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Long-term Effect of Exercise on Bone Mineral Density and Body Composition in Post-Menopausal Ex-Elite Athletes: A Retrospective Study.

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**Running title:** Bone Mineral Density in Ex-Elite Athletes

**Conflict of interest:** The authors declare no conflict of interest.

*Guarantor:* Angela Andreoli

*Contributors:* AA, UT, and SL designed the study. AA and MC were responsible for data collection. RS performed the statistical calculations and data analyses. AA, UT and SLV conducted analyses and wrote the original manuscript. All authors contributed to interpretation of data and critically revised the manuscript.

**Abstract**

**Objective:** Aim of this retrospective study was to determine the long-term effect of exercise on bone mineral density (BMD), bone mineral content (BMC) and body composition (BC) in post-menopausal women who were elite athletes during youth compared with sedentary controls.

**Design:** A Retrospective Study.

**Setting:** Outpatient clinic.

**Subjects & Methods:** Forty-eight post-menopausal women (54 to 73 years of age) were enrolled. The ex-elite athletes with long-term (>20 years) histories of significant training and performance were divided into two groups: weight-bearing sports (runners, n=12) and non-weight-bearing sports (swimmers, n=12). The athletes were age-matched with sedentary controls (n=24). BMD, BMC and BC were measured by DXA. Health care and sport activity histories were evaluated by questionnaire.

**Results:** No significant differences were found for body weight, height, BMI and hours of activity between the two groups of athletes. There were no significant differences in activity levels between athletes and controls at the time of this study. BMD and BMC were not significantly different between athletes; they were significantly higher in athletes versus controls ( $p<0.001$ ). Though the ex-athletes did not significantly differ in BC, left and right lean arm mass and arm BMD were significantly higher in swimmers than runners ( $p<0.0001$ ).

**Conclusion:** The high level of physical activity observed in female athletes is associated with improved muscle mass, **BMD, and BMC, and physical activity in youth appears to have a beneficial effect on bone mass to prevent bone loss with aging.**

**Key Words:** Bone mineral density, Body composition, Menopausal, Female athletes

## Introduction

Osteoporosis is a major public health problem around the world, largely due to the morbidity and mortality associated with osteoporotic fractures (Becker et al., 2006).

Osteoporosis is the most prevalent metabolic bone disease, characterized by diminished bone strength, predisposing the affected individual to an increased risk of fracture. Its incidence is particularly high in post-menopausal women, but it can also affect men and individuals receiving corticosteroid therapy (Becker et al., 2006, Drinkwater BL. 1994, Leung et al., 2002)

The pathogenesis of osteoporosis is complex and multifactorial (Gnudi et al., 2007). A decrease in physical activity may lead to an increased loss of bone mineral density (BMD) and an increase in the incidence of fragility fractures (Duncan et al., 2002, Karlsson 2007).

It is commonly accepted that weight-bearing activity provides an osteogenic stimulus to the bones (Basse et al., 1998). For example, athletes involved in sports that increase the mechanical stress placed on the bones (i.e., weight-bearing activities) have an increased BMD compared with the general population (Andreoli et al. 2001, Taaffe et al., 1995). However, swimmers, who train in a non-weight-bearing environment, have been shown to obtain less skeletal benefits than do athletes who participate in weight-bearing activities (Block et al., 1989, Taaffe et al., 1995).

Researchers have studied the relationship between aerobic activities to BMD, and though the results have been equivocal, there has been more research showing that regular aerobic weight-bearing exercise has a positive impact on BMD; physically active men and

women have higher BMD than those who are sedentary (Taafee et al., 1995). Furthermore, though researchers have examined the impact of strenuous physical training on BMD in young athletic women (Basseby et al., 1998, Creighton et al., 2001, Etherington et al., 1996), there is less information regarding BMD in highly trained older women athletes.

Therefore, the purpose of this retrospective study was to determine the effect of being involved in sports on BMD, bone mineral content (BMC) and body composition in women who were athletes during youth compared with sedentary controls, and to evaluate whether the positive effects of past sports participation persisted during menopause and aging..

## **Methods**

The study was first approved by the Ethical Committee of the University of Rome "Tor Vergata". Each participant gave verbal and written informed consent prior to participation and it was carried out according to the Declaration of Helsinki protocol. None of the participants was taking medications that affected bone and muscle metabolism.

### *Participants*

Forty-eight Caucasian females, 54 to 73 years of age, were enrolled in the study. The sample included two groups of athletes: swimmers (n=12) and runners (n=12). A third group of women included 24 age-matched nonathletic participants who served as the control group. Menstrual history for each participant was obtained through interview.

Information regarding the age of onset of menarche, the average number of menstrual cycles per year pre-menopausally, and the use of oral contraceptives was obtained through interview. Based on this interview, all participants were classified as eumenorrheic (10 to 13 cycles per year) during their younger years.

### *Experimental protocol*

All measurements were conducted when participants were fasted for 12 hours and had not exercised for 24 hours. Participants were also to refrain from alcohol consumption for 48 hours prior to testing.

#### *Physical activity assessment*

Current and past physical activity levels in age-matched sedentary controls were assessed by a validated physical activity questionnaire (Salvini et al., 2002). All athletes were asked to detail their physical activity patterns, including pre-season, in-season, and post-season workouts. The training history, including years of active sport-specific training, training sessions per week, total training hours per year, and the age of onset of the sport-specific training were documented with a validated questionnaire (Salvini et al., 2002). Furthermore a questionnaire including questions on medication use, known diseases, dietary intake, vitamin and mineral supplementation, and the use of alcohol and cigarettes was used (Fidanza et al., 1995). Finally, a specific questionnaire for menstrual cycle and menopausal status of each woman was used (Nappi et al., 2008, , Salvini et al., 2002).

Two categories of sports with different mechanical loading were selected for the present study: weight-bearing versus non-weight-bearing. We classified our athletes as either swimmers or runners.

During their youth, all of the athletes competed at national and international levels and exercised regularly for at least three hours per day, four days per week. Occasionally, control participants participated in activities once or twice a month, but not on a regular basis nor in a competitive sport environment. Their overall physical activity never exceeded one hour per week.

All athletes continued to participate in the same sport activity as when they were young; however, the intensity of training was lower and they were active about four to five hours per week. The control group reported being active at a gymnasium for about three hours per week.

#### *Anthropometric measurements*

Anthropometric measurements were taken according to conventional criteria and measurement procedures. Body weight and height were measured to the nearest 0.1 kg and 0.5 cm, respectively. Body mass index (BMI; kg/m<sup>2</sup>) was calculated using the formula: body weight (kg)/height (m)<sup>2</sup>.

#### *Bone mineral density, bone mineral content and body composition*

Total body and regional measurements of BMD, BMC, fat mass (FM), and lean body mass (LBM) were made using dual-energy x-ray absorptiometry (DXA) (Lunar Corp., model DPX, Madison, WI, software version 3.6). The scanner was calibrated daily against the standard calibration block supplied by the manufacturer to control for possible baseline drift. DXA measures total BMD and BMC with a coefficient of variation (CV) of 0.7%. For total FM and LBM, CVs = 1.6% and 0.8%, respectively.

#### *Statistical analyses*

Statistical comparisons for the different variables among the four groups were performed by applying a one-way analysis of variance (ANOVA). Bonferroni post-hoc tests were performed on all significant mean differences. Correlation and regression analyses between BMD and BC were performed. The test of comparisons and correlation were considered significant if  $p \leq 0.055$ . All statistical analyses were carried out with the Statistical Package for Social Sciences (SPSS Inc., version 10, Chicago, IL).

## **Results**

The characteristics of the three groups are reported in Table 1. There were no significant differences in age, body weight, height and BMI among the groups. The age of menarche was not significantly different between groups.

Most women were greater than seven years post-menopausal and not on estrogen replacement therapy. Menopausal status was not significantly different between the athletes and controls, as well as between swimmers and runners. Years of post-menopause was  $9.0 \pm 7.0$  for the control group,  $8.3 \pm 7.3$  for the runners, and  $8.1 \pm 6.9$  for the swimmers.

### *Physical activity levels*

Table 2 shows physical activity levels for a period of 15 years. When the athletes were competing, they had a significantly greater activity level compared to the control group ( $p < 0.01$ ). The swimmers had significantly higher activity levels during their time of competition compared to the runners ( $p < 0.05$ ). At the time of this study, however, there were no significant differences in activity levels between the athletes and the control group.

Total body BMD in the control group was significantly lower ( $p < 0.05$ ) compared to the athletes; however, no differences were found between the swimmers and the runners (Table 3). Table 3 presents regional BMD and BMC of the three groups. BMD of the arms was not significantly different among the three groups. BMD of the spine was significantly lower in the controls compared to the runners ( $p < 0.01$ ). BMD of the legs was significantly higher in athletes compared to the controls ( $p < 0.001$ ). BMD of the legs was higher in runners compared to swimmers ( $p < 0.01$ ). Athletes had a significantly higher segmental BMC than the control group ( $p < 0.001$ ).

Lean mass was significantly lower in the control group compared to the athletes ( $p < 0.001$ ), but was not significantly different between runners and swimmers (Table 4). Fat mass, in kg and percentage, was significantly higher ( $p < 0.001$ ) in the control group compared with runners and swimmers; but was not significantly different between the runners and swimmers. Swimmers had statistically leaner arms compared to runners ( $p < 0.001$ ) (Table 4). The lean mass of legs between runners and swimmers, was not statistically significant difference. (Table 4).

When the athletes and controls were combined into one group, lean body mass was associated with BMD at all regions. Fat mass was not correlated with BMD. The correlation between BMD and lean mass was 0.488 (equation:  $BMD = 1.16E^{-5} \text{lean} + 0.520$ ); while an inverse correlation was found between BMD and fat mass ( $r = -0.378$ ; equation:  $BMD = -8.2e^{-6} \text{fat} + 1.163$ ) (Figure 1).



## Discussion

The purpose of this retrospective study was to determine the effect of being involved in sports on BMD, BMC and body composition in women who were athletes during youth compared with sedentary controls, and to evaluate whether the positive effects of past sports participation persisted during menopause and aging. Another objective was to evaluate if there were any differences in BMD, BMC and body composition between athletes who have continued physical activity and those who have discontinued physical activity. Weight-bearing exercise is associated with lumbar BMD, and sports that stress the bones are associated with higher BMD than non weight-bearing sports such as swimming (Fehling et al., 1995). When the athletes in the present study were divided into weight-bearing versus non weight-bearing exercisers, runners had higher leg BMD than swimmers.

Previous researchers investigating the effects of exercise on BMD have reported increases in BMD in pre-menopausal women participating in low intensity regular exercise (Aleke et al., 1995, Uusi-Rasi et al., 1998), and following the introduction of an exercise regimen (Drinkwater 1994, Etherington et al., 1996). Though estrogen replacement therapy has been reported to increase BMD in both sedentary pre- and post-menopausal women (Heikkinen 1997), the effect of exercise in post-menopausal women is less clear, with researchers reporting increases (Tinetti et al., 1994, Uusi-Rasi et al., 1998), decreases, or marginal effects (Bassey et al., 1998) on BMD following exercise. Our results showed that athletes with a lifetime history of strenuous physical activity had markedly higher BMD, BMC and appendicular muscle mass than sedentary controls of similar age and menopausal status.

It is well known that bone mineral density increases at sites of maximum stress (Andreoli et al., 2001, Carter 1992, Wolman et al., 1991). The physiological mechanisms involved in the response of bone cells to mechanical stress are still unclear. A possible explanation may be that osteocytes acting as mechanoreceptors respond and release chemical factors capable of promoting osteoblastic proliferation at the local bone site.

Stress applied to a skeletal segment affects the geometry of the bone, the microarchitecture, and the composition of the matrix (Carter 1992).

Physical activity leads to greater BMD in children and adolescents and, to a minor extent, in adults (Carter 1992). Weight-bearing activities, such as walking or run, have a greater effect than non-weight-bearing activities, such as cycling and swimming, whereas a reduction in mechanical loading, i.e., bed rest or space flight, leads to bone loss (Heer et al., 1999).

Therefore, weight-bearing activity has been widely recommended as a possible prophylaxis for age-related bone loss. The skeleton provides more than just a framework for the body. Bone is a calcified conjunctive tissue sensitive to various mechanical stimuli, mainly to those resulting from gravity and muscular contractions.

We have shown that muscle mass was higher in runners compared to swimmers in legs and swimmers were leaner arms compared to runners.

The increased muscle mass in the athletes probably reflects the significant physical training they undergo. The physical training, in turn, positively affected BMD and BMC. In this regard, one might expect that the amount of muscle mass might play a role in skeletal maintenance, which has been reported by others who have conducted prospective studies in this area (Andreoli et al., 2001).

Furthermore, the exercise during growth is important because of the associated changes in bone geometry that translate to greater increases in bone strength than provided by an increase in BMC alone (Ahlborg et al., 2003).

Exercise during growth may be followed by long-term beneficial skeletal effects, which could possibly reduce the incidence of fractures. Exercise during adulthood seems to partly preserve these benefits and reduce the age-related bone loss. (Karlsson 2007, Karlsson et al., 2008). The beneficial effect seems to have occurred due to an exercise-induced periosteal expansion. Alternatively, bone mineral may be deposited on the endosteal surface, producing a thicker cortical shell without a wider bone. (Duncan et al., 2002, Greene et al., 2005, Ward et al., 2005).

The complexity of the skeletal response to loading is also illustrated by the heterogeneity of the geometrical adaptations along the length of a bone (Nappi et al., 2008).

The effects of exercise on BMD in older women and men in randomized controlled trials is required. Impact and resistance exercise should be supporter for the prevention of osteoporosis. Weight-bearing exercise in general, and resistance exercise in particular, along with exercise targeted to improve balance, mobility and posture, should be recommended to reduce the likelihood of falling and its associated morbidity and mortality (Guadalupe-Grau et al., 2009).

In fact, observational studies have reported that the risk to fall decreases with increased physical activity (Tinetti et al., 1994), and low physical activity, presently or previously, have an increased risk of sustaining a hip fracture (Gregg et al., 1998). Other studies conclude that daily physical activity is associated with a reduced hip fracture risk (Kritz-Silverstein et al., 1994, Magnus et al., 2008). Existing data indicate that exercise, in both men and women and independently of age, improves muscle strength even when conducted during a short period. The muscle strength improves far more and much faster than the increase in muscle mass.

The high levels of physical activity observed in women athletes may prevent a decline in muscle mass and also are sufficient to prevent the loss of bone with aging.

The limitation of the present study is that a retrospective study and not a longitudinal one. But, to this regard, we should recognize that it is not easy to make a study like this in a prospective way, in fact in the literature there are no other articles which take into account the physical activity levels, BMD, BMC and segmental body composition of different groups at the same time, then this manuscript showed that physical activity in youth has beneficial effects on all the studied parameters in late age.

Future longitudinal studies should provide more details on the effect of physical activity in youth and confirm the persisted effect during menopause and aging.

In conclusion, physical activity in youth appears to have a beneficial effect on bone mass in late age, physical activity with greater mechanical loading appears to result in a

greater bone mass than non-weightbearing activities, and there appears to be a site-specific skeletal response to the type of loading at each BMD site.

## References

1. Ahlborg HG, Johnell O, Turner CH, Rannevik G, Karlsson MK. (2003). Bone loss and bone size after menopause. *N Engl J Med.* 349: 327\_34.
2. Alekel L, Clasey J, Fehling P, Weigel R, Boileau R, Erdman J, Stillamn R. (1995). Contributions of exercise, body composition and age to bone mineral density in premenopausal women. *Med Sci Sports Exerc.* 27:1477-1485.
3. Andreoli A, De Lorenzo A. (2005). Physical activity and body composition. *Review World Rev Nutr Diet.* 4:60-67.
4. Andreoli A, Monteleone M, Van Loan M, Promezio OL, Tarantino U, De Lorenzo A. (2001). Effects of different sports on bone density and muscle mass in highly trained athletes. *Med Sci Sports Exerc.* 3(4):507-511.
5. Bassey EJ, Rothwell MC, Littlewood JJ, Pye DW. (1998). Pre and post-menopausal women have different bone mineral density responses to the same high impact exercise. *J Bone Miner Res.* 13(12): 1805-1813.
6. Becker C, Crow S, Toman J, Lipton C, McMahon DJ, Macaulay W, Siris E. (2006). Characteristics of elderly patients admitted to an urban tertiary care hospital with osteoporotic fractures: correlations with risk factors, fracture type, gender and ethnicity. *Osteoporos Int.* 17(3):410-416.
7. Block JE, Friedlander AI, Brooks GA Steiger P, Stubbs HA, Genant HK (1989). Determinants of bone density among athletes engaged in weight-bearing and non-weight-bearing activity. *J Appl Physiol.* 67 (3): 1100-1105.
8. Carter D. R. (1992). Skeletal development and bone functional adaptation. *J. Bone Miner. Res.* 7:s389 -s395.
9. Creighton DL, Morgan AL, Boardley D, Brolinson PG. (2001). Weight-bearing exercise and markers of bone turnover in female athletes. *J Appl Physiol.* 90(2):565-570.
10. Drinkwater BL. Does physical activity play a role in preventing osteoporosis? (1994). *Res Q Exerc Sport.* 197-206.
11. Duncan CS, Blimkie CJ, Kemp A, Higgs W, Cowell CT, Woodhead H. (2002) Mid-femur geometry and biomechanical properties in 15- to 18-yr-old female athletes. *Med Sci Sports Exerc* 34: 673-81.

12. Etherington J, Harris PA, Nandra D, Hart DJ, Wolman RL, Doyle DV, Spector TD. (1996). The effect of weight-bearing exercise on bone mineral density: a study of female ex-elite athletes and the general population. *J Bone Miner Res.* 11(9):1333 – 8.
13. Fehling PC, Alekel L, Clasey J, Rector A, Stillman RJ. (1995). A comparison of bone mineral densities among female athletes in impact loading and active loading sports. *Bone.* 17(3):205–210.
14. Fidanza, F., M. G. Gentile, and M. A. Porrini. (1995). Self-administered semiquantitative food frequency questionnaire with optical reading and its concurrent validation. *Eur. J. Epidemiol.* 11:163–170.
15. Guadalupe-Grau A, Fuentes T, Guerra B, Calbet JA. (2009). Exercise and bone mass in adults. *Sports Med.* 29(6):439-468.
16. Gnudi S, Sitta E, Fiumi N. (2007). Relationship between body composition and bone mineral density in women with and without osteoporosis: relative contribution of lean and fat mass. *J Bone Miner Metab.* 25 (5):326-332.
17. Greene DA, Naughton GA, Briody JN, Kemp A, Woodhead H, Corrigan L. (2005). Bone strength index in adolescent girls: does physical activity make a difference? *Br J Sports Med* 39: 622\_7..
18. Gregg EW, Cauley JA, Seeley DG, Ensrud KE, Bauer DC. (1998). Physical activity and osteoporotic fracture risk in older women. Study of Osteoporotic Fractures Research Group *Ann Intern Med* 129: 81-8.
19. Heer M, Kamps N, Biener C, Korr C, Boerger A, Zittermann A, Stehle P, Drummer C. (1999). Calcium metabolism in microgravity. *Eur. J. Med. Res.* 9:357–360.
20. Heikkinen J, Kyllonen E, Kurttila-Matero E, Wilen Rosenquist G, Lankinen K, Rita H, VaananeN H. (1997). HRT and exercise: effects on bone density, muscle strength and lipid metabolism in healthy postmenopausal women. *Maturitas.* 139-149.
21. Karlsson MK. (2007). Does exercise during growth prevent fractures in later life? *Review Med Sport Sci.* 51: 121-136.
22. Karlsson MK, Nordqvist A, Karlsson C. (2008). Physical activity increases bone mass during growth. *Food Nutr Res.* 52. doi: 10.3402/fnr.v52i0.1871.
23. Karlsson MK, Nordqvist A, Karlsson C. (2008). Sustainability of exercise-induced increases in bone density and skeletal structure. *Food Nutr Res.* 52. doi: 0.3402/fnr.v52i0.1872

24. Kritz-Silverstein D, Barrett-Connor E. (1994). Grip strength and bone mineral density in older women. *J Bone Miner Res* 9:45-51.
25. Leung MM, Corliss AB, Volpe SL. (2002). Effect of cortisone injections on college athletes' bone mineral density and biochemical markers of bone turnover. *J Med Sciences*. 2(3):124-129.
26. Magnus K, Karlsson, Anders Nordqvist and Caroline Karlsson. (2008). Physical activity, muscle function, falls and fractures. *Food Nutr Res*. 52. doi: 10.3402/fnr.v52i0.1920.
27. Mazess RB, Barden HS. (1991). Bone density in premenopausal women: effects of age, dietary intake, physical activity, smoking, and birth-control pills. *Am J Clin Nutr*. 53:132-142.
28. Nappi RE, Albani F, Vaccaro P, Gardella B, Salonia A, Chiovato L, Spinillo A, Polatti F. (2008). Use of the Italian translation of the Female Sexual Function Index (FSFI) in routine gynecological practice. *Gynecol Endocrinol*. 24(4):214-9.
29. Robling AG, Hinant FM, Burr DB, Turner CH. Shorter. (2002) More frequent mechanical loading sessions enhance bone mass. *Med Sci Sports Exerc*. 34:196–202.
30. Soules MR, Sherman S, Parrott E, Rebar R, Santoro N, Utian W, Woods N. (2001) Executive summary: Stages of Reproductive Aging Workshop (STRAW). *Fertil Steril* 76:874-878.
31. Ryan AS, Elahi D. (1998). Loss of bone mineral density in women athletes during aging. *Calcif Tissue Int*. 63(4):287-292.
32. Salvini S, Saieva C, Sieri S, Vineis P, Panico S, Tumino R, Palli D. (2002). Physical activity in the EPIC cohort in Italy IARC Scientific Publications, IARC: Lyon, France.; 6, pp 267–269.
33. Taafee DR, Snow-Harter C, Connolly DA, Robinson TL, Brown MD, Marcus R. (1995). Differential effects of swimming versus weight-bearing activity on bone mineral status of eumenorrheic athletes. *J Bone Miner Res*. 586-593.
34. Tinetti ME, Baker DI, McAvay G, Claus EB, Garrett P, Gottschalk M, et al. (1994). A multifactorial intervention to reduce the risk of falling among elderly people living in the community *N Engl J Med* 331: 821-7.

35. Torstveit MK, Sundgot-Borgen J, Wark JD. (2005). Low bone mineral density is two to three times more prevalent in non-athletic premenopausal women than in elite athletes: a comprehensive controlled study *Br J Sports Med.* 39(5):282-287.
36. Uusi-Rasi K, Sievanen H, Vuori OJA P (1998) Associations of physical activity and calcium intake with bone mass and size in healthy women at different ages. *J Bone Miner Res.* 13(1) 133–142.
37. Ward KA, Roberts SA, Adams JE, Mughal MZ. (2005). Bone geometry and density in the skeleton of pre-pubertal gymnasts and school children. *Bone* 36: 1012\_8.
38. Wolman R. L., L. Faulman, P. Clark, R. Hesp, and M. G. Harries.(1991). Different training patterns and bone mineral density of the femoral shaft in elite, female athletes. *Ann. Rheum. Dis.* 0:487– 498.



Figure 1. The correlation between BMD (g/m<sup>2</sup>) and lean body mass (Kg) (A), and fat mass (B).

**Table 1. Participant Characteristics**

**Table 2. Physical Activity Levels of the Three Groups at time of study**

**Table 3. Bone Mineral Density (BMD) and Bone Mineral Content (BMC) of the Three Groups**

**Table 4. Segmental Body Composition Parameters of the Three GroupsReferences**

Table 1. Participant Characteristics

	Sedentary Controls (n=24)	Runners (n=12)	Swimmers (n=12)
Age (years)	60.8 ± 6.7	57.8 ± 6.4	58.4 ± 8.8
Body Weight (kg)	62.6 ± 6.4	60.2 ± 7.9	67.8 ± 12.6
Height (cm)	157.2 ± 7.5	162.9 ± 5.6	167.8 ± 6.5
Body Mass Index (kg/m <sup>2</sup> )	25.3 ± 1.7	22.6 ± 2.5	23.9 ± 3.2
Lean Body Mass (kg)	37.9 ± 3.7	42.8 ± 3.9 <sup>^</sup>	46.1 ± 5.6 <sup>^</sup>
Fat Mass (kg)	23.4 ± 4.3	15.6 ± 4.3 <sup>^</sup>	19.8 ± 8.1 <sup>^</sup>
Percent Body Fat (%)	37.0 ± 4.6	25.4 ± 4.2 <sup>^</sup>	28.3 ± 6.7 <sup>^</sup>

<sup>^</sup> p<0.001. Multiple comparisons Bonferroni test. Controls vs Runner and Swimmers

Table 2. Physical Activity Levels of the Three Groups at time of study

	Sedentary Controls (n=24)	Runners (n=12)	Swimmers (n=12)
Total Physical Activity (hours over 15 years)	910.0 ± 367.7	7088.3 ± 4990.3 <sup>^</sup>	7425.1 ± 3890.0 <sup>^</sup>
Physical Activity (hours/week)	3.0 ± 2.5	22.0 ± 9.0 <sup>^</sup>	30.0 ± 10.0 <sup>^</sup>
Actual Physical Activity (hours/week)	3.0 ± 1.0	4.4 ± 1.0	5.1 ± 2.1

<sup>^</sup> p<0.001. Multiple comparisons Bonferroni test. Controls vs Runner and swimmers.

Table 3. Bone Mineral Density (BMD) and Bone Mineral Content (BMC) of the Three Groups

	Sedentary Controls (n=24)	Runners (n=12)	Swimmers (n=12)
BMD – Left Arm (g/cm <sup>2</sup> )	0.640 ± 0.080	0.692 ± 0.074	0.703 ± 0.057
BMD – Right Arm (g/cm <sup>2</sup> )	0.647 ± 0.068	0.716 ± 0.088	0.710 ± 0.063
BMD – Thoracic Spine (g/cm <sup>2</sup> )	0.694 ± 0.140	0.795 ± 0.100 <sup>^</sup>	0.774 ± 0.081
BMD – Lumbar Spine (g/cm <sup>2</sup> )	0.938 ± 0.164	1.162 ± 0.198 <sup>^</sup>	1.051 ± 0.126
BMD – Left Leg (g/cm <sup>2</sup> )	0.921 ± 0.107	1.130 ± 0.144 <sup>^^</sup>	1.043 ± 0.099 <sup>^</sup>
BMD – Right Leg (g/cm <sup>2</sup> )	0.942 ± 0.112	1.115 ± 0.138 <sup>^^</sup>	1.062 ± 0.090 <sup>^</sup>
BMC – Left Arm (g)	121.8 ± 23.5	134.9 ± 21.5	155.6 ± 24.3 <sup>^^</sup>
BMC – Right Arm (g)	128.3 ± 23.7	146.8 ± 28.2	155.5 ± 27.3 <sup>^^</sup>
BMC – Trunk (g)	400.7 ± 74.6	497.3 ± 83.5 <sup>^^</sup>	493.6 ± 71.3 <sup>^^</sup>
BMC – Left Leg (g)	272.7 ± 52.3	372.8 ± 77.0 <sup>^^</sup>	360.8 ± 50.5 <sup>^^</sup>
BMC – Right Leg (g)	289.6 ± 50.5	389.6 ± 76.5 <sup>^^</sup>	382.9 ± 56.7 <sup>^^</sup>

<sup>^</sup> p<0.01; <sup>^^</sup> p<0.001. Multiple comparisons Bonferroni test. Controls vs runners and swimmers.

**Table 4. Segmental Body Composition Parameters of the Three Groups**

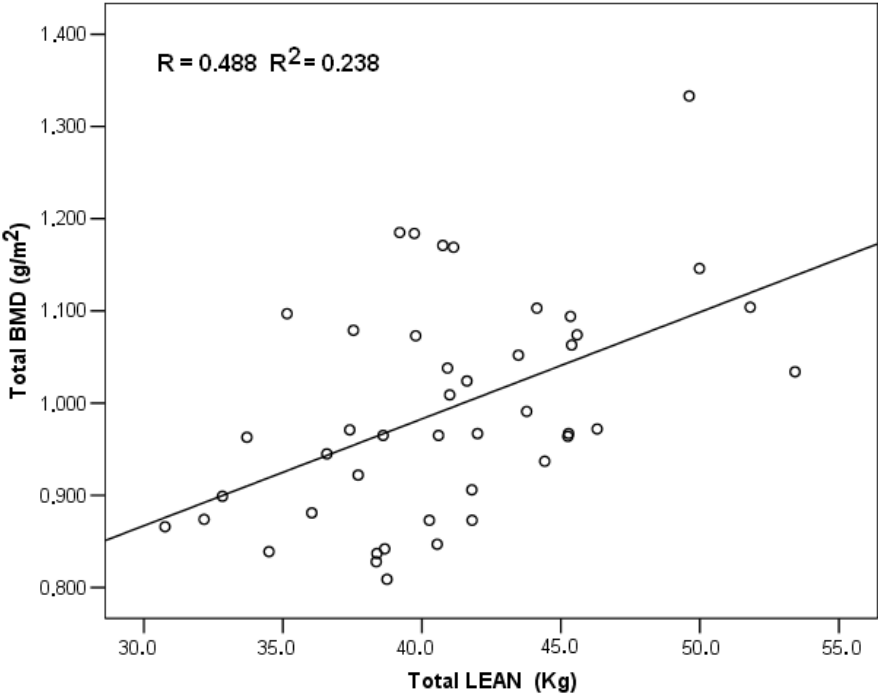
	<b>Sedentary Controls (n=24)</b>	<b>Runners (n=12)</b>	<b>Swimmers (n=12)</b>
<b>Fat Mass – Left Arm (kg)</b>	1.9 ± 0.4	1.0 ± 0.3 <sup>^^</sup>	1.5 ± 0.7 <sup>^</sup>
<b>Fat Mass – Right Arm (kg)</b>	2.0 ± 0.5	1.1 ± 0.3 <sup>^^</sup>	1.6 ± 0.6 <sup>^</sup>
<b>Fat Mass – Trunk (kg)</b>	10.5 ± 2.3	7.1 ± 1.9 <sup>^^</sup>	8.1 ± 4.7 <sup>^^</sup>
<b>Fat Mass – Left Leg (kg)</b>	3.9 ± 0.9	3.1 ± 0.9	3.7 ± 1.1
<b>Fat Mass – Right Leg (kg)</b>	3.9 ± 1.2	3.1 ± 1.0	3.8 ± 1.1
<b>Lean Mass – Left Arm (kg)</b>	2.0 ± 0.2	2.2 ± 0.2	2.8 ± 0.3 <sup>^^**</sup>
<b>Lean Mass – Right Arm (kg)</b>	2.1 ± 0.4	2.4 ± 0.2	2.9 ± 0.4 <sup>^^**</sup>
<b>Lean Mass – Trunk (kg)</b>	18.6 ± 1.9	19.1 ± 0.5	22.4 ± 3.2
<b>Lean Mass – Left Leg (kg)</b>	5.7 ± 0.6	6.8 ± 0.8 <sup>^^</sup>	7.1 ± 0.9 <sup>^^</sup>
<b>Lean Mass – Right Leg (kg)</b>	6.0 ± 0.7	6.9 ± 0.7 <sup>^^</sup>	7.4 ± 1.0 <sup>^^</sup>

<sup>^</sup> p<0.01; <sup>^^</sup> p<0.001; multiple comparisons Bonferroni test Controls vs Athletes

\* p<0.01; \*\* p<0.001; multiple comparisons Bonferroni test Runners vs Swimmers

Figure.1

A



B

