Influence of different playing surfaces on bone mass accretion in male adolescent football players: a one-season study.

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Keywords:	Soccer, body composition, bone density, bone mass, third-generation artificial turf
Abstract:	There are different surfaces on which football is played, but their influence on bone mass accretion still remains unknown. The aims of this study were to compare bone mass accretion between football players and controls and evaluate the influence of two different playing surfaces on bone accretion. Twenty-seven male football players (13.2 \pm 0.5 y) and 15 controls (12.6 \pm 1.1 y) participated in this study. Football players were

classified into two groups according to the surface they trained on: 14 on third-generation artificial turf with elastic layer (3G-EL) and 13 on third-generation artificial turf without elastic layer (3G-NEL). Bone mineral content (BMC) and areal bone mineral density (aBMD) were measured with dual-energy X-ray absorptiometry. Bone mineral apparent density (BMAD) variables were calculated. Bone geometry and strength of the non-dominant tibia were assessed with peripheral quantitative computed tomography. For both football players and controls, bone variables measured at subtotal body, lumbar spine, legs and tibia (p<0.05) significantly increased. Based on the time spent practicing football, the increase in aBMD for the legs (p<0.05) was higher in football players than controls. Moreover, lumbar spine BMAD increased more in 3G-NEL players in comparison with 3G-EL players (p<0.05). Playing football on 3G-EL and 3G-NEL seems to positively affect bone mass during growth. After playing for one season on these playing surfaces, football practice on 3G-NEL with the lower shock absorption seems to have produced the highest increment in aBMD at lumbar spine. Thus, football practice on surfaces with lower shock absorption could provide an extra benefit on bone health.
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8	4	season study
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30 31	21	body, lumbar spine, legs and tibia ($p < 0.05$) significantly increased. Based on the time
32	22	spent practicing football, the increase in aBMD for the legs ($p < 0.05$) was higher in
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36	25 26	season on these playing surfaces, football practice on 3G-NEL with the lower shock
37	20	absorption seems to have produced the highest increment in aBMD at lumbar spine
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39 40	29	benefit on bone health.
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43 44	31	Soccer, body composition, bone density, bone mass, third-generation artificial turf
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Introduction

Childhood and adolescence are crucial periods for bone building and children should reduce the risk of having low bone mass¹ by means of physical exercise and sports participation.² In fact, a recent review by Weaver et al. ³ graded the positive effects of physical activity on bone mass with a grade A (maximum level of evidence). However, the review did not include the effects of individual sports. A study by Mautalen⁴ highlighted the positive effects of football practice on bone mass during adolescent growth. These positive effects on bone mass are mainly explained by the fact that football is a weight-bearing sport which is characterized by high-impact actions, such as accelerations, decelerations, changes of direction, jumps and kicks.⁵ Furthermore, this sport has great importance for young people because football is one of the most, if not the most, practiced sport worldwide.⁶ The positive benefits of football practice on bone tissue have been amply demonstrated;⁷ higher levels of bone mineral content (BMC) or areal bone mineral density (aBMD) levels when compared to a control group (CG) have been reported in youth football players.⁸⁻¹⁰ More importantly, the positive effects generated by football have been shown to remain after 1- and 3-year follow-ups.^{8, 11-15} To assess bone mass, most of studies performed on youth football teams have used dual-energy X-ray absorptiometry (DXA). Although DXA is capable of explaining up to 60% of the variance in bone strength, it cannot directly measure bone geometry variables.¹⁶ For this reason, some studies have used other techniques, such as hip structural analysis (HSA)¹⁴ and peripheral quantitative computed tomography (pOCT)¹⁷⁻¹⁹ for measuring bone geometry in football players. HSA is derived from hip scan images acquired by DXA. According to the International Society for Clinical Densitometry (ISCD), the hip is not the recommended site for evaluating BMC and aBMD in children and adolescents due to its high variability during bone development.²⁰ Thus, bone geometry measured with HSA in young populations could be biased as described above. In contrast, pQCT, which is not influenced by bone size like DXA, measures trabecular and cortical bone, allowing for evaluation of the tibia, which is directly affected by football. Up to now, only one study has compared young male football players and the CG, showing higher bone geometry in football players than the CG.¹⁹ On the other hand, to the authors' knowledge, there are no studies which have evaluated the effects of playing football compared to a population not engaged in any sport on bone geometry and strength measured by pOCT during growth. Ground reaction forces could be described as one of the main contributing factors influencing bone accretion. However, properties of playing surfaces change over time, which may affect this relationship. The number of natural grass football fields is decreasing, whereas the number of artificial turf pitches is increasing.²¹ To replicate the playing properties of natural grass football fields, new developments in construction methods of artificial turf fields include the use of materials such as rubber and sand infill.²¹ At the same time, different infill materials create different mechanical characteristics.²² Thus, the inclusion or lack of an elastic layer in the installation process

generates differences in shock absorption and vertical deformation forces.²² Due to these mechanical properties, different types of surfaces may evoke different loads to the bone. To the authors' knowledge, only Plaza-Carmona et al.²³ compared the influence

of third-generation artificial turf fields and soil football fields on bone mass accrual in

male children football players, finding no differences for BMC and aBMD. However,

the influence of recent third-generation artificial turfs with an elastic layer (3G-EL) and

without an elastic layer (3G-NEL) on bone tissue in young football players is yet unknown. During adolescent growth, the short-term effects on bone mass while playing football versus not playing a sport should be studied more deeply, especially bone geometry and strength. Therefore, the aims of this study were: 1) to compare BMC, aBMD, bone mineral apparent density (BMAD), bone geometry and bone strength between young male football players and the CG; and 2) to evaluate the influence of training and playing football on two playing surfaces (3G-EL or 3G-NEL) on previous bone values. The authors hypothesized that all adolescents will improve bone mass and strength values throughout the season, but football players will have increased bone mass, geometry and strength compared to the CG. Also, those football players who play on 3G-NEL during this period will exhibit additional bone mass gain in comparison with

93 SO-NEL during this period will exhibit additional bone mass gain in comparison with
 94 players on the 3G-EL due to the fact that the 3G-NEL surface will have lower shock
 95 absorption than the 3G-EL. Therefore, the football players will receive increased loads.

97 Methods

98 Participants

Two football clubs and two high schools in Aragon (Spain) were invited to participate. Although 35 football players and 23 controls agreed to participate, 16 participants were excluded because of the following reasons: three football players and three controls did not perform the second measurement citation, four football players and two controls did not wear the accelerometer, and one football player and three controls had blurred DXA or pQCT images. Consequently, the final sample of 27 male football players (13.17±0.52 years) and 15 male controls (CG; 12.58±1.11 years) participated in this study (Fig. 1). Football players were split into two groups according to the surface where they trained and played: 3G-EL (n=14; 13.01±0.61 years) and 3G-NEL (n=13; 13.35±0.34 years). Although the CG were physically active, they were not regularly engaged in any sport. Measurements were performed in Zaragoza (Spain) at the beginning of the season (October-December 2013) and end of the season (May-July 2014) with a mean measurement time of 31.5 ± 6.2 weeks, which followed the protocol recommended by the ISCD²⁰ to evaluate bone changes between DXA scans at a minimum interval of six months.

The years of exposure to football practice prior to the beginning of this study were 5±2 years in 3G-EL players and 5±1 years in 3G-NEL players. Hours of training per week were individually quantified based on the number of training sessions in which the player participated (3G-EL players=2.6±0.2 hours/week; 3G-NEL players=2.3±0.3 hours/week). A sport scientist monitored the type of exercises performed by each team during their training throughout the season. Each training session lasted approximately 90 min, including 5-min warm-up consisting of low-intensity running; 5-10 min of low-intensity games; 60 min of technical football exercises (passing, kicking, running, dribbling); and 5-10 minutes of cool down stretching exercises. Taking into account training sessions and matches played at home and away grounds, the percentage of time spent on surfaces included in the present study were 80.2% for 3G-EL players and 78.1% for 3G-NEL players (i.e. away games reduced the percentages of per time on the study field). Participants, parents and coaches of each club were informed about the protocol, and

Participants, parents and coaches of each club were informed about the protocol, and
 the possible benefits and risks associated with this study. Written informed consent
 from parents and verbal assent from the participants were obtained. This study was
 performed in accordance with the Declaration of Helsinki 1961 (revision of Fortaleza

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3	131	2013). The protocol was approved by the Ethics Committee of Clinical Research from
4	132	the Government of Aragon (CEICA Spain) [C J PI13/0091] The research was
5	133	registered in a public database Clinicaltrials gov [NCT02399553] This longitudinal
6	134	study is part of a larger randomized controlled trial that evaluated the effect of football
7	105	study is part of a larger failed inized controlled that that evaluated the effect of football
8	135	surfaces and boot model on bone mass and strength in male and temale adolescent
9	136	football players. However, female football players were not included in the present
10	137	manuscript because of the low number of participants that could be evaluated in the
11	138	second assessment (some players stopped playing and others did not perform to the
12	139	evaluation). The Transparent Reporting of Evaluations with Nonrandomized Designs
13	140	(TREND) Statement was used as a guideline for reporting non-randomized trials. ²⁴
14	141	
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10	142	Inclusion criteria
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10	143	The inclusion criteria established for the project included: Caucasian, a minimum of one
20	144	year of football practice on the playing surface prior to the beginning of the
21	145	measurements (football players), or not regularly engaged in any sport (controls),
22	146	between the ages of 11 and 14 and free of any medications affecting bone properties.
23	147	
24	117	
25	148	Anthropometric measurements
26		
27	149	Height (stadiometer SECA 225, SECA, Hamburg, Germany; to the nearest 0.1 cm) and
28	150	weight (scale SECA 861, SECA, Hamburg, Germany; to the nearest 0.1 kg) were
29	151	measured without shoes and with minimum clothing. Body mass index (BMI) was
30	152	calculated by dividing the participant's weight (kg) by the squared height (m^2) .
31	153	
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33	154	Maturity status
34	4	
35	155	Pubertal maturity was determined according to the stages proposed by Tanner and
36	156	Whitehouse ²⁵ and using a self-assessment method which has been shown to be a valid
3/	157	and reliable technique. ²⁶
30	158	
40		$C \rightarrow 1$
40	159	Calcium intake
42	160	Millionams of daily calcium intake were calculated by a validated calcium food
43	161	fraguency questionnaire 27 Participants were asked how many times per day, week or
44	101	menths they consumed colorium rich foods
45	162	months they consumed calcium-fich loods.
46	163	
47	1(1	Physical activity magginements
48	104	T hysical activity measurements
49	165	Physical activity was assessed with triaxial accelerometers (GENEActiv developed by
50	166	Unilever Discover Colworth UK and distributed by ActivInsights Ltd Kimbolton
51	167	Cambridge LIK) These accelerometers have been calibrated and validated for
52	160	measuring physical activity in children and adolescents on different hady locations
53	160	including the right and the left wrists ²⁸ All next innexts were CENEA devices on their
54	109	including the right and the left wrists. ²⁰ All participants wore GENEA devices on their
55	170	non-dominant wrist tor seven days, except for football players who had to remove the
56	171	accelerometer during official matches. Data were recorded at 30 Hz and analysed at 1-s
5/	172	epochs. These data were taken within a duration of seven days towards the end of the
50	173	season (May-July 2014). Accelerometer data were analysed using the software RS tudio
60	174	(version RStudio Desktop 1.0.153, Boston, MA, United States). Minutes of valid time

in light, moderate and vigorous physical activity, as well as sedentary time, were calculated using cut-points proposed by Phillips et al.²⁸ for right wrist as follows: light, 2.4 - 7.9 g·s; moderate, 8.0 - 21.0 g·s; vigorous >21.1g·s; sedentary, <2.3 g·s; and for left wrist as follows: light, 2.7 - 7.1 g·s; moderate, 7.2 - 22.5 g·s; vigorous >22.6 g·s; sedentary, <2.6 g·s. Bone measurements DXA Bone and lean masses were measured with DXA QDR-Explorer (pediatric version of the software ODR-Explorer, Hologic Corp. Software version 12.4, Bedford, MA, USA). DXA equipment was calibrated daily following the manufacturer guidelines. Whole body, non-dominant hip and lumbar spine scans were conducted with participants in supine position by the same technician who had been fully been trained to perform the scans. The positioning of the subjects and analysis of the results were performed according to the manufacturer's guidelines. The non-dominant limb was determined by asking which leg would be used to kick a ball.²⁹ Subtotal (total body less head) body BMC (g), legs (calculated as a mean of both legs) aBMD (g/cm²), subtotal lean mass (g) and subtotal percentage of body fat (%) were obtained from whole body scans and lumbar spine BMC was obtained from lumbar spine scans (L1-L4). Femoral neck values used to calculate BMAD were obtained from hip scans. Coefficients of variation for BMC and aBMD at whole body in the laboratory in this study were 2.3% and 1.3%, respectively. However, subtotal body BMC and lumbar spine BMAD were the preferred bone sites for evaluating bone changes during growth.²⁰ Legs aBMD and femoral neck BMAD have also been included in the present study because they could be skeletal sites directly influenced by football actions. Due to the fact that DXA results are highly influenced by skeletal dimensions and BMAD is less sensitive to size changes than aBMD, Carter et al.³¹ and Katzman et al.³² developed new mathematical models to calculate BMAD. In this study, Eqs. (1) - (3)have been used: Whole body BMAD = BMC (whole body) / $[Ap^2 / h]$ (1)where Ap is the projected area (whole body) from DXA and h is the height of the participant.³² Lumbar spine BMAD = BMC (L1-L4) / $Ap^{3/2}$ (2)where Ap is the projected area (L1-L4) from DXA³¹ Femoral neck BMAD = BMC (femoral neck) / Ap^2 (3)where Ap is the projected area (femoral neck) from DXA³¹ pQCT Bone mass, geometry and strength were measured at the non-dominant tibia using a Stratec XCT-2000 L pQCT scanner (Stratec Medizintechnik, Pforzheim, Germany). This device is a rotate-translate scanner that obtains a trans-axial image. Following the guidelines provided by the manufacturer, the pQCT calibration was performed daily using a quality control phantom. Coefficients of variation for each pQCT variable used in the present study were as follows: 0.71% for total volumetric bone mineral density

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2	000	
4	222	1.12% for cortical thickness (Ct.1h), 2.51% for fracture load in X-axis (Frc.LdX); and
5	223	2.08% for polar strength strain index (SSIp).
6	224	Tibia length was determined as the inner border of the medial condyle to the farthest
7	225	point of the medial malleolus of the tibia and it was always measured by the same
8	226	technician using a wooden ruler (to the nearest 1 mm). Then, the non-dominant leg was
9	227	centred in the imaging field and the foot and knee were secured to reduce movement.
10	228	The scanner was positioned on the distal tibia, and a scout view was performed to
11	229	manually set the reference line on the midpoint of the distal tibia end plate. Bone
12	230	parameters were assessed at 4% (distal tibia) and 38% (diaphyseal tibia) of the length of
13	231	the tibia with a voxel dimension of 0.5 mm and a slice thickness of 1 mm. Following
14	232	ISCD ^{34} recommendations for evaluating bone geometry and strength with pOCT.
15	233	Tt vBMD (mg/cm^3) and Th vBMD (mg/cm^3) at the 4% site of the tibia were analysed
17	234	Moreover the parameters measured at 38% of the length of the tibia were total Tt BMC
18	235	(g) Ct vBMD (mg/cm ³) Ct Ar (mm ²) Ct Th (mm) Fre L dX (N) and SSIn (mm ³)
19	235	All nOCT images were analysed with version 6.20 of the manufacturer's software
20	230	An pQC1 images were analysed with version 0.20 of the inalufacturer's software.
21	237	Contour mode 1 with a uneshold of 180 mg/cm ² for the 4% site of the total and 280 $mg/cm3$ for the 200/ site of the tible was used to determine the period to a fithe
22	230	mg/cm ³ for the 38% site of the tibla was used to determine the periosteal surface of the
23	239	bone. At 4% site of the tibla, trabecular bone was determined from a central area
24	240	covering 45% of the total bone cross-sectional area. At 38% site of the tibia, cortical
25	241	bone was obtained using cortical mode 1 with a threshold of 710 mg/cm ³ . Additionally,
20	242	cortical mode 1 with a threshold of 280 mg/cm ³ was used to obtain bone strength
27	243	variables (Frc.LdX and SSIp). After that, bone mineralization of 1200 mg/cm ³ was
20	244	assumed.
30	245	
31		
32	246	Mechanical properties of the pitches
33	247	Two different surfaces were included in the present study: 3G-EL and 3G-NEL By the
34	248	time the study was performed no more than six years had passed since they were
35	210	installed Both nitches presented similar infill characteristics and were constructed by
36	250	the same manufacturer
3/	250	A gaggements of mochanical characteristics of the facthall fields used in the magant
38	251	Assessments of mechanical characteristics of the football fields used in the present
39 40	252	study were performed according to the quality standards proposed by the European
40	253	Committee for Standardisation (EN 15530-1:2007) and the Handbook of Test Methods
42	254	tor Football Turf. ³³ This standard is applied for amateur, educational and recreational
43	255	sport and evaluates the performance and durability of outdoor sport surfaces. Thus, test
44	256	requirements used for evaluating mechanical properties of the football pitches are as
45	257	follows: ball rebound has to be between 0.608 and 1.012 m; ball roll between 4 and 10
46	258	m; shock absorption between 55 and 70%; vertical deformation between 4 and 10 mm;
47	259	and rotational resistance between 25 and 50 N·m. Although maintenance of these
48	260	football fields could vary, both 3G-EL (ball rebound: 0.825 m; ball roll: 10 m; shock
49	261	absorption: 62%; vertical deformation: 7 mm; and rotational resistance: 50 N·m) and
50 E 1	262	3G-NEL (ball rebound: 0.944 m; ball roll: 10 m; shock absorption: 56%; vertical
ט ו כי	263	deformation: 6 mm: and rotational resistance: 41 N·m) were within these parameters
52 52	264	These mechanical characteristics were measured in five field positions following the
54	265	quality standards guidelines. Each test was performed three or five times (according to
55	205	the required attempts) in all field positions. An Advanced Artificial Athlate was used
56	200 267	for measuring shock absorption and vortical deformation variables. The other
57	207 260	machanical characteristics were measured with the equipment proposed by the
58	200	Here the also of Test Methods for Excellent Test 35
50	209	manubook of rest wiethous for football run.

59 60 All tests were performed at stable meteorological conditions at temperatures between 10 and 22°C, wind speed between 0 and 1.2 m/s and humidity between 45 and 60%. Pocket Weather Tracker 4000 (Kestrelmeters, Birmingham, UK) was used to evaluate meteorological conditions. These measurements were performed in April (3G-NEL) and May (3G-EL).

Statistical analyses

Sample size calculation

To the authors knowledge, there have been no studies that have calculated whole body or lumbar spine BMAD. Therefore, data from a Zouch et al.¹³ study evaluating aBMD at whole body in football players and the CG (1.098 \pm 0.093 and 1.010 \pm 0.087 g/cm², respectively) was used to calculate sample size. Due to the fact that the main analysis of the present study was the repeated measures, the sample size calculation was performed for these analyses. The sample size for repeated measures was calculated in whole body aBMD to get a power of $\frac{80\%}{80\%}$ at the 5% alpha level and to reject the null hypothesis $H_0:\mu 1=\mu 2$. Thus, assuming a small to medium effect size (f = 0.20) and a correlation among repeated measures of 0.7 at pre- and post-season, a total sample size of 32 (16) per group) would be needed.

Outcome measures treatment

Statistical Package for the Social Sciences (SPSS) version 22.0 for Mac OS X (SPSS) Inc., Chicago, IL, USA) was used for the statistical analyses. All variables showed normal distribution tested with the Kolmogorov-Smirnov test.

Chi-square test was performed to evaluate differences between pubertal stages. Independent t-tests were applied to examine differences among groups for descriptive characteristics and bone parameters at pre- and post-season. ANOVA for repeated measures were applied to check differences within all football players and the CG, as well as within 3G-EL and 3G-NEL between pre- and post-season without adjusting by covariates (Model 1). After that, these analyses were repeated, including two covariates as follow: Model 1 + minutes per day of moderate-vigorous physical activity (MVPA; Model 2); and Model 2 + total lean mass less head for DXA parameters or tibia muscle area for pQCT parameters (Model 3). MVPA was selected as a covariate to analyse the possible effect of these high intensity activities on bone mass. In addition, lean mass was used as a covariate due to its influence on bone mass.³⁶ Moreover, weight was not used as covariate to avoid multicollinearity in the analysis due to its high correlation with lean mass (Pearson correlation coefficient = 0.922; p < 0.001). Group by time interactions for changes in bone values were also performed by repeated measures analyses.

Effect size statistics using Cohen's d was calculated for independent t-test and partial eta squared (η_p^2) for repeated measures analyses. The effect size for Cohen's d can be small (0.2 – 0.5), medium (0.5 – 0.8) or large (>0.8) and partial eta squared (η^2_p) can be small (0.01 - 0.06), medium (0.06 - 0.14) or large (>0.14). Statistical significance was set at p < 0.05.

- Results
- Descriptive data

2		
3	316	The physical characteristics of the participants are shown in Table 1. No differences
4	317	were found in any descriptive data between football players and controls (Cohen's d
5	210	were round in any descriptive data between rootball players and controls (Control s a
6	310	Tanged from 0.05 to 0.09, $p \ge 0.05$). Between different surfaces (50-EL and 50-NEL),
7	319	no differences were found either (Cohen's <i>a</i> ranged from 0.06 to 0.70 ; $p > 0.05$).
8	320	As expected, there were significant differences for the age, weight, height, BMI,
9	321	subtotal lean mass, tibia length and tibia muscle area between pre- and post-season in all
10	322	groups (n^2 , ranged from < 0.001 to 0.943; $p < 0.05$). Moreover, football players who
11	323	trained on 3G-NEL demonstrated lower percentage of body fat at post- than pre-season
12	223	$(m^2, max 0.257; m < 0.05)$
13	324	$(\eta_p^2 \text{ was } 0.557, p < 0.05).$
14	325	No significant differences were found in MVPA between football players and the CG
15	326	$(93.29\pm19.93 \text{ vs} 95.50\pm33.46 \text{ minutes per day}; 95\% \text{ CI}, -17.54 \text{ to} -21.95; \text{ Cohen's } d$
16	327	was 0.08; $p > 0.05$) and between football players who trained in 3G-EL and 3G-NEL
17	328	$(100.25\pm21.69 \text{ vs } 85.80\pm15.29 \text{ minutes per day}; 95\% \text{ CI}, -29.29 \text{ to } 0.40; \text{ Cohen's } d \text{ was}$
18	329	0.77; p > 0.05).
19	330	
20	550	
21	331	BMC, aBMD and BMAD
22		
23	332	Comparisons between football players and the CG
24	333	Table 2 summarizes BMC and aBMD measured at pre- and post season in football
25	222	rable 2 summarizes blue and abivit measured at pre- and post-season in football
20	334	players and CG. Higher legs abivid was found in football players than the CG at post-
27	335	season (95% C1 = $-0.02 - 0.19$; Cohen s d was 0.72 ; $p < 0.05$). Football players and the
29	336	CG significantly increased subtotal body BMC, lumbar spine BMC, legs aBMD and
30	337	lumbar spine BMAD (η_p^2 ranged from 0.192 to 0.713; $p < 0.05$). Furthermore, a
31	338	significant group by time interaction was found for legs aBMD (percentage changes of
32	339	football players and CG were 7.0% and 4.0% respectively: n^2 , was 0.097 $n < 0.05$
33	340	This interaction showed that the increase in the legs aBMD was significantly greater in
34	2/1	factball players in comparison with the CC. The same result was obtained when MVDA
35	242	included as a service (conserved as a service of football shows and the CC serve
36	342	were included as covariate (percentage changes of football players and the CG were
37	343	7.0% and 4.1%, respectively; η_p^2 was 0.099; $p < 0.05$), but it became non-significant
38	344	when subtotal lean mass was introduced as covariate (percentage changes of football
39	345	players and the CG were 6.9% and 4.5%, respectively; η^2_p was 0.063; $p > 0.05$; Fig. 2).
40	346	Therefore, a lean mass correction could underestimate the effects of this high-impact
41	347	sport on hone mass
42	34.8	sport on cone mass.
43	540	
44	349	Comparison between 3G-EL and 3G-NEL football players
45	250	
40	350	Table 3 summarizes BMC and aBMD measured at pre- and post-season in 3G-EL and
47	351	3G-NEL football players . 3G-EL showed higher lumbar spine and femoral neck BMAD
40	352	at pre- and post-season than 3G-NEL (Cohen's <i>d</i> ranged from 0.80 to 1.45; $p < 0.05$).
47 50	353	Both football groups increased subtotal body BMC, lumbar spine BMC, legs aBMD and
50	354	lumbar spine BMAD from pre- to post-season (n_p^2 ranged from 0.203 to 0.674; $p < 10^{-1}$
52	355	0.05) Moreover 3G-NFL also increased femoral neck RMAD (n^2 was 0.096; $n < 10^{-10}$
53	256	(0.05) . There was a group by time interaction for lumbar spin DMAD (n_p was 0.000, $p > 0.05$).
54	220	v. 05). There was a group by time interaction for futiloal splite DiviAD (percentage
55	35/	changes of 5G-EL and 5G-NEL players were 1.8% and 5.9%, respectively; η_p^2 was
56	358	0.169; $p < 0.05$). This interaction demonstrated that during one year of football practice,
57	359	BMAD at lumbar spine increased more in football players who trained on 3G-NEL than

in those who trained on 3G-EL. On the other hand, no group by time interaction was
 found for lumbar spine BMAD when MVPA was included as covariate (percentage)

362 changes of 3G-EL and 3G-NEL players were 2.6% and 5.9%, respectively; η_p^2 was 363 0.109; p > 0.05; Fig. 3).

365 Bone geometry and strength

366 Comparisons between football players and the CG

Bone geometry and strength measured at the 4% and 38% sites of the tibia in football players and the CG are shown in Table 2. Higher Ct.Ar at pre-season and SSIp at pre-and post-season were found in football players than the CG (Cohen's d ranged from 0.63 to 0.80; p < 0.05). Both groups improved Tt.BMC, Ct.Ar, Ct.Th, Frc.LdX and SSIp (η^2_p ranged from 0.106 to 0.635; p < 0.05). Furthermore, the CG decreased **Tt.**vBMD and **Tb.**vBMD at distal tibia (η_p^2 were 0.102 and 0.128; p < 0.05). No group by time interactions were found in bone geometry and strength values (η_p^2 ranged from <0.001 to 0.053; p < 0.05; however, when tibia muscle area was added as covariate, there was a group by time interaction for Tt.BMC (percentage changes of football players and the CG were 5.7% and 8.1%, respectively; η^2_p was 0.105; p < 0.05; Figure 2). This interaction demonstrated that Tt.BMC increased more in the CG than football players. As determined in DXA parameters, a tibia muscle area correction could modify the differences between groups and, consequently, under-estimate the effects of this high-impact sport on bone mass.

382 Comparison between 3G-EL and 3G-NEL football players

Bone geometry and strength measured at the 4% and 38% sites of the tibia in 3G-EL and 3G-NEL football players are shown in Table 3. At pre- and post-season, 3G-EL players showed higher Tt.vBMD and Tb.vBMD than 3G-NEL (Cohen's *d* ranged from 1.01 to 1.31; p < 0.05). 3G-EL and 3G-NEL players improved Tt.BMC, Ct.Ar, Ct.Th, Frc.LdX and SSIp (η^2_p ranged from 0.199 to 0.683; p < 0.05). There were no group by time interactions between both 3G-EL and 3G-NEL players even when MVPA and tibia muscle area were used as covariates (η^2_p ranged from <0.001 to 0.086; p < 0.05).

Discussion

The main finding of the present study is that one season of football practice, independent of the playing surface, positively affect bone accretion in the lower limbs of young players. Subtotal body BMC and lumbar spine BMAD are the variables that ISCD recommends to compare densitometry results in children and adolescents.²⁰ However, the analysis of legs would help to explain how football practice affects bone mass because legs are the closest site of the body to the floor and support more impact than the other bone sites. On the other hand, football players playing on 3G-EL and 3G-NEL demonstrated similar bone mass, geometry and strength increases in most variables studied, except for lumbar spine BMAD that increased more in football players who played on 3G-NEL than those who played on 3G-EL.

54402The present study has demonstrated that legs aBMD improved more in football55403players than the CG. To the best of the authors' knowledge, six studies have analysed56404the effects of football practice on DXA parameters in young football players and the58405CG.⁸, ¹¹⁻¹⁵ Most of them demonstrated that football practice seems to be a good strategy59406for increasing BMC and aBMD during growth. These results were higher for football60407players than those obtained by the CG. Moreover, they also reported higher BMC and

aBMD at lower limbs in football players than the CG. Most of them also demonstrated differences in lumbar spine, a preferred site to assess densitometry variables during growth.²⁰ Nonetheless, none of them included subtotal body site and BMAD parameters in their study. Therefore, their results could be slightly influenced by bone mass of the skull (site not responsive to physical activity and their loads³⁷) and bone size of their participants.³¹ In the present study, although subtotal body BMC and lumbar spine BMAD were included, no significant differences in these variables were found between football players and the CG. These results could be explained by the fact that the number of hours per week of football training could not be sufficient to have significant bone differences between groups. In summary, football practice during childhood and adolescence might help to attain a higher peak of bone mass and, consequently, to reduce the risk of suffering osteoporosis during adulthood. In terms of bone geometry and strength parameters, the present study showed that bone strength was higher in football players than the CG, with larger SSIp values. Up to now, there are only a cross-sectional study¹⁹ and a 1-year follow-up study¹⁴ that have compared bone geometry and strength values between male football players and the CG using pQCT and HSA, respectively. Despite the use of different techniques, all of them found greater, but not significant, bone geometry and strength in football players than the CG. The lack of differences between these groups could be explained by the fact that cortical bone parameters increase sharply after the age of 14^{38} and the age of participants of the present study was lower. Thus, future studies evaluating bone geometry and strength acquisition before and after 14 years of age will help to clarify the effects of football practice on these bone variables during growth. To date, only a cross-sectional study performed by Plaza-Carmona et al.²³ analysed bone mass in football players who trained on different playing surfaces (artificial and soil fields). These authors showed that neither BMC nor aBMD were different between football players according to playing surface. The present study demonstrated that lumbar spine BMAD, femoral neck BMAD, Tt.vBMD and Tb.vBMD were higher in 3G-EL than 3G-NEL players at both pre- and post-season. Although no significant differences in hours of trainings per week were found between football groups (3G-EL players=2.6±0.2 hours/week; 3G-NEL players=2.3±0.3 hours/week), the extra 15-20 minutes per week of training performed by players who trained in 3G-EL might explain the observed bone differences between both football groups. In addition to this, as demonstrated Varley et al.¹⁸, an increase of training volume improved bone geometry and strength parameters. Artificial fields aim to emulate physical and mechanical characteristics of natural surfaces. In fact, since rubber and sand were added in artificial turf, differences in mechanical variables and the number of injuries between both surfaces were reduced.^{21,} ³⁹ Afterwards, the inclusion of the elastic layer behind the artificial turf systems increased shock absorption,²² and consequently, reduced the amount of load received by football players. Although shock absorption characteristics measured in the present study in 3G-EL (62%) and 3G-NEL (56%) were different, the effects of each surface on bone mass, geometry and strength seem to be similar between fields with the exception of lumbar spine BMAD. The closest bone sites to the ground receive the highest impacts produced by football and progressively, as they move away from the ground to

453 other bone sites, these impacts dissipate. Impacts produced in both 3G-EL and 3G-NEL
454 at tibia and femoral neck sites are high and cause similar bone adaptations. However,

455 only loads produced by football actions in 3G-NEL are capable of causing an extra

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could be limiting the differences between football players. To reinforced this idea, Zouch et al.¹¹ and Varley et al.¹⁸ demonstrated that higher training volume improved both DXA and pQCT parameters. Prior to the beginning of this study, sample sizes of each group were higher than that obtained in the sample size calculation. Nevertheless, some participants were excluded because of the above-mentioned reasons (see Methods section). Consequently, the main limitation of the present study was that sample sizes of 3G-EL (n = 14), 3G-NEL (n = 13) and the CG (n = 15) were lower than the predicted number obtained in the sample size calculation (16 participants per group). Therefore, bone comparisons between groups may have been affected by type II error. Moreover, the type of football exercises performed by each team was similar but not equal. Therefore, the variation in football training exercises could cause slight differences in bone mass. Participants' calcium intake data may be somewhat unreliable due to the fact that questionnaires were undertaken by the youth participants with supervision by the researchers, as opposed to their parents or guardians. Another limitation was that the number of practice hours per week for both teams was lower than those in other studies performed with football players (approximately 2.4 vs 10.0 and 11.9 hours per week).^{14, 18} Moreover, football players could not use accelerometers during matches and accelerations registered could not accurately represent the accelerations of lower limbs as they had to be placed on the wrist. On the other hand, the main strength was that this is the first study that evaluated the influence of two third-generation artificial turf surfaces (3G-EL and 3G-NEL) on bone mass, geometry and strength in male adolescent football players. Moreover, this is also the first study that compares bone geometry and strength between football players and the CG.

Conclusions

> 484 The present study demonstrates that football practice on artificial surfaces with or 485 without an elastic layer seems to increase bone mass in lower limbs during growth 486 compared to not playing football. Moreover, after one-season follow-up, football 487 practice on a 3G-NEL surface with lower shock absorption seems to be an adequate 488 alternative to improve BMAD in the lumbar spine. Thus, soccer practice on surfaces 489 with lower shock absorption could provide an extra benefit to bone health.

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- ⁵⁷₅₈ 501 **Declaration of conflicting interests**
- 59 502 The authors declare that there is no conflict of interest.

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3	503	References
4 5	F04	
6	504	I. Rizzoli R, Bianchi ML, Garabedian M, et al. Maximizing bone mineral mass gain
7	505	during growth for the prevention of fractures in the adolescents and the elderly.
8	506	<i>Bone</i> 2010; 46: 294-305.
9	507	2. Tenforde AS and Fredericson M. Influence of sports participation on bone health in
10	508	the young athlete: a review of the literature. <i>Pm R</i> 2011; 3: 861-867.
11	509	3. Weaver CM, Gordon CM, Janz KF, et al. The National Osteoporosis Foundation's
12	510	position statement on peak bone mass development and lifestyle factors: a
13	511	systematic review and implementation recommendations. Osteoporos Int 2016; 27:
14	512	1281-1386.
15	513	4. Mautalen CA. Soccer and bone development. <i>Osteoporos Int</i> 2016; 27: 3133-3134.
10	514	5. Bangsbo J. The physiology of soccer with special reference to intense intermittent
18	515	exercise Acta Physiol Scand Suppl 1994: 619: 1-155
19	516	6 Kunz M 265 million playing football <i>FIFA magazine</i> July 2007 p 11-15
20	517	7 Lozano-Berges G Matute-Llorente Á González-Agüero A et al Soccer helps
21	518	huild strong bones during growth: a systematic review and meta-analysis Fur I
22	510	Padiate 2018: 177: 205 210
23	520	 Visonta Podriguaz G. Ara I. Paraz Gamaz I. at al. High famoral hana minaral
24	520	6. Vicente-Rounguez O, Ala I, Perez-Gonnez J, et al. High femoral bone infineral density appretion in propulsatel appager playare. Mod Sci Sports Fuero 2004; 26:
25	521	tensity accretion in prepubertal soccer players. <i>Med Sci Sports Exerc</i> 2004, 50.
26 27	522	1/89-1/95. O Nahiah A Dahai H Ellaumi Matal Dana minanal danaita afaranan harararan
27	523	9. Nebign A, Rebai H, Elloumi M, et al. Bone mineral density of young boy soccer
20	524	players at different pubertal stages: relationships with hormonal concentration.
30	525	Joint Bone Spine 2009; 76: 63-69.
31	526	10. Seabra A, Marques E, Brito J, et al. Muscle strength and soccer practice as major
32	527	determinants of bone mineral density in adolescents. Joint Bone Spine 2012; 79:
33	528	403-408.
34	529	11. Zouch M, Jaffre C, Thomas T, et al. Long-term soccer practice increases bone
35	530	mineral content gain in prepubescent boys. <i>Joint Bone Spine</i> 2008; 75: 41-49.
30 27	531	12. Zouch M, Vico L, Frere D, et al. Young male soccer players exhibit additional bone
32	532	mineral acquisition during the peripubertal period: 1-year longitudinal study. Eur J
39	533	<i>Pediatr</i> 2013; 173: 53-61.
40	534	13. Zouch M, Zribi A, Alexandre C, et al. Soccer Increases Bone Mass in Prepubescent
41	535	Boys During Growth: A 3-Yr Longitudinal Study. J Clin Densitom 2015; 18: 179-
42	536	186.
43	537	14. Vlachopoulos D, Barker AR, Ubago-Guisado E, et al. Longitudinal Adaptations of
44	538	Bone Mass, Geometry, and Metabolism in Adolescent Male Athletes: The PRO-
45	539	BONE Study. J Bone Miner Res 2017; 32: 2269-2277.
40 47	540	15. Vlachopoulos D. Barker AR. Ubago-Guisado E. et al. The effect of 12-month
47 48	541	participation in osteogenic and non-osteogenic sports on bone development in
49	542	adolescent male athletes. The PRO-BONE study <i>J Sci Med Sport</i> 2018: 21: 404-
50	543	409
51	544	16 Sievanen H. A physical model for dual-energy X-ray absorptiometryderived hone
52	545	mineral density Invest Radial 2000: 35: 325-330
53	546	17 Anliker F. Sonderegger A and Toigo M. Side-to-side differences in the lower leg
54	540	muscle-hone unit in male soccer players Mod Sci Sports Evers 2012: 45: 1545
55	547 510	1557
50 57	540 E10	1334. 18 Varley I. Hughes DC. Greeves ID at al Increased Training Valume Improves Dena
52	543	Donsity and Cortical Area in A delegant Eactball Disyster Let I Sports Mod 2017.
59	550 EE1	Density and Collical Alea III Adolescent Football Players. In J Sports Med 2017, 29, 241–246
60	221	JO. J41-J4U.

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2			
3 1	552	19.	Lozano-Berges G, Matute-Llorente A, Gomez-Bruton A, et al. Bone geometry in
- 5	553		young male and female football players: a peripheral quantitative computed
6	554		tomography (pQCT) study. Arch Osteoporos 2018; 13: 57.
7	555	20.	Crabtree NJ, Arabi A, Bachrach LK, et al. Dual-energy X-ray absorptiometry
8	556		interpretation and reporting in children and adolescents: the revised 2013 ISCD
9	557		Pediatric Official Positions. J Clin Densitom 2014; 17: 225-242.
10	558	21.	McNitt AS. Synthetic turf in the USA - Trends and issues. <i>ITSRJ</i> 2005; 10: 27-33.
11	559	22.	Burillo P, Gallardo L, Felipe JL, et al. Mechanical assessment of artificial turf
12 12	560		football pitches: The consequences of no quality certification. Sci Res Essays 2012;
13	561		7: 2457-2465.
15	562	23.	Plaza-Carmona MP, Vicente-Rodriguez G, Martin-Garcia M, et al. Influence of
16	563		hard vs. soft ground surfaces on bone accretion in prepubertal footballers. Int J
17	564		Sports Med 2014; 35: 55-61.
18	565	24.	Des Jarlais DC, Lyles C, Crepaz N, et al. Improving the reporting quality of
19	566		nonrandomized evaluations of behavioral and public health interventions: the
20	567		TREND statement. Am J Public Health 2004; 94: 361-366.
21 22	568	25.	Tanner JM and Whitehouse RH. Clinical longitudinal standards for height, weight,
22	569		height velocity, weight velocity, and stages of puberty. Arch Dis Child 1976; 51:
24	570		170-179.
25	571	26.	Duke PM, Litt IF and Gross RT. Adolescents' self-assessment of sexual maturation.
26	572		Pediatrics 1980; 66: 918-920.
27	573	27.	Julián Almárcegui C. Huvbrechts I. Gómez Bruton A. et al. Validity of food-
28	574		frequency questionnaire for estimating calcium intake in adolescent swimmers.
29	575		Nutr Hosp 2015: 32: 1773-1779.
30	576	28.	Phillips LR. Parfitt G and Rowlands AV. Calibration of the GENEA accelerometer
32	577		for assessment of physical activity intensity in children J Sci Med Sport 2013. 16
33	578		124-128
34	579	29	Hoffman M Schrader J Applegate T et al Unilateral postural control of the
35	580	_>.	functionally dominant and nondominant extremities of healthy subjects <i>J</i> Athl
36	581		Train 1998: 33: 319-322
3/	582	30	Gracia-Marco L. Ortega FB. Jimenez-Payon D. et al. Adiposity and bone health in
20 20	583	20.	Spanish adolescents The HELENA study <i>Osteoporos Int</i> 2012: 23: 937-947
40	584	31	Carter DR Bouxsein ML and Marcus R New approaches for interpreting projected
41	585	51.	hone densitometry data I Rone Miner Res 1992: 7: 137-145
42	586	32	Katzman DK Bachrach I K Carter DR et al Clinical and anthronometric
43	587	54.	correlates of hone mineral acquisition in healthy adolescent girls <i>I Clin Endocrinol</i>
44	588		Metab 1991: 73: 1332-1339
45	589	33	Gomez-Bruton A Gonzalez-Aguero A Casajus IA et al Swimming training
40 47	590	55.	repercussion on metabolic and structural hone development: benefits of the
47	591		incorporation of whole body vibration or pilometric training: the
49	502		RENACIMIENTO project Nutr Hosp 2014: 30: 300 400
50	592	21	Adams IE Engelke K. Zamel PS, et al. Quantitative computer tomography in
51	595	54.	abildren and adalassants: the 2012 ISCD Padiatria Official Desitions. <i>I Clin</i>
52	594		Densitem 2014: 17: 258-274
53	595 E06	25	EIEA EIEA Quality account for factball turf. Handback of requirements
54	590	33.	FIFA. FIFA Quality concept for football tuff. Handbook of requirements,
55 56	37/ E00	26	Vicente Rodriguez G. Urzengui A. Messne MI, et al. Diverse lifeteese effect en
57	570 500	30.	vicente-Kouriguez G, Urzanqui A, Mesana Mi, et al. Physical fitness effect on
58	599		bone mass is mediated by the independent association between lean mass and bone
59	600		mass through adolescence: a cross-sectional study. J Bone Miner Metab 2008; 26:
60	001		200-294.

1 2 3 4 5 6 7 8 9 10 11 12 13 14	602 603 604 605 606 607 608 609 610	 Taylor A, Konrad PT, Norman ME, et al. Total body bone mineral density in young children: influence of head bone mineral density. <i>J Bone Miner Res</i> 1997; 12: 652-655. Binkley TL, Specker BL and Wittig TA. Centile curves for bone densitometry measurements in healthy males and females ages 5-22 yr. <i>J Clin Densitom</i> 2002; 5: 343-353. Dragoo JL and Braun HJ. The effect of playing surface on injury rate: a review of the current literature. <i>Sports Med</i> 2010; 40: 981-990.
15 16 17 18 19 20 21 22 23 24 25 26 27 28		
29 30 31 32 33 34 35 36 37 38 39 40 41 42 43		
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Table 1. Subject characteristics of football players who played in different surfaces and controls.

7		Pre-seaso	n moment	Post-seaso	on moment	Pre-seaso	n moment	Post-seaso	on moment
,		All players	players CG All players CG 3G-EL 3G-NEL 3G-EL		3G-NEL				
8		(n = 27)	(n = 15)	(n = 27)	(n = 15)	(n = 14)	(n = 13)	(n = 14)	(n = 13)
9	Age (year)	13.17±0.52	12.58±1.11	13.75±0.51*	13.37±1.15*	13.01±0.61	13.35±0.34	13.61±0.61*	13.90±0.34*
10	Weight (kg)	50.57±11.19	46.26±8.94	54.07±12.09*	50.32±9.77*	50.89±12.01	50.23±10.72	54.41±12.57*	53.69±12.05*
10	Height (cm)	158.32±8.77	153.37±8.82	162.97±9.11*	158.62±9.15*	157.26±10.09	159.47±7.31	161.96±10.62*	164.05±7.42*
11	BMI (kg·m ⁻²)	19.99±3.06	19.54±2.51	20.18±3.27*	19.86±2.61*	20.35±3.24	19.60±2.93	20.54±3.32*	19.80±3.30*
12	Daily calcium intake (mg)	819.88±210.85	793.18±309.33	855.09±329.62	1001.54±505.92	812.27±213.77	828.08±216.06	879.42±432.92	828.88±175.88
12	Subtotal lean mass (g)	34269.71±6804.01	30965.97±5982.53	37438.26±7871.54*	34295.15±7183.19*	34677.22±7597.57	33830.86±6113.04	37979.51±8586.61*	36855.38±7325.65*
15	Percentage of body fat (%)	23.98±6.86	24.35±6.76	22.50±6.59*	23.92±6.61	23.57±7.53	24.42±6.34	22.00±7.69	23.04±5.43*
14	Tibia Length (mm)	359±23	349±26	366±24*	363±32*	357±25	362±21	364±26*	369±21*
15	Tibia Muscle Area (mm ²)	5637.13±972.37	5185.67±985.63	5958.94±1085.76*	5538.15±1335.06*	5823.79±1066.85	5436.12±855.09	6108.96±1168.91*	5797.37±1009.69*
10	Tanner (I/II/III/IV/V)	0/6/11/9/1	0/4/4/7/0	0/3/8/14/2	0/2/6/6/1	0/3/7/3/1	1. 3G-NEL 3G-EL 3G-NEL 4) $(n = 13)$ $(n = 14)$ $(n = 13)$ 0.61 13.35±0.34 13.61±0.61* 13.90±0.34* 2.01 50.23±10.72 54.41±12.57* 53.69±12.05* 10.09 159.47±7.31 161.96±10.62* 164.05±7.42* 3.24 19.60±2.93 20.54±3.32* 19.80±3.30* 213.77 828.08±216.06 879.42±432.92 828.88±175.88 7597.57 33830.86±6113.04 37979.51±8586.61* 36855.38±7325.65* 7.53 24.42±6.34 22.00±7.69 23.04±5.43* 25 362±21 364±26* 369±21* 1066.85 5436.12±855.09 6108.96±1168.91* 5797.37±1009.69* 3/1 0/3/4/6/0 0/2/5/6/1 0/1/3/8/1		
16	Data presented as mean + standar	rd deviation 3G-EL · footba	ll players who trained in t	hird-generation artificial tu	rf with elastic layer: 3G-NE	[· football players who train	ed in third-generation art	ificial turf without elastic la	aver: CG: control group:

Data presented as mean ± standard deviation. 3G-EL: football players who trained in third-generation artificial turf with elastic layer; 3G-NEL: football players who trained in third-generation artificial turf without elastic layer; CG: control group; 17 BMI: body mass index. * significant differences between values obtained at the beginning and end of the season.

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Table 2. Bone mineral content, density, strength and structure in football players and controls.

						asures	
					Within (Group	Group by time
		All players	CG		All players	CG	
		N=27	N=15	<mark>d</mark>	η_p^2	η^2_p	η_p^2
DXA							
BMC (g)							
Subtotal body	T0	1289.290±263.534	1130.329±267.328	<mark>0.60</mark>			
	T1	1467.438±330.159	1288.363±322.811	<mark>0.55</mark>	0.713‡	0.521‡	0.011
Lumbar Spine	T0	38.44±8.10	35.24±8.13	<mark>0.39</mark>			
	T1	43.96±10.14	40.68±10.56	<mark>0.32</mark>	0.642‡	0.492‡	< 0.001
aBMD (g/cm ²)							
Legs	T0	1.089 ± 0.111	1.025 ± 0.127	<mark>0.54</mark>			
	T1	1.165±0.131	1.066±0.144 [#]	<mark>0.72</mark>	0.592‡	0.192*	0.097*
BMAD (g/cm ³)							
Whole body	Τ0	0.093 ± 0.005	0.094 ± 0.006	<mark>0.20</mark>			
-	T1	0.094 ± 0.005	0.094 ± 0.005	<mark>0.07</mark>	0.074	0.006	0.051
Lumbar Spine	Τ0	0.108±0.012	0.107 ± 0.014	<mark>0.08</mark>			
-	T1	0.112±0.011	0.110±0.016	<mark>0.14</mark>	0.440‡	0.213‡	0.013
Femoral Neck	T0	0.184±0.019	0.178 ± 0.025	<mark>0.29</mark>			
	T1	0.186±0.019	0.180±0.031	<mark>0.23</mark>	0.017	0.015	< 0.001
pQCT							
4% site							
Tt.vBMD (mg/cm ³)	Т0	323.239±36.539	322.503±48.332	0.02			
_ ()	T1	318.962 ± 30.043	315.847±48.179	<mark>0.08</mark>	0.078	0.102*	0.009
Tb.vBMD (mg/cm ³)	Т0	298.757 ± 43.691	287.146±51.027	0.71			
	T1	291.867±37.550	275.365±54.061	0.91	0.083	0.128‡	0.016
38% site							
Tt.BMC (g)	Т0	3.072 ± 0.339	2.841±0.511	0.53			
	TI	3.254 ± 0.398	3.061 ± 0.598	0.38	0.635‡	0.586‡	0.026
Ct_vBMD (mg/cm ³)	TO	1057.859±30.134	1055.431 ± 30.778	0.22			
 (g ,)	T1	$1055\ 337\pm28\ 683$	$1061 363 \pm 32 942$	0.28	0.014	0.041	0.053
Ct.Ar (mm ²)	TO	391,991±43,761	357.433±63.992#	0.63			
<u></u> ()	T1	412.398 ± 51.080	382.033 ± 79.129	0.46	0.500‡	0 346‡	< 0.001
Ct.Th (mm)	TO	4.832±0.422	4.605 ± 0.512	0.48	0.000	0.0.0	0.001
<u></u> ()	TI	5017 ± 0418	4779 ± 0.603	0.46	0 192‡	0.106‡	<0.001
Fre LdX (N)	TO	$3142, 342\pm497, 580$	2822.855±763.484	0.50	0.172	0.100	-0.001
	TÎ	3317777 ± 510716	$3050\ 249\pm783\ 238$	0.20	0.280‡	0.266‡	0.012
SSIn (mm ³)	TO	1410 744+228 345	1190 714+314 927#	0.80	0.200	0.200	0.012
cork (mm.)	T1	1502 870+221 134	1296 479+320 088#	0.75	0.259‡	0 204‡	0.003

Data presented as mean ± standard deviation. T0: pre-season moment; T1: post-season moment; CG: control group; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral apparent density; pQCT: peripheral quantitative computed tomography; Tt.vBMD: total volumetric bone mineral density; Tb.vBMD: trabecular volumetric bone mineral density; Tt.BMC: total bone mineral content; Ct.vBMD:

cortical volumetric bone mineral density; Ct.Ar: cortical cross sectional area; Frc.LdX: fracture load (axe X); SSIp: polar strain index; d: Cohen's d; η^2_p : partial eta square.

*Significant differences when compared to all players; *significant differences within groups between the beginning and the final of the season; *significant group by time interaction.

Cohen's *d* can be small (0.2 - 0.5), medium (0.5 - 0.8) or large (>0.8) and η_p^2 can be small (0.01 - 0.06). medium (0.06 - 0.14) or large (>0.14).

$\begin{array}{c c c c c c c c c c c c c c c c c c c $	36-F1 36-NH. Number of the second se						With	Within Group	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	DNA Description Description <thdescription< th=""> <thdes< th=""><th></th><th></th><th>3G-FI</th><th>3G-NEI</th><th></th><th>3G-FI</th><th><u>a Group</u> 3G-NFI</th><th>Group by u</th></thdes<></thdescription<>			3G-FI	3G-NEI		3G-FI	<u>a Group</u> 3G-NFI	Group by u
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Dr.A. Dr.D. Dr.D. <th< th=""><th></th><th></th><th>N=14</th><th>N=13</th><th>d</th><th><u></u> n².</th><th>n².</th><th>n².</th></th<>			N=14	N=13	d	<u></u> n ² .	n ² .	n ² .
$ \begin{array}{l lllllllllllllllllllllllllllllllllll$	EWC (g) Statutal body T0 134.216.305.267 124.0909-211.261 036 0.6744 0.6394 0.004 amhar Spine T0 38.724.97.6 38.146.62.2 007 0.6021 0.5911 -0.001 aBMD (g(m ²) T1 4.2121.21.2 43.702.79.8 0.01 0.6021 0.5911 -0.001 Log T0 0.033.004 0.0944.000 0.53 0.5491 0.5723 0.005 BMD (g(m ²)) T1 0.0944.004 0.0954.007 0.23 0.573 0.090 0.033 Lumbar Spine T0 0.11444.010 0.1022-0.011 1.12 0.090 0.002 Femoral Neck T1 0.1944.011 0.1946.010 0.30 0.203 0.5533 0.1094 PCT T1 0.1944.011 0.1946.010 0.30 0.002 0.096 0.004 MVG (g) T1 3.3484.28.814 0.30 0.112 0.032 0.013 By BMD (g(m ⁰) T0 3.179.14.42.53 0.123.45.23	DXA			1, 15		'I p	Чр	·Ip
	Subtonial body T0 133:216-305.267 [240 096:211.26] 0.36 Lambat Spine T0 38:729-76 38:146-22 007 aBMD (g/cm) Legs T0 1152:01.27 1056-0079 0.00 Logs T0 1152:01.27 1056-0079 0.00 DNA0 (g/cm) Whole hody T0 0.093-0.004 0.094-0.006 0.20 mb of the transmitter of the transmitter of the transmitter of the transmitter of t	BMC (g)							
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Instant Spinc Ti 157 6791357.919 1413.3414272.067 03.21 0.673 ² 0.639 ² 0.091 ² aBMD (g/cm ²) Ti 4.21412.12 2 43.7067.78 83.1446.22 000 0.602 ² 0.591 ² .0001 aBMD (g/cm ²) Ti 1.198-0.150 1.130-0.100 0.53 0.549 ² 0.572 ² 0.005 MAD (g/cm ²) Ti 0.093-0.004 0.094-0.006 0.20 0.577 0.990 0.003 Lumbar Spine Ti 0.014-0.010 0.102-0.011 1.12 0.203 ² 0.533 0.169 ⁴ Fernoral Neck Ti 0.114-0.010 0.102-0.011 1.12 0.002 0.006 ² 0.064 ² QCT Ti 344.8442.814 301.816-21.023 1.01 0.002 0.006 ² 0.016 ⁴ Di VBMD (mg/cm ²) Ti 344.8442.814 301.816-21.023 1.13 0.109 0.225 0.016 Di VBMD (mg/cm ²) Ti 344.8442.814 301.816-32.023 1.13 0.316 ² 0.013 <td>Subtotal body</td> <td>Т0</td> <td>1334.216±305.267</td> <td>1240.909±211.261</td> <td><mark>0.36</mark></td> <td></td> <td></td> <td></td>	Subtotal body	Т0	1334.216±305.267	1240.909±211.261	<mark>0.36</mark>			
Lumbar Spine 10 38.729.76 38.144.0.22 00 TI 44.21412.12 43.704.798 0.05 0.602 ² 0.591 ² -0.0 aBMD (g/cm²) Legs T0 1.125±0.127 1.050±0.079 0.70 Legs T1 1.198±0.150 1.130±0.100 0.53 0.549 ² 0.572 ² 0.00 Whole body T0 0.093±0.004 0.094±0.006 0.20 Lumbar Spine T0 0.114±0.010 0.102±0.011 ¹ 1.12 Femoral Neck T0 0.195±0.018 0.173±0.012 ³ 1.01 0.002 0.096 ⁶ 0.00 pCCT T 0.195±0.021 0.173±0.012 ³ 1.01 0.002 0.096 ⁶ 0.00 pCCT T 0.195±0.021 0.173±0.012 ³ 1.01 0.002 0.096 ⁶ 0.00 D 0.002 0.002 0.002 D 0.002 0.002 0.002 0.002 D 0.002 0.002 0.002 0.002 D 0.002 0.002 0.002 0.002 D 0.002 0.002 0.002 0.002 0.002 D 0.002 0.002 0.002 0.002 0.002 0.002 D 0.002	Lumbur Spine 10 3 34, 249, 76 35, 1419, 22 000 0.602 ² 0.591 ² <0001 aBMD (gcm²) T0 1.125:01.27 1.059:04.079 0.70 bMole body T0 0.093:0.004 0.095:00.07 0.25 0.057 0.990 0.003 bMole body T1 0.093:0.004 0.095:00.07 0.25 0.057 0.990 0.003 bmole body T1 0.014:40.010 0.125:00.17 1.12 bmole body T0 0.114:40.011 0.108:40.010 0.020 0.002 0.996 ² 0.096 ⁴ fmole body T1 0.115:20.021 0.177:20.013 1.00 0.002 0.996 ² 0.096 ⁴ fmole body T1 0.115:20.021 0.177:20.013 1.00 0.002 0.996 ⁴ 0.096 ⁴ fmole body T1 0.115:20.021 0.177:20.013 1.00 0.002 0.996 ⁴ 0.096 ⁴ fmole body T1 0.195:20.021 0.177:20.013 1.01 0.002 0.996 ⁴ 0.096 ⁴ fmole body T1 0.315:20.021 0.177:20.013 1.01 0.002 0.996 ⁴ 0.006 ⁴ fmole body T1 0.315:20.021 0.0177:20.013 1.01 0.002 0.996 ⁴ 0.006 ⁴ fmole body T1 0.315:20.221 0.013 1.01 0.002 0.996 ⁴ 0.004 ⁴ fmole body T1 0.315:20.221 0.013 1.01 0.002 0.996 ⁴ 0.004 ⁴ fmole body T1 0.315:20.223 0.013 0.0683 ³ 0.404 ⁴ 0.086 fmole body T1 0.315:20.229 0.024 0.025 0.017 0.023 0.003 fmole body T1 0.195:20.229 0.024 0.025 0.016 fmole body T1 0.195:20.229 0.024 0.025 0.017 0.023 0.003 fmole body T1 0.195:20.229 0.024 0.025 0.016 fmole body T1 0.195:20.229 0.025 0.016 fmole body T1 0.023 0.0000 0.027 0.001 fmole body T1 0.195:20.229 0.016 fmole body T1 0.023 0.0000 0.027 0.001 fmole body T1 0.0194 0.0000 0.000 0.000 0.000 0.000 0.000 0.0000 0.000 0.0000 0.0000 0.0000 0.0000 0.0000 0.000 0.0000 0.0000		T1	1517.670±375.491	1413.341±278.067	0.32	0.674‡	0.629‡	0.004
aBMD (g/cm ³) Legs T0 1.125±0.127 1.050±0.079 0.70 T1 1.198±0.150 1.130±0.100 0.53 0.549: 0.572 [±] 0.00 BMAD (g/cm ³) Whole body T0 0.093±0.004 0.094±0.006 0.20 Lumbar Spine T0 0.114±0.010 0.102±0.011 [±] 1.12 T1 0.116±0.011 0.108±0.010 [±] 0.80 0.203 [±] 0.553 [±] 0.166 Femoral Neck T0 0.195±0.018 0.173±0.012 [±] 1.45 T1 0.116±0.011 0.108±0.010 [±] 1.12 My BMD (mg/cm ³) T0 340.621±37.567 304.520±25.136 [±] 1.13 T1 0.195±0.02 0.177±0.013 [±] 1.01 T1 334.884±28.814 301.816±2.10.23 [±] 1.31 0.109 0.025 0.00 T1 334.884±28.814 301.816±2.10.23 [±] 1.31 0.109 0.025 0.00 T1 334.834±28.814 301.816±2.10.23 [±] 1.31 0.109 0.025 0.00 T1 334.834±28.814 301.816±2.10.23 [±] 1.31 0.109 0.025 0.00 T1 334.834±28.814 301.816±2.10.23 [±] 1.31 0.109 0.025 0.00 T1 334.894±28.814 301.816±2.10.23 [±] 1.31 0.109 0.025 0.00 T1 3349±0.441 3.153±0.337 1.01 T1 309.011±34.253 273.404±32.739 [±] 1.06 0.112 0.032 0.00 CtAf (mm ³) T0 1053.591±29.836 1062.454±30.967 0.29 CtAf (mm ³) T0 3120.129.836 1062.454±30.967 0.29 CtAf (mm ³) T1 423.714±56.310 400.212±34.860 0.47 0.606 [±] 0.462 [±] 0.00 CtAf (mm ³) T0 3120.1043±53.950 1059.005±39.84 0.47 0.606 [±] 0.462 [±] 0.00 T1 3428.474±53.580 3198.564±473.699 0.46 0.432 [±] 0.199 [±] 0.00 Stilf (mm ³) T0 1452.894±245.22 136.122±20.038 0.44 CtAf (mn ³) T0 424.448+224.994 1458.052±10.58 0.55 T1 3428.474±53.580 3198.564±473.699 0.46 0.432 [±] 0.199 [±] 0.00 Stilf (mm ³) T0 443±453.960 360.900±439.040 0.28 Data presented as mean ± standard deviation. T0: pre-season moment; T1: post-season moment; 3C-EL: football players who trained in third-generation admite lastic layer; DAX: tabal-energy X-ray absorptiometry; BMC: bone mineral density. Tb MMD: bone mineral density. Tb MMD: bone mineral density. Tb MMC bone mineral density. Tb MC: total players who trained in third-generation admite lastic layer; DXA: tabal-energy X-ray absorptiometry; BMC: bone mineral density. CtAr cortical cross sectional area, Fie.LiX, fracture data seayer, *significat tridex: d. Cohen <i>s.d.</i> , η_{1}^{2} partial	abMD (gron) 11 1 + 1.12.12 1, 1.50±0.02 0, 000 0, 000 0, 000 0, 000 1, 1.95±0.01 1, 1.13±0.01 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,	Lumbar Spine	T0 T1	38.72±9.76	38.14 ± 6.22 42.70 ± 7.08	0.07	0.602	0.501	<0.001
$ \begin{array}{c} \mbox{Legs} & \mbox{T0} & 1.125\pm0.127 & 1.050\pm0.079 & 0.70 \\ \mbox{T1} & 1.098\pm0.150 & 1.130\pm0.100 & 0.53 & 0.549^{\pm} & 0.572^{\pm} & 0.00 \\ \mbox{Whole body} & \mbox{T0} & 0.093\pm0.004 & 0.094\pm0.006 & 0.20 \\ \mbox{T1} & 0.094\pm0.004 & 0.095\pm0.007 & 0.25 & 0.057 & 0.090 & 0.00 \\ \mbox{Lumbar Spine} & \mbox{T0} & 0.114\pm0.010 & 0.102\pm0.011^{\pm} & 1.12 \\ \mbox{Femal Neck} & \mbox{T0} & 0.114\pm0.010 & 0.102\pm0.011^{\pm} & 1.12 \\ \mbox{Femal Neck} & \mbox{T0} & 0.195\pm0.018 & 0.173\pm0.012^{\pm} & 1.45 \\ \mbox{T1} & 0.195\pm0.021 & 0.177\pm0.013^{\pm} & 1.01 & 0.002 & 0.096^{\pm} & 0.00 \\ \mbox{PQCT} & & & & & & & & & & & & & & & & & & &$	Legs T0 1.125-0.127 1.050-0.079 0.70 BNAD (cycm) 1.198-0.150 1.130-0.100 0.53 0.5497 0.5725 0.005 Whole body T0 0.095-0.004 0.095-0.007 0.25 0.057 0.090 0.003 Jumbar Spine T0 0.114-0.010 0.102-0.011* 1.12 0.057 0.096 0.004 POCT T1 0.118-0.018 0.173-0.012* 0.0 0.002 0.096* 0.064 POCT T0 0.196-0.021 0.177-0.013* 0.0 0.002 0.096* 0.016 POCT T0 348-0.612-07.567 30.4.520-251.166* 1.3 0.109 0.025 0.016 POCT T0 31.352.03.216* 3.13 0.109 0.025 0.016 Bit DMD (mgcm ²) T0 31.352.03.241 30.154-0.132* 1.06 0.112 0.032 0.011 Bit DMD (mgcm ²) T0 31.352.03.34 0.50 0.53 0.494* 0.086 0.55 <	aBMD (g/cm ²)	11	44.21±12.12	43.70±7.98	0.05	0.002*	0.391*	<0.001
$\begin{array}{c} \mathbf{L} & \mathbf{T} & 1 & 1 \cdot 198 \pm 0.150 & 1 \cdot 130 \pm 0.100 & 0 \cdot 53 & 0 \cdot 549^{\ddagger} & 0 \cdot 572^{\ddagger} & 0 \cdot 00 \\ \mathbf{W} \text{hole body} & \mathbf{T0} & 0 \cdot 093 \pm 0.004 & 0 \cdot 094 \pm 0.006 & 0 \cdot 20 \\ \mathbf{L} \text{umbar Spine} & \mathbf{T0} & 0 \cdot 0 \cdot 144 \pm 0.010 & 0 \cdot 0 \cdot 0 \cdot 0 \cdot 0 \cdot 0 \\ \mathbf{L} \text{umbar Spine} & \mathbf{T0} & 0 \cdot 0 \cdot 144 \pm 0.010 & 0 \cdot 0 \cdot 0 \cdot 0 \cdot 0 \\ \mathbf{T1} & 0 \cdot 1944 \cdot 0 \cdot 0 \cdot 0 & 0 \cdot 0 \cdot 0 \cdot 0 \\ \mathbf{T1} & 0 \cdot 1944 \cdot 0 \cdot 0 \cdot 10 \cdot 10 \cdot 12 & 0 \cdot 11 \\ \mathbf{Femoral Neck} & \mathbf{T0} & 0 \cdot 1954 \cdot 0 \cdot 0 \cdot 10 & 10 \cdot 123 & 101 & 0 \cdot 002 & 0 \cdot 096^{\ddagger} & 0 \cdot 0 \\ \mathbf{POCT} & 74 & 74 & 75 & 10 & 11 \cdot 343 \cdot 854 \cdot 258 & 11 & 301 \cdot 10 \cdot 10 & 0 \cdot 002 & 0 \cdot 0 \\ 74 & \mathbf{5ste} & \mathbf{T1} & 309 \cdot 0 \cdot 154 \cdot 554 & 113 & 0 \cdot 109 & 0 \cdot 025 & 0 \cdot 0 \\ 74 & \mathbf{5ste} & \mathbf{T1} & 309 \cdot 0 \cdot 154 \cdot 255 & 278 \cdot 304 \cdot 33 \cdot 827^{\dagger} & 101 & 0 \cdot 002 & 0 \cdot 0 \\ 75 & 75 & 10 & 317 \cdot 911 \cdot 44 \cdot 056 & 278 \cdot 304 \cdot 333 \cdot 827^{\dagger} & 101 & 0 & 0 \cdot 0 \\ 75 & 75 & 10 & 3135 \cdot 359 & 3004 \pm 0 \cdot 302 & 0 \cdot 0 \\ 75 & 75 & 10 & 3135 \cdot 359 & 309 \cdot 10 & 3135 \cdot 359 & 1062 & 554 & 0 \cdot 39 & 0 \\ 75 & 75 & 10 & 10 \cdot 328 \cdot 325 & 1059 & 1059 & 554 & 0 \cdot 29 \\ 71 & 10 & 10 & 328 \cdot 329 & 10 & 10 & 10 & 303 & 10 & 10 \\ 75 & 96 & 10 & 303 & 10 & 10 & 0 & 303 & 10 \\ 76 & 10 & 10 & 328 \cdot 328 & 3108 & 3034 & 350 & 0 & 303 & 0 \\ 71 & 10 & 328 & 314 & 327 & 10 & 338 & 10 & 384 & 0 & 0 \\ 71 & 10 & 128 & 12 \cdot 21 & 156 & 11 & 12 & 12 & 11 & 12 & 12 & 12 & 13 & 11 & 11 & 11 & 11 & 1$	TI 1.198-0.150 1.130-0.100 0.53 0.549 ² 0.005 Whole body T0 0.093-0.004 0.094-0.006 0.20 0.057 0.090 0.003 Lumbor Spine T0 0.114-0.0104 0.102-0.011 1.12 0.057 0.090 0.003 Femoral Neck T1 0.160.011 0.168-0.010 0.020.011 1.13 0.002 0.096 ² 0.064 pCT T1 0.196-0.014 0.175-0.013 1.01 0.002 0.096 ² 0.064 pCT T1 0.196-0.021 1.776-0.013 1.01 0.002 0.096 ² 0.064 pCT T1 3.49.621+47.567 304.521+27.104 1.13 0.012 0.012 0.012 0.013 BWD (mg/cm) T0 3.17541-44.056 273.404+32.739 1.06 0.112 0.032 0.013 BWD (mg/cm) T1 3.154-0.34 3.154-0.34 3.154-0.34 0.015 0.017 0.023 -0.001 BWD (mg/cm) T1	Legs	Т0	1.125±0.127	1.050±0.079	<mark>0.70</mark>			
$\begin{array}{l c cm} \textbf{BMAD}\left(\textbf{g/cm}^{\prime}\right) & T0 & 0.093\pm0.004 & 0.094\pm0.006 & 0.20 \\ T1 & 0.094\pm0.004 & 0.095\pm0.007 & 0.25 & 0.057 & 0.090 & 0.00 \\ Lumbar Spine & T0 & 0.114\pm0.010 & 0.102\pm0.011^{\prime} & 1.12 \\ T1 & 0.116\pm0.011 & 0.108\pm0.010^{\prime} & 0.80 & 0.203^{\prime} & 0.553^{\prime} & 0.16 \\ Femoral Neck & T0 & 0.195\pm0.018 & 0.173\pm0.012^{\prime} & 1.45 \\ T1 & 0.195\pm0.021 & 0.177\pm0.013^{\prime} & 1.01 & 0.002 & 0.096^{\prime} & 0.00 \\ \textbf{pQCT} & & & & & & & & & & & & & & & & & & &$	BMADE (gc onf) T1 0.093.40.004 0.09440.006 0.20 0.057 0.090 0.003 Immar Spite T0 0.1146.0010 0.020-0011 1.12 0.0553 0.169* Femoral Neck T0 0.1150.0018 0.1750.0018 0.13 0.002 0.096* 0.064 pCT 1 0.1950.021 0.1776.0013 1.03 0.002 0.096* 0.064 pCT T1 0.1950.021 0.1776.0013 1.03 0.002 0.096* 0.064 pCT T1 0.1950.021 0.1776.0013 1.03 0.002 0.016* 0.016 pCT T1 343.843.248.11 30.108 0.022 0.013 0.013 0.012 0.013 0.013 0.013 0.022 0.013 0.013 0.022 0.013 0.013 0.022 0.013 0.022 0.013 0.022 0.013 0.046 0.046 0.023 0.006 0.046 0.040 0.046 0.040 0.045 0.040 <t< td=""><td>•</td><td>T1</td><td>1.198 ± 0.150</td><td>1.130 ± 0.100</td><td><mark>0.53</mark></td><td>0.549‡</td><td>0.572‡</td><td>0.005</td></t<>	•	T1	1.198 ± 0.150	1.130 ± 0.100	<mark>0.53</mark>	0.549‡	0.572‡	0.005
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Whele body 10 0.093-0.004 0.093-0007 0.20 0.057 0.090 0.003 Lumbar Spine T0 0.114-0.010 0.102-0.0111 1.12 0.002 0.095 0.007 Femoral Neck T1 0.195-0.013 0.173-0.013 1.61 0.002 0.096 0.064 PO T T1 0.195-0.013 0.1774-0.013 1.01 0.002 0.096 0.064 PO T T1 340.621+87.567 304.520+25.136 1.3 0.009 0.025 0.016 T1 340.621+87.567 304.520+25.136 1.3 0.09 0.022 0.016 T0 wBMD (mg/cm ¹) T0 343.84+28.814 301.814+20.237 1.01 0.109 0.025 0.016 T1 309.01+44.056 273.404+32.739 1.06 0.112 0.032 0.013 SW MG T1 3.154.0.344 0.50 0.633 0.4944 0.066 CV BMD (mg/cm ¹) T0 3.154.0.344 0.50 0.633 0.4944	BMAD (g/cm ³)	-						
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Lumbar Spine 10 0.0790 0.00000 0.00000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.00	Whole body	T0 T1	0.093 ± 0.004	0.094 ± 0.006 0.005 ± 0.007	0.20	0.057	0.000	0.003
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Tit O. 116-0.011 O. 108-0.016 O. 108 O. 203 0.553 0.169* Femoral Neck T0 0.195+0.021 0.177+0.013 1.0 0.002 0.996* 0.064 PCT	Lumbar Spine	T0	0.094 ± 0.004 0.114±0.010	0.093 ± 0.007 0.102±0.011§	1.12	0.037	0.090	0.003
Femoral NeckT0 0.195 ± 0.018 0.173 ± 0.012^{3} 1.45 PQCT4% siteTL 0.195 ± 0.021 0.177 ± 0.013^{3} 1.01 0.002 0.096^{2} 0.002^{2} 4% siteTL334.884±28.814 301.816 ± 21.023^{3} 1.31 0.109 0.025 0.012^{3} Tb,vBMD (mg/cm ³)T0 317.911 ± 44.056 278.130 ± 33.827^{3} 1.01 0.002 0.032 0.0032^{2} 0.0032^{2} 38% siteT1 334.884 ± 28.814 301.816 ± 21.023^{3} 1.06 0.112 0.032^{2} 0.0032^{2} Cl_VBMD (mg/cm ³)T0 31.35 ± 0.369^{3} 3.004 ± 32.739^{3} 1.06^{2} 0.012^{3} 0.092^{2} 0.012^{3} Cl_VBMD (mg/cm ³)T0 3.13 ± 0.369^{3} 3.004 ± 3.02^{2} 0.33^{4} $0.494^{4}^{2}^{2}^{2}$ $0.017^{2}^{2}^{2}^{2}^{2}^{2}^{2}^{2}^{2}^{2}$	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Euliour Spine	T1	0.116±0.011	$0.102 \pm 0.010^{\$}$	0.80	0.203‡	0.553‡	0.169*
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	TI 0.195±0.021 0.177±0.013 ³ 101 0.002 0.096 ⁴ 0.064 4% site TI 334.854.28.814 301.816.21.023.31 1.1 0.109 0.025 0.016 By MDM (mg/cm ¹) T0 31.93.854.28.814 301.816.21.023.31 1.1 0.109 0.025 0.016 By MDM (mg/cm ¹) T0 31.79.41.40.56 278.1304:33.23.71 1.01 0.032 0.013 38% site TI 30.90.011:34.253 273.404:32.739 1.06 0.112 0.032 0.013 11 3.349.04.41 31.534.03.34 0.50 0.68.3 ¹ 0.494 ⁴ 0.086 CV RMD (mg/cm ¹) T0 193.59.11.44.288 384.43.99.67 0.29 0.017 0.023 <0.001	Femoral Neck	Т0	0.195±0.018	0.173±0.012§	<mark>1.45</mark>			
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	pQCT TextBMD (mg/cm ¹) TO 340.621437.567 304.520425.1365 1.13 By BMD (mg/cm ¹) TO 334.8844.2814 301.816421.023 1.31 0.109 0.025 0.016 By BMD (mg/cm ¹) TO 31.3540.366 278.3104.333.277 1.01 0.012 0.032 0.013 BY osite TI 3.4490.441 3.13540.366 2.0044.5032 0.59 0.683 ² 0.494 ² 0.086 CxVBMD (mg/cm ¹) TO 31.3540.366 3.00440.302 0.39 0.066 ² 0.494 ² 0.086 CxVBMD (mg/cm ¹) TO 31.3540.366 3.00440.302 0.39 0.066 ² 0.494 ⁴ 0.086 CxVBMD (mg/cm ¹) TO 31.3540.366 3.00440.302 0.39 0.067 0.422 ⁴ 0.086 CxVBMD (mg/cm ¹) TO 31.3540.366 3.0044.932 0.057 0.067 0.422 ⁴ 0.036 CxVA TO 32.571.200501 0.400.225 0.55 0.383 ² 0.384 ² 0.002		T1	0.195±0.021	0.177±0.013§	<u>1.01</u>	0.002	0.096‡	0.064
4% site Tt vBMD (mg/cm ³) T0 340.621±37.567 304.520±25.136 [§] 1.13 Tt 334.884±28.814 301.816±21.023 [§] 1.31 0.109 0.025 0.00 Tb vBMD (mg/cm ³) T0 317.911±44.056 278.130±33.827 [§] 1.01 T1 309.011±34.253 273.404±32.739 [§] 1.06 0.112 0.032 0.00 38% site Tt BMC (g) T0 3.135±0.369 3.004±0.302 0.39 T1 3.349±0.441 3.153±0.334 0.50 0.683 ^{§‡} 0.494 ^{§‡} 0.00 Ct vBMD (mg/cm ³) T0 1053.591±29.836 1062.454±30.967 0.29 T1 1051.289±32.829 1059.696±23.984 0.29 0.017 0.023 <0.00 Ct vIBMD (mg/cm ³) T0 1051.591±42.88 384.539±41.377 0.33 Ct vIBMD (mg/cm ³) T0 1053.591±46.288 384.539±41.377 0.33 Ct vIBMD (mg/cm ³) T0 320.438±553.960 3069.009±439.040 0.28 Ct vIBMD (mg/cm ³) T0 3210.438±553.960 3069.009±439.040 0.28 T1 3428.474±535.839 3198.564±473.699 0.46 0.432 ^{§‡} 0.199 ^{§‡} 0.00 Stlp (mm ³) T0 1455.894±245.321 3162.122±207.65 0.55 Tt 3428.474±535.139 3198.564±473.699 0.46 0.432 ^{§‡} 0.199 ^{§‡} 0.00 Stlp (mm ³) T0 1455.894±245.321 3162.122±207.65 0.55 Tt 3428.474±535.839 3198.564±473.699 0.46 0.432 ^{§‡} 0.199 ^{§‡} 0.00 Dt ap resented as mean ± standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generati attificial turf with elastic layer; 3G-NEL: football players who trained in third-generati artificial turf witheut elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral density; PQCT: peripheral quantitati computed tomography. Tt vBMD: total volumetric bone mineral density; CLAr: cortical cross sectional area; Fre.LdX: fracture load (axe X); SSI [§] polar : index, <i>d</i> : Cohen s <i>d</i> , r [§] , partial eta square. *Significant differences when compared to 3G-EL; [‡] significant differences within groups between the beginning and the final of the season; *significant differences when compared to 3G-EL; [‡] significant differences within groups between the beginning and the final of the season; *significant differences when compared to 3G-EL;	4% site 10 340 621±37,567 304.520±25.136 ⁴ 1.3 0.109 0.025 0.016 Thv BMD (mg/cm ³) T0 317,911±44.056 278.130±33.277 106 0.112 0.032 0.013 38% site T1 309 011±34.253 273.40±3.2739 106 0.112 0.032 0.013 38% site T1 3.13±0.369 3.00±4.032 0.39 0.683 ³ 0.494 ⁴ 0.086 ClyBMD (mg/cm ³) T0 1051.591±29.836 1002.454±3.396 72.9 0.017 0.023 <0.001 CAM (mm ²) T0 3059.11±29.2586 1002.454±3.050 7.7 0.33 0.404 0.023 <0.001 CAM (mm ²) T0 3059.91±29.259 0.17 0.023 <0.001 CAM (mm ²) 0.017 0.023 <0.001 CAM (mm ²) T0 338.91±28.283 1031.0256 15.4 0.383 ³ 0.384 ⁴ <0.001 CAM (mm ²) T0 4254.8455.39 0.306.0092439.040 0.28 0.379 ² 0.309	pQCT							
$\begin{array}{c} 10^{+} 340.81^{+} 5.307 \\ 10^{+} 340.82^{+} 22.837 \\ 10^{+} 340.84^{+} 22.814 \\ 10^{+} 301.816\pm 21.023^{+} 1.31 \\ 10^{+} 0.109 \\ 10^{+} 0.025 \\ 10^{+} 0.032 \\ 10^{+$	$ \begin{array}{c} 113 \\ 113 \\ 113 \\ 113 \\ 114 \\ 113 \\ 114 \\ 113 \\ 114 \\ 113 \\ 114 \\ 113 \\ 113 \\ 113 \\ 111 \\ 113 \\ 113 \\ 113 \\ 111 \\ 113 $	4% site	ΤO	240 621127 567	204 520 + 25 1268	1.12			
Tb vBMD (mg/cm³)TiD5 host for 317.911±44.056278.130±33.82731.01 1.01Tb vBMD (mg/cm³)Ti309.011±34.253273.404±32.73981.060.1120.0320.0038% siteTi3.349±0.4413.153±0.3693.004±0.3020.39Ct vBMD (mg/cm³)To1.053.591±29.8361.062.454±30.9670.29T10.1053.591±29.8361.062.454±30.9670.29Ct vBMD (mg/cm³)To1.051.289±32.8291.059.696±23.9840.290.0170.023<0.00	The year of the second state of the second state of the second state state of the second state state of the second state of the second state state state of the second state of the second state of the second state state of the second state of the second state of the second state state state of the second state of the second state of	Tt.VEWD (ing/cill*)	T0 T1	340.021 ± 37.307 334.884+28.814	$304.320\pm 23.130^{\circ}$ $301.816\pm 21.023^{\circ}$	1.15	0.109	0.025	0.016
T1 309.011 ± 34.253 $273.404\pm 32.739^{\circ}$ 1.06 0.112 0.032 0.032 38% siteT1 3.135 ± 0.369 3.004 ± 0.302 0.39 TLBMC (g)T0 3.135 ± 0.369 3.004 ± 0.302 0.39 Ct,vBMD (mg/cm ³)T0 1053.591 ± 29.836 1062.454 ± 30.967 0.29 T1 1051.289 ± 32.829 1059.696 ± 23.984 0.29 0.017 0.023 <0.0023 CtAr (mm ²)T0 $398/11\pm 46.288$ 384.539 ± 41.377 0.333 <0.0023 <0.0023 CtTh (mm)T0 4.941 ± 0.501 4.716 ± 0.295 0.55 $<0.383^{\circ}$ 0.384° $<0.066^{\circ}$ Fre.LdX (N)T0 3210.438 ± 553.960 3069.009 ± 439.040 0.28 $<0.383^{\circ}$ 0.384° $<0.019^{\circ}$ SSIp (mm ³)T0 1455.894 ± 245.232 1362.122 ± 207.083 0.41 $<0.432^{\circ}$ 0.199° 0.002° Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; BMDD: areal bone mineral density; BMAD: bone mineral density; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; CLVBMD: cortical volumetric bone mineral density; CLAr. cortical rootball players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; BMDD: areal bone mineral density; CLAr. cortical rootball players who trained in third-generation artificial turf without elastic layer; SSIp: polar i index; d: Cohen's d; η^2_P : pa	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Tb.vBMD (mg/cm ³)	TO	317.911±44.056	278.130±33.827§	1.01	0.109	0.020	0.010
38% site T0 3.135 ± 0.369 3.004 ± 0.302 0.39 Ct, vBMD (mg/cm ³) T0 1053.591 ± 29.836 1062.454 ± 30.967 0.29 T1 1051.289 ± 32.829 1059.696 ± 23.984 0.29 0.017 0.023 <0.02 Ct, VBMD (mg/cm ³) T0 398.911 ± 46.288 384.539 ± 41.377 0.33 0.66^{2} 0.462^{2} 0.017 0.023 <0.0023 Ct, Th (mm) T0 $3.98.911\pm46.288$ 384.539 ± 41.377 0.33 0.66^{2} 0.462^{2} 0.017 0.023 <0.0023 Ct, Th (mm) T0 4.941 ± 0.501 4.716 ± 0.295 0.55 0.55 0.55 0.383^{2} 0.384^{2} 0.199^{2} 0.002 Fre.LdX (N) T0 3210.438 ± 553.960 3069.009 ± 439.040 0.28 0.432^{2} 0.199^{2} 0.002 SSIp (mm ³) T0 1455.894 ± 245.232 1362.122 ± 207.083 0.41 0.199^{2} 0.002 0.399^{2} 0.002 0.399^{2} 0.002 0.399^{2} 0.002 0.399^{2} 0.399^{2} 0.002 0.399^{2} <th< th=""><td>38% site 11 3.135±0.369 3.044±0.302 0.39 Cir, vBMD (mg/cm) T0 0.135±0.328 0.102.454±3.0967 0.29 CLAY (mm²) T0 103.289±3.28.29 1059.696±3.29.84 0.29 0.017 0.02.3 <0.001</td></th<>	38% site 11 3.135±0.369 3.044±0.302 0.39 Cir, vBMD (mg/cm) T0 0.135±0.328 0.102.454±3.0967 0.29 CLAY (mm ²) T0 103.289±3.28.29 1059.696±3.29.84 0.29 0.017 0.02.3 <0.001		T1	309.011±34.253	273.404±32.739§	<mark>1.06</mark>	0.112	0.032	0.013
It .BMC (g)T0 3.135 ± 0.369 3.004 ± 0.302 0.39 Ct .vBMD (mg/cm ³)T0 105.591 ± 29.836 1062.454 ± 30.967 0.29 Ct. n(mm ²)T0 398.911 ± 46.288 384.539 ± 41.377 0.33 Ct.Ar (mm ²)T0 398.911 ± 46.288 384.539 ± 41.377 0.33 Ct.Ar (mm)T0 4.941 ± 0.501 4.716 ± 0.295 0.55 Ct.Th (mm)T0 4.941 ± 0.501 4.716 ± 0.295 0.55 Fre.LdX (N)T0 3210.438 ± 553.960 3069.009 ± 439.040 0.28 SSIp (mm ³)T0 13428.474 ± 355.839 3198.564 ± 473.699 0.46 0.432^{\ddagger} 0.199^{\ddagger} 0.00 Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generatia artificial turf with elastic layer; 3G-NEL: football players who trained in artificial turf with out elastic layer; OXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; Tb vBMD: bone mineral density; T0 vASHD: cortical volumetric bone mineral density; Tb vBMD: trabecular volumetric bone mineral density; SIP: polar sindex; d: Cohen's d; n ² p; partial eta square. *Significant differences when compared to 3G-EL; *significant differences within groups between the beginning and the final of the season; *significa arginup ty time interaction.Cohen's d can be small (0.2 - 0.5), medium (0.5 - 0.8) or large (>0.8) and n ² p can be small (0.01 - 0.06). medium (0.06 - 0.14) or large (>0.14).	TLBMC (g) T0 3.13540.369 3.00440.302 0.39 T1 3.34940.441 3.13540.334 0.50 0.6831 0.4941 0.086 T1 1051.289432.82 1052.0662.3984 0.29 0.017 0.023 <0.001	38% site							
$\begin{array}{c} 11 & 5.349\pm0.441 & 5.15\pm0.354 & 0.50 & 0.685^{*} & 0.494^{*} & 0.00 \\ \hline Ct vBMD (mg/cm^{3}) & T0 & 1053.591\pm29.836 & 1062.454\pm30.967 & 0.29 \\ \hline T1 & 1051.289\pm32.829 & 1059.696\pm23.984 & 0.29 & 0.017 & 0.023 & <0.017 \\ \hline T1 & 1051.289\pm32.829 & 1059.696\pm23.984 & 0.29 & 0.017 & 0.023 & <0.017 \\ \hline T1 & 423.714\pm56.310 & 400.212\pm43.680 & 0.47 & 0.606^{\ddagger} & 0.462^{\ddagger} & 0.017 \\ \hline T1 & 5.122\pm0.476 & 4.903\pm0.326 & 0.54 & 0.383^{\ddagger} & 0.384^{\ddagger} & <0.017 \\ \hline T1 & 5.122\pm0.476 & 4.903\pm0.326 & 0.54 & 0.383^{\ddagger} & 0.384^{\ddagger} & <0.017 \\ \hline T1 & 3428.474\pm535.839 & 3198.564\pm473.699 & 0.46 & 0.432^{\ddagger} & 0.199^{\ddagger} & 0.017 \\ \hline T1 & 3428.474\pm535.839 & 3198.564\pm473.699 & 0.46 & 0.432^{\ddagger} & 0.199^{\ddagger} & 0.017 \\ \hline SSIp (mm^{3}) & T0 & 1455.894\pm245.232 & 1362.122\pm207.083 & 0.41 \\ \hline T1 & 1544.487\pm224.998 & 1438.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \hline Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generation artificial turf with elastic layer; 3G-NEL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; Tb.vBMD: trabecular volumetric bone mineral density; Tt.BMC: total bone mineral content; cortex volumetric bone mineral density; Tb.vBMD: trabecular volumetric bone mineral density; Tt.BMC: total bone mineral content; cortex volumetric bone mineral density; Ct.Ar: cortical cross sectional area; Fre.LdX: fracture load (axe X); SSIP: polar i index; d: Cohen's d; q^{2}_{p}$; partial eta square. ⁸ Significant differences within groups between the beginning and the final of the season; *significat group by time interaction. Cohen's d can be small (0.2 - 0.5), medium (0.5 - 0.8) or large (>0.8) and q^{2}_{p} can be small (0.01 - 0.06). medium (0.06 - 0.14) or large (>0.14).	$ \frac{1}{C^{3}} (1 - 3) + \frac{1}{2} (1 - 3) + \frac{1}{$	Tt.BMC (g)	T0 T1	3.135±0.369	3.004±0.302	0.39	0 (92†	0.404	0.097
$\begin{array}{c} \mbox{T1} & 1051.289\pm32.829 & 1059.696\pm23.984 & 0.29 & 0.017 & 0.023 & <0.017 \\ \mbox{T1} & 423.714\pm56.310 & 400.212\pm43.680 & 0.47 & 0.606^{\ddagger} & 0.462^{\ddagger} & 0.017 \\ \mbox{T1} & 423.714\pm56.310 & 400.212\pm43.680 & 0.47 & 0.606^{\ddagger} & 0.462^{\ddagger} & 0.017 \\ \mbox{T1} & 423.714\pm56.310 & 400.212\pm43.680 & 0.47 & 0.606^{\ddagger} & 0.462^{\ddagger} & 0.017 \\ \mbox{T1} & 423.714\pm56.310 & 400.212\pm43.680 & 0.47 & 0.606^{\ddagger} & 0.462^{\ddagger} & 0.017 \\ \mbox{T1} & 5.122\pm0.476 & 4.903\pm0.326 & 0.54 & 0.383^{\ddagger} & 0.384^{\ddagger} & <0.017 \\ \mbox{T1} & 5.122\pm0.476 & 4.903\pm0.326 & 0.54 & 0.383^{\ddagger} & 0.384^{\ddagger} & <0.017 \\ \mbox{T1} & 3428.474\pm535.839 & 3198.564\pm473.699 & 0.46 & 0.432^{\ddagger} & 0.199^{\ddagger} & 0.017 \\ \mbox{T1} & 3428.474\pm535.839 & 3198.564\pm473.699 & 0.46 & 0.432^{\ddagger} & 0.199^{\ddagger} & 0.017 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1 & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1 & 1544.487\pm224.998 & 1188.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 1 & 1544.487\pm224.998 & 1188.052\pm216.588 & 0.39 & 0.379^{\ddagger} & 0.399^{\ddagger} & 0.00 \\ \mbox{T1} & 0.548.487\pm2128.553 & 0.488 & 0.488 & 0.54$	$\begin{array}{c} \text{Lativity} (ug) (ug) (ug) (ug) (ug) (ug) (ug) (ug)$	$\frac{Ct}{V}$ vBMD (mg/cm ³)	T0	5.349±0.441 1053 591+29 836	3.153 ± 0.334 1062 454+30 967	0.50	0.083*	0.494*	0.080
Ct.Ar (mm²)T0 398.911 ± 46.288 384.539 ± 41.377 0.33 T1 423.714 ± 56.310 400.212 ± 43.680 0.47 $0.606\ddagger$ $0.462\ddagger$ $0.021\ddagger$ Ct.Th (mm)T0 4.941 ± 0.501 4.716 ± 0.295 0.55 0.55 0.55 0.55 T1 5.122 ± 0.476 4.903 ± 0.326 0.54 $0.383\ddagger$ $0.384\ddagger$ 0.00 Fre.LdX (N)T0 3210.438 ± 553.960 3069.009 ± 439.040 0.28 $0.199\ddagger$ 0.005 SSIp (mm³)T0 1455.894 ± 245.232 1362.122 ± 207.083 0.41 $0.379\ddagger$ $0.399\ddagger$ 0.00 Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; $3G-EL$: football players who trained in third-generation artificial turf with elastic layer; $3G-NEL$: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral apparent density; numeral densi	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Ct. (Bille (ing/till)	T1	1051.289 ± 32.829	1059.696±23.984	0.29	0.017	0.023	< 0.001
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Ct.Ar (mm ²)	Т0	398.911±46.288	384.539±41.377	<mark>0.33</mark>			
Ct.1h (mm)10 4.941 ± 0.501 4.716 ± 0.295 0.55 T1 5.122 ± 0.476 4.903 ± 0.326 0.54 $0.383\ddagger$ $0.384\ddagger$ <0.06 Frc.LdX (N)T0 3210.438 ± 553.960 3069.009 ± 439.040 0.28 SSIp (mm ³)T0 1455.894 ± 245.232 1398.564 ± 473.699 0.46 $0.432\ddagger$ $0.199\ddagger$ 0.025 SSIp (mm ³)T0 1455.894 ± 245.232 1362.122 ± 207.083 0.41 $0.379\ddagger$ $0.399\ddagger$ 0.0025 Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generatia $artificial turf$ with elastic layer; 3G-NEL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-rayabsorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral apparent density; pQCT: peripheral quantitativcomputed tomography; Tt.vBMD: total volumetric bone mineral density; Tb.vBMD: trabecular volumetric bone mineral density; Tt.BMC: total bonemineral content; Ct.vBMD: cortical volumetric bone mineral density; Ct.Ar: cortical cross sectional area; Frc.LdX: fracture load (axe X); SSIp: polar index; d: Cohen's d; η^2_p : partial eta square.*Significant differences when compared to 3G-EL; *significant differences within groups between the beginning and the final of the season; *significant group by time interaction.Cohen's d can be small (0.2 - 0.5), medium (0.5 - 0.8) or large (>0.8) and η^2_p can be small (0.01 - 0.06), medium (0.06 - 0.14) or large (>0.14).	$ \begin{array}{c} {\rm Cr} 1n ({\rm nm}) & 10 & 4.941\pm0.501 & 4.716\pm0.295 & 0.58 \\ {\rm T} & 5.122\pm0.476 & 4.903\pm0.326 & 0.54 & 0.383^{\circ} & 0.384^{\circ} & <0.001 \\ {\rm Fre.LdX} (N) & T0 & 3210.438\pm53.960 & 3069.009\pm439.040 & 0.28 \\ {\rm T1} & 3428.474\pm535.353 & 3198.564\pm73.690 & 0.46 & 0.432^{\circ} & 0.199^{\circ} & 0.057 \\ {\rm SSIp} ({\rm nm}^{\circ}) & T0 & 1455.894\pm245.232 & 1362.122\pm207.083 & 0.41 \\ {\rm T1} & 1544.487\pm224.998 & 1458.052\pm216.588 & 0.39 & 0.379^{\circ} & 0.399^{\circ} & 0.002 \\ {\rm Data \ presented \ as mean \pm standard \ deviation. T0: \ pre-season \ moment; \ 3G-EL: \ football \ players \ who \ trained \ in \ third-generation \ artificial \ tur' \ whot \ taiste \ layer; \ DXA: \ tual-energy X-ray \ absorptionetry; \ BMC: \ bose \ mineral \ density; \ DXA: \ tual-energy X-ray \ absorptionetry; \ BMC: \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ DXA: \ tual-energy X-ray \ absorptionetry; \ BMC: \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ density; \ TLVBMC: \ total \ bose \ mineral \ density; \ TLVBMC: \ total \ density; \ tual \ density; \ tua$		T1	423.714±56.310	400.212±43.680	<mark>0.47</mark>	0.606‡	0.462‡	0.036
Fre.LdX (N)T0 3210.438 ± 553.960 3069.009 ± 439.040 0.28 Fre.LdX (N)T0 3210.438 ± 553.960 3069.009 ± 439.040 0.28 SSlp (mm ³)T1 3428.474 ± 535.839 3198.564 ± 473.699 0.46 $0.432\ddagger$ $0.199\ddagger$ 0.02 SSlp (mm ³)T0 1455.894 ± 245.232 1362.122 ± 207.083 0.41 T1 1544.487 ± 224.998 1458.052 ± 216.588 0.39 $0.379\ddagger$ $0.399\ddagger$ 0.002 Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generation artificial turf with elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral apparent density; pQCT: peripheral quantitative computed tomography; Tt.vBMD: total volumetric bone mineral density; Tb.vBMD: trabecular volumetric bone mineral density; Tt.BMC: total bone mineral density; Ct.Ar: cortical cross sectional area; Fre.LdX: fracture load (axe X); SSIp: polar is index; d: Cohen's d; η^2_p : partial eta square. [§] Significant differences when compared to 3G-EL; [‡] significant differences within groups between the beginning and the final of the season; *significant group by time interaction.Cohen's d can be small (0.2 - 0.5), medium (0.5 - 0.8) or large (>0.8) and η^2_p can be small (0.01 - 0.06), medium (0.06 - 0.14) or large (>0.14).	Fre.LdX11 3.12290476 4.905912926 0.28 0.283 0.284 $<$ $<$ Fre.LdX(N)T0 32104384553.960 309809439040 0.28 0.383 0.384 $<$ 0.002 SSIg (mm ³)T0 14385.844245323 1382.12124207083 0.441 0.339 0.399 0.399 0.399 0.002 Data presented as mean \pm standard deviation. T0. pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generation artificial turf withed static layer; Sd-NEL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral apparent density; Ct Sda bone mineral content; Ct MBD: cortical volumetric bone mineral density; DV MD: thaceular volumetric bone mineral density; T1 MVD: Thabecular volumetric bone mineral density; T1 MVD: transcellar	2 2 2	11		1716 ± 0.205	0.55			
$\frac{11}{1}$ $\frac{11}{3}$	$\frac{100}{100} \frac{100}{100} 10$	Ct.Th (mm)	T0	4.941±0.501	4.710±0.295	0.54	0.202+	0.204*	<0.001
$\frac{\text{SSIp} (\text{mm}^3)}{\text{T1}} = \frac{\text{T0}}{1544.487\pm224.998} = \frac{1362.122\pm207.083}{1458.052\pm216.588} = \frac{0.41}{0.39} = \frac{0.379^{\ddagger}}{0.399^{\ddagger}} = \frac{0.399^{\ddagger}}{0.000} = \frac{0.379^{\ddagger}}{0.399^{\ddagger}} = \frac{0.399^{\ddagger}}{0.399^{\ddagger}} = \frac{0.399^{\ddagger}}{0.39^{\ddagger}} = \frac{0.399^{\ddagger}}{0.399^{\ddagger}} = 0.399^{1$	SSIp (mm ³) T0 1455.894+245.232 1362.122+207.083 0.41 0.379: 0.399: 0.002 Data presented as mean ± standard deviation. T0: pre-season moment: T1: post-season moment: 3G-EL: football players who trained in third-generation artificial turf with elastic layer, DXA: dual-energy X-ray absorptionetry; BMC: bone mineral adbone mineral density; BMD: bone mineral adparent density; DCT: peripheral quantitative computed tomography: Tt vBMD: total volumetric bone mineral density; Dt vBMD trabecular volumetric bone mineral density; BMC: bone mineral density; Dt vBMD: total volumetric bone mineral density; CLAr: cortical cross sectional area, Fre.LdX, fracture load (axe X), SSIP, polar stri index; d: Coher s' d: η ² ₁ , pratile ta square. *Significant differences when compared to 3G-EL; significant differences within groups between the beginning and the final of the season; *significant group by time interaction. Cohen s d can be small (0.2 - 0.5), medium (0.5 - 0.8) or large (>0.8) and η ² _p can be small (0.01 - 0.06), medium (0.06 - 0.14) or large (>0.14).	Ct.Th (mm)	T0 T1 T0	4.941±0.501 5.122±0.476 3210.438+553.960	4.710±0.235 4.903±0.326 3069 009+439 040	0.54 0.28	0.383‡	0.384‡	< 0.001
T1 1544.487±224.998 1458.052±216.588 0.39 0.379 [‡] 0.399 [‡] 0.00 Data presented as mean ± standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generatia artificial turf with elastic layer; 3G-NEL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral apparent density; pQCT: peripheral quantitatic computed tomography; Tt.vBMD: total volumetric bone mineral density; Tb.vBMD: trabecular volumetric bone mineral density; Tt.BMC: total bone mineral density; Tc.vBMD: cortical volumetric bone mineral density; Ct.Ar: cortical cross sectional area; Frc.LdX: fracture load (axe X); SSIp: polar index; <i>d</i> : Cohen's <i>d</i> ; η^2_p : partial eta square. ⁸ Significant differences when compared to 3G-EL; [‡] significant differences within groups between the beginning and the final of the season; *significant group by time interaction. Cohen's <i>d</i> can be small (0.2 – 0.5), medium (0.5 – 0.8) or large (>0.8) and η^2_p can be small (0.01 – 0.06). medium (0.06 – 0.14) or large (>0.14).	T1 1544.487+224.998 1458.052+216.588 0.39 0.379 0.399: 0.002 Data presented as mean ± standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMD: Dotoparphy; T1: VBMD: total volumetric bone mineral density; T1: trabecular volumetric bone mineral density; PCCT: peripheral quantitative computed tomography; T1: VBMD: total volumetric bone mineral density; T1: Trabecular volumetric bone mineral density; T1: BMC: total bone compared to 3G-EL; 'significant differences within groups between the beginning and the final of the season; *significant group by time interaction. Cohen's <i>d</i> : <i>q</i> : ρ: partial eta square. "Significant differences when compared to 3G-EL; 'significant differences within groups between the beginning and the final of the season; *significant group by time interaction. Cohen's <i>d</i> : <i>a</i> : be small (0.2 – 0.5), medium (0.5 – 0.8) or large (>0.8) and η ² _p can be small (0.01 – 0.06), medium (0.06 – 0.14) or large (>0.14).	<mark>Ct.Th</mark> (mm) Fre.LdX (N)	T0 T1 T0 T1	4.941 ± 0.501 5.122 ±0.476 3210.438 \pm 553.960 3428.474 \pm 535.839	4.903±0.326 3069.009±439.040 3198.564±473.699	0.54 0.28 0.46	0.383‡ 0.432‡	0.384 [‡] 0.199 [‡]	<0.001 0.057
Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generatia artificial turf with elastic layer; 3G-NEL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral apparent density; pQCT: peripheral quantitatic computed tomography; Tt.vBMD: total volumetric bone mineral density; Tb.vBMD: trabecular volumetric bone mineral density; Tt.BMC: total bone mineral density; Ct.Ar: cortical cross sectional area; Frc.LdX: fracture load (axe X); SSIp: polar sindex; <i>d</i> : Cohen's <i>d</i> ; η^2_p : partial eta square. ⁸ Significant differences when compared to 3G-EL; [‡] significant differences within groups between the beginning and the final of the season; *significant group by time interaction. Cohen's <i>d</i> can be small (0.2 – 0.5), medium (0.5 – 0.8) or large (>0.8) and η^2_p can be small (0.01 – 0.06). medium (0.06 – 0.14) or large (>0.14).	Data presented as mean \pm standard deviation. T0: pre-season moment; T1: post-season moment; 3G-EL: football players who trained in third-generation artificial turf with elastic layer; 3G-NEL: football players who trained in third-generation artificial turf without elastic layer; DXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; aBMD: areal bone mineral density; BMAD: bone mineral density; pQCT: peripheral quantitative computed tomography; TtvBMD: total volumetric bone mineral density; CLAr: cortical volumetric bone mineral density; cortex volumetric bone mineral density; CLAR: cor	<mark>Ct.Th</mark> (mm) Frc.LdX (N) SSI <mark>p</mark> (mm³)	T0 T1 T0 T1 T1 T0	$\begin{array}{r} 4.941\pm 0.501\\ 5.122\pm 0.476\\ 3210.438\pm 553.960\\ 3428.474\pm 535.839\\ 1455.894\pm 245.232\end{array}$	4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083	0.54 0.28 0.46 0.41	0.383 [‡] 0.432 [‡]	0.384 [‡] 0.199 [‡]	<0.001 0.057
group by time interaction. Cohen's <i>d</i> can be small (0.2 – 0.5), medium (0.5 – 0.8) or large (>0.8) and η_p^2 can be small (0.01 – 0.06). medium (0.06 – 0.14) or large (>0.14).	group by time interaction. Cohen's <i>d</i> can be small (0.2 – 0.5), medium (0.5 – 0.8) or large (>0.8) and η ² _p can be small (0.01 – 0.06). medium (0.06 – 0.14) or large (>0.14).	Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc	TI T0 T1 T0 T1 T0 T1 e standard de layer; 3G-N one mineral	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m	4.710 ± 0.293 4.903 ± 0.326 3069.009 ± 439.040 3198.564 ± 473.699 1362.122 ± 207.083 1458.052 ± 216.588 ent; T1: post-season momentiation arti- nineral density; BMAD: bool	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf wone mineral a	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la pparent densiti	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t tyer; DXA: dual- cy; pQCT: periphe Identity: TF BM	<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _p : [§] Significant differences w	T0 T1 T0 T1 T0 T1 e standard de layer; 3G-N one mineral tvBMD: to D: cortical v partial eta sy	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season nom IEL: football players who trai content; aBMD: areal bone mineral d rolumetric bone mineral dens quare. red to 3G-EL; [‡] significant dif	4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 ent; T1: post-season mome ned in third-generation arti- nineral density; BMAD: bo lensity; Tb.vBMD: trabecu ity; Ct.Ar: cortical cross se ferences within groups bet	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w one mineral a lar volumetri cctional area; ween the be;	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera <u>i</u> Frc.LdX: frac ginning and the	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t iver; DXA: dual- y; pQCT: periphe I density; Tt.BMG ture load (axe X); e final of the sease	<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone (SSIp: polar stra on; *significant
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM; index; d: Cohen's d; η ² _p : [§] Significant differences w group by time interaction Cohen's d can be small ((TO TI TO TI TO TI TO TI e standard de layer; 3G-N one mineral t.vBMD: to D: cortical v partial eta so vhen compan	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dons quare. red to 3G-EL; [‡] significant dif medium (0.5 – 0.8) or large (>	4.710±0.293 4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 ent; T1: post-season momends ned in third-generation arti- pineral density; BMAD: boo- lensity; Tb.vBMD: trabecu- ity; Ct.Ar: cortical cross sease ferences within groups bet 0.8) and η^2_p can be small (0.1000)	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w one mineral a lar volumetr ictional area; ween the be; 0.01 - 0.06.	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera is Fre.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t tyer; DXA: dual- y; pQCT: periphe I density; Tt.BM(ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone SSIp: polar stra on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM. index; d: Cohen's d; η ² _p : ⁸ Significant differences w group by time interaction Cohen's d can be small (0	TO TO TI TO TI TO TI TO TI To To To to to per mineral Cortical v partial eta so vhen compan	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral do rolumetric bone mineral dension quare. red to 3G-EL; [‡] significant diff medium (0.5 – 0.8) or large (>4	4.710±0.293 4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 tent; T1: post-season moment ned in third-generation arti- tineral density; BMAD: bo- lensity; Tb.vBMD: trabecu- ity; Ct.Ar: cortical cross seases ferences within groups bet 0.8) and η_{p}^{2} can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w ificial turf w one mineral a lar volumetric volumetric bectional area; ween the be; 0.01 - 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera is Fre.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t tyer; DXA: dual-o y; pQCT: periphe l density; Tt.BM0 ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone ; SSIp: polar stra on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bo computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _p : ⁸ Significant differences w group by time interaction Cohen's d can be small (f	TO TO T1 T0 T1 T0 T1 e standard de layer; 3G-N one mineral tvBMD: too D: cortical v partial eta su vhen compan	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dense quare. red to 3G-EL; ‡significant diff hedium (0.5 – 0.8) or large (>4	4.903 \pm 0.326 3069.009 \pm 439.040 3198.564 \pm 473.699 1362.122 \pm 207.083 1458.052 \pm 216.588 eent; T1: post-season momend in third-generation arti- nineral density; BMAD: bo- lensity; Tb.vBMD: trabecu- ity; Ct.Ar: cortical cross see ferences within groups bet 0.8) and η^2_p can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w me mineral a lar volumetr cctional area; ween the be; 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent densiti ic bone minera j. Frc.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t aver; DXA: dual- y; pQCT: periphe I density; Tt.BM4 ture load (axe X); e final of the sease - 0.14) or large (<0.00 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone SSIp: polar str on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _p : ^S Significant differences w group by time interaction Cohen's d can be small (f	TO TO T1 T0 T1 T0 T1 t_{0} standard de layer; 3G-N one mineral t.vBMD: too D: cortical v partial eta so vhen compan	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dense quare. red to 3G-EL; [‡] significant diff nedium (0.5 – 0.8) or large (>4	4.710±0.295 4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 tent; T1: post-season moment ned in third-generation arti- nineral density; BMAD: bo- lensity; Tb.vBMD: trabecu- ity; Ct.Ar: cortical cross set ferences within groups bet 0.8) and η_p^2 can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w one mineral a lar volumetr icctional area; ween the be; 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera Frc.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t tyer; DXA: dual- y; pQCT: periphe l density; TLBM ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone ; SSIp: polar stra on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _p : ^S Significant differences w group by time interaction Cohen's d can be small (f	TO TO T1 T0 T1 T0 T1 t_{0} standard de layer; 3G-N one mineral t'.vBMD: to D: cortical v partial eta so vhen compan D: 2 - 0.5), m	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dens quare. red to 3G-EL; [‡] significant dif hedium (0.5 – 0.8) or large (>4	4.710±0.295 4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 tent; T1: post-season moment interal density; BMAD: bo lensity; Tb.vBMD: trabecu ity; Ct.Ar: cortical cross set ferences within groups bet 0.8) and η_p^2 can be small (6)	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w me mineral a lar volumetr ictional area; ween the be; 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera Frc.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t yer; DXA: dual- y; pQCT: periphe I density; Tt.BM0 ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone ; SSIp: polar stra on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM significant differences w group by time interaction Cohen's d can be small (f	TO TO T1 T0 T1 T0 T1 standard de layer; 3G-N one mineral t'.vBMD: too D: cortical v partial eta so vhen compar 0.2 - 0.5), m	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dense quare. red to 3G-EL; ‡significant dif hedium (0.5 – 0.8) or large (>4	4.710±0.293 4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 tent; T1: post-season moment interal density; BMAD: bo lensity; Tb.vBMD: trabecu ity; Ct.Ar: cortical cross set ferences within groups bet 0.8) and η^2_p can be small (6)	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w me mineral a lar volumetr cctional area; ween the bep 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera ; Frc.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t aver; DXA: dual- y; pQCT: periphe l density; Tt.BMG ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone ; SSIp: polar stra on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM significant differences w group by time interaction Cohen's d can be small (f	TO TO T1 TO T1 TO T1 standard de layer; 3G-N one mineral t'.vBMD: tor D: cortical v partial eta so vhen compar	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dense quare. red to 3G-EL; ‡significant dif medium (0.5 – 0.8) or large (>4	4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 tent; T1: post-season moment interal density; BMAD: bo lensity; Tb.vBMD: trabecu- ity; Ct.Ar: cortical cross set ferences within groups bet 0.8) and η^2_p can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w me mineral a lar volumetr cctional area; ween the be; 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera Frc.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t iver; DXA: dual- y; pQCT: periphe I density; Tt.BMG ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone SSIp: polar stra on; *significant >0.14).
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		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _p : ^S Significant differences w group by time interaction Cohen's d can be small (f	TO TO T1 T0 T1 T0 T1 e standard de layer; 3G-N one mineral tvBMD: to D: cortical v partial eta su vhen compan 0.2 – 0.5), m	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dens quare. red to 3G-EL; [‡] significant dif nedium (0.5 – 0.8) or large (>1	4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 tent; T1: post-season moment neral density; BMAD: bo lensity; Tb.vBMD: trabecu- ity; Ct.Ar: cortical cross set ferences within groups bet 0.8) and η^2_p can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w one mineral a lar volumetrictional area; ween the be; 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent densiti ic bone minera j Frc.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] s who trained in t iver; DXA: dual- y; pQCT: periphe I density; Tt.BM4 ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone (SSIp: polar stra on; *significant >0.14).
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		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _p : [§] Significant differences w group by time interaction Cohen's d can be small (f	TO TO T1 TO T1 TO T1 To T1 To T1 To T1 To T0 T1 To T0 T1 TO T0 T1 TO T0 T0 T0 T0 T0 T0 T0 T0 T0 T0 T0 T0 T0	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dens quare. red to 3G-EL; ‡significant dif medium (0.5 – 0.8) or large (>1	4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 eent; T1: post-season momend in third-generation arti- ineral density; BMAD: trabecu- ity; Ct.Ar: cortical cross see ferences within groups bet 0.8) and η^2_p can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w ne mineral a lar volumetr icctional area; ween the be; 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent densit ic bone minera Fre.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t hyer; DXA: dual- y; pQCT: periphe I density; Tt.BMd ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone SSIp: polar stra on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _p : ⁸ Significant differences w group by time interaction Cohen's d can be small (f	T0 T1 T0 T1 T0 T1 e standard de layer; 3G-N one mineral t.vBMD: to D: cortical v partial eta so vhen compan	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dens quare. red to 3G-EL; [‡] significant dif medium (0.5 – 0.8) or large (>1	4.903 \pm 0.326 3069.009 \pm 439.040 3198.564 \pm 473.699 1362.122 \pm 207.083 1458.052 \pm 216.588 eent; T1: post-season momend in third-generation artinineral density; BMAD: bolensity; Tb.vBMD: trabecuity; Ct.Ar: cortical cross see ferences within groups bet 0.8) and η^2_p can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w ificial turf w lar volumetr cctional area; ween the be; 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent densit ic bone minera Fre.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t hyer; DXA: dual- y; pQCT: periphe I density; Tt.BMd ture load (axe X); e final of the sease - 0.14) or large (<0.001 0.057 0.002 hird-generation energy X-ray ral quantitative C: total bone SSIp: polar stra on; *significant >0.14).
		Ct.Th (mm) Frc.LdX (N) SSIp (mm ³) Data presented as mean ± artificial turf with elastic absorptiometry; BMC: bc computed tomography; T mineral content; Ct.vBM index; d: Cohen's d; η ² _P : ⁸ Significant differences w group by time interaction Cohen's d can be small (f	T0 T1 T0 T1 T0 T1 e standard de layer; 3G-N one mineral t, vBMD: to D: cortical v partial eta so vhen compan	4.941±0.501 5.122±0.476 3210.438±553.960 3428.474±535.839 1455.894±245.232 1544.487±224.998 eviation. T0: pre-season mom IEL: football players who trai content; aBMD: areal bone m tal volumetric bone mineral dens quare. red to 3G-EL; [‡] significant dif medium (0.5 – 0.8) or large (>1	4.710-0.293 4.903±0.326 3069.009±439.040 3198.564±473.699 1362.122±207.083 1458.052±216.588 ent; T1: post-season momention and in third-generation arti- tineral density; BMAD: bo- lensity; Tb.vBMD: trabecu- ity; Ct.Ar: cortical cross set ferences within groups bet 0.8) and η^2_p can be small (0	0.54 0.28 0.46 0.41 0.39 ent; 3G-EL: ificial turf w ificial turf w lar volumetr at volumetr actional area; ween the bep 0.01 – 0.06).	0.383 [‡] 0.432 [‡] 0.379 [‡] football player ithout elastic la upparent density ic bone minera ; Frc.LdX: frac ginning and the medium (0.06	0.384 [‡] 0.199 [‡] 0.399 [‡] s who trained in t nyer; DXA: dual- y; pQCT: periphe I density; Tt.BMd ture load (axe X); e final of the sease – 0.14) or large (<0.001 0.057 0.002 hird-generation ral quantitative C: total bone (SSIp: polar stra on; *significant >0.14).







Figure 2 Legs aBMD and BMC38 interactions in football players and CG. aBMD: areal bone mineral density; BMC38: total bone mineral content at the 38% of the length of the tibia; CG: control group; T0: pre-season moment; T1: post-season moment; Model 1: unadjusted data; Model 2: adjusted data by MVPA; Model 3: adjusted data by MVPA and subtotal lean mass (legs aBMD)/tibia muscle area (BMC38). *: Significant interactions were set at p < .05.

95x48mm (300 x 300 DPI)

Journal name

