MOVEMENT VARIABILITY IN THE SPINAL KINEMATICS OF FAST BOWLERS

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The purpose of this study was to quantify the inter- and intra-individual spinal movement variability in a group of pre-elite and elite fast bowlers. Eleven pre-elite and elite level bowlers from the Otago region (New Zealand) took part in the study. Each bowler bowled two six-over spells, while being recorded by a 3D motion analysis system in two sessions, one week apart. Thorax and lumbopelvis segments were modelled and analysed. Between session changes in spine kinematics were greatest for lateral bending (p = .0001). Inter-individual variability was much greater than the average within-participant variability (more than double), highlighting the need for individual analyses of fast bowlers in the future. Inter- and intra-individual variability in spinal movement among a homogenous group of fast bowlers found in the current study will be important for designing future studies on cricket fast bowlers.

KEYWORDS: movement variability, cricket, fast bowling, spine kinematics

INTRODUCTION: Fast bowling is a complex movement, encompassing many degrees of freedom moving through large ranges of motion and exerting large horizontal and vertical ground reaction forces (Bayne, Elliott, Campbell, & Alderson, 2016). Bowlers can be required to perform upwards of 300 repetitions of the same action over a 4–5 day period (Orchard, Kountouris, & Sims, 2016). The highly repetitive nature of fast bowling has been suggested as one of the reasons for the high injury rates reported (Stretch, 2003).

Variation between subsequent repetitions of the same movement has been reported within (intra-) and between (inter-) individuals for various activities (Preatoni et al., 2013). However, movement variability in cricketers, specifically in fast bowlers, has been scarcely examined. The purpose of this study was to quantify and compare the inter- and intra-individual movement variability among a group of pre-elite (provincial A and U19) and elite (first-class) fast bowlers. Variability was measured in two spinal kinematic variables – axial rotational velocity and lateral bending. These variables were selected because they have been previously studied (often together as ‘crunch factor’) for the role they might play in injury (Cole & Grimshaw, 2014; Glazier, 2010; Joyce, Chivers, Sato, & Burnett, 2016).

METHODS: Pre-elite and elite fast bowlers (n=11) were chosen to participate in the study to provide insight into movement variability associated with high level performance. All bowlers were free of lumbar stress fractures and disc herniations within the last two years. Due to laboratory restrictions, 21 m was allowed for a run-up, with the ball bowled into a net 6 m in front of the popping crease. A standard Vicon 10-camera set-up (Vicon Motion Systems, Oxford, UK) sampling at 200 Hz was used to track the motion of the bowlers. An AMTI LG6-3-1 (AMTI, Massachusetts, USA) force plate sampling at 1000 Hz was used to measure front-foot ground reaction forces. A custom marker model set was developed to define thoracic, lumbopelvic segments. Markers on the right and left greater trochanters and iliac crest tubercles defined the lumbopelvic segment. Markers on the right and left acromia and L5 defined the thorax segment. A marker was also placed on the middle finger of the bowling hand and on the ball to determine time of release and ball speed.

The protocol involved participants bowling two six-over spells each in a session one week apart (36 x 2 = 72 balls total). Game-like breaks between overs were provided. Bowlers were instructed to bowl “as fast as possible without risking injury”. Biomechanical models of the thoracic spine, lumbar spine and pelvis were developed using Visual3D (C-motion, Germantown, MD), the lumbar spine and pelvis were combined into a lumbopelvis segment. Spine axial rotational velocity was defined as the angular velocity about the longitudinal axis of the thorax relative to the lumbopelvis segment. Spine lateral bending was the Euler angle between the thorax and the lumbopelvis segment about the anteroposterior axis. Trials began with front-foot contact (FFC) on the force plate and ended with ball release (separation of the ball and finger markers). Data were filtered in MATLAB (R2017b; The MathWorks Inc., Natick, MA) using a low-pass double 2nd order Butterworth filter (cut-off 14 Hz). Trials were time-normalised to 25 frames.

Interquartile range (IQR) was used as the variability measure for the spinal kinematic variables because it was robust in handling mean values close to zero. For Group (inter-individual) variability, IQR was calculated at each normalised time point of the delivery for all trials followed by the mean across time points. For Participant (intra-individual) variability, IQR was calculated at each normalised time point for all trials of each participant, followed by the mean across time points and participants. Spinal kinematics at release were compared between sessions using non-parametric Kruskall-Wallis tests because assumptions of normality were not satisfied. All analyses were performed in MATLAB.

RESULTS: Figure 1 shows the individual-specific movement patterns of the spine for six of the bowlers from FFC to ball release. Individual movement patterns and movement variability varied a great deal across the group; some participants were relatively consistent (e.g. P1) while others were more variable within sessions (e.g. P6) and between sessions (e.g. P5). Some participants showed similar spine positions at FFC and release (e.g. P4), while other participants' positions were much different at these events (e.g. P5).

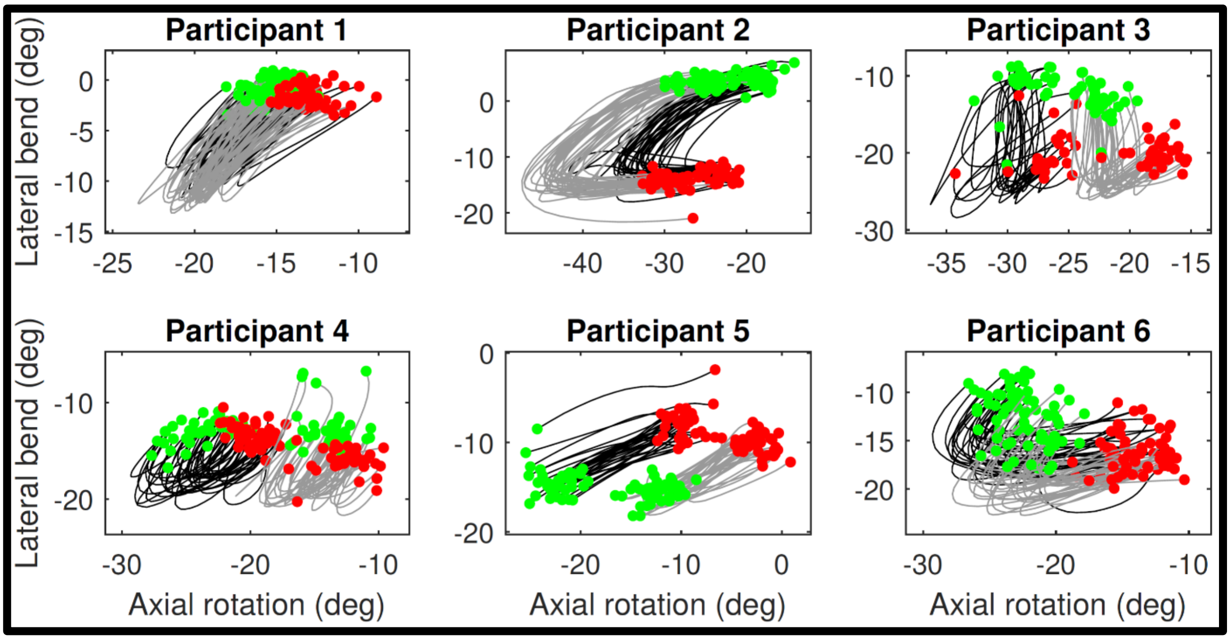

Figure 1: Angle-angle diagrams showing spine lateral bend versus axial rotation from front-foot contact (green dots) to ball release (red dots) for six participants in session one (black) and session two (grey).

Group variability for spine lateral bending (7.6°) was more than double that for Participant variability (2.9°). Similarly, for axial rotation velocity, Group variability was much higher (334.1°/s) than Participant variability (144.4°/s). Furthermore, the peak IQR values for both variables were much higher for the group compared to the mean for each participant: 9.0° vs 3.3° for lateral bending and 507.4°/s vs 195.5°/s for axial rotation velocity, respectively.

Lateral bending at release differed substantially between sessions, $H(1) = 14.9$, $p = .0001$, while axial rotation velocity varied comparatively less between sessions, $H(1) = 0.76$, $p = .38$. Differences in spine kinematic *variability* within-sessions (first three overs compared to last three overs) and between-sessions (session one compared to session two) were bi-directional with no obvious pattern. There was also no clear relationship between spine kinematic variability and ball release speed – either within or between sessions.

DISCUSSION: The current study found that the variability in lateral bending and axial rotation velocity across a small group of elite and pre-elite fast bowlers was much greater than for the average of each individual bowler. Although participants were selected from a similar cohort, there were still differences in their skill level, bowling speed and style (e.g. front-on/side-on, medium-fast/fast). These differences alone, however, do not appear to explain the magnitude of inter-participant variability seen in the current study. The individual movement patterns organising in accordance to the unique constraints of each individual, which includes for example, their anatomy, training and injury history (Renshaw & Chappell, 2010) also likely explain the degree to which individual movement patterns varied. The between session variability in lateral bending may have been related to fatigue accumulated in the week of training between sessions.

An association between coordination variability (i.e. lateral bending and axial rotational velocity variability) and end-point variability (i.e. release speed variability) had not been previously described in fast bowlers and was not found in the current study. Previously, it has been reported that coordination variability may be compensatory and help to reduce the variability in release parameters and can be common in elite athletes (Button et al., 2003; Wagner, Pfusterschmied, Klous, von Duvillard, & Müller, 2012). When examining the relationship in this study, it should be taken into consideration how short the period of time between FFC and ball release actually is – an average of 0.092 seconds. Examining the amount of movement variability in other aspects of the action e.g. run-up, pre-delivery stride, follow through, etc. (Bartlett, Stockill, Elliott, and Burnett, 1996) would help provide better understanding of the relationship between coordination variability and end-point variability in fast bowlers.

The average and peak movement variability of the fast bowlers in the current study was consistent between and within two six-over spells and a potential relationship with fatigue could not be identified from the current study. Although the variability of certain variables did differ by as much as 1.7 times (e.g. within-session group mean for axial rotational velocity), differences were often bi-directional for both the group and participants, i.e. variability for some participants increased from session one to session two, while it decreased for others. Negligible changes in technique across a spell has been reported previously (Burnett, Elliott, & Marshall, 1995; Schaefer et al., 2018). Because there was no significant decrease in release speed as the session progressed, it can be assumed that no fatigue occurred over the course of either spell. Had fatigue occurred, there may have been a change in movement variability (Cortes, Onate, and Morrison, 2014; Gates and Dingwell, 2011). While the literature suggests a relationship between fatigue and movement variability, it appears to be bi-directional and influenced by factors such as the level of fatigue and the task being performed (Cortes et al., 2014). Understanding the relationship between fatigue and movement variability in fast bowlers may give a better idea as to injury mechanisms. Subconsciously changing technique to avoid overloading of the same tissues may be protective for fast bowlers; however, if the 'new' tissues that are being loaded are not sufficiently prepared, there is the potential that the added stress could be harmful.

Recognising the amount of movement variability across a group of fast bowlers is an important consideration for any future studies that examine fast bowling kinematics or technique. Generalising the results of a group to individuals within that group (and vice versa) is often misleading (Fisher, Medaglia, & Jeronimus, 2018), especially in sports biomechanics involving highly individual specific techniques. Based on our findings we emphasise the need for individual analyses (even at the elite level), particularly for intervention studies.

The small sample size is a limitation of the current study, future studies on similar samples as well as different skill levels, ages and sexes should be conducted to substantiate and extend the findings of the current study. The reapplication of markers between sessions may have contributed to some of the inter-session variability, although identifiable bony landmarks were used to define the segments and the same, experienced operator applied the markers in all sessions.

CONCLUSION: Movement variability in the spinal kinematics of a group of fast bowlers is much higher than the average variability of the participants within the group. The inter-individual variability was consistent between and within different bowling sessions/spells and there appears to be little strength to any association between coordination variability and end-point variability for the fast bowlers that took part in the study. Further studies that examine the potential effect of workload (and perhaps fatigue) on movement variability, and how this in-turn affects performance (e.g. release speed) would start to give an indication as to how movement variability in fast bowlers could be used as a performance analysis and/or injury prevention tool.

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