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

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, 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.

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.

According to the World Health Organization, cases of osteoporosis are expected to double by the year 2050. Currently, osteoporosis affects about 50% of women and 20% of men over the age of 50 years-old. 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. Studies have shown that resistance exercises, impact activities, and sports preserve bone health.

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...
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\textsuperscript{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\textsuperscript{15} these nine studies had between 18 and 23 points (Table 1). Their data is presented in chronological order in Table 1.
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\textsuperscript{21}, concentric and eccentric\textsuperscript{27} exercises, as well as impact\textsuperscript{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\textsuperscript{22}.

Furthermore, a combination of resistance and aerobic exercises tend to produce better results\textsuperscript{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\textsuperscript{20}.

Duration of training appears to be efficient when it is performed during a period equal to or greater than 5 months\textsuperscript{16,21,22}. The results obtained in studies with interventions of 8 and 12 weeks\textsuperscript{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 observed at different intensities

\begin{table}
\centering
\caption{Characteristics of Studies Analyzing the Influence of Physical Activity on BMD of Young Adults, 2005/2018.}
\begin{tabular}{|l|l|l|l|l|l|l|}
\hline
Study & Downs & Black & N & Protocol & Analyzed part of the body & Intensity & Weekly training Volume & Outcome \\
\hline
Kato et al.\textsuperscript{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 \\
\hline
Nickols-Richardson et al.\textsuperscript{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 \\
\hline
Ryan et al.\textsuperscript{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 \\
\hline
Maimoun et al.\textsuperscript{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 \\
\hline
Lester et al.\textsuperscript{20}, 2009 & 21 Points & 36 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 \\
\hline
Almstedt et al.\textsuperscript{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 \\
\hline
Liang et al.\textsuperscript{22}, 2011 & 23 Points & 31 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 \\
\hline
Ramirez-Campillo et al.\textsuperscript{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 \\
\hline
Scanforth et al.\textsuperscript{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 \\
\hline
\end{tabular}
\end{table}

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 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.

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