mean	Min	Max	SD
Age	560	65.92	47.39	93.17	8.53
Weight (kg)	534	74.75	43.65	123.75	14.25
Height (cm)	552	171.48	147.32	205.74	9.83
Body mass index	530	25.55	16.95	46.05	3.91
Bone mineral density	560	0.14	–3.50	6.90	1.37
	n	%			
Race					
Nonminority	510	91.07			
Minority	50	8.93			
Sports participation					
High impact	271	48.39			
Non-high-impact	289	51.61			
Gender					
Male	262	46.79			
Female	298	53.21			
Doctor-diagnosed obesity					
No	533	95.18			
Yes	27	4.82			
Osteoporosis medication					
No	525	93.75			
Yes	35	6.25			

[a]N, 560.

a positive effect of high-impact sports in this population, especially for the hip.[3,27] Thus, high-impact sports may be of benefit in women throughout, as well as after, menopause.

Overall, the well-known effects of menopause on bone health have made women the focal point of osteoporosis research, but men have been shown to have a significantly increased risk of death owing to complications from osteoporotic fracture, compared to women.[14] However, high-impact exercise has been shown to benefit men as well as women. Daly and Bass (2005) reported that a greater lifetime osteogenic index, a measure of participation in weightbearing activities, was associated with better bone health in the legs of men aged 50 to 87 years.[5] Time (minutes) spent engaged in physical activity was not associated with better bone health, raising the possibility that a lesser amount of weightbearing exercise may be more beneficial than a larger amount of

Table 3. Correlations between bone mineral density *T* score and primary study variables.

Predictors	Bone Mineral Density
Age	–.21***
Minority status	.00
Female	–.24***
Osteoporosis medication	–.19***
Doctor-diagnosed obesity	–.13***
High-impact sport	.19***

[a]n, 559.***
P < .001.

Table 4. Linear regression using involvement in high-impact sports to predict bone density after controlling for potential confounds in senior athletes.[a]

	B	*SE*	β	R^2	ΔR^2
Step 1					
Age	–.04	.01	–.25***		
Minority status	.06	.19	.01		
Female	–.67	.11	–.25***		
Osteoporosis medication	–.72	.23	–.13**		
Doctor-diagnosed obesity	–.59	.26	–.09*	.15***	
Step 2					
Age	–.04	.01	–.24***		
Minority status	.05	.19	.01		
Female	–.69	.11	–.25***		
Osteoporosis medication	–.76	.22	–.14***		
Doctor-diagnosed obesity	–.44	.25	–.07		
High-impact sport	.49	.11	.18***	.18***	.032***

[a]N, 560.
*$P < .05$. **$P < .01$. ***$P < .001$.

nonweightbearing exercise for bone quality and strength. Overall, meta-analysis of high-impact exercise and bone health in men has noted a positive effect.[18]

Although there remains evidence both for and against the use of high-impact sports in the elderly, the most accurate picture of bone health in the elderly may come from a population that eliminates certain confounders that are common in the elderly—namely, bone disease and disuse. This study used a large and unique population—Senior Olympians, a population that likely gives the most accurate prototype for healthy bone aging. Our results in regression analysis indicate that high-impact sports are a significant positive contributor to BMD in elderly athletes. In addition, the average *T* score of an athlete in the high-impact group was 0.4 ± 1.3, as opposed to the –0.1 ± 1.4 average *T* score seen in the non-high-impact group.

Although it appears that there is significant evidence suggesting that high-impact exercise may lead to improved bone health, there remains little direct evidence indicating that exercise specifically reduces hip fracture. Indirect evidence indicates that a lack of exercise is a risk factor for hip fracture in the elderly: Sedentary elderly men and women were more than twice as likely to sustain a hip fracture as their physically active counterparts.[13] In addition, a study of more than 61 000 postmenopausal women found that women who walked at least 4 hours per week had a 41% lower risk of hip fracture than did those who walked less than 1 hour per week.[7] Thus, at this point, there is at least a negative association between exercise and hip fracture.

However, it is clear that not every elderly person can participate in high-impact sports. Whereas eliminating confounders may help in determining the most accurate conclusions regarding high-impact exercise and bone health, morbidities such as osteoarthritis and heart disease must be accounted for to determine the appropriate role for high-impact exercise in the general elderly population. Certainly, high-impact sports should be used cautiously in elderly with hip or knee osteoarthritis. Low-impact sports may be of use in these instances, not only for bone health, but also for pain reduction, improved function, and attenuating progression of the osteoarthritis. Note, however, that non-high-impact exercise has not shown the same effects on bone health as high-impact exercise.[19,20] Also, whereas the benefits of high-impact exercise on cardiovascular health are clear, the American Heart Association recommends screening of elderly who are about to begin an exercise program, with special attention to those perceived as being higher risk for coronary artery disease.[23]

This study suggests that high-impact sports can be a significant part of healthy bone aging. With high-impact sports and several well-known factors determining bone density accounting for only 18% of the variance in BMD, there is much more to learn when it comes to bone loss and fracture risk in the elderly. An easy solution is unlikely. Thus, a multifactorial approach with the appropriate use of high-impact exercise may be more effective than the current treatment strategies not using it. Although Senior Olympians serve as a prototype for healthy bone aging, they are not a representative sample, being mostly middle class, Caucasian, and well educated. They may have benefited from improved health care or easier access to exercise facilities. Furthermore, all data in this study other than *T* scores were self-reported; the study was cross-sectional; and there was no randomization of the sample (ie, all who responded to the survey and had a BMD measurement were included). Thus, more research is warranted to properly explore the use of high-impact sports in the elderly.

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