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Influence of different sports on bone mass in growing girls

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Abstract

The aim of this study was to analyse whether there are differences in bone mass in girls playing different sports. Two hundred girls (10.6 ± 1.5 years old, Tanner stages I–III) participated in the study and were divided into groups of 40 (swimmers, soccer players, basketball players, handball players and controls). Bone mineral content and bone mineral density (BMD) (whole body and hip) were measured using dual-energy X-ray absorptiometry. The degree of sexual development was determined using Tanner test, and physical activity habits were recorded through a questionnaire designed ad hoc for this research. Girls were divided by pubertal stage and the type of sport. In the prepubertal group, intertrochanteric BMD was significantly higher in both handball and soccer players compared with the control group ($P < 0.05$). Furthermore, in the pubertal group, total BMD, mean arms BMD, pelvis BMD, femoral neck BMD, intertrochanteric BMD and Ward's triangle BMD were significantly higher in soccer and handball players compared with the control group ($P < 0.05$), and the swimmers showed significantly higher values in the mean arms BMD compared with the control group ($P < 0.01$). Our data suggest that sport practice during puberty, especially in activities that support the body weight, may be an important factor in achieving a high peak bone mass and improving bone health in girls.

Keywords: *body composition, bone mass, DXA, female players, physical activity*

Introduction

In the past years, the interest in bone health in childhood has grown meaningfully as a result of the increase of osteoporosis cases in adults (Bailey, McKay, Mirwald, Crocker, & Faulkner, 1999; Bellew & Gehrig, 2006). Osteoporosis is considered a public health problem because of the increased number of people who are suffering from it and the economic repercussions, which are generated during treatment and rehabilitation (Cruz et al., 2009). In fact, the costs derived from bone fracture as a consequence of this disease are higher than those produced by breast cancer and prostate cancer (Clark, Carlos, & Vázquez-Martínez, 2010). Currently, there are more than 200 million people who are suffering from this illness around the world (Schurman et al., 2013). About 1.7 million of hip fractures related to osteoporosis took place in 1900 (Manzarbeitia, 2005). By 2050, that number will be about 6 million (Gullberg, Johnell, & Kanis, 1997).

The International Osteoporosis Foundation (2014), with the aim of avoiding this social and economic repercussion, proposed that prevention is the best method to fight against this disease. One of the best ways to improve bone health and, therefore, reduce the risk of suffering osteoporosis is through physical activity (Mesa-Ramos, 2010). An increment in the level of physical activity in children would result in higher bone mass accrual and a diminution of the risk of suffering bone fractures during adulthood (Karlsson, Nordqvist, & Karlsson, 2008). This increase can be achieved with 30 min of exercise impact, 3 days per week, gaining BMD in the greater trochanter by 1.4% over a period of 8 months (McKay et al., 2000). Indeed, approximately 20% of the variation of the peak bone mass is explained through lifestyle (Ferrari, 2005).

As a result of that situation, the interest in the diverse osteogenic effects of physical activity has grown to know which discipline produces the best bone development (Weidauer, Eilers, Binkley, Vukovich, & Specker, 2012). However, although there are many research studies that have investigated this aspect in other populations, for example, in the elderly and adults (Gómez-Cabello, Ara, González-Agüero,

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Casajús, & Vicente-Rodríguez, 2012; Verschueren et al., 2013), still, there are few studies that analyse the effect of exercise on bone growth in girls and its relation in the prevention of bone disease in adulthood, focusing most research only on children (Ackerman, Skrinar, Medvedova, Misra, & Miller, 2012; Andreoli et al., 2001; Plaza-Carmona et al., 2014; Zouch et al., 2008).

Previous studies have demonstrated that the accumulation of bone mass and its persistence in adulthood are favoured by doing sport or physical activity at early ages, between 8 and 15 years (Baxter-Jones, Eisenmann, Mirwald, Faulkner, & Bailey, 2008). Moreover, the effect of exercise is bigger when it is done before puberty (Vicente-Rodriguez et al., 2003). According to Bailey, Martin, McKay, Whiting, and Mirwald (2000), 25% of bone mineral content (BMC) is achieved between 11 and 13 years in girls and between 12 and 14 years in boys. The exercise produces not only an increase in the bone mass but also structural changes that can persist for life (Gustavsson, Thorsen, & Nordström, 2003). Sixty per cent of the osteoporosis cases in adulthood are related to a low BMC, which has been acquired during adolescence (Baroncelli, Bertelloni, Sodini, & Saggese, 2005). For that reason, the childhood is a key stage because the risk of suffering osteoporosis during adulthood can be reduced if the maximum peak of bone mass is increased during the growth (Rizzoli, Bianchi, Garabédian, McKay, & Moreno, 2010). Furthermore, immature bones are more sensible to mechanic tension (Vicente-Rodriguez et al., 2003).

The exercise suggested to improve the bone mineral density (BMD) is fundamentally the impact – ones which consist in applying plyometric exercises such as jumps and races (Asikainen, Kukkonen-Harjula, & Miilumpalo, 2004). For that reason, sports such as soccer, basketball or handball produce high stimulus in bones because of the reaction forces applied to the play surface during the development of the different game actions, being beneficial to calcium deposition and remodelling (González-Aramendi, 2003). In fact, research carried out by Vicente-Rodríguez et al. (2004), Vicente-Rodriguez, Dorado, Perez-Gomez, Gonzalez-Henriquez, and Calbet (2004) and Vicente-Rodriguez et al. (2003) showed that participation in football and handball in girls reduces the risk of skeletal fractures later in life.

Nevertheless, while practicing low-impact sports, as for example swimming, the bones do not get so many stimuli, so the bone density values are lower (Karlsson et al., 2008). In fact, in a review carried out by Gómez-Bruton, Gónzalez-Agüero, Gómez-Cabello, Casajús, and Vicente-Rodríguez review (2013), it is concluded that swimmers have a bone structure weaker than high-impact sports athletes and stronger when compared to sedentary control groups.

Although there are studies that analyse sports separately, to our knowledge, there is no research that examines the impact of different sports together in girls. Therefore, the objective of this study was to evaluate the influence of different sports with different grades of osteogenic impact in prepubertal and pubertal girls. The result of this study will dictate which sport discipline is best to guarantee the highest bone mass development in girls at early ages.

Materials and methods

Participants

The study sample is 200 Spanish girls from the province of Madrid, Toledo and Ciudad Real, and their age is from 9 to 13 years (10.6 ± 1.5 years old; Tanner stages I–III). All participants took part in the project voluntarily and were divided into five groups according to the sport type that they practice (swimming, soccer, basketball, handball and control group). The general characteristics of each group are described in Table I, divided per prepubertal girls (Tanner I) and pubertal (Tanner II–III). Once the sample was recruited, the participants realised a series of tests to assess their degree of sexual development and their body composition (bones mass, fat mass and muscle mass).

The sample was obtained by means of contacting with sport clubs and schools in the case of girls in the control group. According to the answer given by fathers in the personal interview, the control group participants did not participate in any kind of sport. The girls answered a medical general questionnaire and other questionnaires about their physical activity habits designed ad hoc for this research, collecting information such as years of practicing their sports, bone diseases, injuries, number of hours of training per week, practice of other sport type, medicines and illness known. Other inclusion requirements were that they had to practice their sport a minimum of 3 h per week (Vicente-Rodríguez et al., 2004) and have been practicing their sports at least 8 months (Ferry, Lespessailles, Rochcongar, Duclos, & Courteix, 2013).

Parents and girls were informed about the research goal and its procedure, as well as its possible risk. Girls gave their consent verbally and their parents signed the written informed consent. The study protocols were approved by the ethical committee from the University of Castilla–La Mancha (Toledo, Spain) on 15 December 2010 (no 4520), according to the Helsinki Declaration about ethic principles of medical research in humans. All measurements were taken in the same condition, following the same actuation protocol with each participant. All evaluations were done from October to December 2013.

Table I. Descriptive characteristics of five groups of prepubertal and pubertal girls.

	Swimming (a)	Soccer (b)	Basketball (c)	Handball (d)	Control (e)
N	20	20	20	20	20
Prepubertal					
Age (year)	9.16 ± 0.69	9.63 ± 0.98	10.36 ± 0.51[a,b]	9.86 ± 0.64	10.01 ± 0.52[a]
Height (cm)	135.03 ± 6.19	141.20 ± 9.84	151.18 ± 10.74[a,b,d,e]	142.04 ± 8.24	141.15 ± 6.32
Body mass (kg)	29.01 ± 4.38	35.73 ± 8.74	43.04 ± 9.34[a]	37.50 ± 8.69[a]	38.44 ± 8.79[a]
Body mass index (BMI, kg · m^{-2})	15.85 ± 1.66	17.67 ± 2.60	18.74 ± 2.98[a]	18.52 ± 3.86	19.12 ± 3.38[a]
Years training	4.68 ± 2.00	3.85 ± 1.81	3.37 ± 1.52	3.35 ± 1.35	0
Weekly training hours	3.83 ± 1.89	3.00 ± 0.00	2.88 ± 0.39	3.05 ± 0.22	0
Total BMC (g)	973.68 ± 115.32	1171.74 ± 186.41[a]	1302.71 ± 286.73[a,e]	1133.46 ± 183.35	1122.66 ± 151.6
Total BMD (g · cm^{-2})	0.78 ± 0.06	0.86 ± 0.07[a]	0.87 ± 0.09[a]	0.84 ± 0.06	0.82 ± 0.06
Total lean mass (kg)	19.63 ± 2.46	23.70 ± 4.36	28.18 ± 5.28[a,b,e]	25.19 ± 4.83[a]	23.26 ± 5.02
Total fat mass (kg)	7.78 ± 2.81	9.39 ± 3.11	12.43 ± 4.61[a]	10.59 ± 4.75	12.65 ± 4.60[a]
Percentage of body fat	26.86 ± 6.79	26.99 ± 5.55	28.94 ± 5.62	27.81 ± 6.90	32.38 ± 5.65
Pubertal					
Age (year)	12.20 ± 0.62	12.31 ± 0.60	13.05 ± 0.34[a,b,e]	12.69 ± 0.86	12.10 ± 0.72
Height (cm)	154.55 ± 8.41	153.85 ± 6.25	163.12 ± 8.27[a,b,e]	159.96 ± 8.14	155.76 ± 8.32
Body mass (kg)	49.06 ± 11.24	45.61 ± 9.95	56.85 ± 13.20[b,e]	52.66 ± 11.21	46.39 ± 11.27
Body mass index (BMI, kg · m^{-2})	20.34 ± 3.13	19.13 ± 3.40	21.11 ± 3.51	20.35 ± 2.73	18.91 ± 3.24
Years training	4.08 ± 2.36	4.45 ± 1.70	4.35 ± 1.42	3.90 ± 1.77	0
Weekly training hours	4.44 ± 2.71	3.55 ± 0.76	3.09 ± 0.19	4.20 ± 2.78	0
Total BMC (g)	1458.32 ± 271.96	1488.10 ± 233.64[e]	1761.62 ± 409.35[a,e]	1784.40 ± 410.98[a,b,e]	1207.70 ± 131.84
Total BMD (g · cm^{-2})	0.93 ± 0.08[e]	0.95 ± 0.08[e]	1.00 ± 0.13[e]	1.01 ± 0.12[e]	0.83 ± 0.04
Total lean mass (kg)	33.72 ± 6.49[e]	29.71 ± 4.90	36.16 ± 5.95[b,e]	35.58 ± 5.89[b,e]	27.00 ± 3.96
Total fat mass (kg)	12.78 ± 5.66	12.25 ± 4.58	16.55 ± 6.44[e]	14.35 ± 5.04	11.38 ± 4.93
Percentage of body fat	25.83 ± 6.23	27.43 ± 4.71	29.32 ± 6.50	26.99 ± 4.90	27.74 ± 7.06

Notes: Differences concerning the mentioned group at a (swimming), b (soccer), c (basketball), d (handball), e (control) $P < 0.05$.
BMC: bone mineral content; BMD: bone mineral density.

Anthropometric measurements

Body mass (kg) and height (cm) were evaluated by means of the SECA scale (model 711; SECA GmbH & Co, KG, Hamburg, Germany). The body mass index (BMI) of each girl was calculated through the measurement of these variables and expressed in kg · m^{-2}.

Pubertal state

Participants were evaluated individually to determinate the degree of their sexual maturity, by means of the tool designed by Marshall and Tanner (1969). This test assesses the degree of breast development and pubic pilosity through five different states. It is a reliable method with recognised validity and has been used in many studies (Bailey et al., 1999; Vicente-Rodriguez et al., 2004). This test decides which participant belongs to a certain group. Two groups were divided: prepubertal girls (Tanner I) and pubertal girls (Tanner II and III).

Bone mass measurements

The bone mass, fat mass and lean mass were calculated by means of dual-energy X-ray absorptiometry (DXA) (Hologic Series Discovery QDR, Software Physician's Viewer, APEX System Software Version 3.1.2. Bedford, MA, USA). DXA equipment was calibrated using a lumbar spine phantom and following the Hologic guidelines. Participants were scanned in supine position, with their body and limbs fully extended and inside the limits set by the scan lines. The BMC (g) and BMD (g · cm^{-2}) were measured in the whole body and in the hip. The subregions used in this study were the following: whole body test (whole body, mean arms, mean legs and pelvis) and hip test (hip, femur neck, trochanter, intertrochanter and Ward's triangle). The lean mass was expressed in kilograms and the fat mass in percentage and kilograms.

Statistical analysis

All data were analysed statistically by means of the SPSS program, V19.0 for Windows, with the significance level in $P < 0.05$. The Kolmogórov–Smirnov test (K–S test) had, as a result, a normal distribution of the variables. The characteristics of the study groups (mean and standard error of the mean) were determined through basic descriptive test. Table I shows the descriptive data for all variables.

The differences between groups were determined using a covariance analysis (ANCOVA) including height and lean mass as covariates. These covariates were used because of the scientific evidence of their influence in bone mass (Courteix et al., 1998). To identify meaningful changes, confidence intervals (CI 95%) and effect sizes (ES; Cohen's *d*) were calculated. ES was assessed using the following criteria: 0–0.2 = trivial, 0.2–0.5 = small, 0.5–0.8 = moderate and >0.8 = large (Cohen, 1992).

A preliminary analysis indicates that the BMC and BMD differed significantly between prepubertal and peripubertal girls. Therefore, because of the interactions between Tanner groups and the bone mass variables, every analysis was made independently between prepubertal and pubertal girls.

Results

In relation to the general results in Table I, we can observe the differences in descriptive characteristics of the participants. In the prepubertal group, the basketball players had higher age than the swimmers ($P < 0.01$) and soccer players ($P < 0.05$), higher height compared with the other groups ($P < 0.05$) and higher body mass ($P < 0.01$), BMI ($P < 0.05$) and fat mass ($P < 0.01$) than the swimmers. Moreover, the basketball players had data that are significantly higher than the swimmers ($P < 0.01$), soccer players ($P < 0.05$) and control group ($P < 0.01$) in the lean mass. The control group had higher age, body mass, BMI and fat mass than the swimmers ($P < 0.01$). The handball players showed higher values of body mass ($P < 0.05$) and lean mass ($P < 0.01$), compared to the swimmers.

In the pubertal group, the basketball players had data that are significantly higher ($P < 0.05$) than the swimmers, soccer players and control group in the age and weight. In terms of body mass and lean mass, the basketball players also showed higher values than the soccer players and the control group ($P < 0.05$). The swimmers showed higher values of lean mass ($P < 0.01$) than the control group. Finally, the handball group had higher lean mass ($P < 0.01$) compared to the soccer players and the control group.

Prepubertal

The results of bone densitometry (BMC and BMD) in the five groups of prepuberty are shown in Table II. According to the BMC, there are no significant differences between any of the groups in whole body, mean arms, mean legs and Ward's triangle. The control group had between 19% and 31% less BMC in the pelvis ($P < 0.05$) compared with soccer (−26.73 g; CI 95%: −42.60 to −7.48 g; ES = 1.17), basketball (−34.36 g; CI 95%: −38.38 to −0.68 g; ES = 1.47) and handball (−43.12 g; CI 95%: −52.84 to −17.16 g; ES = 1.87). Besides, the handball players had higher BMC ($P < 0.01$) in the hip than the swimmers (5.13 g; CI 95%: −0.05 to 5.66 g, ES = 1.61). The soccer group had data that

Table II. Bone mineral density and bone mineral content at different sites in the five groups of prepubertal girls.

	Swimming (a)	Soccer (b)	Basketball (c)	Handball (d)	Control (e)
BMC (g)					
Whole body	973.68 ± 115.32	1171.74 ± 186.41	1302.71 ± 286.73	1133.46 ± 183.35	1122.66 ± 151.6
Mean arms	60.11 ± 7.77	57.95 ± 10.89	73.34 ± 17.00	59.98 ± 12.69	59.61 ± 10.58
Mean legs	160.16 ± 27.19	216.50 ± 42.44	239.87 ± 61.09	198.32 ± 38.41	207.78 ± 39.26
Pelvis	99.39 ± 16.31	136.00 ± 29.70^{e}	143.63 ± 49.87^{e}	152.39 ± 29.91^{a,e}	109.27 ± 16.10
Hip	20.34 ± 3.30	22.98 ± 3.07^{a}	25.14 ± 1.86^{a}	25.47 ± 3.07^{a}	21.03 ± 2.95
Femoral neck	2.25 ± 0.52	3.08 ± 0.44^{a,c}	3.01 ± 0.77	2.84 ± 0.66	2.73 ± 0.54
Trochanter	3.80 ± 0.71	5.30 ± 1.18^{a,c,e}	5.25 ± 1.60	4.92 ± 1.16	4.17 ± 0.67
Intertrochanter	12.13 ± 3.61	13.95 ± 2.62	18.12 ± 6.14^{e}	20.28 ± 4.18^{a,b,e}	11.87 ± 2.01
Ward's triangle	0.85 ± 0.19	0.90 ± 0.14	0.83 ± 0.17	0.84 ± 0.13	0.82 ± 0.10
BMD ($g \cdot cm^{-2}$)					
Whole body	0.78 ± 0.06	0.86 ± 0.07	0.87 ± 0.09	0.84 ± 0.06	0.82 ± 0.06
Mean arms	0.48 ± 0.05	0.54 ± 0.07	0.58 ± 0.06	0.55 ± 0.06	0.53 ± 0.06
Mean legs	0.74 ± 0.06	0.86 ± 0.09	0.93 ± 0.13	0.89 ± 0.09^{a}	0.85 ± 0.10
Pelvis	0.73 ± 0.10	0.86 ± 0.10	0.91 ± 0.14	0.86 ± 0.09	0.83 ± 0.09
Hip	0.78 ± 0.04	0.81 ± 0.05	0.80 ± 0.07	0.84 ± 0.06^{e}	0.77 ± 0.08
Femoral neck	0.61 ± 0.10	0.73 ± 0.06^{a}	0.71 ± 0.12	0.70 ± 0.09	0.68 ± 0.07
Trochanter	0.63 ± 0.06	0.70 ± 0.05	0.69 ± 0.10	0.72 ± 0.06^{a}	0.70 ± 0.04
Intertrochanter	0.80 ± 0.11	0.91 ± 0.09^{e}	0.93 ± 0.13	0.98 ± 0.10^{a,c,e}	0.83 ± 0.07
Ward's triangle	0.71 ± 0.14	0.74 ± 0.16	0.69 ± 0.14	0.70 ± 0.10	0.68 ± 0.06

Notes: Differences concerning the mentioned group at a (swimming), b (soccer), c (basketball), d (handball), e (control) $P < 0.05$.
BMC: bone mineral content; BMD: bone mineral density.
Data adjusted by height and lean mass.

are significantly higher ($P < 0.05$) than swimmers and basketball players in the femur neck and trochanter. In the case of trochanter, soccer players had a 21.3% more BMC ($P < 0.05$) than the control group (1.13 g; CI 95%: 0.31 to 1.87 g; ES = 1.22). Handball players had 31% to 42% more BMC ($P < 0.01$) than the swimming, soccer and control groups in the intertrochanter. Also, basketball players had highest values ($P < 0.01$) in the intertrochanter (6.25 g; CI 95%: 0.96 to 7.38 g; ES = 1.53), compared with the control group. Finally, swimmers had values that are significantly lower in the hip ($P < 0.05$) compared with the rest of the participants in other sport types (soccer, basketball and handball).

Regarding BMD, there were no significant differences between any of the groups in the whole body, mean arms, pelvis and Ward's triangle. However, handball players had 12% to 17% more BMD than swimmers in the variables such as mean legs ($0.15\ g \cdot cm^{-2}$; CI 95%: 0.01 to $0.17\ g \cdot cm^{-2}$; ES = 2.00) and trochanter ($0.09\ g \cdot cm^{-2}$; CI 95%: 0.01 to $0.12\ g \cdot cm^{-2}$; ES = 1.50). Soccer players had the highest values ($0.12\ g \cdot cm^{-2}$; CI 95%: 0.01 to $0.16\ g \cdot cm^{-2}$; ES = 1.50) in the femur neck compared with swimmers (all $P < 0.05$). In the intertrochanter, handball players had 5% to 19% more BMD ($P < 0.05$) than swimmers, basketball players and the control group, whereas soccer players had higher values than the control group. Finally, handball players had the highest significant differences in their hip ($P < 0.05$) with respect to the control group ($0.07\ g \cdot cm^{-2}$; CI 95%: 0.01 to $0.13\ g \cdot cm^{-2}$; ES = 1.00).

Pubertal

The results obtained from the bone densitometry (BMC and BMD) from the five girls in pubertal groups are shown in Table III. Soccer players had 2% to 22% more BMC than swimmers and 9% to 26% more BMC than the control group in variables such as whole body, mean legs, hip, femur neck and trochanter ($P < 0.05$). Also, soccer players showed a higher level in the pelvis (50.75 g; CI 95%: 3.91 to 72.77 g; ES = 2.03) and Ward's triangle (0.19 g; CI 95%: 0.03 to 0.27 g; ES = 1.65), compared with the control group (all $P < 0.05$). On the other hand, handball players had 18% to 35% more BMC than swimmers and 32% to 51% more BMC than the control group in the variables whole body, mean legs, mean arms, hip, pelvis, femur neck, trochanter and intertrochanter ($P < 0.05$). Besides, handball players obtained the highest results in pelvis (60.78 g; CI 95%: 1.66 to 69.58 g; ES = 1.43) and intertrochanter (9.95 g; CI 95%: 2.85 to 11.10 g; ES = 2.59) in front of soccer players (all $P < 0.05$). The basketball group showed the highest significant values in variables such as mean arms (9.45 g; CI 95%: 0.34 to 18.56 g; ES = 2.47), hip (9.64 g; CI 95%: 0.82 to 10.11 g; ES = 3.46) and femur neck (1.41 g; CI 95%: 0.82 to 8.11 g; ES = 2.01) compared with the control group ($P < 0.05$) and in

Table III. Bone mineral density and bone mineral content at different sites in the five groups of pubertal girls.

	Swimming (a)	Soccer (b)	Basketball (c)	Handball (d)	Control (e)
BMC (g)					
Whole body	1458.32 ± 271.96	1488.10 ± 233.64^{a,e}	1761.62 ± 409.35	1784.40 ± 410.98^{a,e}	1207.70 ± 131.84
Mean arms	86.10 ± 2.11	89.10 ± 1.98	91.90 ± 2.04^{e}	93.87 ± 2.01^{e}	82.45 ± 2.00
Mean legs	256.69 ± 8.02	316.95 ± 7.53^{a,e}	297.00 ± 7.74^{a}	299.60 ± 7.63^{a}	275.03 ± 8.73
Pelvis	194.67 ± 57.15	180.39 ± 32.41^{e}	220.80 ± 68.08	241.17 ± 79.30^{a,b,e}	129.64 ± 17.68
Hip	26.87 ± 0.80	35.08 ± 0.85^{a}	37.16 ± 0.82^{a,e}	36.22 ± 0.80^{a}	27.52 ± 0.92
Femoral neck	3.28 ± 0.67	3.59 ± 0.51^{a,e}	4.07 ± 0.75^{e}	4.04 ± 0.99^{a,e}	2.66 ± 0.65
Trochanter	5.67 ± 1.29	7.26 ± 1.41^{a,e}	6.55 ± 1.64	7.34 ± 1.52^{a,b,e}	4.74 ± 0.87
Intertrochanter	17.36 ± 4.66	14.71 ± 2.97	19.41 ± 7.31	24.66 ± 4.70^{b,c,e}	14.49 ± 5.09
Ward's triangle	0.92 ± 0.16	0.93 ± 0.15^{e}	0.92 ± 0.16	1.00 ± 0.15	0.74 ± 0.08
BMD ($g \cdot cm^{-2}$)					
Whole body	0.92 ± 0.02	0.98 ± 0.02^{e}	0.95 ± 0.02	0.98 ± 0.02^{e}	0.90 ± 0.02
Mean arms	0.63 ± 0.01^{e}	0.64 ± 0.01^{e}	0.62 ± 0.01	0.64 ± 0.01^{e}	0.59 ± 0.01
Mean legs	0.99 ± 0.10	0.99 ± 0.08	1.09 ± 0.17	1.10 ± 0.14^{a}	0.88 ± 0.06
Pelvis	0.93 ± 0.02	1.06 ± 0.02^{a,e}	1.01 ± 0.02	1.06 ± 0.02^{a,e}	0.94 ± 0.03
Hip	0.93 ± 0.03	0.96 ± 0.07^{a,e}	1.01 ± 0.06^{e}	1.03 ± 0.07^{a,e}	0.88 ± 0.07
Femoral neck	0.75 ± 0.02	0.83 ± 0.02^{e}	0.78 ± 0.02	0.83 ± 0.02^{a,e}	0.70 ± 0.02
Trochanter	0.73 ± 0.06	0.73 ± 0.08	0.76 ± 0.09	0.81 ± 0.09	0.73 ± 0.14
Intertrochanter	0.99 ± 0.03	1.04 ± 0.02^{e}	0.99 ± 0.03	1.10 ± 0.02^{a,c,e}	0.92 ± 0.03
Ward's triangle	0.76 ± 0.10	0.78 ± 0.12^{e}	0.79 ± 0.14	0.85 ± 0.12^{e}	0.66 ± 0.09

Notes: Differences concerning the mentioned group at a (swimming), b (soccer), c (basketball), d (handball), e (control) $P < 0.05$.
BMC: bone mineral content; BMD: bone mineral density.
Data adjusted by height and lean mass.

variables such as mean legs (40.31 g; CI 95%: 7.94 to 72.66 g; ES = 1.11) and hip (10.29 g; CI 95%: 1.06 to 13.76 g; ES = 3.23) compared with swimmers ($P < 0.01$).

In BMD results, the only variable that did not show significant differences in any of the groups was the trochanter. Soccer players had 12% to 23% more BMD than the control group in variables such as whole body, mean arms, femur neck, intertrochanter and Ward's triangle and 5% to 17% more BMD in pelvis and hip compared with swimmers and the control group (all $P < 0.05$). On the other hand, handball players had 17% to 30% more BMD than the control group ($P < 0.05$) in whole body (0.08 g · cm^{-2}; CI 95%: 0.01 to 0.15 g · cm^{-2}; ES = 2.25), mean arms (0.05 g · cm^{-2}; CI 95%: 0.02 to 0.08 g · cm^{-2}; ES = 2.40), hip (0.15 g · cm^{-2}; CI 95%: 0.05 to 0.18 g · cm^{-2}; ES = 2.00), pelvis (0.12 g · cm^{-2}; CI 95%: 0.02 to 0.22 g · cm^{-2}; ES = 0.58), femoral neck (0.13 g · cm^{-2}; CI 95%: 0.04 to 0.23 g · cm^{-2}; ES = 2.08), intertrochanter (0.18 g · cm^{-2}; CI 95%: 0.07 to 0.29 g · cm^{-2}; ES = 2.30) and Ward's triangle (0.19 g · cm^{-2}; CI 95%: 0.01 to 0.21 g · cm^{-2}; ES = 1.81). The swimmers group also had 10% to 16% less BMD than the handball players ($P < 0.05$) in variables such as mean legs, hip, pelvis, femoral neck and intertrochanter. Basketball players showed values that are significantly lower in the intertrochanter (−0.11 g · cm^{-2}; CI 95%: −0.21 to 0.02 g · cm^{-2}; ES = 0.59) than handball players ($P < 0.05$), but they had values that are significantly higher in the hip ($P < 0.01$) compared with the control group (0.08 g · cm^{-2}; CI 95%: 0.02 to 0.16 g · cm^{-2}; ES = 1.14). Lastly, swimmers had 15.6% more BMD than the control group (0.04 g · cm^{-2}; CI 95%: 0.01 to 0.08 g · cm^{-2}; ES = 2.00) in the variable of mean arms ($P < 0.01$).

Discussion

The goal of this study was to assess the influence of different sport types in bone mass in prepubertal and peripubertal girls. In this manner, we discover which sport type is better to obtain higher benefits at the osteogenic level in growing girls. The recommended exercise to improve BMC and BMD is mainly based on impact, i.e., plyometric exercises, jumps, races and any activity based on own body weight, as soccer, basketball and handball (Asikainen et al., 2004). The first result observed after analysing the collected data was that in the pubertal status, the bone development is more advanced, so, the differences between groups are more evident. That might be because there are higher bone mass peaks during the prepubertal stage (Długołęcka, Czeczelewski, & Raczyńska, 2011; Vicente-Rodríguez et al., 2008). That result is similar to the study made by Gustavsson et al. (2003) where they showed how the physical activity has, as a result, an increasing effect in BMD in those participants who had passed the prepubertal period. Because girls who participated in this study trained a mean of 3.2 ± 0.6 h per week, it was shown that there are osteogenic benefits with only 3 h of impact of physical activity per week, as in the study of Vicente-Rodriguez et al. (2004).

The control group has obtained the lowest results in all the variables. Zouch et al. (2008) conclude that bone mass is higher in those bones that support the impacts and changes of directions, as it happens in sports such as soccer, basketball and handball; the reason is that people who do sport and force their bones to support impacts and load have better bone health than sedentary people (Bedogni et al., 2002). According to Ermin, Owens, Ford, and Bass (2012) and Nikander, Sievänen, Heinonen, and Kannus (2005), exercises with high impact improve the BMD in femoral neck. In our study, the sports of high impact are soccer, basketball and handball, which show higher values compared with sports of low impact (swimming) and a lack of exercise.

Our results show that soccer practice improves BMC levels in comparison with swimming practice in prepubertal and pubertal girls. In terms of BMD, the practice of soccer results in higher values in the hip area if compared to sedentary activities and swimming in pubertal girls. The researchers about soccer show that this sport increases the level of BMD in comparison with swimming and sedentary in different age groups, such as adults (Creighton, Morgan, Boardley, & Brolinson, 2001; Morel, Combe, Francisco, & Bernard, 2001), teenagers (Bellew & Gehrig, 2006; Seabra et al., 2012) and prepubertal boys and girls (vicente-Rodriguez et al., 2004; Vicente-Rodriguez et al., 2003). The hip is the weight-bearing zone, which is very influenced by the mechanical loading (Nikander et al., 2005).

In relation to handball, there are only few studies that analyse the bone mass in this sport. It is a sport in which there are many jumps and sprints, which cause a big mechanical loading on the bones of the lower extremities because of the reaction forces made during the races (Freychat, Belli, Carret, & Lacour, 1996). Also, there is a big involvement of the upper extremities in actions such as shooting and blocking (Vicente-Rodriguez et al., 2004). All these make the handball a sport that brings big benefits on bone mass (Calbet, Herrera, & Rodríguez, 1999). Besides, Vicente-Rodriguez et al. (2004) showed better BMD and BMC in variables such as the pelvis, lower body and femur neck in handball players in comparison with the control group. Our results support this conclusion because the participation in handball is associated with higher BMC and BMD in girls, especially during the pubertal stage.

The second group with the lowest values of bone mass is the swimming group. In prepubertal girls, a higher BMD in the variable of mean arms was observed, compared with the control group. It might be because they develop more muscle mass in the upper body; therefore, it is related to improve the bone mass (Andreoli et al., 2001). In fact, previous studies in boys have demonstrated that lean mass is the best predictor of deposition of bone mass (Faulkner et al., 1993). This may be because more developed muscles are able to apply higher forces on bones where they are joined together (Vicente-Rodriguez et al., 2004). Results demonstrate that because of water weightlessness, bones obtain fewer stimuli than when someone does sport outside it. For that reason, in sports such as basketball, soccer and handball in which the player must support his own weight, the values of BMC and BMD are higher (Derman et al., 2008; González-Aramendi, 2003).

Basketball players have obtained the highest significant values in some variables, compared with swimmers and the control group. Despite the fact that there are only few differences, we support the studies carried out by Carbuhn, Fernandez, Bragg, Green, and Crouse (2010) and Banfi, Lombardi, Colombini, and Lippi (2010), where they concluded that those people who do sport with jumps, for example, soccer, basketball and handball, have higher levels of BMC and BMD. In basketball, these differences have only been in BMC and not in BMD.

This study could include more sports because it would have been interested to see if higher values of BMC and BMD are produced in other sports with higher and lower osteogenic impact. Also, we could have included boys to see if there are differences between sports and gender, as it is done in other studies (Gracia-Marco et al., 2011). Moreover, a larger sample size could have made the differences between groups clearer, especially in basketball, where the SE (standard error of the mean) is quite high. In future research, it might be interesting to develop this study longitudinally so as to see if there is a cause–effect relation. Longitudinal studies are required to check if elevated values of BMC and BMD at this stage can be maintained in adulthood.

Conclusion

Our study shows that the type of sport is a variable that can have an influence on girls' bone health during childhood. The results of this research can be useful as a prevention method of bone diseases in adulthood. In relation to the academic formation years in Spain, Physical Education is divided into stages in which different sports (including impact and non-impact sports) are learnt. The schools are relatively free to organise the contents of these stages, so differences about the stages can be found at different schools. Even so, this study demonstrated that physical activity done at schools, just 2 h per week, is not enough to improve bone health at early ages, as affirmed by previous studies (McKay et al., 2000; Valdimarsson, Linden, Johnell, Gardsell, & Karlsson, 2006). In short, we conclude that the practice of a sport with high osteogenic impact at early ages ensures greater accumulation of bone mass compared with sports with low osteogenic impact and with lack of sports. Therefore, these types of sports may constitute a preventive measure in osteoporosis in the future.

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