PHYSICAL CHARACTERISTICS ASSOCIATED WITH LUMBAR BONE STRESS INJURY RELATED TECHNIQUE IN MALE FAST BOWLERS

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The purpose of this study was to determine whether physical characteristics were associated with cricket fast bowling technique previously associated with lumbar bone stress injury, rear hip flexion at back foot contact and lumbopelvic extension at front foot contact (FFC). Forty-one elite male cricket fast bowlers underwent 3D biomechanical analysis of their bowling technique and movement competency of the lower limbs and lumbopelvic region. Further, participants completed range of motion, lumbopelvic stability, core endurance and lower body power tests. Moderate-strong significant correlations were found between lumbopelvic extension at FFC with back bowling hip dynamic leg swing extension and front bowling hip external rotation range. Physical competencies including hip flexibility or lumbopelvic control may influence injurious bowling techniques.

KEYWORDS: lumbopelvic stability, hip flexibility.

INTRODUCTION: Lumbar bone stress injuries (LBSI) have the highest prevalence of any injury in male cricketers despite near exclusively affecting fast bowlers (Orchard et al. 2016). While aetiology of LBSIs are multifactorial, fast bowling technique is a strong predictor of future LBSI, where greater back hip flexion at back foot contact (BFC) and greater lumbopelvic extension at front foot contact (FFC) suggest greater LBSI risk (Alway et al., 2021). It is plausible that movement competency, strength, power and flexibility may underpin fast bowling technique. This has previously been demonstrated in baseball pitching where measures of hip flexibility correlated with torso rotation and stride length (Albeiro et al., 2022). Previous research has also highlighted a potential relationship between lumbo-pelvi-femoral control and low back pain in adolescent fast bowlers (Bayne et al. 2016). However, no research to date has explored relationships between physical characteristics and fast bowling technique associated with injury. Therefore, understanding the extent to which physical factors may influence bowling technique is potentially advantageous to reducing LBSI risk. The aim of this study was to determine whether physical characteristics were associated with fast bowling technique factors associated with LBSI.

METHODS: Forty-one male academy and professional cricket fast bowlers (Mean ± SD. Age: 18.4 ± 1.3 years; Height: 1.87 ± 0.06 m; Mass: 79.8 ± 7.7 kg; Peak bowling speed: 76.6 ± 3.4 mph) completed written informed consent, a health screen questionnaire and were confirmed as “fit to play” by their club physiotherapist, prior to participation in the study. The study was approved by the Loughborough University ethics committee. Testing was conducted on an artificial cricket pitch, with space for a full-length run-up, where an 18-camera Vicon Motion Analysis System (Vicon, OMG Plc, Oxford, UK) operating at 250 Hz was used to record kinematic data. Prior to bowling data collection, forty-six retro-reflective markers were placed on anatomical landmarks (Worthington et al., 2013). All participants completed a self-selected warm-up, prior to bowling 12 maximum intensity good-length deliveries. Kinematic data and ball release speed (Stalker Pro II+ Speed radar gun, TX, USA) was recorded for each delivery. Kinematic data was also collected from a series of functional movement tests (Table 1) and a series of musculoskeletal assessments were conducted to determine capabilities across several physical characteristics (Table 2). An average of three attempts was taken unless stated.

Table 1: Functional movement procedures.

Test (outcome measure)	**Procedure**
Single-leg squat (knee stability)	Balanced on one leg, with hands on the hips, and the non-testing leg flexed at the knee with the foot off the ground behind them, participants squat to 90˚ knee flexion.
Split squat *(lumbopelvic stability)*	With hands on hips and feet positioned in-line with the hips a suitable distance apart so that both knees are flexed to 90˚ at the bottom of the squat.
Overhead split squat (lumbopelvic stability)	Hold a stick above the head with arms fully extended. Feet are positioned in-line with the hips a suitable distance apart so that both knees are flexed to 90˚ at the bottom of the squat.
Lateral hop *(knee stability)*	Balanced on one leg, with hands on the hips, and the non-testing leg flexed at the knee with the foot off the ground behind them, participants hop to the inside direction of the testing leg, a self-selected distance and land as stable as possible.
Forward hop (knee stability)	Balanced on one leg, with hands on the hips, and the non-testing leg flexed at the knee with the foot off the ground behind them, hop forward a self-selected distance and land as stable as possible.
Drop landing *(knee stability)*	Stand on a platform (32cm high) on the non-testing leg, with hands on hips with the testing leg hovering off the edge of the platform, Fall onto the testing leg and land as stable as possible.
Leg swing (dynamic hip flexibility)	Swing the leg forwards and back as far as possible in both directions.

The bowling trial with the fastest delivery speed for each participant was used for analysis. Trials were labelled using Vicon Nexus software (Version 2.11, OMG Plc, Oxford, UK) and whole-body kinematics were defined and processed using MATLAB software (Version R2021b, MathWorks, MA, USA). Joint centres and angles were calculated according to Worthington et al. (2013). Rear hip flexion joint angles at the point of BFC and lumbopelvic extension joint angles at FFC were extracted from bowling trials. Peak knee valgus, lumbar extension and anterior pelvic tilt angles were extracted from the functional movement trials.

Statistical analysis was completed using IBM SPSS software (v.28 IBM, USA). Normality of data was determined by the Shapiro-Wilk test. If data was normally distributed, the Pearson's product moment correlation analysis was used to determine relationships between physical characteristics and fast bowling technique associated with injury ($\alpha = p \leq 0.05$). If the assumption of normality was violated, Spearman's rank correlation coefficient was used.

Table 2: Musculoskeletal assessment procedures.

Test (outcome measure)	**Procedure**
Plank holds (Trunk endurance)	Lying in prone, supine, and left and right side positions, on top of a platform, with arms across the chest and upper body suspended. Time to failure is recorded. One time was recorded for each test.
Lumbo-pelvic stability test *(Lumbopelvic control)*	Lying supine, an inflatable pad is placed under the lumbopelvic region. The participants attempt to complete a series of lower body movements and progress through levels 1-5 (as described by Bayne et al., 2016) progressing to the next level by controlling each movement to limit the variation in pressure at the lumbopelvic region. Three attempts were allowed, the highest level completed was recorded.
Overhead reach (Unilateral overhead shoulder range of motion)	Standing with the feet away from the wall, back flat against the wall and legs straight. The testing arm is extended and raised along the sagittal plane towards the vertical, reaching as close to the wall as possible. The distance from the wall to the base of the thumb is recorded at the furthest point reached before the shoulder opens up, the elbow flexes or the lumbar or thoracic spine curves away from the wall.
Combined elevation *(bilateral overhead shoulder range of motion)*	Lying prone on the floor with the head down, arms extended overhead and fingers interlinked, the arms are raised as far off the ground as possible whilst keeping the head on the floor and the elbows extended. The distance is measured from the wrist to the floor.
Countermovement jump (bilateral lower body power production)	With hands on the hips, and feet slightly wider than shoulder-width apart, participants squat to self-selected depth and jump as high as possible with a balanced landing. Jump height is recorded using an impulse-momentum measurement from VALD forcedecks. The maximum height of three jumps was used.

Single-leg countermovement jump *(unilateral lower body power production)*	As above, but on a single leg. The maximum height of three jumps was used.
Triple hop for distance (unilateral lower body power production)	Start balanced on one leg on a 'start line' (0cm) with hands on the hips. Make three consecutive hops on one leg, landing the third hop balanced. The distance is taken in line with the landing heel. The furthest distance of three trials was used.
Forty-metre sprints *(acceleration and power production)*	From a stationary position at the start line, participants sprint forty-metres as fast as possible. Ten- and twenty-metre splits are also recorded. The fastest of three sprints was used.
Two-km (aerobic capacity)	Participants complete five laps of a four-hundred metre running track as fast as possible. This was completed once and the time recorded.
Internal and external hip rotation *(hip rotation range of motion)*	Lie prone on a physio bed, flex one leg at the knee to 90˚. The researcher moves the tibia laterally to the end range of motion in both directions (to the point in which the hip moves).
Straight leg raise (hamstring flexibility)	Position the hip at 90º whilst lying supine on a physio bed and maximally extend the knee. The knee angle is recorded.
Thomas Test *(hip flexor flexibility)*	Lying supine with the hips aligned on the edge of a physio bed, participants allow the testing hip to fall passively and pull the opposite knee towards the chest. The angle of the femur relative to the horizontal from the greater trochanter is measured.
Heel to Buttock (hip flexor flexibility)	Lying prone, the knee is flexed as far as possible pulling the heel to the buttocks. The distance between the heel and the buttock is measured.
Finger to floor *(bilateral hamstring flexibility)*	Stand with feet hip-width apart, legs straight and reach both hands as close as possible to the floor. The distance from the fingertips to the floor is measured.

RESULTS: Significant relationships were observed for lumbopelvic extension angle at FFC with front hip (in relation to position at FFC) external rotation range of motion (r=-0.441, p=0.027, Figure 1a), and back hip dynamic extension (r=-0.516, p=0.034, Figure 1b).
Trends ($p < 0.100$) were also observed between lumbopelvic extension angle at FFC and front leg heel to buttock distance (r=0.366, p=0.072), maximum front hip dynamic extension (r=-0.422, p=0.076) and front hip internal rotation range of motion, (r=-0.352, p=0.085) as well as peak lumbopelvic extension in both regular (r=0.512, p=0.051) and overhead split squats (r=0.400, p=0.065) on the back bowling leg.

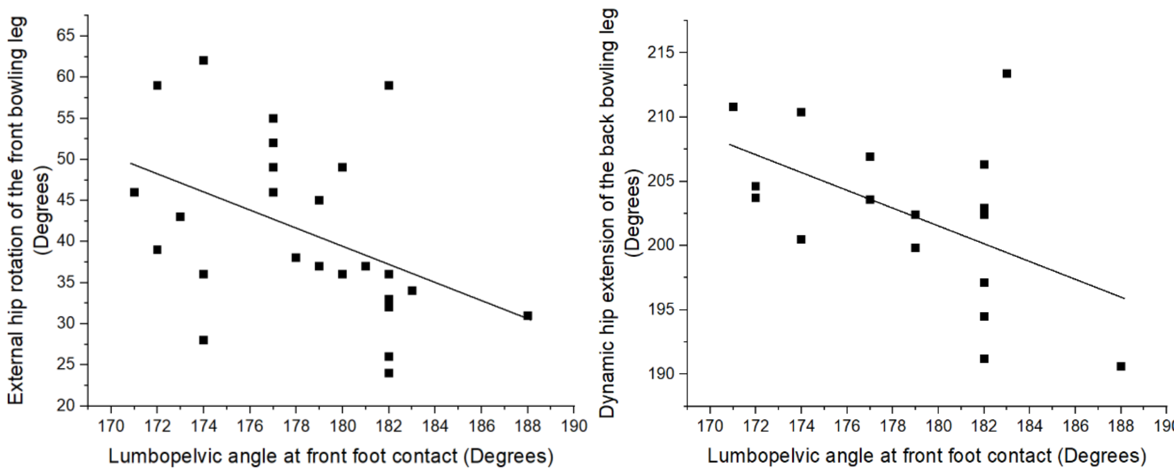

Figure 1. Relationships between the lumbopelvic angle at FFC and (a - left) front hip external rotation range of motion and (b - right) back hip dynamic extension.

No significant relationships were observed between rear hip flexion at BFC and any musculoskeletal assessment. However, trends were identified between rear hip flexion angle at BFC and: bowling side plank hold (r=0.338, p=0.054), bowling side lumbopelvic stability score (r=0.424, p=0.056) and non-bowling side lumbopelvic stability score (r=0.383, p=0.087).

No other relationships were found between other functional movement of musculoskeletal test outcomes and fast bowling technique.

DISCUSSION: This study is the first to explore physical characteristics associated with injurious fast bowling technique and found moderate-strong correlations between physical characteristics and fast bowling technique.

Lumbopelvic extension at FFC was consistently associated with measures of hip flexibility. This included moderate-strong significant correlations with front bowling hip external rotation range of motion and dynamic extension of the back bowling hip. Additionally, other moderate-strong non-significant correlations with lumbopelvic extension at FFC were observed for tests including heel to buttock distance, dynamic hip extension and internal hip rotation range of motion for the front bowling leg. Therefore, hip flexibility could play an important role in helping to adopt a less injurious bowling technique. Having less range of motion in the hips when bowling could result in more anterior pelvic tilt at FFC which may contribute to the extension of the lumbar spine. Less range of motion at both hips could result in a shorter delivery stride, resulting in a less efficient transfer of linear to angular momentum within the bowling action, and may require greater lumbar extension at FFC to compensate for the loss of momentum.

While no significant correlations were found between physical characteristics and rear hip flexion at BFC trends were seen with bowling side trunk endurance and lumbopelvic stability on both sides. A shorter bowling side plank hold and worse performances on the lumbopelvic stability test, showed associations with a more flexed rear hip at BFC. This may implicate trunk endurance and lumbopelvic control in LBSI aetiology as previously speculated by Alway et al. (2021) & Bayne et al. (2016).

Finally, lumbopelvic extension measured in a split squat position on the back bowling leg, when either hands remained on the hips or with arms extended overhead, appeared to show a trend with lumbopelvic extension at FFC. This may imply that the lumbopelvic extension angles of certain movements (such as the split squat) may be representative of the lumbopelvic extension that occurs within the bowling action at the point of front foot contact.

CONCLUSION: The findings from this study indicate that fast bowlers who adopt bowling techniques previously associated with LBSI also appear to be associated with having worse hip flexibility, particularly of the front hip, as well as worse control over their lumbopelvic stability, relating to both sides, and reduced core endurance on their bowling side. Future research should explore if improvement of physical characteristics associated with injurious technique is associated with improvements in technique factors associated with LBSI.

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