Case Study: Bone Mineral Density of Two Elite Senior Female Powerlifters

Peter H. Walters, Joel J. Jezequel, and Mary B. Grove

Health and Human Performance Laboratory, Department of Applied Health Science, Wheaton College, Wheaton, Illinois

Abstract

Walters, PH, Jezequel, JJ, and Grove, MB. Case study: bone mineral density of two elite senior female powerlifters. *J Strength Cond Res* 26(3): 867–872, 2012—The purpose of this case study was to examine the bone mineral density (BMD) of 2 women, aged 48 and 54 years, who had engaged in high-intensity resistance training for >30 years each and gained national prominence for their lifting performances. Each subject was measured using a dual x-ray absorptiometry (GE Lunar Prodigy, Fairfield, CT, USA) for both the BMD (grams per centimeter squared) and bone mineral content (grams) of the lumbar spine, dual femur, and total body. The Z and T scores of the 49-year-old subject were significantly higher than either age and gender-matched or peak BMD norms (lumbar spine $Z+2.2$, $T+1.8$, femoral mean $Z+1.1$, $T+0.6$, total body $Z+2.4$, $T+2.0$). The Z and T scores of the 54-year-old mark the largest ever reported in the literature for a Caucasian woman of this age (lumbar spine $Z+2.8$, $T+2.2$, femoral mean $Z+1.4$, $T+1.9$, total body $Z+2.6$, $T+3.0$). Although these results do not prove any causal relationship between long-term high-intensity strength training and elevated BMDs among women, they do raise questions that some type of relationship may exist.

Key Words osteoporosis, osteopenia, strength training, resistance training, weightlifting

Introduction

Many health care professionals recommend weight-bearing activities to the 44 million Americans diagnosed with either low bone mineral density (BMD) or osteoporosis. Yet the scientific support for this recommendation is not entirely conclusive (1,8,10,15,16,22). There are many unanswered questions related to the effectiveness of weight-bearing activities on the prevention and treatment of low BMD, osteoporosis, and ultimately, skeletal fractures. The questions include which modality of weight bearing activity (WBA) best develops BMD, what degree of external loading is required to maintain or promote skeletal health, and what levels of frequency and duration are needed to develop or sustain skeletal health. Questions of modality, intensity, frequency, and duration of WBA have all been included in the primary research agenda of the National Osteoporosis Foundation (13). These applied research questions provided the impetus for designing this case study.

The National Osteoporosis Foundation groups weight-bearing activities into 3 subgroups: high-impact (basketball, gymnastics, jogging, tennis, etc.), low-impact (elliptical training, stair-step machines, crosscountry skiing, walking, etc.), and muscle-strengthening (exercise bands, yoga, Pilates, weightlifting) (12). This investigation focuses on weightlifting, a type of muscle-strengthening activity. Throughout the past 5 decades, several studies have examined the effect of weightlifting (commonly referred to as strength or resistance training) on the maintenance or development of BMD. Several of these studies suggest a positive relationship between the practice of resistance training and increases in BMD. Shackelford et al. investigated resistance exercise as a countermeasure to patients confined to bed rest. In this 17-week study, experimental subjects who engaged in strength-training activities (while in bed) had significantly greater levels of BMD in their lumbar spine, hip, and pelvis than did bed resting subjects who did not perform resistance activities (18). Ryan et al. investigated the effect of 6 months of whole-body resistance training on the BMD of women and men ranging from 20 to 74 years of age. Regardless of gender or age, the subjects experienced significant improvements in all BMD measures (femoral neck, Ward's triangle, and greater trochanter) when compared with pretest scores (17). In a 2-year study that examined the effect of strength training and cycling on the development of BMD, Kerr et al. reported a significantly greater effect for subjects who strength trained. Of the 126 postmenopausal women in this investigation, those that performed resistance training had significantly greater BMDs of both intertrochanteric hip and total body skeletal densities than did either the control group, which was not physically active, or the group that regularly cycled (7). These are but a few of the studies that suggest

Address correspondence to Dr. Peter H. Walters, peter.walters@wheaton.edu.

26(3)/867–872

Journal of Strength and Conditioning Research

that resistance training is an effective measure for the development of BMD in humans (1,8,15,16,21).

However, not all investigators report a positive relationship between strength training and increased BMD. Chilibeck et al. reported no significant differences in the BMD of young women who participated in a 20-week strength training program when compared with those who did not (1). In another study of 34 active women over the age of 60 years, Nichols et al. reported that although subjects who engaged in resistance training had greater levels of muscular strength at the end of the 12-month study, they did not differ significantly in BMD when compared with women who did not strength train (14). Likewise, although Rhodes et al. reported significant strength differences between the subjects (men and women, average age 68.8 years) who engaged in resistance training and those who did not, no such differences in BMD were observed (15).

The evidence for resistance training is more consistent when investigations are limited to competitive weight lifters and powerlifters. Although only 7 studies have examined the BMD of competitive lifters, each has reported optimistic findings. Heinonen et al. reported that female weight lifters had the highest weight-adjusted BMD of any athletic group (orienteers, crosscountry skiers, and cyclists) in their investigation (4). Conroy et al. reported the BMD at the lumbar spine and proximal femur of 25 male junior weight lifters (age, 17.4 ± 1.4 years) to be significantly greater than age-matched controls or of men 10 years older (2). In a study of 5 male powerlifters, Tsuzuku et al. reported the BMD of the lumbar spine, arm, leg, and pelvis to be significantly greater than those of gender- and age-matched subjects who were either physically active or sedentary (19). In a study comparing 14 female weight lifters (mean age 30.6 years) with 14 nonlifting control subjects, the investigators reported that the trabecular densities of the distal radius, radial shaft, distal femur, and tibia midshaft of the lifters were all significantly superior to those of the subjects in the control group (5). In an investigation of the BMD of 59 male competitive weight lifters, ages 15–20 years, Virvidakis et al., reported significantly greater BMD among weight lifters than in gender- and age-matched controls (22). In a case study, Dickerman et al. measured the BMD of the lumbar spine in a male powerlifter who, at the time of the study, was the current world record holder in the squat. According to Dickerman et al., the BMD of the lumbar spine of this lifter was "well above the normal range and the highest reported to date" (3). Finally, Tsuzuke et al. measured the BMD differences of powerlifters, recreational weight lifters, and sedentary controls who were all gender and age matched. The powerlifters had a significantly greater BMD at all sites measured (lumbar spine, proximal femur, and total body). Of the 7 previously published studies, 5 examined the BMD of men and 2 of women. In every study, regardless of gender, individuals who engaged in competitive lifting had significantly greater levels BMD than did subjects who were either sedentary or recreationally active.

Methods

Experimental Approach to the Problem

In light of the previous research, this case study was designed to observe the maximum potential benefit that resistance training could have on the BMD of women. Because of the consistency of findings in competitive lifters, only women who engaged in competitive weightlifting were considered as subjects. Because the duration of strength training required to facilitate maximal BMD adaptation has not been adequately explored, it was determined that only women who had at least 20 years of lifting history would be research candidates. In addition, because women beginning at the age of 30 typically experience losses in BMD in part because of aging it was deemed important to investigate older women (~50 years of age and older) to see if gains from resistance training would be maintained with age. Finally, because of the potential for confounding results, only competitive weight lifters who had never engaged in the use of anabolic steroids were considered for this study. Two women who met preestablished criteria were identified and voluntarily participated as case study subjects. This study is unique in that it is the first study to date which examines the effect of high intensity, long-term resistance training without the use of anabolic steroids on the BMD of mature (mean age ≥ 50 years) women.

Because of the high validity and reliability of Dual x-ray absorptiometry (DEXA), this technique was used to measure BMD (grams per centimeter squared) and bone mineral content (BMC) (grams) (11). Based upon reported locations in previous studies, the lumbar spine, dual femur, and total body measures were selected as points of interest in this study.

Subjects

After receiving Institutional Review Board approval for this study, 2 elite powerlifters, both winners in their age and weight divisions at the 2009 National Masters Powerlifting Championship, were recruited to participate in this study. During the recruitment phase, each subject was given a verbal explanation identifying key aspects of the study and an informed consent document that outlined the purpose of the study, methodology, and the possible health risks and benefits that may result from participation were explained. Both the subjects voluntarily agreed to participate in the study and signed an informed consent in accordance with the American College of Sports Medicine guidelines.

Procedures

During the testing phase, the subjects were interviewed concerning their demographic status, health history, duration and consistency of resistance training, and best performance measures related to competitive powerlifting movements (squat, bench press, and deadlift). After the interview, each subject was weighed and measured for height and then

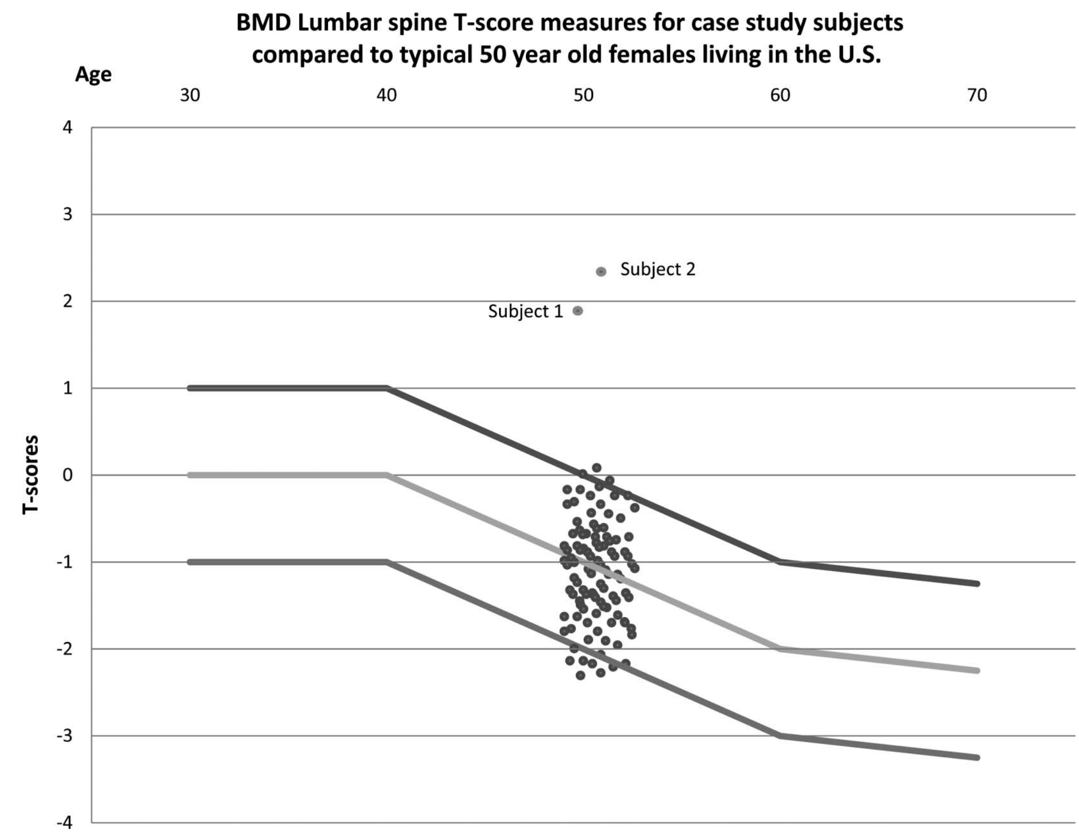

Figure 1. Bone mineral density (BMD) lumbar spine *T*-score measures for case study subjects compared with those of typical 50-year-old women living in the USA.

given a verbal explanation regarding the administration of the DEXA scans. Each subject was then measured using a DEXA–GE Lunar Prodigy unit for BMD and BMC. The lumbar spine measurement was taken first, followed by the dual femur, and finally a total body scan. After all the measurements, the subjects were given a printed copy of their results, along with a verbal prompt that stated that the results were not to be used for any type of medical diagnosis.

The first subject was a 48-year-old woman with a height of 163.8 cm and a weight of 60.9 kg. She began resistance training at the age of 18 years and reported consistent continuation of training with short periods (2–3 weeks) of cessation until present (32 years). During this time, subject 1's resistance training primarily consisted of 3 fundamental movements (Squat, Bench Press, and Deadlift) and accompanying auxiliary exercises. Additional exercise variation was

Table 1. Subject 1: lumbar spine DEXA measurements.*

L spine	BMD ($g\cdot cm^{-2}$)	BMC (g)	Area (cm^2)	YA (%)	YA (*T*-score)	AM (%)	AM (*Z*-score)
L1	1.20	13.37	11.13	106.00	0.6	111.00	1.0
L2	1.37	18.41	13.41	114.00	1.4	119.00	1.8
L3	1.43	19.90	13.94	119.00	1.9	124.00	2.3
L4	1.55	22.79	14.69	129.00	2.9	135.00	3.3
L1–L4	1.40	74.46	53.17	119.00	1.8	124.00	2.2

*BMD = bone mineral density; BMC = bone mineral content; DEXA = dual x-ray absorptiometry; L spine = lumbar spine; YA = young adult; AM = age matched.

Table 2. Subject 1: dual femur and total body DEXA measurements.*

	BMD ($g \cdot cm^{-2}$)	BMC (g)	Area (cm^2)	YA (%)	YA (*T*-score)	AM (%)	AM (*Z*-score)
Left femur	1.08	31.47	29.04	108.00	0.6	115.00	1.1
Right femur	1.08	32.14	29.66	108.00	0.6	115.00	1.1
Femoral mean	1.08	31.81	29.35	108.00	0.6	115.00	1.1
Total body	1.29	2,703.00	2,100.00	114.00	2.0	118.00	2.4

*BMD = bone mineral density; BMC = bone mineral content; DEXA = dual x-ray absorptiometry; YA = young adult; AM = age matched.

gained by introducing slight alterations within the 3 fundamental movements such as hand and foot position, bar height, and dumbbells. Excluding warm-up, approximately 70% of subject 1's repetition range per set consisted of lifting near maximum weight for 1–5 repetitions. The remaining 30% of training consisted of using near maximum weight for 8–2 repetitions per set.

In 1998, 21 years after initiating the training, subject 1 entered her first competitive power lifting event. During this competition, this subject lifted a combined total (Squat, Bench Press, and Deadlift) of 363.6 kg. Throughout the next 11 years of competition, subject 1's highest and lowest cumulative lifting totals were 397.7 and 358.1 kg, respectively. Beginning in 2003 and every year to date, subject 1 won her age/weight division at the U.S. Women's National Powerlifting Championship. Her best single-lift performances were a 137.73-kg squat, 90.91-kg bench press, and a 155.45-kg deadlift. In 2009, this subject won her age/weight division with a combined total of 368.1 kg.

Subject 1 reported no use of anabolic steroids at any time. Most of the competitive events this subject entered have been drug tested competitions, and there is no record of this subject failing a drug test. It is noteworthy to mention that this subject reported no significant physical injuries throughout her resistance training history.

The second subject was a 54-year-old woman with a height of 163.8 cm and a bodyweight of 68.6 kg. Like subject 1, the second subject began her resistance training at the age of 18 reporting only brief periods (2–3 weeks) of training cessation for the next 36 years. Subject 2's resistance training consisted of 3 fundamental lifts (Squat, Bench Press, and Deadlift with slight variations) and accompanying auxiliary exercises. Excluding warm-up, approximately 75% of subject 1's repetition range per set consisted of lifting near maximum weight for 1–5 repetitions. The remaining 25% of training consisted of using near maximum weight for 8–12 repetitions per set.

Ten years after initiating training, subject 2 entered her first competitive powerlifting event in 1988. During the next 21 years, subject 1's highest competitive total was 429.5 kg. Her best single-lift performances were a 170.91-kg squat, 85-kg bench press, and a 175.45-kg deadlift at a bodyweight between 60 and 67.5 kg. During her competitive career, subject 2 won several national and world powerlifting titles. In 2009 subject 2 won her age/weight division at the U.S. Women's National Powerlifting Championship with a combined total of 379 kg.

Subject 2 reported no use of anabolic steroids at any time. The vast majority of competitive lifting events subject 2 entered have been drug tested competitions. There is no record of this subject failing a drug test. Subject 2 reported no significant physical injuries throughout her resistance training history.

Collected data were then compared with prevalence rates published by the World Health Organization and the National

Table 3. Subject 2: lumbar spine DEXA measurements.*†

L spine	BMD ($g \cdot cm^{-2}$)	BMC (g)	Area (cm^2)	YA (%)	YA (*T*-score)	AM (%)	AM (*Z*-score)
L1	1.31	17.77	13.54	116.00	1.5	124.00	2.1
L2	1.48	19.27	13.02	123.00	2.3	131.00	2.9
L3	1.51	24.18	16.00	126.00	2.6	134.00	3.2
L1–L3	1.44	66.22	42.56	123.00	2.2	131.00	2.8

*BMD = bone mineral density; BMC = bone mineral content; DEXA = dual x-ray absorptiometry; L spine = lumbar spine; YA = young adult; AM = age matched.

†Because of a lack of vertebral distinction L4 was omitted from this analysis.

TABLE 4. Subject 2: dual femur and total body DEXA measurements.*

	BMD ($g \cdot cm^{-2}$)	BMC (g)	Area (cm^2)	YA (%)	YA (*T*-score)	AM (%)	AM (*Z*-score)
Left femur	1.19	38.43	32.37	118.00	1.4	126.00	2.0
Right femur	1.18	36.80	31.10	117.00	1.4	126.00	1.9
Femoral mean	1.19	37.61	31.73	118.00	1.4	126.00	1.9
Total body	1.34	3,167.00	2,372.00	119.00	2.6	122.00	3.0

*BMD = bone mineral density; BMC = bone mineral content; DEXA = dual x-ray absorptiometry; YA = young adult; AM = age matched.

Health and Nutrition Examination Survey III (9,23). These large database norms constitute widely accepted standards among scientist, doctors, and professional organizations such as the International Society for Clinical Densitometry (6).

Results

The DEXA lumbar, dual femur, and total body scans reveal a similar trend for both subjects in this study. The greatest differences in skeletal *T*-score density, from previously published normative data, were measured in the total body scan. The lowest differences were measured in the dual femur. The results from the lumbar scans fell between those from the femur and total body scans in their variation from the published norms. Therefore, it seemed that the best overall comparison could be observed by examining differences in the lumbar region. Figure 1 illustrates these differences for of the 2 women in this study compared with normative data.

A DEXA lumbar scan for subject 1 revealed greater than normal BMD values when compared with gender- and age-matched norms (Table 1). Consistent with the lumbar measurement, the first subject's dual femur and total body scans demonstrated higher than average BMD, both with respect to age- and gender-matched norms and normative peak BMD (Table 2).

As with the first subject, subject 2's DEXA lumbar scan revealed greater than average BMD values when compared with gender- and age-matched norms (Tables 3 and 4). In both the dual femur and total body scans, Subject 2 had higher than average BMDs.

Discussion

This study provides a number of meaningful insights. First, the results of this study add support to the general hypothesis that weight-bearing activities do aid the development of BMD in humans. Although not conclusive, the extent of the evidence for weight-bearing activities as a tool for prevention and treatment of low BMD is growing. Second, the National Osteoporosis Foundation recommends high-impact, weight-bearing activities (such as aerobic dancing, basketball, dancing, field hockey, gymnastics, hiking, jogging or running, jumping rope, lacrosse, racquet sports, soccer, stair climbing, tennis, and volleyball) as the "best exercises" for keeping bones strong (12). The results of this study suggest that muscle-strengthening activities may be a viable alternative to high-impact activities for the enhancement of BMD. Finally, the observations suggest that competitive powerlifters, specifically women, who consistently engage in high-intensity resistance training are more likely to develop higher levels of BMD than those normally found in gender- and age-matched population samples.

Despite the optimistic results of this case study, there are several limitations of this report. As with other studies, this investigation was limited by a small sample size, the selection of atypical cases, gathering retrospective data based on subject recall, and the lack of control for confounding variables. These limitations call for more extensive research in answering a host of additional questions. Would the preliminary findings of this case study be substantiated in a larger, randomly selected group of female powerlifters? To what degree do attributes other than competitive powerlifting such as diet, rest, and activities not associated with resistance training increase or attenuate BMD? To what extent does the more popular high-volume, low-intensity resistance training affect BMD in women? Is there a maximal capacity of bone density attained via resistance training upon which additional training has little effect? These questions and others will need further investigation.

Practical Applications

The implications of these findings are vital, especially for women, who, according to a report by the Office of the Surgeon General, are most susceptible to skeletal fractures associated with low BMD (20). According to that study, approximately 85% of women in the USA >50 years suffer from either low BMD (*T* score between -1.0 and 2.49) or osteoporosis (*T* score ≤ -2.5). The 2 women in the study, with an average age of 52, had *T* scores that were not only well above pathological levels but also far above the average 20- to 29-year-old woman at the peak of her BMD.

Duration and training intensity are 2 factors that distinguish the subjects in this study from many of the previous investigations. Previously stated, both the subjects in this

investigation had consistently engaged in resistance training for an average of 30 years and used loading intensities that met or exceeded each subject's bodyweight. Several previous investigations that reported resistance training having little to no effect on BMD measured changes during <1 year of training and prescribed loading strategies far lower than the 1 repetition maximums typically performed by competitive lifters like the subjects of this study. This may suggest that duration and intensity prescriptions need to be considerably enlarged for skeletal changes like those seen in this investigation to be observed.

Acknowledgments

The authors wish to thank Angela Simons (U.S. Powerlifting Executive Director, Saint Paul, MN, USA), Ruth Welding (Iron Body Strength and Fitness, Elk Grove Village, IL, USA), David Watt (Orthopedic Associates of DuPage, Naperville, IL, USA), Moria Petit (University of Minnesota, Minneapolis, MN, USA), Brian Hunt (Wheaton College, Wheaton, IL, USA) Susan Vendeland (Wheaton College), and Sarah Jamieson (Wheaton College) for their invaluable assistance at various stages of this study. The results of this study do not constitute endorsement by the National Strength and Conditioning Association. May Jesus Christ be honored as a result of this research effort.

References

1. Chilibeck, PD, Calder, A, Sale, DG, and Webber, CE. Twenty weeks of weight training increases lean tissue mass but not bone mineral mass or density in healthy, active young women. *Can J Physiol Pharm* 74: 1180–1185, 1996.
2. Conroy, BP, Kraemer, WJ, Maresh, CM, Fleck, SJ, Stone, MH, Fry, AC, Miller, PD, and Dalsky, GP. Bone mineral density in elite junior Olympic weightlifters. *Med Sci Sports Exerc* 25: 1103–1109, 1993.
3. Dickerman, RD, Pertusi, R, and Smith, GH. The upper range of lumbar spine bone mineral density? An examination of the current world record holder in the squat lift. *Int J Sports Med* 21: 469–470, 2000.
4. Heinonen, A, Oja, P, Kannus, P, Sievänen, H, Mänttäri, A, and Vuori, I. Bone mineral density of female athletes in different sports. *Bone Miner* 23: 1–14, 1993.
5. Heinonen, A, Sievänen, H, Kannus, P, Oja, P, and Vuori, I. Site-specific skeletal response to long-term weight training seems to be attributable to principal loading modality: A pQCT study of female weightlifters. *Calcified Tissue Int* 70: 469–474, 2002.
6. International Society for Clinical Densitometry. *ISCD Official Positions.* Middletown CT: International Society for Clinical Densitometry, 2011.
7. Kerr, D, Ackland, T, Maslen, B, Morton, A, and Prince, R. Resistance training over 2 years increases bone mass in calcium-replete postmenopausal women. *J Bone Miner Res* 16: 175–181, 2001.
8. Layne, JE and Nelson, ME. The effects of progressive resistance training on bone density: A review. *Med Sci Sports Exerc* 31: 25–30, 1999.
9. Looker, A, Melton, L, Harris, T, Borrud, L, and Shepherd, J. Prevalence and trends in low femur bone density among older US adults: NHANES 2005–2006. *J Bone Miner Res* 20: 64–71, 2010.
10. Martyn-St James, M and Carroll, S. Progressive high-intensity resistance training and bone mineral density changes among premenopausal women: Evidence of discordant site-specific skeletal effects. *Sports Med* 36: 683–704, 2006.
11. Mazess, R, Barden, H, Bisek, J, and Hanson, J. Dual-engery x-ray absorptiometry for total-body and regional bone mineral and soft tissue composition. *Am J Clin Nutr* 51: 1106–1112, 1990.
12. National Osteoporosis Foundation. *Exercise for Your Bone Health.* Washington, DC: National Osteoporosis Foundation, 2010. pp. 2.
13. National Osteoporosis Foundation Web site [Internet]. Washington (DC): National Osteoporosis Foundation. Available at: http://www.nof.org/professionals/research/nofresearchagenda. Cited October 6, 2010.
14. Nichols, JF, Nelson, KP, Peterson, KK, and Sartoris, DJ. Bone mineral density responses to high-intensity strength training in active older women. *J Aging Phys Activ* 3: 26–38, 1995.
15. Rhodes, EC, Martin, AD, Taunton, JE, Donnelly, M, Warren, J, and Elliot, J. Effects of one year of resistance training on the relation between muscular strength and bone density in elderly women. *Br J Sports Med* 34: 18–22, 2000.
16. Rikli, RE and McManis, BG. Effects of exercise on bone mineral content in postmenopausal women. *Res Q Exerc Sport* 61: 243–249, 1990.
17. Ryan, AS, Ivey, FM, Hurlbut, DE, Martel, GF, Lemmer, JT, Sorkin, JD, Metter, EJ, Fleg, JL, and Hurley, BF. Regional bone mineral density after resistive training in young and older men and women. *Scand J Med Sci Sport* 14: 16–23, 2004.
18. Shackelford, LC, LeBlanc, AD, Driscoll, TB, Evans, HJ, Rianon, NJ, Smith, SM, Spector, E, Freback, DL, and Lai, D. Resistance exercise as a countermeasure to disuse-induced bone loss. *J Appl Physiol* 97: 119–129, 2004.
19. Tsuzuku, S, Shimokata, H, Ikegami, Y, Yabe, K, and Wasnich, RD. Effects of high versus low-intensity resistance training on bone mineral density in young males. *Calcified Tissue Int* 68: 342–347, 2001.
20. U.S. Department of Health and Human Services. *Bone Health and Osteoporosis: A Report of the Surgeon General.* Rockville, MD: US Department of Health and Human Services, Office of the Surgeon General, 2004.
21. Vincent, KR and Braith, RW. Resistance exercise and bone turnover in elderly men and women. *Med Sci Sports Exerc* 34: 17–23, 2002.
22. Virvidakis, K, Georgiou, E, Korkotsidis, A, Ntalles, K, and Proukakis, C. Bone mineral content of junior competitive weightlifters. *Int J Sports Med* 11: 2244–2246, 1990.
23. World Health Organization. *Scientific Group on the Prevention and Management of Osteoporosis.* Geneva, Switzerland: World Health Organization, 2000.