Impact of Strength Training on Bone Mineral Density in Patients Infected With HIV Exhibiting Lipodystrophy

Wlaldemir R. Santos,[1] Walmir R. Santos,[2] Pedro P. Paes,[1,3] Isac A. Ferreira-Silva,[2] André P. Santos,[4] Natan Vercese,[1] Dalmo R.L. Machado,[2] Francisco José A. de Paula,[4] Eduardo A. Donadi,[4] Anderson M. Navarro,[4] and Ana Paula M. Fernandes[1]

[1]Department of General and Specialized Nursing, Nursing School of Ribeirão Preto, University of São Paulo, São Paulo, Brazil; [2]School of Physical Education and Sport of Ribeirão Preto, University of São Paulo, São Paulo, Brazil; [3]Department Physical Education, Health Sciences Center, Federal University of Pernambuco, Recife, Brazil; and [4]Department of Medical Clinical, Faculty of Medicine of Ribeirão Preto, University of São Paulo, São Paulo, Brazil

Abstract

Santos, WR, Santos, WR, Paes, PP, Ferreira-Silva, IA, Santos, AP, Vercese, N, Machado, DRL, de Paula, FJA, Donadi, EA, Navarro, AM, and Fernandes, APM. Impact of strength training on bone mineral density in patients infected with HIV exhibiting lipodystrophy. *J Strength Cond Res* 29 (12): 3466–3471, 2015–This study aimed to evaluate the impact of strength training on bone mineral density (BMD) in individuals harboring HIV exhibiting lipodystrophy. The study included 20 subjects (16 men) aged 50.60 ± 6.40 years with reduced BMD, presenting positive serology for HIV, using highly active antiretroviral therapy, and performing no regular practice of physical exercise before being enrolled in the study. Bone mineral density levels were evaluated by dual-energy x-ray absorptiometry in the lumbar spine, femoral neck, and 1/3 radius, before and after 36 sessions (12 weeks) of strength training. Compared with pre-exercise period, the results showed increased BMD in lumbar spine (3.28%; $p = 0.012$), femoral neck (8.45%; $p = 0.044$), and 1/3 radius (5.41%; $p = 0.035$). This is the first study evaluating the impact of strength training in patients living with HIV and exhibiting lipodystrophy, showing an increased BMD in all the regions measured (lumbar spine, femoral neck, and 1/3 radius). This study showed the beneficial impact of the strength training on BMD increase in patients living with HIV as an effective and available approach to improve bone health.

Key Words osteoporosis, prevention, physical exercise, AIDS, HAART

Address correspondence to Ana Paula M. Fernandes, anapaula@eerp.usp.br.

29(12)/3466–3471

Journal of Strength and Conditioning Research

Introduction

Because the advent of highly active antiretroviral therapy (HAART) and the improvement in survival among patients living with HIV, studies have shown that reduction of bone mineral density (BMD), osteopenia, and osteoporosis are common among these patients (3,10,17,34).

HIV infection, HAART use, and patient characteristics such as genetic factors, hormonal changes, and lifestyle are associated with osteopenia and osteoporosis (3,12,16,22,27,39). Nevertheless, few strategies to minimize the reduction of BMD in people with HIV are found in the literature, thus hindering its progression (10). It may includes HAART switch strategies, pharmacologic interventions, and lifestyle modifications (3,5,20). In individuals not infected with HIV, the physical activity is a major environmental factor that positively influences bone mineral accrual (11,12,19,24,31) and strength training a great resource to increase BMD because its mechanical characteristics lead to a greater osteogenic effect (14,15).

However, in patients living with HIV, it remains unknown. Looking the absence of targeted studies to patients living with HIV and the influence of physical activity in reducing bone loss, this study aimed to evaluate the impact of strength training on BMD in patients living with HIV with lipodystrophy.

Methods

Experimental Approach to the Problem

This nonrandomized experimental study was conducted in 12 weeks, between January and December 2013, in the Clinics Hospital of the School of Medicine at Ribeirão Preto from the University of São Paulo (HCFMRP-USP) and in the Education and Orientation for Adults and Elderly of the Nursery School of Ribeirão Preto from the University of São Paulo (COEAI/EERP-USP), in Ribeirão Preto, São Paulo, Brazil, financially aid by the Foundation for the Support of

Research of the State of São Paulo (FAPESP), processes 2011/7300-4 e 2011/03136-5.

The subjects were male and female patients living with HIV who are under HAART for at least 12 weeks, ages from 35 to 70 years, who were patients at HCFMRP-USP, and participate the dietitian-counseling program; none of them used nutritional supplementation. The subjects included in this study had BMD reduction, measured by dual-energy x-ray absorptiometry (DXA), did not exercise regularly for at least 3 months, and had attested cardio conditions to accomplish the training protocol. The exclusion criteria were the use of any hormonal replacement therapy, any clinical alteration during the training protocol, or absenteeism of more than 25% of the training sessions (9 in total).

Subjects

This study was approved by the Research Ethics Committee of HCFMRP-USP (protocol- 6692/2010), and all the subjects signed the agreement term stating to participate in the study voluntarily and being able to quit the study at any time. Subjects were recruited among 112 patients, from both sexes (86 males), undergoing medical supervision at HCFMRP-USP, and were included on the dietitian-counseling program. To select the subjects, personal invitations were made during medical supervision or dietitian-counseling days and by phone calls. From the 112 patients, 97 were contacted and 48 agreed to take part on the study. Among them, 13 were excluded for not fitting the inclusion criteria and 3 gave up before beginning the training protocol because of lack of time for fulfilling the entire program. Therefore, 32 patients begun the training program, and from them, 12 were excluded for not being able to attend 75% of the sessions, leaving the final sample with 20 subjects, 16 of them male.

Patients underwent to BMD measurement of lumbar spine (L1–L4), femoral neck, and 1/3 radius, before and after the strength training protocol. These regions were selected for showing the highest rate of low BMD and were used for the diagnosis of osteoporosis and osteopenia (11). The regions evaluated in this study are also cited as reference values for BMD in patients living with HIV (24,38).

The strength training protocol consisted of 36 sessions (12 weeks) of approximately 40 minutes (between 02:00 and 05:00 PM) every Monday, Wednesday, and Friday, at 48- to 72-hour intervals (1). In all sessions, the patients were under the supervision of 3 researchers, all majored in Physical Education. The 36 sessions were divided into 3 consecutive phases: (a) preparation, 6 sessions with 3 series of 15 repetitions and 60-second intervals between the exercises (1). The intensity was determined using the Borg and Noble scale (8) scoring between 11 (almost easy) and 13 (bit tiring); (b) transitional, 6 sessions with 3 series of 15 repetitions and 60-second intervals between the exercises, with intensities ranging from 40 to 50% of the result obtained in the 1 maximum repetition test (MR) (1); (c) specific, 24 sessions with 3 series of 8 repetitions and 90-second intervals, with intensities ranging from 70 to 80% of 1 MR (1). Based on the basic principles for periodization and physical exercise prescription (13) and because of the natural adaptation process to physical exercise, at the end of the 12th session from the specific period (total of 24 sessions), a new 1 MR test was applied to readapt the intensity of training load, still fixed at 70–80% of 1 MR (1).

The strength training was composed by the following exercises, in order: warm-up (active stretching), bench press, lat pull-down, leg extension, leg flexion, elbow flexion, elbow extension, abdominal exercise, sole flexion, and cool-down (active stretching). The exercise order was planned to prioritize the utilization of the main muscles (1).

Before each session, the subjects were asked to talk about their general health, and vital signs were measured (blood pressure, heart rate, respiratory frequency, and oxygen saturation). During the session, the subjects were monitored for rehydration with water and between each series of exercises for clinical conditions. If any subject showed any clinical instability, before, during, or after the training sessions, he would be excluded from the study and immediately sent to HCFMRP-USP for medical care. Furthermore, the patients were advised about the significance of rest and sleep between the training sessions.

Materials and Methodology

Personal data from the subjects such as age, time with viral infection, time of treatment, and drugs used were collected using a questionary applied before the beginning of the training protocol. Data were confirmed using the medical records from each patient, adding the number of $CD4^+$ cells and viral load, also from medical records, together with body mass and height. All data are presented in Table 1.

Body mass and height were measured using a Welmy stadiometer and scale with a minimum detectable of 0.1 kg for body mass and 0.1 cm for height.

A DXA (Hologic QDR 4500A scanner; Hologic Inc., Waltham, MA, USA) was used to measure the BMD of the lumbar spine (L1–L4), femoral neck, and 1/3 radius, before and after the strength training protocol (National Osteoporosis Foundation, 2010; WHO 2007), under instructions and recommendations from the manufacturer.

The strength training protocol was completed using a training station (Athletic Way) with two 180-kg independent columns that allows 2 persons simultaneously.

To define the intensity used in training, a Borg and Noble Perceived Effort Scale was used. The preparatory phase had the main goal of learning the movements, so it was needed an easy load to the patients reach the goal, between almost easy and bit tiring efforts (13). The patients were asked to point out their physical effort according to the Borg and Noble scale (8) right after finishing the series, and when the value pointed was different from the expected, the load was adjusted. In all sessions of this phase, the patients were oriented about how to execute the movements correctly,

Table 1. Characterization of the patients included in the study regarding age, weight, height, time of HIV infection, time of use of HAART, TCD4+ cell count, viral load, class of medications at the time of the study, and frequency in the training program.*

Variable ($N = 20$)	Mean (min–max)	95% confidence interval
Age (y)	50.6 (38.0–67.0)	46.895–54.305
Weight (kg)	71.8 (51.1–111.2)	65.386–78.233
Height (cm)	169.3 (151.0–185.0)	165.352–173.198
Time of HIV infection (y)	11.3 (1.0–23.0)	8.147–14.453
Use of HAART (y)	9.8 (1.0–23.0)	6.648–12.951
TCD4+ cells (cells·μl^{-1})	449.8 (105.0–1,073.0)	322.422–577.278
Viral load (copies·μl^{-1})	75.2 (<50.0–111.0)	48.270–61.830
Use of PI, *n* (%)	15/20 (75)	0.673–1.527
Use of NRTI, *n* (%)	19/20 (95)	1.336–1.964
Use of NNRTI, *n* (%)	10/20 (50)	0.260–0.740
Training frequency (%)	90 (81–100)	1.57–8.44

*HAART = highly active antiretroviral therapy; PI = protease inhibitors; NRTI = nucleoside reverse transcriptase inhibitors; NNRTI = nonnucleoside reverse transcriptase inhibitors.

under supervision all the time to accomplish the correct amplitude, body position, and correct breathing.

After learning the movement in the previous phase, the patients underwent the 1 MR test to determine the training intensity for subsequent sessions in 3 time points (before transition phase, in the middle of this phase [12 sessions], and at the ending of the program). The evolution of the loads is described in Table 2. This test aims to record the maximum weight that the subject is able to lift on a single repetition with the correct amplitude of movement. The load was increased until the subjects are not able to complete the required amplitude, being the previous load recorded (1,21). This test is widely used with HIV patients (5,33). However, only 6 tries were allowed in intervals of 80 seconds, if it was not possible to identify the 1 MR value, a new test was made 72 hours after the completion of the previous one (21). The sole flexion was made unilaterally on the floor and did not had 1 MR measured.

Table 2. Maximum strength test (1RM) before (pre) and after training (post).*

		Descriptive			Paired differences					
Exercise (1RM–kg)	($N = 20$)	Mean	*SD* (min–max)	*SD* error	Mean (%)	*SD*	*SD* error	*T*	*df*	*p*
Bench press	Pre	29.33	4.80 (20.41–38.56)	1.07	4.19 (14.29)	3.23	0.72	−5.81	19	0.0001
	Post	33.22	4.30 (27.22–40.82)	0.96						
Lat pull-down	Pre	37.08	3.39 (31.75–43.09)	0.76	3.29 (8.87)	2.38	0.53	−6.17	19	0.0001
	Post	40.37	1.89 (39.56–43.09)	0.42						
Leg extension	Pre	28.46	5.38 (15.88–34.02)	1.20	3.29 (11.56)	2.49	0.56	−5.90	19	0.0001
	Post	31.75	5.26 (20.41–36.29)	1.18						
Leg flexion	Pre	13.04	3.03 (6.80–15.88)	0.68	3.40 (26.07)	2.02	0.45	−7.54	19	0.0001
	Post	16.44	2.19 (13.61–20.41)	0.49						
Elbow extension	Pre	15.88	2.44 (11.34–18.14)	0.55	2.38 (14.99)	2.14	0.48	−4.98	19	0.0001
	Post	18.26	2.26 (15.88–20.41)	0.51						
Elbow flexion	Pre	16.22	3.23 (11.34–20.41)	0.72	2.04 (12.58)	2.84	0.63	−3.22	19	0.005
	Post	18.26	2.70 (13.61–22.68)	0.60						
Abdominal	Pre	18.48	3.70 (11.34–22.68)	0.83	2.15 (11.63)	2.26	0.51	−4.26	19	0.0001
	Post	20.64	2.38 (15.88–24.95)	0.64						

*IRM = 1 repetition maximum.

Table 3. BMD determined before (pre) and after (post) the strength training protocol.*

Region (BMD–g·cm^{-2})	(N = 20)	Descriptive			Paired differences					
		Mean	*SD* (min–max)	*SD* error	Mean (%)	*SD*	*SD* error	*T*	*df*	*p*
Lumbar spine	Pre	0.914	0.133 (0.652–1.195)	0.029	0.029 (3.28)	0.048	0.010	−2.777	19	0.012
	Post	0.944	0.145 (0.696–1.213)	0.032						
Femoral neck	Pre	0.793	0.186 (0.470–1.207)	0.416	0.067 (8.45)	0.139	0.031	−2.156	19	0.044
	Post	0.860	0.167 (0.510–1.271)	0.375						
1/3 radius	Pre	0.573	0.745 (0.455–0.722)	0.166	0.031 (5.41)	0.060	0.013	−2.274	19	0.035
	Post	0.604	0.983 (0.466–0.910)	0.219						

*BMD = bone mineral density.

Statistical Analyses

A Shapiro-Wilk normality test was used to determine if the data were normally distributed. The sample was characterized by descriptive analysis with maximum and minimum values of age, body weight, height, time of infection, use of HAART, CD4$^+$ cell count, viral load, and therapeutic regime. The BMD of the lumbar spine, femoral neck, and 1/3 radius was measured before and after the training. Data were analyzed by the paired samples test (35), using software SPSS 13.00, with the level of significance set at $p \leq 0.05$.

Results

The study was conducted on 20 individuals, 16 men (80%), with a mean age of 50.6 years (range, 38.0–67.0 years), body weight of 71.8 kg (51.1–111.2 kg), and height of 169.3 cm (151.0–185.0 cm). Mean duration of HIV infection was 11.3 years (1.0–23.0 years), HAART use was 9.8 years (1.0–23.0 years), TCD4$^+$ cell count was 449.8 (105.0–1,073.0) cells per microliter, and viral load was 75.2 (<50.0–111.0) copies per microliter. Regarding the composition of therapy, 75% patients used protease inhibitors, 95% used nucleoside reverse transcriptase inhibitors, and 50% nonnucleoside reverse transcriptase inhibitors. Regarding the frequency of training, patients had an average frequency of 90% (81–100%) of sessions (Table 1).

After strength training, patients showed a significant increase of maximum strength, measured by the 1 repetition maximum test in all trained exercises. On bench press, the average increase was 14.29% ($t = -5.81$; $p = 0.0001$), lat pulldown 8.87% ($t = -6.17$; $p = 0.0001$), leg extension 11.56% ($t = -5.90$; $p = 0.0001$), leg flexion 26.07% ($t = -7.54$; $p = 0.0001$), elbow extension 14.99% ($t = -4.98$; $p = 0.0001$), elbow flexion 12.58% ($t = -3.22$; $p = 0.005$), and abdominal exercise 11.63% ($t = -4.26$; $p = 0.005$; Table 2).

As well as muscle strength, patients showed a significant increase in BMD in all regions measured, with the BMD increasing 3.28% ($t = -2.777$; $p = 0.012$) for the lumbar spine, 8.45% ($t = -2.156$; $p = 0.044$) for the femoral neck, and 5.41% ($t = -2.274$; $p = 0.035$) for the 1/3 radius, as shown in Table 3.

Discussion

Bone mineral density indicates the structure of the bone matrix, and its reduction leads to osteopenia/osteoporosis, characterized as an asymptomatic disease of a systemic and skeletal nature that makes the bone structure weak and susceptible to fractures (10,12,24,29), more frequently affecting the bone matrix of the vertebrae lumbar spine, femoral neck, and 1/3 radius.

Recommendations for bone health consider the mechanical loading characteristics that have the greatest osteogenic effect (14,15). During physical activity, bone suffers from mechanical forces exerted by muscle contraction and gravitational impact, and at the cellular level, the osteocytes, perceive these mechanical forces as cell deformation, communicate with osteoblasts and osteoclasts to modulate bone formation and reabsorption (6,9,12,17,18,37).

As the strength increased after the training protocol in all patients, it may increase the BMD because of the more expressive traction of the muscles to the bones. This physiological response from their bodies could result in the prevention of the problems related with mineral loss.

Some studies conducted on different populations of people not infected with HIV, using diverse protocols of strength training, have shown an increase in BMD. Increase in the femoral neck and 1/3 radius arising from the strength training have been reported in young women with 20 weeks of training (26). In contrast, Almstedt et al. (2), in a 6-month study on men and women, obtained an increase in BMD only in the femoral neck of men, with no positive results for women, just as Bemben and Bemben (4). Similarly, significant increases occurred when the training includes menopausal women (7). Menkes et al. (23), using a protocol of 16 weeks of training for healthy men (59 ± 2 years), showed a significant increase in BMD in

the femoral neck (1.0%) and lumbar spine (0.9%) but in lumbar spine it was not signficantly different from control group.

Specifically addressing patients living with HIV, many factors contribute to low BMD including HIV infection, exposure to antiretroviral treatment (12,22), altered levels of hormones and inflammatory cytokines, vitamin D and calcium deficiency, and physical inactivity (17,33). The literature does not describe specific treatment for BMD reduction in persons living with HIV that can support for the clinical management of patients (27,28). Some studies (20,31) have stated that the management is the same as that used for people not infected by HIV (change in lifestyle, hormone replacement, calcium and vitamin D intake, and physical exercise). Additionally, there are no published data on the preventative strategy to fracture risk and bone health knowledge among adults living with HIV (32).

The main concern raised by the reduction of BMD is the development of osteopenia, osteoporosis, and fracture risk because several studies have shown high rates of fractures among persons living with HIV (10,25,30,36), with a consequent increase in morbidity and mortality (10).

This is the first study evaluating the impact of strength training on BMD in persons living with HIV. The protocol used showed a significant increase in BMD in all regions measured, specifically the lumbar spine (3.28%; $p = 0.012$), femoral neck (8.45%; $p = 0.044$), and 1/3 radius (5.41%; $p = 0.035$). The study also found a significant increase in the maximum strength of all exercises performed, which may have aided in increasing BMD because of greater tension exerted by the muscles to strengthening. Otherwise, the increase in BMD can improve the patient functional capacity and hence quality of life. However, this was not a variable found in this study.

Measures of bone health must be interpreted in the context of effects of HIV infection, HAART use, and other lifestyle factors. This study showed the beneficial impact of the strength training on BMD increase in patients living with HIV as an effective and available approach to improve bone health. Given the striking increase in BMD after short-course strength training, this protocol is an attractive approach and warrants further study. More studies are needed to clarify that strength training can be a resource to increase BMD in individuals harboring HIV.

Practical Applications

The results suggest that strength training, with a short period (12 weeks), increased the BMD in individuals harboring HIV at the regions of lumbar spine, femoral neck, and 1/3 radius. It can be used as an adjunctive treatment for the management of osteopenia and osteoporosis, reducing the risk of fractures, morbidity and mortality, and consequently, improving the quality of life of persons living with HIV.

Because osteoporosis is often an asymptomatic condition with long latency until fracture, the practical applications of this study contribute to the management of patients living with HIV to improve bone health and to prevent fractures in at-risk patients before they occur and to reduce the likelihood of their recurrence. Our findings support the acceptability of future clinical trials in this area.

Acknowledgments

All authors significantly contributed to the results of this article. We thank the Foundation for the Support of Research of the State of São Paulo (FAPESP) for the financial support (A.P.M. Fernandes, #2011/07300-4; W.R. Santos, #2011/03136-5; F.J.A. de Paula, #2011/306027-9).

References

1. ACSM. Position stand: Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc* 43: 1334–1359, 2011.
2. Almstedt, HC, Canepa, JÁ, Ramirez, DA, and Shoepe, TC. Changes in bone mineral density in response to 24 weeks of resistance training in college-age men and women. *J Strength Cond Res* 25: 1098–1103, 2011.
3. Bedimo, R, Maalouf, NM, Zhang, S, Drechsler, H, and Tebas, P. Osteoporotic fracture risk associated with cumulative exposure to tenofovir and other antiretroviral agents. *AIDS* 26: 825–831, 2012.
4. Bemben, DA and Bemben, MG. Dose-response effect of 40 weeks of resistance training on bone mineral density in older adults. *Osteoporos Int* 22: 179–186, 2011.
5. Bhasin, S, Storer, TW, Javanbakht, M, Berman, N, Yarasheski, KE, Phillips, J, Dike, M, Sinha-Hikim, I, Shen, R, Hays, RD, and Beall, G. Testosterone replacement and resistance exercise in HIV-infected men with weight loss and low testosterone levels. *JAMA* 283: 763–770, 2000.
6. Bonaiuti, D, Shea, B, Iovine, R, Negrini, S, Robinson, V, Kemper, HC, Wells, G, Tugwell, P, and Cranney, A. Exercise for preventing and treating osteoporosis in postmenopausal women. *Cochrane Database Syst Rev* 3: CD000333, 2011.
7. Borba-Pinheiro, CJ, Carvalho, MCGA, Silva, NSL, Bezerra, JCP, Drigo, AJ, and Dantas, EHM. Effects of resistance training on low bone density-related variables in menopausal women taking alendronate. *Rev Bras Med Esp* 16: 121–125, 2010.
8. Borg, GAV and Noble, BJ. Perceived exertion. *Exerc Sports Sci Rev* 2: 131–153, 1974.
9. Braith, RW, Mills, RM, Welsh, MA, Keeller, JW, and Pollock, ML. Resistance exercise training restores bone mineral density in heart transplant recipients. *J Am Coll Cardiol* 28: 1471–1477, 1996.
10. Brown, TT and Qaqish, RB. Antiretroviral therapy and the prevalence of osteopenia and osteoporosis: A meta-analytic review. *AIDS* 20: 2165–2174, 2006.
11. Casado, JL, Bañon, S, Andrés, R, Perez-Elías, MJ, Moreno, A, and Moreno, S. Prevalence of causes of secondary osteoporosis and contribution to lower bone mineral density in HIV-infected patients. *Osteoporos Int* 25: 1071–1079, 2014.
12. Cazanave, C, Dupon, M, Lavignolle-Aurillac, V, Barthe, N, Lawson-Ayayi, S, Mehsen, N, Mercié, P, Morlat, P, Thiébaut, R, and Dabis, F. Reduced bone mineral density in HIV-infected patients: Prevalence and associated factors. *AIDS* 22: 395–402, 2008.
13. Dantas, EHM. *The Physical Preparation Practice*. Rio de Janeiro, Brazil: Shape, 2003.
14. Faigenbaum, AD, Kraemer, WJ, Blimkie, CJR, Jeffreys, I, Micheli, LJ, Nitka, M, and Rowland, TW. Youth resistance training: Updated position statement paper from the national strength and conditioning association. *J Strength Cond Res* 23: S60–S79, 2009.

15. Greendale, GA, Huang, MH, Wang, Y, Finkelstein, JS, Danielson, ME, and Sternfeld, B. Sport and home physical activity are independently associated with bone density. *Med Sci Sports Exerc* 35: 506–512, 2003.

16. Grund, B, Peng, G, Gibert, CL, Hoy, JF, Isaksson, RL, Shlay, JC, Martinez, E, Reiss, P, Visnegarwala, F, and Carr, AD. Continuous antiretroviral therapy decreases bone mineral density. *AIDS* 23: 1519–1529, 2009.

17. Huang, JS, Rietschel, P, Hadigan, CM, Rosenthal, DI, and Grinspoon, S. Increased abdominal visceral fat is associated with reduced bone density in HIV-infected men with lipodystrophy. *AIDS* 15: 975–982, 2001.

18. Karlsson, MK, Johnell, O, and Obrant, KJ. Bone mineral density in weight lifters. *Calcif Tissue Int* 52: 212–215, 1993.

19. Kelley, GA, Kelley, KS, and Tran, ZV. Exercise and bone mineral density in men: a meta-analysis. *J Appl Physiol* 88: 1730–1736, 2000.

20. Lima, AL, De Oliveira, PR, Plapler, PG, Marcolino, FM, De Souza, ME, Sugawara, A, Gobbi, RG, Dos Santos, AL, and Camanho, GL. Osteopenia and osteoporosis in people living with HIV: Multiprofessional approach. *HIV AIDS (Auckl)* 3: 117–124, 2011.

21. Mayhew, DL and Mayhew, JL. Cross-validation of the 7-10-RM method for predicting 1-RM bench press performance in high school male athletes. *J Health Phys Educ Recreat Dance* 12: 49–55, 2002.

22. McComsey, GA, Tebas, P, Shane, E, Yin, MT, Overton, ET, Huang, JS, Aldrovandi, GM, Cardoso, SW, Santana, JL, and Brown, TT. Bone disease in HIV infection: A practical review and recommendations for HIV care providers. *Clin Infect Dis* 51: 937–946, 2010.

23. Menkes, A, Mazel, S, Redmond, RA, Koffler, K, Libanati, CR, Gundberg, CM, Zizic, TM, Hagberg, JM, Pratley, RE, and Hurley, BF. Strength training increases regional bone mineral density and bone remodeling in middle-aged and older men. *J Appl Physiol* 74: 2478–2484, 1993.

24. National Osteoporosis Foundation. *Clinician's Guide to Prevention and Treatment of Osteoporosis*. Washington, DC: National Osteoporosis Foundation, 2010.

25. Negredo, E, Domingo, P, Ferrer, E, Estrada, V, Curran, A, Navarro, A, Isernia, V, Rosales, J, Pérez-Álvarez, N, Puig, J, Bonjoch, A, Echeverría, P, Podzamczer, D, and Clotet, B. Peak bone mass in young HIV-infected patients compared with healthy controls. *J Acquir Immune Defic Syndr* 65: 207–212, 2014.

26. Nickols-Richardson, SM, Miller, LE, Wootten, DF, Ramp, WK, and Herbert, WG. Concentric and eccentric isokinetic resistance training similarly increases muscular strength, fat-free soft tissue mass and specific bone mineral measurements in young women. *Osteoporos Int* 18: 789–796, 2007.

27. Ofotokun, I, McIntosh, E, and Weitzmann, MN. HIV: Inflammation and bone. *Curr HIV/AIDS Rep* 9: 16–25, 2012.

28. Pacifici, R. The immune system and bone. *Arch Biochem Biophys* 503: 41–53, 2010.

29. Park, SY, Lee, SH, and Han, SB. Atypical subtrochanteric femoral fracture. *J Orthop Sports Phys Ther* 42: 44, 2012.

30. Prior, J, Burdge, D, Maan, E, Milner, R, Hankins, C, Klein, M, and Walmsley, S. Fragility fractures and bone mineral density in HIV positive women: A case-control population-based study. *Osteoporos Int* 18: 1345–1353, 2007.

31. Ross, AC, Taylor, CL, Yaktine, AL, and Heather, BDV. *Dietary Reference Intakes for Calcium and Vitamin D. Institute of Medicine (US) Committee to Review Dietary Reference Intakes for Vitamin D and Calcium*. Washington, DC: National Academies Press, 2011.

32. Santos, WR, Paes, PP, Santos, AP, Machado, DRL, Navarro, AM, and Fernandes, APM. Impact of progressive resistance training in Brazilian HIV patients with lipodystrophy. *J AIDS Clin Res* 4: 1–4, 2013.

33. Taras, J, Arbess, G, Owen, J, Guiang, CB, and Tan, DH. Acceptability of bone antiresorptive therapy among HIV-infected adults at different stages of antiretroviral therapy. *Patient Prefer Adherence* 24: 1311–1316, 2014.

34. Tebas, P, Powderly, WG, Claxton, S, Marin, D, Tantisiriwat, W, Teitelbaum, SL, and Yarasheski, KE. Accelerated bone mineral loss in HIV-infected patients receiving potent antirretroviral therapy. *AIDS* 14: 63–67, 2000.

35. Thomas, JR, Nelson, JK, and Silverman, SL. *Research Methods in Physical Activity*. Porto Alegre, Brazil: Artmed, 2012.

36. Triant, VA, Brown, TT, Lee, H, and Grinspoon, SK. Fracture prevalence among human immunodeficiency virus (HIV)-infected versus non-HIV-infected patients in a large U.S. healthcare system. *J Clin Endocrinol Metab* 93: 3494–3504, 2008.

37. Turner, CH and Robling, AG. Exercises for improving bone strength. *Br J Sports Med* 39: 188–189, 2005.

38. Wheeler, AL, Tien, PC, Grunfeld, C, and Schafer, AL. Teriparatide treatment of osteoporosis in an HIV-infected man: A case report and literature review. *AIDS* 29: 245–246, 2015.

39. Williams, I, Churchill, D, Anderson, J, Boffito, M, Bower, M, Cairns, G, Cwynarski, K, Edwards, S, Fidler, S, Fisher, M, Freedman, A, Geretti, AM, Gilleece, Y, Horne, R, Johnson, M, Khoo, S, Leen, C, Marshall, N, Nelson, M, Orkin, C, Paton, N, Phillips, A, Post, F, Pozniak, A, Sabin, C, Trevelion, R, Ustianowski, A, Walsh, J, Waters, L, Wilkins, E, Winston, A, and Youle, M. British HIV. Association guidelines for the treatment of HIV-1-positive adults with antiretroviral therapy 2012. *HIV Med* 13: 1–85, 2012.