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Original Article

Bone Density and Cross-sectional Geometry of the Proximal Femur Are Bilaterally Elevated in Elite Cricket Fast Bowlers

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Abstract

The skeleton of a cricket fast bowler is exposed to a unique combination of gravitational and torsional loading in the form of substantial ground reaction forces delivered through the front landing foot, and anterior-posterior shear forces mediated by regional muscle contractions across the lumbo-pelvic region. The objectives of this study were to compare the hip structural characteristics of elite fast bowlers with recreationally active age-matched controls, and to examine unilateral bone properties in fast bowlers. Dual-energy X-ray absorptiometry of the proximal femur was performed in 26 elite male fast bowlers and 26 normally active controls. Hip structural analysis (GE Lunar; enCORE version 15.0) determined areal bone mineral density (BMD) of the proximal femur, and cross-sectional area, section modulus (Z), cross-sectional moment of inertia, and femoral strength index at the narrow region of the femoral neck. Mean femoral neck and trochanter BMD were greater in fast bowlers than in controls ($p < 0.001$). All bone geometry properties, except for cross-sectional moment of inertia, were superior in fast bowlers ($p < 0.05$) following adjustment for height and lean mass. There were no asymmetries in BMD or bone geometry when considering leg dominance of the fast bowlers ($p > 0.05$). Elite fast bowlers have superior bone characteristics of the proximal femur, with results inferring enhanced resistance to axial compression (cross-sectional area), and bending (Z) forces, and enhanced strength to withstand a fall impact as indicated by their higher femoral strength index. No asymmetries in hip bone properties were identified, suggesting that both torsional and gravitational loading offer significant osteogenic potential.

Key Words: cricket; DXA; fast bowling; imaging; loading.

Introduction

Bone adapts architecturally to reflect its habitual loading environment *(1)* and responds to a wide range of biochemical and physical stimuli *(1,2)*. In particular, the musculoskeletal loading sustained during exercise serves as a major osteogenic stimulus *(3)* that is essential for the development of a functionally and mechanically appropriate skeleton, the attainment of optimal peak bone mass, and the subsequent maintenance of bone strength as a prophylaxis against osteoporosis *(4,5)*. This phenomenon is comprehensively described in the Mechanostat theory *(6)*, which proposes that when all else is equal, individuals that are physically active should possess stronger bones than their less active peers.

The osteogenic response to loading is site-specific and is reflected through differences in bone mass and size between the dominant and nondominant limbs *(7,8)*, and the site-specific bone loss during unilateral limb immobilization *(9)*. To date, a large number of studies have demonstrated the effectiveness of gravitational loading in stimulating bone anabolic responses in various regions of the hip over an individual's life span *(4,10)*. This is important

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because the hip, and in particular the femoral neck, is the site at which osteoporotic fractures are most devastating and costly *(11)*. It has been proposed that regional muscle forces offer the greatest mechano-stimulus to bone *(12)*, with studies building on early evidence provided by Rubin et al *(13)* that torsional loading is a more compelling anabolic stimulus than axial loading in disuse-related bone loss.

The skeletal loading generated through playing cricket appears to be beneficial for bone density at the hip *(14)* and, in particular, fast bowlers appear to be exposed to a unique loading environment that is worthy of investigation. Substantial ground reaction forces are transmitted through the landing foot, representing axial gravitational loading, and torsional loading is generated through peak transverse plane rotation moments and anterior-posterior shear forces across the lumbo-pelvic region *(15,16)*. A typical fast bowling delivery is initiated with a run-up to the wicket, culminating in the delivery stride or bowling action, and ending in the follow-through *(17,18)*. Sequentially, the delivery stride comprises the back foot contact, front foot contact, and ball release phases *(18)*. At front foot contact, bowlers absorb ground reaction forces of between 3.8 and 9.0 times body mass *(15,17,19)*. On impact, greater mean peak loading rates have been documented at the front foot (298 $BW \cdot s^{-1}$) when compared with the back foot (79 $BW \cdot s^{-1}$) *(15)*. These forces coincide with lower trunk movements known to produce high contralateral facet joint contact forces, and have been posited as a major cause of lower back injury in fast bowlers *(17–19)*. Attenuated forces are transmitted to the lumbosacral junction via trunk hyperextension, and torsional forces by way of lateral flexion and twisting during the delivery stride are also endured *(20)*. Despite the considerable and differential musculoskeletal stresses encountered by fast bowlers, only limited studies have investigated the skeletal characteristics of this population, with much of the existing work focusing on the biomechanical factors underlying performance and the epidemiology of injury *(16,18,19,21)*.

To date, only 2 studies have investigated bone properties in elite fast bowlers using dual-energy X-ray absorptiometry (DXA), with both elite fast bowlers *(7)* and cricketers in general *(14)* possessing greater total-body bone mineral content (BMC) compared with controls. Adjusted for age and height, cricketers also demonstrate greater bone mineral density (BMD) for the total-body, proximal femur, femoral neck, and lumbar spine, with no site-specific differences between playing positions *(14)*. More recently, we have observed greater unilateral differences in the arm BMC of fast bowlers compared with controls, alongside greater BMC of the bowling vs the non-bowling arm *(7)*. In addition to BMC and BMD, DXA images of the proximal femur can be used to obtain geometrical measures that are associated with bone strength. Hip structural assessment (HSA) provides quantification of bone geometry in the narrow regions parallel to thin cross-sectional slices of bone at specific locations throughout the proximal femur. This method compares favorably with volumetric qualitative computed tomography *(22)* and enables DXA-derived data to be expressed in ways that are more mechanically interpretable, such that the geometric properties that underlie the prognostic value of BMD measurements can provide deeper insights into bone strength.

Given the unique loading environment associated with fast bowling *(15,16,19)*, the characterization of both total and unilateral femoral bone structure in bowlers would provide valuable insights with relation to hip structural characteristics and surrogate measures of bone strength. We therefore undertook the study presented here, with the specific objectives of (1) characterizing hip geometrical and structural qualities in fast bowlers and normally active controls, and (2) investigating, in fast bowlers, potential asymmetry in bone strength between the front (leading in the delivery stride) and the back (balancing in the delivery stride) leg proximal femurs, which might be reflective of the differential loading endured during the delivery phase.

Methods

Study Design

The present study was carried out using a cross-sectional research design.

Participants

The participants were 26 (n = 26) elite male fast bowlers from a first-class county cricket club and 26 (n = 26) recreationally active (<3 sports-specific sessions per week) controls matched for age and ethnicity. The age range of both groups was 16–36 years. The descriptive characteristics for each group are presented in Table 1. Written informed consent was obtained before completing the study, and all procedures were carried out in accordance with the

Table 1
Descriptive Characteristics of Elite Male Fast Bowlers and Controls.

Variable	Controls (n = 26)	Fast bowlers (n = 26)	*p* Value	Cohen *d*
Age (yr)	24.3 ± 4.2	22.4 ± 5.7	0.186	0.38
Height (cm)	178.3 ± 7.6	186.7 ± 5.0	<0.001	1.31
Body mass (kg)	77.2 ± 8.8	86.7 ± 5.9	<0.001	1.27
BMI (kg/m^2)	24.3 ± 2.4	25.1 ± 1.9	0.170	0.37
Fat mass (kg)	15.6 ± 5.5	15.3 ± 2.9	0.815	0.07
LTM (kg)	57.8 ± 5.9	67.6 ± 4.3	<0.001	1.75
%TFM	20.9 ± 6.0	18.4 ± 2.8	0.056	0.53
BMC (g)	3183 ± 356	3888 ± 338	<0.001	2.03

Data presented as mean ± SD.
Abbr: %TFM, percentage tissue fat mass; BMC, bone mineral content; BMI, body mass index; LTM, lean tissue mass.