FUNCTIONAL SCREENING TEST ASSOCIATED WITH ALTERED TRUNK AND PELVIS KINEMATICS AND LOW BACK INJURY INCIDENCE IN ADOLESCENT FAST BOWLERS

Helen Crewe[1], Jacqueline Alderson[1], Amity Campbell[2] and Bruce Elliott[1]

University of Western Australia, Perth, Australia[1]
Curtin University of Technology, Perth, Australia[2]

This study investigated the relationship between pelvi-femoral stability and low back injury incidence in adolescent fast bowlers using the single leg decline squat test, and examined the relationship between knee kinematics during this clinical test and bowling kinematics during the delivery stride. Twenty-five uninjured male fast bowlers participated in a prospective cohort study. Bowlers who suffered a low back injury had significantly increased knee valgus angle during the single leg decline squat on the dominant leg (8.6° ±3.2 vs 4.5° ±2.6, t=3.495, p=0.002) and non-dominant leg (9.1° ±4.2 vs 5.5° ±3.3, t=2.362, p=0.027). Increased knee valgus angle during the test was associated with increased frontal plane hip and knee motion, pelvis rotation and thorax lateral flexion during bowling, which may lead to increased torsional stress on the lumbar spine.

KEY WORDS: cricket, core stability, musculoskeletal screening.

INTRODUCTION: Musculoskeletal screening is a clinical tool intended to identify potential weaknesses that can be modified to reduce injury risk and is a common procedure in many sports (Whatman, Hing & Hume, 2011). The single leg squat has been advocated as a functional screening tool to assess dynamic trunk and lower extremity alignment because it replicates the running or landing position adopted in many sports activities (Kibler, Press & Sciascia, 2006). Excessive hip adduction and internal rotation during a single leg squat can cause the knee joint centre to move medially relative to the planted foot (Powers, 2010). This dysfunctional movement, as well as weakness of the hip muscles that control this motion, have been linked to the development of lower limb injury (Powers, 2010).

Dysfunctional hip mechanics is also thought to influence the lumbar spine given the multiple shared muscles, and the involvement of the pelvis as the common segment in both the hip and lumbo-pelvic joints (Reiman, Weisbach & Glynn, 2009). Control of the lumbo-pelvic-hip complex can be divided into the following three critical indicators: intra-pelvic, pelvi-femoral and lumbo-pelvic stability (Mitchell, Colson & Chandramohan, 2003). Intra-pelvic stability is provided by the deep abdominal and pelvic floor muscles, as well as passive structures such as joint ligaments. Pelvi-femoral stability is concerned with the interaction between the pelvis and the femur, and lumbo-pelvic stability is concerned with the orientation of the spine on the pelvis (Mitchell et al., 2003). Increased medial knee shift during a single leg squat is regularly used as a clinical indication of poor pelvi-femoral stability. Further, it has been suggested that trunk stability during dynamic motion cannot be achieved without pelvic stability (Powers, 2010). Logically, if the alignment of the pelvis on the femur is altered, then the position of the lumbar spine relative to the pelvis would be affected.

Adolescent fast bowlers are particularly prone to low back injuries, with up to 55% of bowling injuries affecting this area (Stretch, 1995). Clinical screening protocols employed by Cricket Australia include the single leg decline squat (SLDS) as a functional test of pelvi-femoral stability, as part of an injury prevention program (Timms, Shield, Portus, Sims & Farhart, 2010). However, it is not known whether variations in lower limb kinematics during the SLDS are associated with low back injury or fast bowling kinematics.

Therefore, the aims of this study were (1) to investigate the relationship between knee kinematics during a SLDS and future low back injury occurrence in adolescent fast bowlers, and (2) to examine the relationship between knee kinematics during the SLDS and lower limb and trunk kinematics during fast bowling.

METHODS: Twenty-five male fast bowlers (15.8 ±1.4 y, 178 ±7.7 cm, 69.3 ±9.6 kg) from Western Australian district and/or state junior cricket squads volunteered to participate in the study. Ethical approval was obtained from the University of Western Australia's Human Research Ethics Committee and all participants (and their guardians where required) provided informed, written consent to participate in this research. All participants were free of low back pain for at least the preceding three months, and underwent magnetic resonance imaging (MRI) prior to the start of the 2010/11 cricket season. Participants who were found to have pre-existing pars interarticularis abnormalities by a qualified radiologist were excluded from the study.

Data collection was undertaken at the biomechanics laboratory at the School of Sports Science, Exercise and Health at the University of Western Australia. A 12-camera Vicon MX motion analysis system (Vicon, Oxford Metrics, Oxford, UK) operating at 250 Hz was used to collect kinematic data.

Retro-reflective markers were affixed to the participants' skin according to a customised marker set and model for the lower limbs and trunk (Dempsey, Lloyd, Elliott, Steele, Munro, & Russo, 2007). Static subject calibration trials were collected with markers placed on the medial and lateral malleoli and medial and lateral femoral condyles, with dynamic functional methods adopted to determine the bilateral knee joint axes of rotation and corresponding joint centres and hip joint centres (Besier, Sturnieks, Alderson & Lloyd, 2003). All lower limb anatomical and joint coordinate systems were calculated in accordance with the standards outlined by the International Society of Biomechanics (Wu & Cavanagh, 1995).

Participants performed two practice trials of a single leg squat standing on board that had been constructed with a decline angle of 25°. They were then instructed to complete five continuous squats without placing the non-weight bearing foot on the floor. This was followed by a self-directed warm-up, following which participants were required to bowl three overs at match pace. From these 18 deliveries the trials comprising the four highest ball release speeds were selected for analysis.

The three-dimensional (3D) data were prepared and processed using Vicon Nexus software (Vicon, Oxford Metrics, Oxford, UK). Marker trajectories were filtered using a fourth-order low-pass Butterworth filter operating at a cut-off frequency of 15 Hz following a residual analysis to determine the appropriate cut-off frequency. The peak knee frontal plane angle ("valgus") during the middle three of the five SLDS repetitions was calculated.

Participants were required to report all cases of low back pain during the subsequent cricket season to the researchers. This was then classified as a low back injury if the level of pain (a) was significant enough to affect a bowler's ability to perform in a match or training or (b) was deemed not to have affected the bowler's performance but persisted for a period of two weeks. A single sports physician evaluated all injuries and ordered further diagnostic tests where required. All bowlers who did not experience low back symptoms during the cricket season underwent repeat MRI at the conclusion of the season in order to determine whether any asymptomatic pars abnormalities had developed.

Bowlers were categorised into two groups: Those who developed a low back injury (INJ) and those who did not (NON-INJ). Independent sample t-tests were carried out using SPSS 19.0 (SPSS Inc., Chicago, IL.) to compare knee valgus angle during SLDS between the groups. Pearson correlation coefficients were calculated to assess the association between knee valgus angle during the SLDS on the non-dominant leg (the support limb between front foot contact and ball release, or "delivery phase") and knee, hip, pelvis and trunk kinematics during the delivery phase. Statistical significance was set at $p<0.05$.

RESULTS: Of the 25 bowlers, 12 developed a low back injury (INJ), including three who developed a symptomatic bone stress injury during the season, three who remained asymptomatic but showed bone stress changes on post-season MRI, and six who suffered a low back injury that was not bone stress related. The remaining 13 bowlers suffered no low back injury during the season and also showed no bony abnormalities on MRI in the post-season scan (NON-INJ).

Bowlers in the INJ group had significantly increased knee valgus angle during the SLDS on the dominant leg (INJ 8.6° ±3.2, NON-INJ 4.5° ±2.6, t=3.495, p=0.002) and non-dominant leg (INJ 9.1° ±4.2, NON-INJ 5.5° ±3.3, t=2.362, p=0.027). This equates to a Cohen's d effect size of 1.4 and an achieved power of 0.96.

There were significant correlations indicating that increased peak knee valgus angle during the SLDS on the non-dominant leg was associated with increased peak knee valgus angle (r=0.644, p <0.01), increased peak hip adduction angle (r=0.448, p=0.025), increased global pelvis rotation range of motion (r=0.426, p=0.034) and increased thorax lateral flexion range of motion (r=0.401, p=0.047) during the delivery phase of the bowling action.

DISCUSSION: Optimal function of the lumbo-pelvic-hip complex provides stability for the efficient generation of force and transfer of energy to the distal segments (Kibler et al., 2006). Inadequate strength and neuromuscular control may therefore lead to a decrement in athletic performance and increased injury risk (Leetun, Ireland, Willson, Ballantyne & McClay Davis, 2004; Kibler et al., 2006).

This is the first prospective cohort study to describe a relationship between poor pelvi-femoral control and low back injury incidence in cricket bowlers. During the fast bowling action, cricketers experience large vertical and horizontal ground reaction forces while undergoing complex and vigorous three-dimensional motion of the trunk (Elliott, 2000). The function of the lumbo-pelvic-hip complex is therefore severely tested during fast bowling. Based on the results of the current study, it appears that inadequate pelvi-femoral stability is associated with excessive rotation of the pelvis and increased thorax lateral flexion (Figure 1), which may act as a compensatory movement related to the increased frontal plane motion of the hip and knee towards the midline. The combination of pelvis rotation and thorax lateral flexion may serve to generate large torsional stress on the lumbar spine. Indeed, it has been hypothesised that these motions are key in the development of lumbar stress fractures in fast bowlers (Elliott, 2000; Ranson, Burnett, King, Patel & O'Sullivan, 2008; Glazier, 2010).

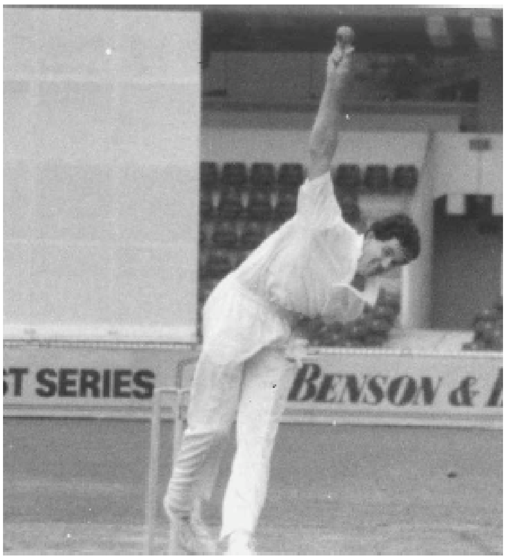

Figure 1: A bowler exhibiting excessive pelvis rotation and trunk lateral flexion at the instant of ball release (from Elliott, 2000).

The current study utilised 3D motion analysis to calculate the valgus angle at the knee, whereas musculoskeletal screening is generally performed using two-dimensional (2D) techniques with the front plane projection angle of the knee used to quantify knee valgus motion. This 2D measurement technique has been shown to be both reliable on repeated testing (Munro, Herrington & Carolan, 2011) and valid when compared with 3D motion analysis (McLean, Walker, Ford, Myer, Hewett, & van den Bogert, 2005). Therefore, the findings of this study suggests that a 2D analysis of a single leg squat may be a valuable screening tool for low back injury risk in cricket fast bowlers where 3D motion analysis of the bowling action is prohibitive due to financial or labour constraints, or simply unavailable.

CONCLUSION: This is the first prospective cohort study to report a relationship between poor pelvi-femoral stability during a functional clinical test (a single leg decline squat) and low back injury incidence in adolescent cricket fast bowlers. Bowlers with poor pelvi-femoral stability exhibited excessive frontal plane motion of the hip and knee during the delivery stride as well as increased pelvis rotation and trunk lateral flexion, which may act to generate increased torsional stress on the lumbar spine. The single leg decline squat is recommended as a functional screening tool in athletes at risk of low back injury, such as adolescent fast bowlers.

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