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Original research

The effect of 12-month participation in osteogenic and non-osteogenic sports on bone development in adolescent male athletes. The PRO-BONE study

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A B S T R A C T

Objectives: Research investigating the longitudinal effects of the most popular sports on bone development in adolescent males is scarce. The aim is to investigate the effect of 12-month participation in osteogenic and non-osteogenic sports on bone development.
Design: A 12-month study was conducted in adolescent males involved in football, swimming and cycling and compared with an active control group.
Methods: 116 adolescent males (13.1 ± 0.1 years at baseline): 37 footballers, 37 swimmers, 28 cyclists and 14 active controls were followed for 12 months. Bone mineral content (BMC) was measured by dual-energy X-ray absorptiometry, and bone stiffness was measured by quantitative ultrasound. Bone outcomes at 12 months were adjusted for baseline bone status, age, height, lean mass and moderate to vigorous physical activity.
Results: Footballers had higher improvement in adjusted BMC at the total body, total hip, shaft, Ward's triangle, legs and bone stiffness compared to cyclists (6.3–8.0%). Footballers had significantly higher adjusted BMC at total body, shaft and legs compared to swimmers (5.4–5.6%). There was no significant difference between swimmers and cyclists for any bone outcomes. Swimming and cycling participation resulted in non-significant lower bone development at most sites of the skeleton compared to controls (−4.3 to −0.6%).
Conclusions: Football participation induces significantly greater improvements in BMC and bone stiffness over 12 months compared to cycling and swimming.
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1. Introduction

Bone development occurs most rapidly during childhood and adolescence, with 80–90% of peak bone mass (PBM) acquired by late adolescence depending on the site of the skeleton.[1] PBM is largely determined by genetics[2] and by modifiable factors, such as nutrition and physical activity (PA).[3,4] Exercise during this period of life can enhance bone mineral content (BMC) and bone mineral density (BMD)[5] and be maintained into adulthood.[6] Football,

Abbreviations: BMC, bone mineral content; BMD, bone mineral density; DXA, Dual energy X-Ray Absorptiometry; MVPA, moderate to vigorous physical activity; PA, physical activity; QUS, quantitative ultrasound; PBM, peak bone mass; T0, baseline measurements; T1, 12-months measurements.

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cycling and swimming are among the most popular sports performed by adolescents around the world.[7] However, participation in these sports may have different effects on bone development.[8] Participation in "osteogenic" sports, such us football, can augment BMC at the loaded sites of the skeleton.[9,10] However, participation in "non-osteogenic sports", such as swimming and cycling, may have a negative or no impact on bone outcomes,[11] which may compromise the achievement of a higher PBM and increase the risk of osteoporotic fractures in adulthood. From a public health perspective, understanding how the most popular sports worldwide among youth affect bone development is of great importance.

Cross-sectional studies have evaluated differences in BMC between adolescents engaged in different sports in comparison to a control group.[11] Specifically, footballers were found to have higher adjusted-BMC and BMD at most sites of the skeleton compared with age-matched controls.[9] In contrast, previous evidence found that adolescent male swimmers had lower adjusted-BMC and BMD at several sites compared to controls,[12] but a recent systematic review concluded that swimmers have similar bone mass compared to sedentary controls.[13] Similarly, in a cross-sectional analysis we found that adolescent male swimmers and cyclists had lower bone outcomes compared to footballers.[8] However, other studies showed that cycling during adolescence may negatively influence bone health.[11,14] To date, there are only a few longitudinal studies on this topic and it was found that 3 years of football participation increased femoral neck BMD by 10% and improved femoral neck and intertrochanteric BMC twice as much compared to age-matched controls in prepubertal males.[15] Previously, 8 months of football training significantly improved bone outcomes at total body, intertrochanteric site, lumbar spine and femoral neck in female adolescent footballers, whereas 8 months of swimming training had no effect on bone outcomes in female adolescent swimmers.[16] Research investigating the longitudinal effects of the most popular sports on bone development in adolescent males is scarce. In a recent study we showed the effect of these sports on clinically relevant sites, including hip geometry estimates and trabecular texture, as well as biochemical markers.[17] It should be noted that a comprehensive analysis of potential confounders, such as lean mass and objectively measured moderate-to-vigorous PA (MVPA) should be used to control for important predictors of bone status in these sports.[18]

In addition to Dual energy X-ray Absorptiometry (DXA), quantitative ultrasound (QUS) can indicate the risk of osteoporotic fractures at the calcaneus site that is particularly important for adolescent athletes due to their high prevalence of injuries.[19,20] In a cross-sectional study, it was shown that swimming had no effect on bone stiffness compared to age-matched controls in adolescent males and females.[12] Also, in a cross-sectional analysis it was found that footballers had higher bone stiffness than controls but there were no differences in swimmers and cyclists compared to controls.[8] However, there is lack of longitudinal studies comparing the effects of osteogenic and non-osteogenic sports on QUS bone outcomes in adolescent males athletes.[21] Therefore, the purpose of this study is to investigate the effect of 12-month participation on BMC and bone stiffness in osteogenic (football) and that non-osteogenic sports (swimming and cycling) compared to an active control group after controlling for baseline bone outcomes, age, height, lean mass and MVPA.

2. Methods

The present study represents a 12-month analysis of sport participation as part of the PRO-BONE study, whose purpose and methodology have been described elsewhere.[22] For the present study, data obtained at baseline (T0) during autumn/winter 2014/15 and at follow-up (T1) during autumn/winter 2015/2016 were used (mean difference of visits = 372 days). Five participants were excluded because they did not complete the second visit (n = 3) or they had missing data (n = 2). For the present study, 116 adolescent males (37 swimmers, 37 footballers, 28 cyclists and 14 active controls not engaged in these sports more than 3 hour per week) aged 13.1 years ± 1.0 at T0 and 14.1 years ± 1.0 at T1 were included. The inclusion criteria at T0 were: (1) males 12–14 years old, engaged (≥3 h/week) in osteogenic (football) and/or non-osteogenic (swimming and cycling) sports for the last 3 years or more; (2) males 12–14 years old not engaged in any of these sports (≥3 h/week) in the last 3 or more years (control group). The exclusion criteria were at T0 were: (1) participants not taking part in another clinical trial; (2) participants not having any acute infection lasting until <1 week before inclusion; (3) participants free of any medical history of diseases or medications affecting bone metabolism or injured; (4) white Caucasian ethnicity. Ethics approval received from the following committees: (1) the Ethics Review Sector of Directorate-General of Research (European Commission, ref. number 618496); (2) the Sport and Health Sciences Ethics Committee (University of Exeter, ref. number 2014/766) and (3) the National Research Ethics Service Committee (NRES Committee South West—Cornwall & Plymouth, ref. number 14/SW/0060).

A DXA scanner (GE Lunar Prodigy Healthcare Corp., Madison, WI, USA, 2006) was used to measure BMC (g), fat mass (g) and lean mass (g, excluding bone and fat mass). The total body scan was used to obtain BMC at the arms, legs, and total body (excluding head). Dual hip scans were performed to obtain BMC for total hip, femoral neck, Ward's triangle, trochanter and shaft sub-regions and the mean of right and left hip scans was used. The coefficient of variation (CV) for measurement reliability was not determined in the present study. Previous paediatric studies have shown that the DXA between-day CV was between 1.0% and 2.9% depending on the region.[23] In addition, QUS measurements were performed with a Lunar Achilles Insight (TM Insight GE Healthcare, Milwaukee, WI, USA). This portable device measures bone stiffness using ultrasound waves. QUS is a non-ionising radiation technique and evaluates bone stiffness based on broadband ultrasound attenuation (dB/MHz) and speed of sound (m/s).[24] The real-time image of the calcaneus and the region of interest ensures that the measurement is reliable and valid to assess bone health as demonstrated in paediatric population.[25] Daily calibration was completed at all visits and measurements were taken according to the standard procedure provided by the manufacturer. The positioning was standardised between visits by using an adapter for the children's feet in order to get the same position of the calcaneus. Both feet were measured twice and the mean of the two measures was used for statistical analyses.

Stature (cm) and body mass (kg) were measured by using standard procedures and sexual maturity was self-reported using adapted drawings of the five stages of pubic hair development.[26] Physical activity was measured for seven consecutive days at T0 and T1 using wrist accelerometers (GENEActiv, GENEA, UK). The validity and reliability of the accelerometer has been established previously in children and adolescents.[27] Data were collected at 100 Hz and analysed at 1 s epoch intervals to establish time spent in MVPA using a validated cut-point.[27] Weekly training hours were obtained by face to face interviews at T0 at T1. In addition, the coaches indicated participation in weight-training exercises for a subsample of participants.

Statistical analyses were performed using the SPSS IBM statistics (version 21.0 for Windows, Chicago, IL, USA). Data were normally distibuted and presented as mean and standard deviation. Data were analysed in two stages: (1) raw (unadjusted) data using one-way analysis of variance (ANOVA) with Bonferroni post hoc or Chi-Square tests at T0 and T1 to detect the differences in BMC, and

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