

The effect of a 12-week exercise programme on bone mineral density in young South African females

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(Received: 29 July 2009 Revision Accepted: 9 October 2009)

Abstract

A longer lifespan has increased the emphasis on bone health, which is often compromised with age. Studies have shown that exercise yields a positive influence on bone mineral density (BMD), especially when done during the early years of life (second to third decades). A 12-week study was undertaken using dual-energy X-ray absorptiometry (DEXA) to assess changes in BMD (total, lumbar and neck of the femur) in 70 females (mean age 20.1 years) before and after a 12-week intense exercise programme. The exercise programme consisted of a daily 5 km run and two isolated resistance exercises for each body region. The Wilcoxon signed-rank test was used to determine if any changes took place after the intervention. Statistically significant increases occurred in only the BMD of the lumbar spine (L1-L4) (2.54%) and neck of the femur (NOF) (9.35%), with clinical significance shown only in the NOF, as the increase was greater than 7%. This study's results thus indicate that a relatively short intense intervention of 12 weeks can improve BMD in young women, thereby possibly assisting in preventing osteoporosis and fractures later on in life. Further studies are recommended to determine the minimum time needed to achieve a clinically significant change in the total BMD as well as the lumbar spine BMD.

Key words: *Bone mineral density, young females, exercise.*

Introduction

Exercise is known to offer many benefits to those who regularly undergo its rigorous demands. It has beneficial effects, both anatomical and physiological, on all body tissues, most especially the heart, muscles and bones (Fletcher et al., 1996; Clausen, 1997). It also gives a state of psychological well being, so much so that it could be looked upon as being addictive (Griffiths, 1997).

Adolescence and early adulthood (second to third decade of life) is the period of life in which a lot of bone accumulation occurs, with an increase in bone mineral density (BMD) by between 10% and 20% in loading bones compared with sedentary controls (Vincente-Rodriguez et al., 2008).

It has been suggested that the type and intensity of exercise have independent and additive effects on total and regional bone density (Magkos, Yannakoulia, Kavouras & Sidossis, 2007). In this study, the researchers compared the effect of

swimming and running on bone density and found that runners had a higher femur and total BMD than swimmers. They also showed that the intensity of exercise affected BMD, with sprint athletes having a significantly higher BMD than endurance athletes in the arms, legs, trunk and total body (Magkos et al., 2007). The authors attributed these results to the strain placed on the skeleton by the ground reaction forces during running. This strain causes deformation of bone. The mechanostat theory proposes that bone is capable of sensing biomechanical strain through an internal “mechanostat”, thereby adjusting the level of remodelling accordingly to increase bone accretion (Snow, 1996; Barr & McKay, 1998; Voss, Fadale & Hulstyn, 1998; Kemmler et al., 2006; Liu & Lebrun, 2006).

BMD accrual usually protects against osteoporosis and subsequent fractures later on in life, especially in females. This accrual is determined mainly by genotype, i.e. heredity, while only 30% is determined by phenotype, which can be influenced by environmental factors such as exercise (Vincente-Rodriguez et al., 2008). The increased bone mass due to exercise is, however, only maintained with regular physical activity (Rautava et al., 2007).

The current study therefore examined the beneficial effects of intensive exercise on BMD in young women. A time frame of 12 weeks was selected for the intervention, as no documented minimum time frame for which exercise needs to be done to achieve an increase in bone density was found.

Methods

The study protocol was approved by the University of Pretoria’s Ethics Committee. Informed consent was voluntarily obtained from the participants before the study.

A group of 70 young females were randomly selected from 89 female soldiers enrolled for Basic Military Training. They were aged between 18 and 22 years was used for the study (mean age: 20.1 years; mean height: 159.57 cm \pm 5.53; mean weight: 59.5 kg \pm 8.79; mean BMI: 23.09 kg/m² \pm 3.33). Two of the participants withdrew during the course of the study due to their inability to comply with the exercise requirement. The group acted as their own controls, as baseline measures were used for comparison.

Before commencing the exercise programme, the BMD measurements of all the candidates were taken using a dual energy X-ray absorptiometry (DEXA) machine (Prodigy, GE Lunar Corp., Madison, WI). The scan was repeated after the 12-week programme using the same machine and the same radiologist.

The exercise programme was completed as part of the Basic Military Training Programme and consisted of 45 minutes exercises sessions completed 4 times per week for the 12-week period. The exercise programme was designed based on the ACSM (2006) exercise guidelines. Each exercise session included a warm-up, cardiovascular component (5km run), two isolated resistance exercises for each body region, stretching and a cool down. The exercise programme had a progressive build-up, from walking to jogging the 5km, on grassed sports fields, allowing sufficient periods of recovery from weight-bearing stress during the early weeks (Scully & Besterman, 1982; Popovich, Gardner, Potter, Knapik, & Jones, 2000). Additionally the two isolated resistance exercises for each body region were varied so that no same exercises for a muscle group were repeated on consecutive days to allow for sufficient recovery to take place (Heyward, 2002; Armstrong, Rue, Wilckens, & Frassica, 2004).

The data collected were analysed by means of the Statistical Product and Service Solutions package. The mean and standard deviations of each of the parameters were determined. The non-parametric Wilcoxon signed-rank test was used to determine if any changes took place after the intervention as the pre- and post-intervention results were compared with each other. Non-parametric statistics were used to accommodate the small sample size. An α level of 0.05 was used for all statistics.

Results

Table 1 presents the group's pre- and post-test descriptive statistics as well as changes that took place within the group between the pre- and post-test measurements. The changes that were statistically significant are highlighted in Figure 1. These include the L1-L4 BMD and BMD neck of femur (NOF). In both of these measurements the post-test scores were higher than the pre-test scores ($p < 0.05$).

Table 1: Changes in the mean values of BMD (g/cm^2) measurements and body mass (kg)

Parameter	Pre-tests		Post-tests		Mean difference	% change
	N	Mean \pm SD	N	Mean \pm SD		
tBMD	70	1.15 \pm 0.07	68	1.15 \pm 0.07	0.00	0
L1-L4	70	1.18 \pm 0.12	68	1.21 \pm 1.20	0.03	2.54*
NOF	70	1.07 \pm 0.11	68	1.17 \pm 0.12	0.1	9.35*
Mass	70	59.5 \pm 8.79	68	59.96 \pm 7.48	0.46	0.77

Values are mean \pm SD. Mean difference between pre-test and post-test and % change that was observed in female participants; * Significant change from the pre-test to the post-test at the end of the 12-week exercise programme: $p < 0.05$.

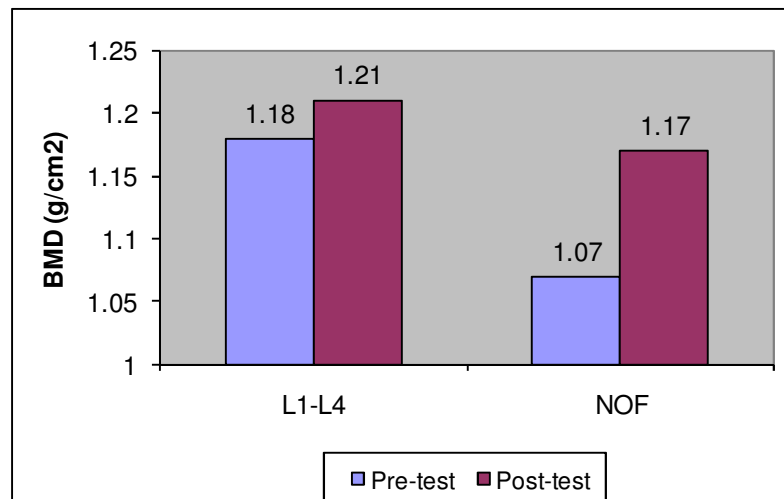


Figure 1: Statistically significant differences ($p < 0.05$) between pre-test and post-test BMD (g/cm^2) measurements following the 12-week exercise programme.

Discussion

BMD varies according to race, age group and gender (Rupich, Specker, Lieuw-A-Fa & Ho, 1996; Horlick et al., 2000). In recent years studies have investigated the effects of some interventions on BMD (Deng, et al., 2000; Mora & Gilsanz,

2003). The aim of all these studies was to determine which intervention achieved the most positive results. The studies done using female participants were especially important, as BMD decreases by 10% in the decade following menopause in women not receiving hormone replacement therapy (Phillips & Phillipov, 2006). This differs in males, where bone loss remains low until 70 years of age (Phillips & Phillipov, 2006).

The present study shows that a 12-week intensive exercise period caused an increase in the total BMD in young women, as well as the BMD in the lumbar region of the spine and the neck of the femur. This result correlates with many other studies which also show the positive influence of physical activity on BMD (Miller et al., 2007; Heikkinen, Vihriala, Vainionpaa, Korpelainen & Jamsa, 2007; Rautava et al., 2007). There are, however, some studies which dispute this. A study on male hockey players showed that most of the benefits (increased BMD) are reduced, predominantly in weight bearing bones (Nordstrom, Olsson & Nordstrom, 2005), whilst Kelley and Kelley (2006) suggest that exercise does not improve femoral BMD in post-menopausal women.

For an increase in BMD to be clinically significant, there must be a change of 0.050 g/cm^2 (or a 4-7% increase) (Phillipov, Seaborn & Phillips, 2001; Phillips & Phillipov, 2006). Although the participants in the present study experienced a statistically significant increase ($p < 0.05$) in both the lumbar region of the spine (L1-L4) and the femur neck ($p = 0.00$), the increase in BMD at the femur neck was the only area to have a clinically significant increase (9.4%).

The greatest increase in BMD was seen at the neck of the femur, which has also been shown in other studies (Magkos et al., 2007; Hind & Burrows, 2006). As the legs support the weight of the body, a greater magnitude of loading (stress) occurs at the hip region (Hind & Burrows, 2006). This may have been further influenced by the exercise programme followed by the participants, which included a 5 km daily run.

Although it has been shown that physical activity started before or during early puberty is more effective in enhancing bone mass than if started post-adolescence (Barnekow-Bergkvist, Hedberg, Pettersson & Lorentzon, 2006), this study showed that a clinically significant change can occur in the neck of the femur post-adolescence.

Although this increase in BMD may offer some protection against osteoporosis and fractures later on in life (Rautava et al., 2007; Heikkinen et al., 2007;

Villareal et al., 2006), Rautava et al. (2007) confirm in their study that bone gain induced by exercise is not permanent without sustained physical activity throughout life.

In summary, the 12-week exercise programme consisting of two isolated resistance exercises against own body weight for each body region and a daily 5 km run caused a clinically significant increase in BMD in the neck of the femur in young females aged 18-22 years.

The study failed to achieve a significant change in BMD of the spine as well as total BMD, which may be attributed to the short duration of the intervention not being sufficient for adequate remodelling of the bones to occur. Remodelling refers to the coupled process by means of which fatigue damaged bone is replaced by new bone. It occurs in both growing and adult bones, determining bone shape and mass in adults. Remodelling occurs in cycles, which involve breakdown of bone by osteoclasts and laying down of new bone matrix by osteoblasts. These osteoblasts begin to mineralise after 13 days. It takes 124-168 days for these broken down areas to be filled (Hill, 1998). Therefore, further studies with a longer intervention period following a similar exercise programme are recommended.

Acknowledgement

The authors would like to thank the Department of Statistics of the University of Pretoria for their assistance with the statistical analysis.

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