REVIEW ARTICLE

# Influence of physical training on bone mineral density in healthy young adults: a systematic review

Josiel Almeida de Avila[1]
Rafael Almeida de Avila[2]
Ezequiel Moreira Gonçalves[1]
Gil Guerra-Junior[1]

1. Laboratório de Crescimento e Desenvolvimento (LabCreD), Centro de Investigação em Pediatria (CIPED), Faculdade de Ciências Médicas (FCM), Universidade Estadual de Campinas (UNICAMP), Campinas, SP, Brasil
2. Faculdade de Ciências Médicas, Universidade Federal de Santa Maria (UFSM), Santa Maria, RS, Brasil

http://dx.doi.org/10.1590/1806-9282.65.8.1102

KEYWORDS: *Review. Bone Density. Exercise. Young Adult.*

## INTRODUCTION

Bone density is related to genetic, hormonal, nutritional, and environmental factors. Among the environmental factors, physical activity is identified as a major contributor to bone density gain during different periods of life[1,2], since the formation of bone is associated with the elastic compressive force of muscle contractions and weight support. Thus, activities that impose heavier loads on the bone structure cause more significant gains in bone density[3,4].

Bone Mineral Density (BMD) can be analyzed using x-rays, neutron activation, absorptiometry dual-energy x-ray absorptiometry (DXA), and high-resolution magnetic resonance imaging. The first two techniques present a disadvantage because they expose the patient to a large amount of radiation. Currently, the most commonly used method for evaluating bone health is DXA, which estimates the content of the bone area, and is considered the gold standard to evaluate bone density. Furthermore, this technique has low cost and little exposure to ionizing radiation[5-7].

According to the World Health Organization, cases of osteoporosis are expected to double by the year 2050[8]. Currently, osteoporosis affects about 50% of women and 20% of men over the age of 50 years-old[9]. The illnesses linked to bone health are dependent on inherent bone loss due to age, but they are also influenced by bone acquisitions that occur during adolescence and adult life[10,11]. Studies have shown that resistance exercises, impact activities, and sports preserve bone health[12,13].

Although many cross-sectional studies show that physical activity is related to BMD, longitudinal studies are still scarce. Thus, this systematic review aimed to determine how the variables of physical training (duration, volume, intensity, type of activity, and frequency of training) influence BMD evaluated by DXA in young adults.

## METHODS

This is a systematic review of literature about the influence of physical activity on BMD of healthy young adults. The method utilized as reference was PRISMA (Preferred Reporting Items for Systematic reviews

DATE OF SUBMISSION: 10-Feb-2019
DATE OF ACCEPTANCE: 13-May-2019
CORRESPONDING AUTHOR: Josiel Avila
126 Tessália Vieira de Camargo Rue, Cidade Universitária Zeferino Vaz, Campinas – 13083-872 – São Paulo, Brasil
E-mail: josielavila@me.com

and Meta-Analyses)[14]. The PRISMA recommendations include a checklist of 27 items that guide the authors of systematic reviews regarding information that should be clearly described in the manuscript, including specific instructions for title, abstract, methods, results, and financial support.

This systematic review conducted searches in the electronic databases PubMed and Bireme in July 2018. Only works published between 2000 and 2018 were included in this study. The search was conducted by two authors (JAA and RAA), during different moments, in English and Portuguese. Our searches had the following English language descriptors and the respective Portuguese translations: absorptiometry, Dual X-Ray, young adult or adolescent, bone density or bone mineral density or bone mineral content, motor activity or physical activity or sport or exercise.

The criteria for article selection was: studies involving healthy young adults with no history of illness or use of medications that could influence bone health original human research; the use of DXA to identify BMD, and articles published in Portuguese and English, from 2000 to 2018. In addition, the articles should use physical activity as a modifying factor for BMD. Review articles, thesis, and dissertations were not included.

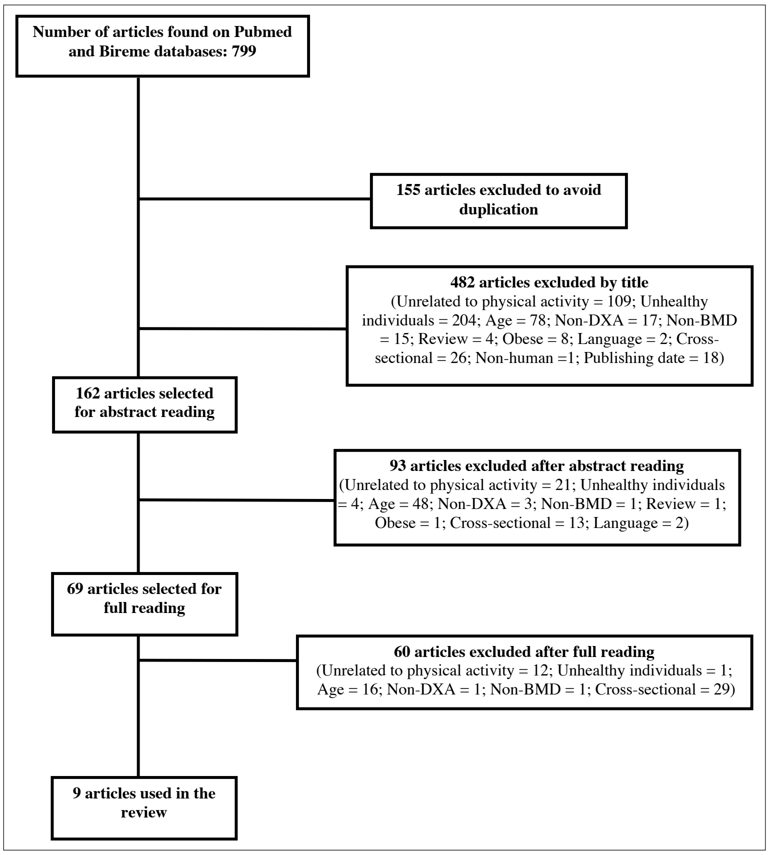
The internal quality of the selected studies was evaluated with the Downs and Black scale. This scale aims to evaluate studies that do not have a randomized clinical trial design, including five sub-items related to the form of reporting results (if the information presented in the study allows the reader to interpret the data and results without bias), external validity, bias, confounding factors, and the power of the study. The maximum score achieved, throughout the 27 gathered items, was 31 points[15].

## RESULTS

A total of 799 articles were identified (PubMed=520 and Bireme=279) with the use of the previously mentioned descriptors. Of these, 155 articles were excluded due to duplicity; 482 articles were excluded after title reading; 93 were excluded after abstract reading; and 60 were excluded after full article reading. Only nine articles (PubMed=8 and Bireme=1) were finally included in this review, as illustrated in Figure 1.

According to Downs & Black[15] these nine studies had between 18 and 23 points (Table 1). Their data is presented in chronological order in Table 1.

**FIGURE 1.** PRISMA FLOWCHART



## DISCUSSION

Longitudinal studies that evaluate the influence of physical activity on BMD in young adults are rare. However, following this systematic review, it was possible to verify that some aspects appear to exert a positive effect on BMD.

As for the type of exercise performed, it seems that resistance[21], concentric and eccentric[17] exercises, as well as impact[16] exercises, have a positive influence on BMD. In a study that evaluated impact exercises and weight training, it was found that the impact exercises caused a higher BMD. However, the difference in BMD among the groups was more substantial after 6 months than after 12 months of training. This finding shows that impact activities result in an effect on BMD that is more immediate and of greater magnitude. Therefore, resistance exercises cause more delayed effects. However, it should be noted that both activities bring beneficial changes in BMD[22].

Furthermore, a combination of resistance and aerobic exercises tend to produce better results[20]. This finding was observed in a study comparing aerobic and combined (resistance and aerobic) training. In this study, only the combined training group presented a significant increase in BMD of the tibia[20].

Duration of training appears to be efficient when it is performed during a period equal to or greater than 5 months[16,17,21,22]. The results obtained in studies with interventions of 8 and 12 weeks[20,23] appeared not to be significant. However, significant changes in biomarkers of bone formation were observed after 8 weeks. However, the same significant changes were

**TABLE 1.** CHARACTERISTICS OF STUDIES ANALYZING THE INFLUENCE OF PHYSICAL ACTIVITY ON BMD OF YOUNG ADULTS, 2005/2018.

| Study | Downs & Black | N | Protocol | Analyzed part of the body | Intensity | Weekly training Volume | Outcome |
|---|---|---|---|---|---|---|---|
| Kato et al.16, 2006 | 22 Points | 36 W (20-23 years old) | 6 months of high jumps | Spine and proximal femur | High | 30 jumps | Jump Training increased femur and spine BMD after 6 months |
| Nickols-Richardson et al.17, 2007 | 20 Points | 70 W (18-26 years old) | 5 months of eccentric and concentric training | Totality of body, proximal femur, distal tibia and forearm | 6 RM | 18 - 90 repetitions | Eccentric and concentric exercises increased total proximal femur and forearm BMD |
| Ryan et al.18, 2004 | 20 Points | 13 M and 21 W (20-29 years old) | 6 months of resistance exercises | Totality of body, spine, greater trochanter, Ward's triangle and femoral neck | 12-15 RM | 3 weekly sessions of 3 11-exercise series | No significant changes |
| Maimoun et al.19, 2004 | 19 Points | 7 W (18-20 years old) | Before and after 32-week season for triathlon athletes | Totality of body, proximal femur, intertrochanteric region, spine, radio, distal tibia and forearm | High, moderate and low | Varied | No significant increases were noted between pre- and post-season |
| Lester et al.20, 2009 | 21 Points | 56 W (20,3±1,8 years old) | 8 weeks of resistance, combined and aerobic training | Totality of body, hips, lower body, pelvis and tibia | High, moderate and low | 90 to 270 minutes | Combined training showed increased in tibia BMD |
| Almstedt et al.21, 2011 | 20 Points | 14 M e 15 W (18-23 years old) | 24 weeks of resistance training | Hips and spine | 67 to 90% 1 RM | 90 minutes | Men in the resistance training group increased spine BMD |
| Liang et al.22, 2011 | 23 Points | 51 W (20-35 years old) | 12 months of HIS and weight training | Totality of body, spine, hips, legs, arms, heels and wrists | IS (High) and weight training (65-70% and 80% of 1 RM) | IS (180 minutes) weight training (40 minutes) | IS increased heel BMD in women after 6 and 12 months |
| Ramírez-Campillo et al.23, 2013 | 18 Points | 7 M e 4 W (23±1 years old) | 12 weeks of non-dominant leg resistance training | Totality of body, upper body, arms and legs | 10-30% of 1 RM | 240 minutes | No significant changes in BMD |
| Stanforth et al.24, 2016 | 21 Points | 212 W (18-23 years old) | Before and after 3 years of university season (Soccer, Volleyball, Running, Swimming and runners) | Totality of body, arm, leg, pelvis, and spine | High, moderate and low | Varied | IS cause larger variation in BMD |

Abbreviations: M= Men; W= Women; IS= Impact Sport; DXA= Dual-energy X-ray Absorptiometry; RM = Repetition Maximum; BMD= Bone Mineral Density.

not observed in biomarkers related to bone reabsorption. This finding suggests that the results of BMD tend to appear after a greater period of intervention[20].

As for training intensity, it seems that intense[16,17,22] and moderate[21] training cause a greater effect on the variation of BMD. Low-intensity training[23], even with large volumes, does not show significant differences in BMD.

Despite the different locations of evaluation of BMD utilized in the reviewed articles, the locations where more significant changes occur are the femur and the spine[16,17,21]. However, other sites showed a significant increase in BMD. In a study that evaluated the effect of concentric and eccentric exercises on BMD, it was observed that the upper limbs are more sensitive to changes when compared with the femoral neck[17]. Therefore, it can be concluded that physical training affects both the axial skeleton as well as the appendicular skeleton.

As for the frequency of training during the week, it was not possible to draw further conclusions since all studies used 3 practice sessions a week as the training protocol. However, this variation does not appear to be essential in producing effects on BMD since even when using the same frequency of training some studies showed an increase in BMD[16,17,21,22] and others did not present significant differences[20,23].

## LIMITATIONS

As a limitation of this systematic review, it was possible to determine that the analyzed studies differ on training protocols, duration, and intensity of workouts. Furthermore, some studies differ about the location of evaluations of BMD, which may have caused a bias in the analysis of these articles.

## CONCLUSIONS

Regardless of the limitations described above, it can be concluded that the increase in BMD occurs on the axial skeleton as well as the appendicular skeleton. Impact, resistance, and combined exercises cause an increase in BMD. Frequency and the weekly volume of training do not necessarily produce effects on BMD. On the other hand, more intense training causes a more significant effect on BMD, and the results are obtained when training is performed with duration equal to or greater than 5 months.

The availability of longitudinal studies that evaluate the effects of physical activity on BMD is limited. Thus, further studies are necessary for better analysis of the effects of training variables on BMD in young adults.

PALAVRAS-CHAVE: *Revisão. Densidade Óssea. Exercício. Adulto Jovem.*

## REFERENCES


1. Havill LM, Mahaney MC, Binkley TL, Specker BL. Effects of genes, sex, age, and activity on BMC, bone size, and areal and volumetric BMD. J Bone Miner Res. 2007;22(5):737-46.
2. Davies JH, Evans BA, Gregory JW. Bone mass acquisition in healthy children. Arch Dis Child. 2005;90(4):373-8.
3. Gunter K, Baxter-Jones AD, Mirwald RL, Almstedt H, Fuchs RK, Durski S, et al. Impact exercise increases BMC during growth: an 8-year longitudinal study. J Bone Miner Res. 2008;23(7):986-93.
4. Scerpella TA, Davenport M, Morganti CM, Kanaley JA, Johnson LM. Dose related association of impact activity and bone mineral density in pre-pubertal girls. Calcif Tissue Int. 2003;72(1):24-31.
5. Cole ZA, Dennison EM, Cooper C. The impact of methods for estimating bone health and the global burden of bone disease. Salud Publica Mex. 2009;51(Suppl 1):S38-45.
6. Cummings SR, Bates D, Black DM. Clinical use of bone densitometry: scientific review. JAMA. 2002;288(15):1889-97.
7. Njeh CF, Fuerst T, Hans D, Blake GM, Genant HK. Radiation exposure in bone mineral density assessment. Appl Radiat Isot. 1999;50(1):215-36.
8. Reginster JY, Burlet N. Osteoporosis: a still increasing prevalence. Bone. 2006;38(2 Suppl 1):S4-9.
9. Sambrook P, Cooper C. Osteoporosis. Lancet. 2006;367(9527):2010-8.
10. Hui SL, Slemenda CW, Johnston CC Jr. The contribution of bone loss to postmenopausal osteoporosis. Osteoporos Int. 1990;1(1):30-4.
11. Seeman E, Hopper JL, Bach LA, Cooper ME, Parkinson E, McKay J, et al. Reduced bone mass in daughters of women with osteoporosis. N Engl J Med. 1989;320(9):554-8.
12. Winters-Stone KM, Snow CM. Musculoskeletal response to exercise is greatest in women with low initial values. Med Sci Sports Exerc. 2003;35(10):1691-6.
13. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR; American College of Sports Medicine. American College of Sports Medicine Position Stand: physical activity and bone health. Med Sci Sports Exerc. 2004;36(11):1985-96.
14. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. PLoS Med. 2009;6(7):e1000100.

**15.** Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health. 1998;52(6):377-84.

**16.** Kato T, Terashima T, Yamashita T, Hatanaka Y, Honda A, Umemura Y. Effect of low-repetition jump training on bone mineral density in young women. J Appl Physiol (1985). 2006;100(3):839-43.

**17.** Nickols-Richardson SM, Miller LE, Wootten DF, Ramp WK, 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. 2007;18(6):789-96.

**18.** Ryan AS, Ivey FM, Hurlbut DE, Martel GF, Lemmer JT, Sorkin JD, et al. Regional bone mineral density after resistive training in young and older men and women. Scand J Med Sci Sports. 2004;14(1):16-23.

**19.** Maïmoun L, Galy O, Manetta J, Coste O, Peruchon E, Micallef JP, et al. Competitive season of triathlon does not alter bone metabolism and bone mineral status in male triathletes. Int J Sports Med. 2004;25(3):230-4.

**20.** Lester ME, Urso ML, Evans RK, Pierce JR, Spiering BA, Maresh CM, et al. Influence of exercise mode and osteogenic index on bone biomarker responses during short-term physical training. Bone. 2009;45(4):768-76.

**21.** Almstedt HC, Canepa JA, Ramirez DA, 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. 2011;25(4):1098-103.

**22.** Liang MT, Braun W, Bassin SL, Dutto D, Pontello A, Wong ND, et al. Effect of high-impact aerobics and strength training on BMD in young women aged 20-35 years. Int J Sports Med. 2011;32(2):100-8.

**23.** Ramírez-Campillo R, Andrade DC, Campos-Jara C, Henríquez-Olguín C, Alvarez-Lepín C, Izquierdo M. Regional fat changes induced by localized muscle endurance resistance training. J Strength Cond Res. 2013;27(8):2219-24.

**24.** Stanforth D, Lu T, Stults-Kolehmainen MA, Crim BN, Stanforth PR. Bone mineral content and density among female NCAA Division I athletes across the competitive season and over a multi-year time frame. J Strength Cond Res. 2016;30(10):2828-38.