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Lumbar bone stress injuries and risk factors in adolescent cricket fast bowlers

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ABSTRACT

Cricket fast bowling is associated with a high prevalence of lumbar bone stress injuries (LBSI), especially in adolescent bowlers. This has not been sufficiently explained by risk factors identified in adult players. This study aimed to examine the incidence of LBSI in adolescent fast bowlers over a prospective study and potential risk factors. Forty asymptomatic male fast bowlers (aged 14–17 years) received baseline and annual lumbar dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI) scans, and musculoskeletal and bowling workload assessment; 22 were followed up after one year. LBSI prevalence at baseline and annual incidence were calculated. Potential risk factors were compared between the injured and uninjured groups using T-tests with Hedges' g effect sizes. At baseline, 20.5% of participants had at least one LBSI. Subsequent LBSI incidence was 27.3 ± 18.6 injuries per 100 players per year (mean ± 95% CI). Injured bowlers were older on average at the beginning of the season preceding injury (16.8 versus 15.6 years, g = 1.396, P = 0.047). LBSI risk may coincide with increases in bowling workload and intensity as bowlers step up playing levels to more senior teams during late adolescence whilst the lumbar spine is immature and less robust.

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KEYWORDS
Injury prevention; athlete health; osteogenic adaptation; physical activity; lumbar spine

Introduction

Lumbar bone stress injuries (LBSI), overuse injuries resulting from microdamage accumulation and propagation in bone (Warden et al., 2014), are the most prevalent injury in elite cricket (Orchard et al., 2016) and can be career ending. These injuries to the lumbar vertebrae differ in severity based on the bone stress continuum (Warden et al., 2014): from stress reactions to incomplete and complete lumbar stress fractures (LSF). Fast bowling has been associated with asymmetrical bone stress response with injuries occurring more commonly on the contralateral side to the bowling arm (93% of injuries), in the pedicle (23%) and pars interarticularis (77%), and at L4 (35%) and L5 (32%) (Alway et al., 2019a). Despite the high prevalence of LBSI, fast bowlers exhibit substantial lumbar bone mineral with up to 14.6% and 18.1% greater bone mineral density (BMD) and bone mineral content (BMC) on the contralateral side to the bowling arm (Alway et al., 2019b).

LBSI risk factors are multifactorial with several factors previously being investigated. Chronological age has been considered a LBSI risk factor with studies identifying that younger bowlers are more likely to suffer LSF between 15 and 22 years of age (Alway et al., 2019a; Engstrom & Walker, 2007). Previous research has linked site-specific low BMD in elite English fast bowlers (Alway et al., 2019b) with LBSI, as well as reduced trunk and pelvis flexibility in active adolescents (Kemmochi et al., 2018). In addition, reduced ankle dorsiflexion of the contralateral leg and increased hip internal rotation of the ipsilateral leg, when measured statically and not during bowling, have been shown to increase the risk of repetitive microtrauma injury to the trunk, back and lower limb in junior and senior Australian fast bowlers (Dennis et al., 2008). Increased bowling volume and frequency increased overuse injury risk in Australian junior fast bowlers (Dennis et al., 2005), and high peaks in 7-day (Alway et al., 2019a) and 90-day workload (Orchard et al., 2015) have been shown to elevate LBSI risk in senior English and Australian fast bowlers, respectively. The bowling technique involving extreme tri-planar trunk movements coupled with high vertical ground reaction forces (VGRF) has also been suggested to place the lumbar posterior elements under great stress and thus may facilitate LBSI (Glazier, 2010; Ranson et al., 2008; Standaert & Herring, 2000), the extent and effect of which may be largely determined by skeletal robustness, workload, and physical strength and flexibility.

Research is needed to prospectively investigate chronological and skeletal age and site-specific BMD in regard to LBSI risk, as this has not been previously examined and to provide an overview of LBSI risk factors in adolescent fast bowlers. Therefore, this study aimed to establish the incidence and prevalence of LBSI in adolescent fast bowlers over a prospective period of one year and determine whether previously identified or hypothesised risk factors of LBSI differ between the adolescent bowlers who remain injury free and those that develop LBSI. It is hypothesised that a higher incidence of LBSI will be seen in adolescents compared to previous research in adult fast bowlers and that risk factors should be similar with potentially the greatest differences

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between injured and uninjured bowlers due to skeletal maturation and lumbar BMD, rapid increases in loading identified by bowling workload, and a lack of movement control potentially identified by increased flexibility of lower limb joints.

Methods

Participants and ethics approval

Forty adolescent male bowlers were recruited from professional academies or schools and clubs with well-developed cricket programmes. Participants were identified as "fast" bowlers if the wicket keeper would normally stand back from the stumps (Orchard et al., 2016). All bowlers received a baseline pre-season magnetic resonance imaging (MRI) and dual-energyX-ray absorptiometry (DXA) scan and subsequent annual DXA scans and an exit MRI scan after one or two years (22 bowlers), during the cricket pre-season of the respective year. Follow-up MRI scans took place on average 1.31 ± 0.05 years and 2.26 ± 0.03 years after baseline. Skeletal age and musculoskeletal measures were assessed annually at the same time as the scans and bowling workload was measured continually between MRI scans. Ethical approval for the study was obtained and approved by both the Loughborough University Ethics Approvals (Human Participants) Sub-Committee and the National Research Ethics Service. Written informed consent, and/or assent from a parent or guardian in the case of participants under 16 years of age, was obtained prior to study inclusion.

MRI

Participants received a lumbar spine (L3-L5) MRI scan (3.0 T Discovery MR750w, GE Healthcare, Milwaukee, WI) using the following three sequences: T1 sagittal, T2 fat suppression sagittal, and T2 axial. Scans were analysed by a musculoskeletal radiologist with extensive experience in analysing LBSI in cricket fast bowlers. LBSI were defined as either stress reactions, where there was evidence of bone marrow oedema (without fracture line), or LSF identified as either an acute or chronic stress fracture identified by evidence of incomplete or complete stress fracture with (active) or without (old, possibly inactive) bone marrow oedema, respectively. Acute LBSI cases that presented during the prospective study required radiological confirmation of diagnosis prior to inclusion as a prospective case.

DXA

Each participant received an anterior-posterior lumbar spine and total body DXA scan (GE Lunar iDXA, GE Healthcare, USA). BMD, BMC and vertebral area were derived for each vertebral body using dedicated software (Lunar enCore v17, GE Healthcare, USA). A custom analysis was used to define regions of interest which measured the bone mineral in the lateral third of the ipsilateral and contralateral sides of each vertebra (respective to bowling arm) (Alway et al., 2019b). Fat-free mass (FFM, kg) was determined from the total body scan. Stature (height) and body mass were assessed prior to the DXA scan.

Skeletal age

Skeletal age was assessed using a DXA scan of the left hand (Romann & Fuchslocher, 2016) and analysed using the Tanner and Whitehouse Three method (Tanner et al., 2001) for each of the fast bowlers. Skeletal age was further used to assess whether participants' skeletal maturation was delayed (skeletal age younger than chronological age by >1.0 year), advanced (skeletal age older than chronological age by >1.0 year), average (skeletal age within 1.0 year of chronological age), or complete compared to the comparative normal population (Malina et al., 2004).

Bowling workload

Bowling workload was self-recorded using an online questionnaire in which participants detailed the number of balls bowled per day. The following variables were calculated: total balls bowled during the season, the number of bowling days per week (for weeks in which they were bowling) and the peak acute (7-day) and medium-term (90-day) workload during the cricket season (April to September).

Musculoskeletal assessment – flexibility and range of motion (ROM)

A trained researcher (LK) performed a musculoskeletal assessment protocol (Supplementary material) in both legs (ipsilateral and contralateral to bowling arm), prior to bowling which was found to be reproducible in a preliminary reliability study (ICC ≥ 0.946). The protocol included passive hip internal and external rotation, bent knee fallout, passive straight leg raise, sit and reach, and ankle dorsiflexion (Supplementary material: Table 1).

Analysis

LBSI were described, and the cross-sectional prevalence was determined at the beginning and end of the study as the percentage of the cohort that had LBSI during the study. The annual LBSI incidence was calculated as the number of injuries per 100 players per year ± 95% confidence interval (Orchard et al., 2016).

Prospective cases were defined as any participant who had radiologically confirmed LBSI during the longitudinal study as well as participants with evidence of LBSI on the exit MRI scan. To determine the injury risk factors, independent t-tests with corrected Hedges' g effect sizes were performed between injured and uninjured groups of participants. Mann–Whitney U tests were performed in the case of non-parametric data where the data were not normally distributed (Shapiro–Wilk test $P < 0.05$) or variances were heterogeneous (Levene's test $P < 0.05$). Injured participants were compared to uninjured participants in relation to the following variables which were measured in the testing session preceding injury: chronological age,

Table 1. Details of the baseline and prospective lumbar bone stress injuries that occurred in adolescent fast bowlers.

Recorded	Descriptive	Category	Number of LBSI	LBSI/bowler* or LBSI/100 bowlers/year#
Baseline	Age (years)	14	3	0.19*
		15	1	0.09*
		16	3	0.43*
		17	1	0.17*
	Maturation	Delayed	1	
		Normal	6	
		Advanced	1	
	Lumbar level	L2	1	
		L4	1	
		L5	4	
		Multi-level	2	
	Location	Superior articular process	1	
		Pedicle	1	
		Pars interarticularis	7	
		Pedicle and pars interarticularis	2	
	Side	Ipsilateral	1	
		Contralateral	6	
		Bilateral	2	
	Severity	Bone stress	5	
		Chronic bone stress	2	
		Chronic stress fracture	2	
Prospective	Age (years)	14	0	0
		15	0	0
		16	0	0
		17	2	25#
		18	4	80#
	Maturation	Delayed	2	
		Normal	4	
	Lumbar level	L4	2	
		L5	2	
		Multi-level	2	
	Location	Pars interarticularis	8	
	Side	Contralateral	8	
	Severity	Bone stress	2	
		Incomplete stress fracture	6	

The side of the vertebra is respective to bowling arm. The number of injuries are reported, not the number of injured players. LBSI: lumbar bone stress injuries.

skeletal age, and maturity rating; L3 and L4 contralateral side BMD and vertebral area; variables from the musculoskeletal assessment, and workload variables.

Results

Baseline characteristics of the fast bowlers were as follows: (mean ± SD) age: 15.5 ± 1.1 years; height: 1.79 ± 0.07 m; weight: 68.3 ± 10.6 kg; L1-L4 BMD Z-score: +0.77 ± 1.10.

During the study, three fast bowlers changed playing position or stopped playing high-level cricket, one participant had an operation which prevented him from playing cricket for over one year and 16 were unable to return for follow-up due to other commitments or apprehension over the Covid-19 pandemic.

Evaluation of lumbar bone stress injuries in adolescent fast bowlers

At baseline, 20.5% of the cohort aged 14.2–17.3 years had evidence of acute or chronic LBSI (Table 1). Six participants sustained LBSI during the study, which resulted in an incidence of 27.3 ± 18.6 LBSI per 100 players per year and a specific incidence of incomplete LSF of 22.7 ± 17.3 LSF per 100 players per year. No bowlers who sustained injuries prospectively were injured at baseline and details of individual LBSI can be found in Table 1.

Differences between prospectively injured and uninjured adolescent fast bowlers

Only chronological age significantly differed at the 0.05 alpha level between prospectively injured and uninjured bowlers ($P = 0.006$), with a large effect size ($g = 1.396$; Table 2). Injured bowlers were 1.3 years older at the beginning of the season preceding injury than uninjured bowlers on average although there was little difference in average skeletal age or maturation ($g = 0.274$ and 0.611, respectively, $P \geq 0.278$). However, 33% of the injured bowlers had delayed maturation, compared to only 13% of the uninjured bowlers. There were also four further non-significant ($P \geq 0.090$) large effect sizes of L3 and L4 contralateral BMD ($g \geq 0.812$), hip internal rotation of the contralateral leg ($g = 0.987$), and peak acute workload ($g = 0.942$; Table 2). Four participants also experienced lower back pain during bowling, which required physiotherapy treatment and rest from bowling.

Workload was self-reported for 11 players in total, five of whom were included in the injured group. Total, peak acute and medium workloads were non-significantly higher in injured than uninjured players ($g \geq 0.526$, $P \geq 0.150$).

Discussion

This study has demonstrated a high incidence of both asymptomatic baseline and prospective LBSI in adolescent fast bowlers (27%) in the first study of its kind in this population. The

Table 2. Comparison of uninjured and prospectively injured fast bowlers.

		Injured group (95% CI) *n* = 6	Uninjured group (95% CI) *n* = 16	Mean difference between groups (95% CI)	T-test *p* value	Hedges' g effect size
Height (cm)	CL[a]	184.8 (181.1–188.6)	180.9 (177.6–184.3)	3.9 (2.4–10.2)	0.215	0.587**
Weight (kg)	IL	75.1 (71.1–79.0)	69.1 (63.7–74.5)	6.0 (3.8–15.8)	0.218	0.586**
Fat-free mass (kg)	CL	62.7 (58.0–67.3)	58.0 (53.7–62.2)	4.7 (3.3–12.7)	0.235	0.564**
Chronological age (years)	IL	16.8 (16.2–17.5)	15.6 (15.1–16.0)	-1.3 (−2.1 – −0.4)	**0.006**	1.396***
Skeletal age (years)[a]	CL	15.9 (15.1–16.7)	15.6 (15.2–16.0)	-0.3 (−1.2–0.7)	0.278	0.274*
Skeletal maturity rating[a]	IL	-0.3 (−0.8–0.0)	0.0 (−0.3–0.3)	0.3 (−0.2–0.9)	0.363	0.611**
L3 CL BMD (g/cm^2)[a]	CL	1.625 (1.357–1.894)	1.419 (1.315–1.523)	-0.206 (−0.455–0.042)	0.178	0.812***
L4 CL BMD (g/cm^2)	IL	1.667 (1.370–1.963)	1.432 (1.317–1.547)	-0.235 (−0.509–0.040)	0.090	0.849***
L3 vertebral area (cm^2)		17.65 (16.52–18.78)	16.64 (15.67–17.62)	-1.01 (−2.87–0.86)	0.273	0.519**
L4 vertebral area (cm^2)		19.08 (18.08–20.07)	18.29 (17.15–19.42)	-0.79 (−2.88–1.30)	0.439	0.377*
CL ankle dorsiflexion (cm)		9.3 (7.9–10.6)	11.2 (9.59–12.75)	1.92 (−1.01–4.85)	0.187	0.634**
CL ankle dorsiflexion (°)		54.7 (51.6–57.8)	51.6 (47.3–55.9)	-3.1 (−10.9–4.7)	0.421	0.380*
Sit and reach length (cm)[a]		19.0 (14.0–24.1)	17.5 (14.7–20.4)	-1.5 (−7.5–4.6)	0.369	0.238*
Hip internal rotation (°)		32.3 (25.7–39.0)	39.5 (36.3–42.7)	7.2 (0.1–14.3)	0.115	0.987***
Hip external rotation (°)		33.3 (27.0–39.7)	36.9 (32.5–41.2)	3.5 (−5.2–12.2)	0.406	0.395*
Bent knee fall out (°)		34.2 (28.4–40.0)	33.5 (26.9–40.0)	-0.7 (−10.3–8.9)	0.879	0.056
Straight leg raise (°)		31.0 (22.6–39.4)	33.7 (28.9–38.4)	2.7 (−7.3–12.6)	0.582	0.261*
Total balls bowled (n. balls)		62.5 (58.3–66.7)	55.5 (49.4–61.6)	-7.0 (−18.1–4.2)	0.207	0.603**
Bowling days per week (n. days)[a]		60.2 (54.4–65.9)	55.5 (49.5–61.6)	-4.6 (−16.0–6.8)	0.405	0.393*
Peak acute workload (n. balls)		68.0 (65.1–70.9)	67.9 (64.3–71.4)	-0.1 (−6.7–6.4)	0.966	0.019
Peak medium workload (n. balls)		68.0 (64.7–71.3)	68.9 (65.8–72.1)	0.9 (−5.0–6.9)	0.746	0.151
		1608 (1035–2181)	1237 (911–1563)	-371 (−1314 – 572)	0.397	0.526**
		2 (1–3)	2 (2–3)	-0 (−1 – 1)	1.000	0.092
		229 (171–286)	165 (134–196)	-64 (−155 – 28)	0.150	0.942***
		1214 (796–1631)	885 (677–1094)	-328 (−973 – 316)	0.279	0.700**

[a]Mann–Whitney test. CL: contralateral; IL: ipsilateral; BMD: bone mineral density. P < 0.050 in bold. ***large effect size (g ≥ 0.80), **medium effect size (0.80 > g ≥ 0.50), * small effect size (0.50 > g ≥ 0.20).

study prospectively monitored a wide range of potential LBSI risk factors that had received little or no previous investigation in adolescent fast bowlers. Chronological age was significantly greater, by one year (16.8 versus 15.6 years) at the beginning of the season preceding injury, in injured bowlers compared to uninjured, despite little difference in average skeletal age and maturity.

LBSI incidence

At baseline, 20.5% of participants had evidence of LBSI upon radiological assessment, with half of them having chronic lesions and the other half exhibiting active bone stress, in bowlers as young as 14 years. This prevalence is similar to previous research in adolescent fast bowlers (Engstrom & Walker, 2007) and together our results suggest that early adolescence is a time of increased risk of LBSI development. All participants with chronic lesions had experienced lower back pain during bowling previously, whereas only half of those with acute LBSI had. The nature of the LBSI in adolescents is similar to that seen in adult bowlers (Alway et al., 2019a) with 92.3% of unilateral injuries occurring on the contralateral side to the bowling arm, but a higher proportion of injuries occurring at L5 (52.6% compared to 32.0% in adults (Alway et al., 2019a)), which may relate to the relatively delayed development of the iliolumbar ligament which stabilises L5 (Luk et al., 1986). This may permit increased extension at the lumbopelvic joint, which has been implicated in the aetiology of LBSI in adult elite fast bowlers (Alway et al., 2021). LBSI incidence determined in this study (annual incidence of 27.3 per 100 bowlers) is much higher than that determined for symptomatic injury presentations in elite senior fast bowlers in the same country (annual incidence of 2.5 per 100 bowlers (Alway et al., 2019a)) and a slightly older cohort of young fast bowlers (11.0% seasonal incidence (Foster et al., 1989)) as these studies did not prospectively screen fast bowlers using MRI and would not have captured asymptomatic LBSI. However, other studies of adolescent fast bowlers which employed asymptomatic MRI screening found incidences of 22.0% (Engstrom & Walker, 2007) and 23.0% (Kountouris et al., 2018) for symptomatic pars stress injury and LSF, respectively, similar to the current study.

It has previously been demonstrated that young adult professional fast bowlers have a greater incidence of LBSI (Alway et al., 2019a), and the current study shows that this trend continues in adolescent fast bowlers who may be at an increased risk of injury compared to their senior counterparts during early and late adolescence. This could result from skeletal immaturity (Henry et al., 2004; Walsh et al., 2009), incomplete ossification (Hardcastle, 1991) and ossification centres within the vertebra (Micheli & Wood, 1995), as well as physical immaturity. The adolescents studied in our investigation were shorter (1.79 versus 1.88 m) and had less fat-free mass (56.48 versus 74.72 kg), lower L1-L4 BMD (1.20 versus 1.56 g/cm^2) and lower L1-L4 Z-score (0.77 versus 2.45), as well as lower workloads compared to senior elite bowlers (Alway et al., 2019a; Alway et al., 2019b), in alignment with national bowling guidelines (England and Wales Cricket, 2020a, 2020b). A retrospective study found that younger, taller bowlers who bowled with a faster ball speed were at an increased risk of LBSI (Sims et al., 2021). This finding may implicate the period of relative skeletal fragility due to under-mineralisation of bone during axial growth (Bailey et al., 1999; Fournier et al., 1997). Additionally, biomechanical studies have shown that younger, immature spines are more susceptible to LSF (Cryon & Hutton, 1978; Farfan et al., 1976) and more mobile (Hilton et al., 1979; Taylor & Twomey, 1980), possibly resulting from greater elasticity of supporting structures (Hawkins & Metheny, 2001) and lower stiffness of intervertebral discs (Twomey & Taylor, 1983). This increased mobility and lack of support may transmit greater forces to the posterior elements (Cryon & Hutton, 1978; Hadley et al., 1988); these forces are likely to be substantial during the bowling action. This study identified that although the average skeletal maturation score was typical for biological age in this cohort, 33% of the injured bowlers had delayed maturation, compared to only 13% of the uninjured bowlers. Thus, greater relative stress and skeletal immaturity in the lumbar spine could potentially increase LBSI risk in younger bowlers, which requires further investigation.

Chronological age

Bowlers who developed new LBSI prospectively during the study were significantly older than uninjured bowlers on average at the start of the season preceding injury (16.8 versus 15.6 years, respectively), with all LBSI occurring at 17 and 18 years of age. At the age of 17 and 18 years, when injuries were seen in our cohort, fast bowlers commonly step up to a more senior or elite playing level with an accompanying increase in workload, dictated by national bowling guidelines (England and Wales Cricket, 2020a, 2020b), and greater access to strength and conditioning. Increases in workload and bowling intensity, as well as muscle mass and body size, may increase bone strain in the posterior elements of the lower lumbar spine during bowling. This could in turn increase LBSI risk as microdamage accumulates and propagates at a greater rate than can be repaired and before bone can adapt its mechanical competence to the increased typical loads (Frost, 2003). Therefore, coaches and medical practitioners of adolescent fast bowlers who have made the step-up from junior to adult elite cricket need to manage their bowlers carefully and consider the use of rest weeks within their schedule to permit repair of bone microdamage and adaptation to withstand the heightened loading.

Acute workload

Peak acute workload in the preceding season was on average 64 balls (39%) higher in injured bowlers compared to uninjured bowlers, although this was non-significant. This could be indicative of an extra game a week or step-up in workload at a more senior level of the game. The non-significance may be largely impacted by the small sample sizes recorded, but despite this, a clear relationship was seen which supports previous research. High acute workloads have been implicated in adult fast bowlers (Alway et al., 2019a) and may result in microdamage accumulation and propagation outpacing the repair mechanisms of bone. However, the injurious result of acute peaks in workload may be dependent on the long-term career workload (Sims et al., 2017; Warren et al., 2018) meaning conditioned, mature bone, which is likely evident in bowlers who have reached full lumbar adaptation to fast bowling, may be better able to withstand an increase in acute workload, but young, under-adapted, immature bone may not be robust to sudden spikes.

BMD

Site-specific low BMD in the lumbar spine has also been identified in lumbar stress fracture cases in senior fast bowlers (Alway, Peirce et al., 2019b), although this was assessed in bowlers who had previously been injured and was also statistically non-significant. It would be logical to suggest that low bone density may be implicated in the aetiology of bone stress injury as bone density is a large determinant of bone strength (Ammann & Rizzoli, 2003); thus, low bone density would decrease the mechanical competence of bone. However, bowlers who suffered LBSI in our study had non-significantly greater contralateral side BMD on average as well as greater vertebral area at the beginning of their year of injury. This could be due to the comparatively greater chronological age of the group or related to the increased bowling volume, intensity and muscular strength demands. Yet, this still may not have been sufficient to withstand fast bowling loading, suggesting that bowling workload may be dependent on lumbar BMD to prevent LBSI.

Hip internal rotation

Hip internal rotation of the contralateral leg was non-significantly 7.2 degrees less in injured fast bowlers compared with uninjured bowlers (32.3 versus 39.5 degrees, respectively), which could facilitate different bowling kinematics that increase LBSI risk through increasing strain in the lumbar spine, although this requires further investigation. Reduced hip internal rotation may be related to poor lumbo-pelvic-femoral control, which has been implicated in the aetiology of LBSI (Bayne et al., 2016). Further, cricket fast bowling is a complex action, which likely requires different actions of opposing hips. Greater muscle activity around the ipsilateral hip occurs during the stride phase (Forrest et al., 2016) as it stabilises the pelvis and conserves the momentum from the run-up (Alway et al., 2021). Greater muscle activity around the contralateral hip occurs during the delivery phase (Forrest et al., 2016) to resist large vertical and horizontal ground reaction forces (Worthington et al., 2013) and to prevent the hip and trunk buckling into flexion (Lieberman et al., 2006), which would likely reduce bowling velocity. Conversely, a prospective study of adolescent and senior bowlers found reduced hip internal rotation on the ipsilateral leg reduced musculoskeletal injury risk (Dennis et al., 2008). However, this was performed in a wide range of ages and considered any injury to the back, trunk or lower limb, most of which were not LBSI. Whilst it is unwise to directly compare the two studies, it is clear that further investigation is required to identify how hip flexibility affects kinematics of the lumbo-pelvic-hip complex during the bowling action.

Strengths and limitations

The main strength of this study is the prospective nature of the investigation allowing LBSI incidence and risk factors to be elucidated. Although this study encompasses a broad range of factors, it is limited by the modest sample size which may have concealed other factors of interest, although there is a relatively small population to recruit from and the study was similar in size to a previous risk factor study in adolescent fast bowlers (Bayne et al., 2016). MRI follow-up was postponed by four months due to the Covid-19 pandemic, which also limited the follow-up sample size and would have reduced bowling workload for around 10 weeks prior to follow-up. Thus, LBSI incidence may have been slightly affected. Apart from this, physical exercise was not monitored during this time. However, the injuries seen on the exit MRI were entirely in keeping with the pattern of fast bowling during the study rather than other activities so were included in the prospective cases. Bowling workload was self-recorded which may be inherently limited by adherence and validity of individual reporting; however, self-reporting in elite players has been found to be valid (Warren et al., 2018). Moreover, Bonferroni correction was not used to account for inflated type I error rate due to repeat testing, in order to reduce likelihood of type II errors (Sinclair et al., 2013) which may have concealed factors related to injury. Therefore, results should be considered with caution as significant results could be an artefact of multiple testing. Thus, we also indicated the effect sizes to give more value to the results.

Conclusion

In conclusion, the prospective incidence of LBSI was 27.3 ± 18.6 injuries per 100 players per year in adolescent fast bowlers. Injured bowlers were over a year older on average than the uninjured group. The occurrence of injuries later in adolescence may not be due to age per se but may coincide with increases in bowling workload, intensity and muscle mass as fast bowlers step up playing levels to more senior or elite teams, while their lumbar spine is immature, less robust, and not yet adapted to the demands imposed upon it. Future research should investigate potential risk factors identified in larger cohorts, as well as the role bowling technique plays in LBSI development, to provide more guidance on how to manage young fast bowlers to protect them from serious injury as they progress in their athletic career.

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