Journal of Science and Medicine in Sport 19 (2016) 117–122

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

Lumbar load in adolescent fast bowlers: A prospective injury study

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ARTICLE INFO

Article history:
Received 24 July 2014
Received in revised form
10 November 2014
Accepted 27 February 2015
Available online 5 March 2015

Keywords:
Biomechanics
Cricket
Low back injury

ABSTRACT

Objectives: This study aimed to identify modifiable mechanisms associated with low back injury in adolescent cricket fast bowlers.
Design: A prospective study design examined the association between intrinsic risk factors, workload, bowling kinematics, lumbar load and low back injury incidence.
Methods: Twenty-five injury free fast bowlers, aged 14–19 years, were assessed prior to the start of a cricket season and observed during the season for low back injuries.
Results: The twelve bowlers who suffered a low back injury displayed; decreased hip flexion at front foot contact ($46 \pm 6°$ vs $51 \pm 6°$), increased pelvis rotation ($287 \pm 11°$ vs $277 \pm 11°$) increased thorax lateral flexion ($50 \pm 6°$ vs $40 \pm 8°$) at ball release, and larger peak lumbar flexion ($10.5 \pm 4.9\,\mathrm{Nm\,kg^{-1}\,m^{-1}}$ vs $6.9 \pm 2.5\,\mathrm{Nm\,kg^{-1}\,m^{-1}}$) and lateral flexion moments ($12.5 \pm 2.6\,\mathrm{Nm\,kg^{-1}\,m^{-1}}$ vs $10.6 \pm 1.9\,\mathrm{Nm\,kg^{-1}\,m^{-1}}$). They also exhibited reduced muscular endurance of the back extensors (103 ± 33 s vs 132 ± 33 s) and increased knee valgus angle during a single leg decline squat on the dominant ($9 \pm 3°$ vs $5 \pm 4°$) and non-dominant leg ($9 \pm 4°$ vs $6 \pm 3°$) in comparison to uninjured bowlers.
Conclusions: Bowlers who experience greater lumbar loads during bowling, have reduced back extensor muscle endurance, and demonstrate impaired control of the lumbo–pelvic–hip complex, are at increased risk of low back injury. This combination of strength, control and biomechanical factors may be key mechanical elements of low back injury causation in adolescent fast bowlers.

1. Introduction

Adolescent cricket fast bowlers are vulnerable to low back injuries, with a prevalence of between 11% and 67% reported in the literature.[1] The multifactorial nature of low back injury requires investigation of numerous risk factors and injury mechanisms in order to fully understand the aetiology, so that appropriate preventive measures may be developed.[2,3]

According to Meuwisse's model of athletic injury aetiology, intrinsic risk factors predispose an athlete to injury.[3] Hamstring and low back flexibility, foot arch height, trunk muscle asymmetry and trunk muscle function are intrinsic risk factors that have been previously linked with low back injury in fast bowlers.[1] Dynamic tests of lumbo–pelvic and pelvi–femoral control have been advocated as screening measures for injury risk, although their role in fast bowling back injuries has not been clarified.[4,5]

A predisposed athlete may be exposed to extrinsic risk factors and the occurrence of an inciting event finally leads to injury. A description of the inciting event or mechanism of injury requires examination of whole body biomechanics and detailed analysis of the involved joint.[2,3] The relationship between whole body fast bowling biomechanics and injury has received significant attention in the literature, identifying shoulder counter-rotation (SCR) – the change in alignment of the shoulders between back foot contact (BFC) and front foot contact (FFC) – as an observable movement that may be linked to the true mechanisms responsible for low back injury. This increased SCR has been shown to be associated with increased risk of lumbar stress fractures and disc degeneration in adolescent bowlers,[6–8] however, a detailed biomechanical analysis of the lumbo–pelvic joint during bowling has thus far not been conducted in a prospective low back injury study.

Overuse injuries occur when the load tolerance level of the tissue is exceeded through repetitive application of force. Of all overuse injuries, lumbar stress fractures result in the greatest amount of lost playing time in cricket. In order to better understand the mechanism of this injury it is important to quantify and analyse the externally applied loads acting through the lumbar spine

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http://dx.doi.org/10.1016/j.jsams.2015.02.011
1440-2440/

during the bowling action. Recent advances in three-dimensional (3D) motion analysis and biomechanical modelling[9,10] have facilitated the estimation of lumbar forces and moments during dynamic sporting activities, although these methods have not yet been applied to investigation of the relationship between lumbar loading and low back injury risk.

Biomechanical analysis can be used to examine the magnitude and rate of load application, but the frequency of application is another vital element of the loading-injury paradigm. Indeed, several studies have associated increased bowling workload with increased injury risk in fast bowlers.[11–13] Therefore, the current study aimed to investigate intrinsic risk factors, whole body and detailed lumbo–pelvic biomechanics, and bowling workload, in a prospective cohort study examining low back injuries in male adolescent fast bowlers. Finally, the relationship between pelvi–femoral control (using a single leg decline squat test) and bowling biomechanics was examined in order to investigate the possible association between dynamic screening tests, fast bowling mechanics and injury risk.

2. Methods

Forty-six male fast bowlers from district and/or state junior cricket squads volunteered to participate in this 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 the study. All participants were free of low back pain for at least 3 months preceding data collection and underwent magnetic resonance imaging (MRI) screening prior to the commencement of the cricket season.

Fifteen participants were found to have the appearance of acute or chronic lumbar bone stress abnormalities during MRI screening.[14] Although chronic defects are common in fully functioning adult fast bowlers,[15] it has been shown that bowlers with acute bone stress reactions are at increased risk of developing lumbar stress fracture in the subsequent cricket season.[16,17] These fifteen bowlers were therefore excluded from further participation in the study to ensure there was no influence of pre-existing radiological abnormalities on future injury incidence. Participants also underwent a follow-up MRI at the completion of the cricket season to identify participants with asymptomatic bone stress.

MRI, musculoskeletal screening and 3D biomechanical bowling analyses were performed on each participant within a 7-day period. The bowler's age was determined as per age-group eligibility (at the start of the cricket season), while height and mass were recorded on the day of the biomechanical analysis. Six participants withdrew from the research during the course of the season; therefore, data from 25 bowlers was obtained for this study (mean age 15.8 years, height 178 cm, mass 69.3 kg).

MRI was undertaken using a GE 1.5 Tesla Signa Excite scanner (General Electric Healthcare, Wisconsin, USA) according to a previously described protocol, and assessed for any abnormal findings by a radiologist.[14]

The selected musculoskeletal screening tests were drawn from common screening protocols used in cricket, and the testing procedures adopted from Cricket Australia guidelines or previously published methods as outlined in Table 1.

Biomechanics data collection was performed 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 and a 1.2 m × 1.2 m force plate (Advanced Mechanical Technology Inc., Watertown, MA) sampling at 2000 Hz were used to collect kinematic and ground reaction force (GRF) data respectively. A cricket crease was marked on the force platform to facilitate the collection of ground reaction force data.

Retro-reflective markers were affixed to the participants' skin according to a customised marker set and model for the lower limbs and trunk.[18] 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 bilateral hip joint centres, and knee joint axes of rotation and corresponding joint centres.[19] Markers placed on the L1 and L5 spinous processes and approximately 5 cm on either side of the spine at the level of L4 (LLL, RLL) defined the lumbar segments.[9]

After carrying out a self-directed warm-up, participants were required to bowl three overs (each over consisting of six deliveries) at match intensity. Pilot testing demonstrated no significant difference in kinematics or kinetics within or between overs. Therefore four trials, in which each bowler achieved their highest ball release speeds across 18 deliveries, were selected for analysis.

The 3D data were processed using Vicon Nexus motion analysis software (Vicon, Oxford Metrics, Oxford, UK). Data were filtered using a fourth-order low-pass Butterworth filter at a cut-off frequency of 15 Hz for the marker trajectories and 50 Hz for the GRF data. Cut-off frequencies were determined using a residual analysis method.[20]

The lumbar segment was defined using the L5 marker to represent the origin of the lumbar coordinate system. The y axis was defined using a vector from the L5 to L1 marker, the x axis was calculated from the cross product of the y axis, and a defining line between the LLL and RLL markers. The z axis was calculated as the cross product of the y and x axes. The lumbo–pelvic joint location was defined using previously established methods.[10]

Scaled inertial parameters for the lower limb, pelvis and lumbar segments were incorporated in the inverse dynamics model for the calculation of lumbo–pelvic kinetics.[9] Peak forces and moments between FFC and ball release ("the delivery phase") were calculated. Lumbo–pelvic angles and moments were defined as positive in flexion, and in lateral flexion and rotation towards the non-dominant side. Joint moments and powers were normalised to body mass and height. Forces were normalised to body mass and defined as positive in the anterior direction, vertically upwards and towards the dominant side medio-laterally.

Participants were followed for injury surveillance purposes during the 6-month cricket season and communicated weekly with researchers, reporting all cases of low back pain. Injury was defined as pain that affected a bowler's ability to perform in a match, consistent with the consensus of cricket injury.[21] Additionally, the definition of injury was expanded to include asymptomatic participants with radiological evidence of lumbar bone stress, as previous cricket studies has demonstrated a link between radiological bone stress and the development of symptomatic bone stress injuries.[16,17]

Participants who reported back pain were evaluated by a single sports physician and further diagnostic tests were ordered as required. If a bowler was diagnosed with a lumbar bone stress injury, the surveillance period ended and the participant took no further part in the study.

Each bowler was asked to record the number of deliveries bowled each day throughout the season and this information was communicated to the researcher weekly. At the completion of the cricket season, the following variables were computed from these data: average number of overs per week, average number of sessions per week, average number of overs per session, maximum number of overs in a single session, maximum number of overs in single week, maximum number of overs in any 2-week period,