A comparison of bone mineral density in amateur male boxers and active non-boxers

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Abstract

To examine the site-specific osteogenic effect of upper limb impact-loading activity we compared the forearm and arm bone mineral density (BMD) of male boxers to that of active controls. A cross-sectional study was performed with 30 amateur male boxers (aged 18-44 years) and 32 age-matched, non-boxing, active controls. Participants had their regional and whole body BMD and bone mineral content (BMC) assessed by dual-energy x-ray absorptiometry. Hand grip strength, testosterone, oestradiol, sex hormone-binding globulin, vitamin D, lean and fat mass, and past and current physical activity were also assessed. Forearm and arm BMD were 1.5-2.2% higher in boxers than the control group although this was not statistically significant ($p>0.05$), with no significant difference for BMC ($p>0.05$). There were no differences between groups for spine, hip, or whole body BMD or BMC, or for body composition or hormone status. Within the arms, lean mass was associated with BMD and BMC in both boxers and the control group (BMD, r=0.60-0.76, $p<0.001$; BMC, r=0.67-0.82, $p<0.001$). There were no significant differences between amateur boxers and the control group for upper limb BMD and BMC. However, muscle mass appears to be particularly important to bone health of the upper limbs.

Introduction

Cross-sectional studies have shown that chronically trained athletes involved in sports that impart high-impact, weight-bearing strains on the skeleton, such as volleyball [1] and gymnastics [13], have higher bone mineral density (BMD) at the hip and lumbar spine than non-athletes. It is well established that exercise can play a vital role in improving bone health and reviews of exercise interventions have concluded that regimens involving resistance training alone or in combination with impact-loading exercise (e.g. jumping, hopping, skipping) are the most beneficial mode(s) of exercise to improve BMD of adults at weight bearing sites [3,10,11]. However, these systematic reviews of exercise and bone have generally focused on the influence of exercise on hip and lumbar spine BMD rather than forearm or arm BMD.

The principles of effective bone loading are well established and indicate that bone tissue must be subjected to mechanical loading above that experienced in daily activities to improve bone density. Mechanical loading should induce high bone strains, be dynamic rather than static, novel rather than customary and may be short in duration (i.e. a small numbers of loading cycles) [20]. Given the beneficial effect weight-bearing impact-loading activities and sports have on BMD of the hip and spine, it would seem prudent to presume that boxing, which imparts brief, high-impact loads on the upper limb, would be beneficial for forearm and arm BMD. To date, only one study has examined the effect of boxing on upper-limb BMD. Trutschnigg and colleagues compared the BMD of 11 female boxers to physically active female non-boxers of low (n=16) and average (n=17) body fat mass [19]. It was concluded that arm, leg and spine BMD was significantly higher in boxers than the control group with low fat mass, while compared to those with average body fat mass, boxers only presented higher BMD than non-boxers in the arm.

To the best of our knowledge, only two studies have compared the BMD of male boxers to a non-boxing control group. Sabo et al. examined the BMD of six internationally ranked boxers recruited from the Kienbaum National Training Centre in Germany [17]. The boxers had significantly greater lumbar spine BMD than the control group; however upper limb BMD was not assessed. Likewise, Dolan et al. [7] compared whole body, hip and lumbar spine BMD of male boxers (n=14), to that of jockeys (n=30) and recreationally active controls (n=14); jockeys were found to have the lowest BMD and boxers the highest. As a health promotion strategy, boxing training, which can be undertaken as a general fitness activity, presents itself as a potentially attractive method of upper limb impact-loading exercise. To increase our understanding of the influence boxing may have on BMD, larger studies of male boxers are required with upper limb BMD as a primary outcome measure. Therefore, the aim of the study was to examine and compare the site-specific osteogenic effect of upper limb impact-loading activity on the forearm and arm BMD of male boxers and active controls. It was hypothesised that upper limb BMD of the boxers would be higher than that of the control group.

Methods

Sixty-two male amateur boxers (n=30) and non-boxing controls (n=32) aged 18-44 years were recruited from the Brisbane metropolitan area (Queensland, Australia) to participate in this cross-sectional study. Boxers were involved in regular (on average at least two sessions each week) boxing training at the time of testing and for the two years prior to testing, and each training session must have included at least 10 min of punching activities against pads or bags. Men in the control group were excluded if they had performed any regular (on average two or more times each week) boxing, hitting or punching sports within the last five years, or had participated in racquet sports more frequently than once a month in the last two years. Due to the nature and physical requirements of boxing, it is common for boxers to also be resistance trained. Consequently, efforts were made to match boxers and control group participants for resistance training to ensure that there were no statistically significant differences in the percentage of resistance trained individuals between the groups. To match for resistance training between groups, we analysed the percentage of boxers (based on the first 10 boxers recruited for the study) who completed resistance training i.e. of the first 10 boxers recruited for this study, 8 (80%) performed resistance training. We then recruited non-boxers to the study based on this percentage to ensure ~8 of every 10 non-boxing participants undertook resistance training. Whilst the percentage of boxers who were resistance trained slightly decreased as recruitment continued, the final difference between groups was small and non-significant, indicating successful matching of resistance training between groups. Potential participants were excluded if they were taking any medications know to affect bone metabolism at the time of recruitment or testing. The study was approved by The University of Queensland Medical Research Ethics Committee (approval number HMS11/1208.r1) and has therefore been performed in accordance with the ethical standards laid down in an appropriate version of the Declaration of Helsinki. This study meets the ethical standards of the Journal [12]. Written informed consent was obtained from all participants.

Primary measures were forearm and arm BMD (g/cm²), which were derived by dual-energy x-ray absorptiometry (DXA, Hologic Discovery W, Waltham, MA),. Forearm BMD included the total radius and ulnar and was derived from a forearm scan, while arm BMD included the humerus, radius, ulna, carpals, metacarpals and phalanges, and was derived from sub-region analysis of the whole body scan [18]. The coefficient of variation (CV) in our laboratory for forearm and arm BMD are 1.1% and 2.0%, respectively.

Secondary measures were whole body, total hip, and lumbar spine BMD (g/cm²) and bone mineral content (BMC, g), and forearm and arm BMC, which were derived by DXA (Hologic Discovery W, Waltham, MA). Whole body bone mineral-free lean mass, fat mass, percentage body fat (BF %), right and left arm lean and fat mass and appendicular lean mass (sum of upper limbs and lower limbs) was derived from the whole body DXA scan. Participants were instructed to eat as they normally would on the day of and leading up to the testing session and arrive at the testing session well hydrated. The CVs in our laboratory for whole body and regional BMD are <2.0%, and for whole body and appendicular soft-tissue composition <1.0%. The CV refers to the variability of duplicate scans on participants from our laboratory; this is on-off table repeats.

Isometric hand grip strength was measured using a spring-loaded grip dynamometer (TTM, Tokyo, Japan). Participants were asked to perform a maximal contraction with each hand in a standing position, elbow at 90° flexion and forearm in a neutral position. The test was performed in triplicate with a brief rest period (approximately 30 s) provided between subsequent attempts, with the highest value used for analysis. The CV in our laboratory for isometric grip strength is 3.6%.

A venous blood sample (6 mL) was collected from the antecubital vein of the rested participants using a 21 G needle into prepared vacutainers by a qualified phlebotomist. Participants were in a rested state during blood collection. Blood samples were allowed to clot in 6 mL serum tubes for 30 min then centrifuged at 5500 x g at 4˚C for 10 min. Serum was removed and placed in 400 µL storage tubes and then frozen at -80º C until later analysis. Testosterone (Elecsys Testoserone II assay), oestradiol (Elecsys Estradiol II assay), sex hormone-binding globulin (SHBG) (Elecsys SHBG assay) and vitamin D (Elecsys Vitamin D total assay) were analysed using a Roche Cobas e411 electrochemilumescence immunoassay autoanalyser (Roche Diagnostics, Switzerland). The CVs in our laboratory for testosterone, oestradiol, SHBG and vitamin D are 2.3%, 7.7%, 3.9% and 4.8%, respectively.

Participants completed a self-administered questionnaire on lifestyle habits, which included resistance training and smoking status, average weekly alcohol units and hand dominance. The Bone Physical Activity Questionnaire (BPAQ) was used to assess past physical activity [21]. Participants were asked to record type, frequency and years of physical activity involvement for the past (from one year of age; pBPAQ) and current (previous 12 months; cBPAQ) sections of the questionnaire and return the questionnaire within 7 days of the testing session. Total BPAQ (tBPAQ) was derived from the average of the pBPAQ and cBPAQ scores. All activities listed in the BPAQ online calculator (www.fithdysign.com/BPAQ/) were entered and the remaining activities not listed were categorised into alternate options: 'other - low impact', 'other - moderate impact', or 'other - high impact'. Intra-class correlation coefficients for inter- and intra-tester reliability for the BPAQ are very high (0.92 and 0.97, respectively) [22]. Height and body mass were measured using a stadiometer (Seca, Birmingham, United Kingdom) and electronic scales (A & D Mercury, Pty Ltd, Thebarton, Australia), respectively.

Data were analysed using SPSS Statistics Version 20 for Windows (IBM SPSS, Chicago, IL, USA). To achieve 80% power at an alpha level of 0.05 (two-tailed), ~ 30 participants per group were required to demonstrate a 0.75 standard deviation (SD) difference between groups for arm and forearm BMD, which we would consider to be clearly important. Normality of the distribution for outcome measures was assessed using the Kolmogorov-Smirnov test. Analyses included standard descriptive statistics, Chi-square, and independent t-tests or Mann-Whitney U tests, as appropriate. Pearson's or Spearman's correlations were used to examine the association between years of boxing activity and number of boxing sessions per week (for boxers only), grip strength, arm lean mass, BPAQ scores and forearm and arm BMD, BMC and BMD/height. To account for differences in body size, analyses between BPAQ and BMD variables were undertaken by also adjusting BMD for height (BMD/height) as proposed by Reid and colleagues [16]. To account for multiple testing, Bonferroni corrections were applied to the Pearson's and Spearman's correlations for the total number of comparisons made (n=48). All tests were two-tailed and statistical significance was set at $p \leq 0.05$. Results are given as the mean ± SD unless stated otherwise.

Results

Characteristics of the boxers and the control group are presented in Table 1. There were no differences between groups for body composition, hand grip strength or blood markers. The boxers were currently undertaking an average of 4.2±1.9 boxing sessions per week and had been boxing for 6.0±4.1 years. The majority of participants in both groups performed recreational resistance training. For those who did resistance exercise, training was undertaken on average twice per week. In the control group, one participant rowed once per week, one participated in European handball once a week, and one undertook rock climbing once per week. All other activities performed were predominantly lower extremity activities such as soccer, rugby and touch football. There were no significant differences in BPAQ scores between the two groups ($p=0.466$). All participants were right hand dominant, with the exception of four participants (boxers n=2, control n=2). BMD of the participants were classified as 'normal', with an average hip and lumbar spine T-score of 0.1±0.9 and 0.2±0.8 for the boxers, and 0.2±1.2 and 0.2±1.2 for the control group, respectively. Data on right forearm BMD was unavailable for one of the boxers due to poor image quality that prevented analysis.

Forearm and arm BMD were 1.5-2.2% higher in boxers than the control group although this was not statistically significant ($p>0.05$) (Table 1). There were no statistically significant differences in BMC at the forearm or arm. When comparing only resistance trained participants in both the boxing (n=19/30) and the control group (n=25/32), differences in BMD and BMC between the groups remained non-significant. Additionally, there were no differences between groups for BMD or BMC at the lumbar spine (BMD p=0.992; BMC p=0.433), hip (BMD; p=0.673; BMC p=0.477) or whole body (BMD p=0.803; BMC p=0.900).

Relationships between grip strength, arm lean mass, and arm and forearm BMD and BMC are shown in Table 2 and between pBPAQ, cBPAQ, tBPAQ and arm and forearm BMD and BMD/height are shown in Table 3. There were significant positive relationships between arm lean mass with arm BMD and BMC in boxers (BMD, r=0.71–0.76, p<0.001; BMC, r=0.80-0.82, p<0.001) and the control group (BMD, r=0.60–0.68, p<0.001; BMC, r= 0.67-0.73, p<0.001). In the boxers, lean mass also was related to forearm (r=0.74-75, p<0.001) and arm BMC (r=0.80-0.82, p<0.001), whereas grip strength was only related to right forearm (r=0.69-, p<0.001) and right arm BMC (r=0.66, p<0.001). Years of boxing and number of boxing sessions per week were not significantly associated with BMD or BMC. Grip strength and BPAQ scores were not significantly related to BMD in either group. However, when adjusted for height, tBPAQ was significantly associated with right and left arm BMD and pBPAQ with right arm BMD in the boxing group only.

Discussion

The aim of this study was to determine if the repeated impacts undertaken as part of boxing training has a beneficial effect on enhancing upper limb BMD in men. As a result, this is the first study to examine the arm and forearm BMD, as well as BMC, of male boxers and active controls, and although the amateur boxers assessed had trained on average for 6 years, there were no statistically significant differences in forearm or arm bone mineral when compared to similarly aged non-boxing counterparts. Moreover, there were no differences at the lumbar spine, hip or whole body between the two groups suggesting that in men amateur boxing may not provide a sufficient upper extremity osteogenic effect to enhance BMD relative to active non-boxing controls.

The findings from our study in men differ from the previous study conducted in female boxers. Trutschnigg et al. [19] compared the BMD of female boxers (n=11) to physically active women with low (<21%; n=16) and average (21-32%; n=17) body fat mass who did not participate in boxing training. BMD of the arms, legs and spine were significantly higher (8-12%) in boxers than in women with low body fat mass, while only arm BMD was significantly higher (8%) in boxers than women with average body fat mass. However, in comparison to the current study, while the women in the control group were required to be training twice weekly, aerobic-based exercise (including running, soccer, swimming, jogging, as well as martial arts) was the predominant modality, not resistance training. It may well be that the effect of resistance training in both groups within our study may have masked any beneficial effect of repeated impacts via boxing. Additionally, forearm scans were not performed in the Trutschnigg et al. [19] study, making it difficult to compare their results to those in the current study.

Similarly, Sabo and co-workers compared lumbar spine bone density of German internationally competitive male boxers, as well as other athletes, to age-matched controls and found BMD in the boxers to be 17-19% greater than the control group [17]. The boxers were also resistance trained; however, the physical activity levels and training status of the control group were not described. Given that BMD of the upper limb wasn't assessed and the lack of information regarding the control group, it is difficult to make comparisons between the results of the study by Sabo et al. [17] and the current study. Findings from studies of racquet sport players have shown differences in bone mass and geometry between the dominant and contralateral arms, indicating that the skeleton's response to mechanical loading is site-specific [6,14]. By measuring the lumbar spine rather than the forearm or arm the difference in BMD may not be an accurate reflection of the isolated effects of boxing but rather inherent differences between the groups as well as the effects of resistance training which load the spine.

The significant relationships between lean mass and arm BMD in both groups in the current study are of interest. While the presence of the relationship is not surprising given the well-established muscle-bone relationship [8,9], it reinforces the importance of muscle mass for bone health. Similar findings in cross-sectional studies of athletes have also reported significant relationships ($p<0.05$) between appendicular lean mass and forearm BMD in competitive male and female ten-pin bowlers [23] and appendicular lean mass and regional and total body BMD in elite, male judo, karate and water polo athletes [2]. Systematic reviews of exercise and bone health in adults generally conclude that progressive resistance training of a moderate to high intensity (expressed as a percentage of 1-repetition maximum) is beneficial for bone [3,10,11].

What isn't clear is which type of exercise, high-impact or resistance, is optimal for bone health of men, although the research to date indicates that a combination of both may be superior [11]. Although it is difficult to directly compare the two exercise modalities, evidence from exercise trials suggests that high-impact exercise appears to be more beneficial [11]. In line with our current understanding of bone's adaptation to mechanical loading, it would seem prudent to expect that boxers would have greater bone density than resistance trained individuals because of the high-impact, unusual and repeated loading patterns associated with boxing [20]. Prospective studies investigating the effects of impact-loading activity on upper limb BMD in men are needed before conclusions can be made on the benefits of boxing for bone health. Moreover, randomised controlled trials comparing the effects of upper extremity impact-loading activities or resistance training in isolation on upper limb bone health are required to improve our understanding of the optimal mode of exercise for this skeletal region.

There are several limitations of this study that are worthy of comment. First, this is a cross-sectional study and, as such, we can only report associations and not infer cause and effect. Second, although BMD as derived by DXA is the accepted clinical measure of osteoporosis detection and skeletal health classification, there are concerns regarding this method and its inability to provide structural information (size, shape and structure) important for bone strength [4]. Consequently, there is growing interest in using quantitative computed tomography to assess bone strength and, where possible, researchers should aim to use this method in conjunction with DXA to give a more complete indication of the role that mechanical loading may have on whole bone strength. Third, the majority of the boxers also undertook resistance training; therefore the effect of resistance training may have masked the effects of boxing. Future randomised controlled trials of boxing alone are required to examine the effect of boxing on upper extremity BMD. Finally, differences in time of day, post-prandial content and timing, and hydration status, may have minimally influenced the measurement error for DXA and blood biomarker analysis [5,15].

Conclusion

In conclusion, results from the current study suggest that there were no significant differences in forearm and arm BMD between amateur boxers and age-matched, non-boxing, active controls. While boxing training appears to be beneficial for the forearm and arm bone health of men, these benefits may not be superior to those achieved by regular resistance training.

Conflict of interest

All authors have no conflict of interest. No funding was received for this study.

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