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ORIGINAL ARTICLE

Body composition, strength static and isokinetic, and bone health: comparative study between active adults and amateur soccer players

Composição corporal, força estática e isocinética, e saúde óssea: estudo comparativo entre adultos ativos e futebolistas amadores

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ABSTRACT

Objective: To compare tissue composition, total and regional bone mineral content and bone mineral density, static hand grip and knee joint isokinetic strength between amateur soccer players and Control Group. **Methods:** Cross-sectional study. Air displacement plethysmography was used to estimate body volume and, in turn, density. Body composition, bone mineral content and bone mineral density were assessed for the whole body and at standardized regions using dual energy X-ray absorptiometry. Static grip strength was assessed with an adjustable dynamometer, and peak torque derived from isokinetic strength dynamometer (concentric muscular knee actions at 60°/s). Magnitude of the differences between groups was examined using d-Cohen. **Results:** Compared to healthy active adults, soccer players showed larger values of whole body bone mineral content (+651g; d=1.60; p<0.01). In addition, differences between groups were large for whole body bone mineral density (d=1.20 to 1.90; p<0.01): lumbar spine, *i.e.* L1-L4 (+19.4%), upper limbs (+8.6%) and lower limbs (+16.8%). Soccer players attained larger mean values in strength test given by static hand grip protocol (+5.6kg, d=0.99; p<0.01). **Conclusion:** Soccer adequately regulates body composition and is associated better bone health parameters (bone mineral content and density at whole-body and at particular sites exposed to mechanical loadings).

Keywords: Sports; Isokinetic dynamometer; Body composition; Muscle strength

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RESUMO

Objetivo: Comparar a composição de tecidos, o conteúdo mineral ósseo e a densidade mineral óssea totais e por regiões do corpo, a força de preensão manual estática, e força isocinética da articulação do joelho, entre um grupo de jogadores de futebol amadores e um Grupo Controle. **Métodos:** Estudo transversal utilizando pletismografia de ar deslocado para estimar o volume corporal, para subsequente cálculo da densidade corporal. A composição de tecidos, o conteúdo mineral ósseo e a densidade mineral óssea foram avaliados para o corpo todo e regiões padronizadas através da absorciometria de raios-X de dupla energia. A força de preensão manual estática foi avaliada por um dinamômetro ajustável. Os momentos máximos de força das ações musculares concêntricas para os extensores e flexores do joelho foram avaliados pela dinamometria isocinética (60°/s). Foi calculado o valor d-Cohen para apreciar a magnitude do efeito das diferenças entre grupos. **Resultados:** Os futebolistas apresentaram níveis superiores de conteúdo mineral ósseo em comparação com os adultos ativos do Grupo Controle (+651g; d=1,60; p<0,01) e obtiveram valores superiores de densidade mineral óssea (d: 1,20 a 1,90; p<0,01) para a coluna lombar, L1-L4 (+19,4%), membros superiores (+8,6%) e membros inferiores (+16,8%). Para a força de preensão (estática) a diferença foi moderada (d=0,99; p<0,01) com valores mais elevados apresentados pelo futebolistas (+5,6kg; d=0,99; p<0,01). **Conclusão:** A prática de futebol promove uma regulação adequada da composição corporal (tecidos magro e gordo) e ganhos na densidade mineral óssea, mais acentuada em partes do corpo com maior exposição aos impactos mecânicos da atividade motora.

Descritores: Esportes; Dinamômetria isocinética; Composição corporal; Força muscular

INTRODUCTION

Physical activity corresponds to the movement produced by skeletal muscle and entails daily energy expenditure in three different contexts, namely daily living, occupational and leisure activities. Obesity and related chronic metabolic disorders have been attracting significant attention from a public health perspective.[1,2] Not surprisingly, the battle against obesity and physical inactivity, in particular, have led to the emergence of a preventive paradigm in behavioral medicine, which focuses on lifestyle rather than communicable diseases factors. A high value is attributed to interventions aimed to promote physical activity,[3] and special emphasis is placed on high-intensity activities, which are more effective for body composition regulation.[4]

Adiposity, especially in adult life, may lead to several metabolic disorders, which are risk factors for metabolic syndrome[5] and cardiovascular disease-related mortality.[6] In contrast, lean mass appears to be protective against cardiovascular disease-related mortality.[6] Also, muscle mass development may partially attenuate the association between higher adiposity and cardiovascular diseases,[6] being an important component of adult health.

Moreover, bone health is another relevant issue in modern society, given the growing population aging and the resulting loss of functional autonomy, with high impact on the quality of life of older adults and significant healthcare, social and familiar implications. Researches investigating associations between functional indicators, body composition and bone health parameters are increasingly being undertaken, and emphasize the holistic view of health and quality of life.

Even during aging, women have a higher risk of fractures due to decreased periosteal apposition,[7] men aged over 50 years have a 27% risk of osteoporotic fracture.[8] Physical activity has been consistently associated with metabolic, mental and cardiovascular health benefits, regardless of age and sex, and the same holds true for bone health indicators. Increased bone mineral content (BMC) in response to muscular strength exercise is somewhat of a consensus, and mechanical load is thought to play a significant role in bone strengthening.[9-11] However, associations between sports practice and bone health remain unclear - both from a tissue component and specific strength test (relatively to tested muscle groups and forms of manifestation of static and isokinetic forces perspective).[12,13]

OBJECTIVE

To compare fat and lean tissue mass, mineral bone content and density, and physical fitness indicators between experienced amateur competitive soccer players and physically active young adults of similar age but not involved in officially recognized sports.

METHODS

Data collection was carried out in compliance with international ethical standards with humans,[14] after approval by the Ethics Committee of the *Universidade de Coimbra* (CE/FCDEF-UC/00102014). All participants were informed about the aims, the protocol and procedures, and signed written informed consent. Participation was voluntary and each participant could withdraw at any time.

Sample

The sample comprised 66 male adults aged 18.5 to 29.9 years, allocated in one of two groups: healthy adults (G1, n=35) and amateur soccer players (G2, n=31). At the G1 participants had no means of transport, kept on average more than 10 thousand steps per day, had no diseases, including neuromuscular limitations, and no sports practice over the last 5 years or longer (participation in school sports was limited to one subject). The G2 was locally recruited (*i.e.*, third national division). Soccer practice experience (years) was provided by the selected clubs and confirmed by the respective Association. Inclusion criteria for G2 were as follows: minimum of 4 years of participation in competitive soccer; at least four weekly training sessions in clubs registered at *Federação Portuguesa de Futebol.* The mean soccer practice experience in the G2 was 14.5±4.2 years.

Anthropometric measurements
Height was measured to the nearest 0.1cm using a stadiometer (Harpenden Stadiometer 98.603, Holtain Ltd., Crosswell, UK).

Air-displacement plethysmography
Body volume and body density were determined using a Bod Pod Body Composition System (model Bod Pod 2006, Life Measurement, Inc., Concord, USA). Body mass was determined to the nearest 0.1kg using an electronic scale connected to the Bod Pod system. Calibration was performed prior to individual test, using a 50.225L cylinder. Participants wore lycra swimsuit and a cap and were tested, sited in the chamber of the Bod Pod, motionless while the system estimated the body volume two consecutive times and, when necessary, three times, considered valid if their difference was less than 150mL. Thoracic gas volume was predicted based on body volume. Body density (body mass/body volume) was calculated and then used for the estimation of the fat tissue percentage.[15] A single and experienced investigator performed measurements.

Dual-energy X-ray absorptiometry
Body composition parameters were measured using dual-energy X-ray absorptiometry (DXA), with patients being assessed in the supine position. A Lunar (DPX-PRO/NT/MD+ DXA) machine was used for lean tissue mass (LTM), fat tissue mass (FTM), BMC and bone mineral density (BMD) quantification. An experienced technician acted in a certified clinic and performed all measurements.

Handgrip dynamometry (static strength)
Upper limb isometric strength was assessed using a mechanical dynamometer (Hand Dynamometer, Lafayette 78010, USA). Maximal handgrip strength (kg) was measured bilaterally with limbs unsupported.

Isokinetic dynamometry
Isokinetic testing (Biodex System 3, Shirley, New York, USA) of knee extensor and flexor muscles was performed in concentric mode (CON), at $60°/s^{-1}$ angular velocity. Participants were assessed in the sitting position with the lever arm aligned with the lateral epicondyle of the knee and the stabilization strap positioned over the tibiotarsal joint, 3 to 5cm distant from the lateral malleolus of the tibia. Participants were instructed to keep their hands on their shoulders throughout the test. The range of motion was defined according to maximal voluntary extension (0° to 90° knee flexion). Lever arm calibration was performed at the start of each measurement for gravity effect correction (at 30 degrees position). Participants were instructed to perform the maximum voluntary muscle contraction. One set of five consecutive maximum intensity knee extension and flexion repetitions were performed and the peak torque (PT in N.m) recorded. Warm up consisted of cycling exercise (Monark Ergomedic 894E Peak Bike, Monark AB, Varberg, Sweden) with minimal resistance (≤60rpm), three static stretching exercises (20 seconds) for the quadriceps, hamstring and adductor muscles, and three standardized extension/flexion repetitions at the test velocity. Data filtering and curves windowing were performed using AcqKnowledge software, version 4.1 (Biopac Systems, Inc., California, USA).

Statistical analysis
Descriptive statistics (range, mean, standard error of the mean, 95% confidence interval of the mean and standard deviation) were calculated for the overall sample. Data normality was tested using the Kolmogorov-Smirnov test. The effect size of intergroup comparisons was estimated using Cohen's d. Statistical analyses were performed using IBM Statistical Package for Social Science (SPSS) version 22.0 (SPSS, Inc., Chicago, Ilinois, USA) and the level of significance set at 5%.

RESULTS
Table 1 summarized descriptive statistics for anthropometry (including air displacement plethysmography), DXA whole body and regional body composition, and parameters extracted from handgrip and isokinetic dynamometry. Several variables violated the assumption of normal distribution reflecting intergroup heterogeneity.

Characteristics of the healthy adults (G1) and soccer players (G2) are presented in table 2. Soccer players had significantly higher body density (+0.016L/kg; d=1.22). Healthy adults displayed higher percentages

Table 1. Descriptive statistics and test for normal distribution

Variable	Minimum-Maximum	Mean			Standard deviation	Normality (Kolmogorov-Smirnov)	
		Value	Standard error	95%CI		p value	p value
Chronological age, years	18.48-29.93	22.49	0.30	(21.80; 23.17)	2.80	0.146	<0.01
Height, cm	155.8-191.5	176.9	0.7	(175.4; 178.4)	6.0	0.068	0.20
Body mass, kg	50.1-101.9	74.6	1.3	(71.8; 77.2)	10.9	0.142	<0.01
Body volume, L	46.2-100.2	70.1	1.4	(67.3; 72.9)	11.2	0.160	<0.01
Body density, L/kg	1.018-1.092	1.066	0.002	(1.061;1.070)	0.019	0.139	<0.01
LTM: whole body, kg	44.57-71.80	56.82	0.80	(55.53; 58.44)	6.50	0.095	0.20
LTM: lower limbs, kg	6.06-12.49	8.79	0.18	(8.42; 9.16)	1.49	0.106	0.06
LTM: upper limbs, kg	2.32-7.65	4.75	0.09	(4.58; 4.92)	0.69	0.111	0.04
FTM: whole body, kg	2.39-36.74	13.25	1.04	(11.18; 15.33)	8.44	0.167	<0.01
FTM: whole body, %	4.8-39.1	17.3	1.1	(15.1; 19.4)	9.7	0.154	<0.01
FTM: lower limbs, kg	0.41-8.61	2.30	0.24	(1.82; 2.79)	1.97	0.168	<0.01
FTM: upper limbs, kg	0.14-2.63	0.62	0.08	(0.45; 0.78)	0.07	0.314	<0.01
BMC: whole body, g	2220-4910	3370	650	(3240; 3500)	525	0.079	0.20
BMD: whole body, g/cm^2	1.029-1.576	1.302	0.015	(1.273; 1.332)	0.120	0.052	0.20
BMD: lumbar (L1-L4), g/cm^2	0.931-1.852	1.307	0.023	(1.312; 1.408)	0.193	0.089	0.20
BMD: lower limbs, g/cm^2	1.370-2.257	1.741	0.025	(1.691; 1.791)	0.203	0.077	0.20
BMD: upper limbs, g/cm^2	0.900-1.303	1.109	0.011	(1.073; 1.111)	0.091	0.050	0.20
PT: knee extensors (60°/s), N.m	138-306	214	4	(206; 223)	35	0.061	0.20
PT: knee flexors (60°/s), N.m	45-164	113	3	(107; 120)	25	0.066	0.20
Hand grip strength, kg	30.0-61.5	45.1	0.8	(43.6; 46.7)	6.1	0.071	0.20

Results presented as range, mean, standard error of the mean, 95% confidence limits of the mean, standard deviation.
95%CI: 95% confidence interval; LTM: lean tissue mass; FTM: fat tissue mass; BMC: bone mineral content; BMD: bone mineral density; L1-L4: 1st lumbar to 4th lumbar; PT: peak torque.

Table 2. Descriptive statistics by group and mean differences on anthropometry and functional variable means

Variable	Dependent variable		Difference (CI95%)	*t* Student		Effect size	
	G1 (n=35)	G2 (n=31)		*t*	p value	d	(qualitative)
Chronological age, years	21.65 (20.74; 22.54)	23.44 (22.48; 24.39)					
Training experience, years		14.4 (13.3; 15.5)					
Stature, cm	175.1 (173.2; 177.0)	178.9 (176.9; 180.9)	-3.7 (-6.5; -1.0)	-2.702	<0.01	0.67	Moderate
Body mass, kg	73.7 (70.0; 77.4)	75.6 (71.7; 79.5)	-1.9 (-7.1; +3.3)	-0.724	0.47	0.16	Trivial
Body density, L/kg	1.059 (1.053; 1.065)	1.075 (1.068; 1.081)	-0.016 (-0.024; -0.007)	-3.838	<0.01	1.22	Large
LTM: whole body, kg	52.76 (51.12; 54.41)	61.41 (59.66; 63.16)	-8.65 (-11.05; -6.25)	-7.195	<0.01	1.75	Large
LTM: upper limbs, kg	4.85 (4.62; 4.39)	4.64 (4.39; 4.89)	0.21 (-0.13; +0.55)	1.247	0.21	0.30	Small
LTM: lower limbs, kg	9.60 (9.18; 10.01)	7.89 (7.434; 8.32)	1.72 (+1.116; +2.321)	5.703	<0.01	1.39	Large
FTM: whole body, %	20.6 (17.9; 23.1)	13.5 (10.6; 16.3)	7.1 (+3.1; +11.0)	3.735	<0.05	0.87	Moderate
FTM: whole body, kg	15.82 (13.11; 18.54)	10.35 (7.47; 13.24)	5.47 (+1.50; +9.43)	2.756	<0.01	0.67	Moderate
FTM: upper limbs, kg	0.92 (0.71; 1.12)	0.28 (0.06; 0.49)	0.64 (+0.35; +0.94)	4.317	<0.01	1.05	Moderate
FTM: lower limbs, kg	3.50 (2.99; 4.01)	0.95 (0.41; 1.49)	2.55 (+1.81; +3.29)	6.888	<0.01	1.67	Large
BMC: whole body, g	3.06 (2.93; 3.21)	3.72 (3.57; 3.76)	-0.65 (-0.85; -0.45)	-6.369	<0.01	1.60	Large
BMD: whole body, g/cm^2	1.23 (1.20; 1.27)	1.38 (1.35; 1.41)	-0.14 (-0.19; -0.10)	-1.593	<0.01	0.99	Moderate
BMD: lumbar (L1-L4), g/cm^2	1.24 (1.20; 1.29)	1.49 (1.43; 1.54)	-0.24 (-0.31; -0.17)	-6.423	<0.01	1.90	Large
BMD: upper limbs, g/cm^2	1.05 (1.03; 1.07)	1.14 (1.12; 1.16)	-0.09 (-0.13; -0.05)	- 4.874	<0.01	1.22	Large
BMD: lower limbs, g/cm^2	1.61 (1.56; 1.66)	1.88 (1.83; 1.94)	-0.27 (-0.35; -0.20)	-7.554	<0.01	1.90	Large
PT: knee extensors, N.m	212 (200; 224)	217 (205; 230)	-5 (-22; +12)	-0.282	0.562	0.14	Trivial
PT: knee flexors, N.m	113 (104; 121)	114 (104; 123)	-1 (-14; +11)	-0.223	0.824	0.03	Trivial
Hand grip strength, kg	42.5 (40.6; 44.3)	48.1 (46.1; 50.1)	-5.6 (-8.3; -2.9)	-4.156	<0.01	0.99	Moderate

Resultads expressed as mean value (95% confidence interval).
G1: health adults; G2: adult soccer players; LTM: lean tissue mass; FTM: fat tissue mass; BMC: bone mineal content; BMD: bone mineral density; L1-L4: 1st lumbar to 4th lumbar; PT: peak torque.

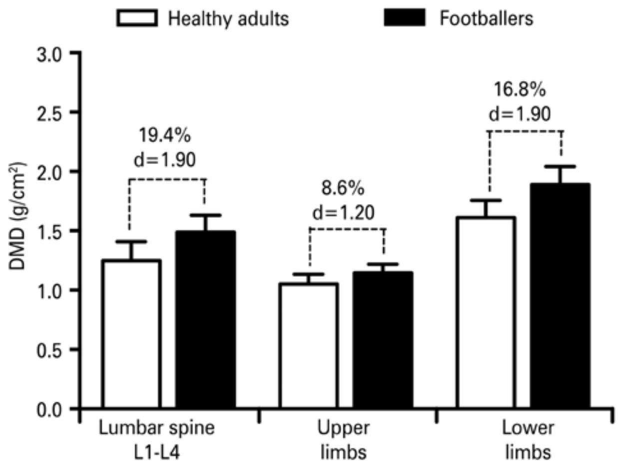

Figure 1. Lumbar spine, upper and lower limb bone mineral density differences between healthy adults and adult amateur soccer players

of fat tissue at the different regions of interest (d=0.67 to 1.67) and lean soft tissue (d=1.39) at the lower limbs. Soccer players had significantly greater BMC (+651g; d=1.60) and BMD (lumbar L1 - L4: +0.24g/cm^2; +19.4%; d=1.90; upper limbs: +0.09g/cm^2; +8.6%; d=1.20; lower limbs: +0.27g/cm^{-2}; +16.8%; d=1.90) than healthy adults as shown in figure 1. Soccer players attained better performance in the static grip strength (+ 5.6kg; d=0.99).

DISCUSSION

Intrinsic (*e.g.*, sex and age) and extrinsic (*e.g.*, diet and physical exercise) factors have been associated with bone mass differences.[16] Extrinsic factors may be regulated according to individual health. In this study, body composition, bone health and functional parameters were compared between active healthy adults not practicing any particular sport and amateur competitive soccer players. Major findings suggest that soccer practice, which is associated with mechanical loads, promote largely whole body BMC and moderately whole body BMD increase, with more significant increments (effect size) in specific regions (lumbar spine and appendicular regions, *i.e.*, upper and lower limbs). This is true even when the effect size of differences in forms of muscle effort is low (trivial or moderate). Also, higher fat tissue mass indices in healthy adults suggest specific sports programs may impact energy balance, and therefore the maintenance of ideal body mass, or promote improvement of bone health indicators, which persist even when sports practice is not associated with high levels of competition and relevant functional differences between sports practitioners and physically active healthy adults are lacking.

Findings of this study confirm results of previous study[17] reporting 12% higher whole body BMD in soccer players compared to controls. However, contrary to expectations, isokinetic strength did not differ between groups. Similar isokinetic strength across individuals in this sample indicates their respective levels of physical activity was sufficient to induce quantitative and functional muscle adaptations in all cases, and suggests bone adaptations require higher levels of specific stimuli (*i.e.*, mechanical impact).[9] Higher strength values in soccer players compared to healthy adults support the premise that the user-friendly handgrip test has good diagnostic capability regarding overall musculoskeletal status, and may also be used for brief assessment of undernourished groups.[18]

Bone mineral content did not differ significantly in one study comparing soccer players and runners.[19] Nonetheless, in this study soccer players were compared with active healthy adults not necessarily involved in any specific sports practice. Being a high mechanical impact sport, soccer may be assumed to promote increased BMC and BMD from an early age.[20] Higher BMC and BMD values in response to soccer practice may have occurred via different pathways. Firstly, the mechanical impact associated with this particular sport must be accounted for. Secondly, soccer is played outdoors, therefore soccer players tend to have higher vitamin D levels, which is associated with higher BMC and BMD.[21] Finally, given the recreational nature of soccer playing among participants of this study, their training volume was also higher, which is another factor associated with higher BMC and BMD.[22]

An inverse association between lean and fat tissue mass in different body segments could be observed, which can be derived from high intensity sprints, jumps, accelerations and decelerations associated with soccer practice.[23] Although soccer players had less lean tissue mass compared to active adults, they also had about three times less lower limb fat, suggesting a higher lean/fat tissue ratio in this group. This finding emphasizes the relevance of physical activity regimens with varying intensity, acyclic movement patterns and mechanical impact components. One study with 88 peripubertal female participants (6 to 11 years; 30 highly competitive gymnasts training 16 hours per week on average, 29 gymnasts training 1 to 5 hours per week, and 29 youth not practicing gymnastics)[24] and evaluating lean tissue mass, upper limb BMC and BMD, forearm bone geometry and results of three upper limb functional performance tests concluded that gymnasts with more modest training regimens achieved higher functional performance and had more favorable bone tissue geometry and resilience values, while total muscle mass and maximum forearm muscle cross-sectional area were larger in the elite gymnast group.

Results of the present study have clear practical applications. Having in mind the high incidence and prevalence of osteoporotic injuries[25,26] and the growing rates of obesity globally,[2] sports practice may not only enhance BMC and BMD but also reduce body fat. Soccer is a largely practiced high impact, high intensity sport[27] and, according to findings of this study, should be sufficient to enhance BMD.

This study has some limitations. The use of a cross-sectional data derived from a relatively small sample comprising exclusively male adults limit the result extrapolation to other populations. Future investigations of similar differences in younger subjects and the inclusion of female individuals, with greater body size and composition variability, are warranted and should provide a starting point for the design of programs and interventions aimed at bone health promotion during growth, maturation and development in children and youth, with increased osteoporosis prevention potential. Also, the type of exercise performed by participants in both groups was not controlled, as the only criteria adopted were the practice of soccer and being physically active.

CONCLUSION

Soccer practice, even at the recreational level, may lead to an increased bone mineral content, bone mineral density, reduced body fat and greater handgrip strength. Soccer is a good intervention alternative for achievement and maintenance of ideal body mass, with added benefits regarding lean, fat and bone tissue composition.

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