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Is the 'Crunch Factor' an Important Consideration in the Aetiology of Lumbar Spine Pathology in Cricket Fast Bowlers?

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Abstract

The 'crunch factor' is defined as the instantaneous product of lateral flexion and axial rotational velocity of the lumbar spine. It was originally implicated in the development of lumbar spine pathology and lower back pain in golfers and, although empirical evidence supporting or refuting the crunch factor is inconclusive, it remains an intuitively appealing concept that requires further investigation, not only in golf, but also in other sports involving hitting and throwing motions. This article considers whether the crunch factor might be instrumental in the aetiology of contralateral lumbar spine injuries sustained by cricket fast bowlers. Based on recent empirical research, it is argued that the crunch factor could be important in cricket fast bowling especially considering that peak crunch factor appears to occur just after front foot impact when ground reaction forces are known to be at their highest. The crunch factor may also occupy an integral role in lower back injuries sustained in other sports involving unilateral overhead throwing (e.g. javelin throwing) and hitting (e.g. tennis serving) actions where the spatial orientation of the arm at release or impact is largely determined by lateral flexion of the trunk and where the transfer of energy and momentum along the kinetic chain is initiated by a rapid rotation of the pelvis. Further research is required to empirically verify the role of the crunch factor in the development of lower back injuries in cricket fast bowling and sports that involve similar lower trunk mechanics. This research programme should ideally be supported by modelling work examining the stresses imposed on bony, disc and joint structures by lateral flexion and axial rotation motions so that their respective contribution to injury can be identified.

1. Background

Epidemiological studies undertaken in Australia,[1] South Africa,[2] England[3] and the West Indies[4] have repeatedly demonstrated that fast bowlers have the highest risk of injury in cricket with the lower back being most susceptible to both traumatic and overuse injuries.[5] Although the aetiology of stress-related injuries to the lumbar spine is generally considered to be multifactorial,[6] mechanical variables have consistently shown to be statistically linked to the appearance of abnormal radiological features and lower back pain (see Elliott[7] for a review). Specifically, the 'mixed' bowling technique, characterized by a counter-rotation of the shoulder axis relative to the hip axis in the transverse plane between back foot impact and front foot impact, has repeatedly been shown to be associated with the development of spondylolysis, spondylolisthesis, pedicle sclerosis, intervertebral disc degeneration and protruding annulus fibrosus.[8-11] Of all these abnormal radiological features, spondylolysis (a unilateral or bilateral fracture of the pars interarticularis[9]) is the diagnosis that results in the greatest loss of cricket playing time[1] and most lesions occur on the contralateral (non-bowling arm) side of the lower lumbar spine.[12]

Recently, however, Ranson et al.[13] suggested that counter-rotation of the shoulder axis between back foot impact and front foot impact, in itself, may not be wholly responsible for lower back injuries sustained by fast bowlers. They argued that as the lower trunk is in a relatively neutral position between back foot impact and front foot impact and because ground reaction forces are typically low during this period, the contralateral pars interarticularis remains relatively stress free. Instead, they proposed that excessive contralateral flexion and ipsilateral rotation of the lumbar spine at front foot impact through to ball release and beyond are likely to be the main predisposing factors in the development of contralateral stress fractures to the pars interarticularis and intervertebral disc degeneration.

In this article, these ideas are expanded upon and the concept of the 'crunch factor' is introduced. This concept has been implicated in the aetiology of lower back injuries in golf but may prove to have greater significance to cricket fast bowling. The relevance of the crunch factor to other sports involving unilateral throwing and hitting motions is also briefly explored.

2. The Crunch Factor: Definition and Empirical Evidence

The term 'crunch factor' was originally introduced by Sugaya et al.[14] to describe the instantaneous product of lateral trunk flexion and axial trunk rotational velocity during the golf swing. Morgan et al.[15] subsequently revised this definition to target more specifically the motion of the lumbar spine as they demonstrated that focusing on the whole back can introduce ambiguities when attempting to relate loading patterns with the onset of pain. Based on a combination of epidemiological, radiographical and biomechanical data, Sugaya et al.[16] and Morgan et al.[17] postulated that a high crunch factor, particularly during the impact and early follow-through phases of the golf swing, is likely to increase the magnitude of asymmetric compression and shear forces leading to the onset of lower back pain and the development of lumbar spine pathology in golfers.

Recently, several empirical studies comparing differences in spine motion between golfers with and without lower back pain have produced results that appear to question the usefulness of the crunch factor. Both Lindsay and Horton[18] and Cole and Grimshaw[19] reported lower, albeit not significantly so, crunch factors in golfers experiencing pain compared with those who did not. However, a number of issues need to be taken into account when interpreting these results. First, neither study examined the crunch factor of the lumbar spine, as advocated by Morgan et al.[15] but rather, calculated the crunch factor for the whole back. Lindsay and Horton[18] used a lightweight triaxial electrogoniometer that did not permit lumbar spine motion from being separated from thoracic spine motion. Similarly, Cole and Grimshaw[19] simply used the angle formed by the intersection of the spine axis (defined as the vector between the mid-hip and mid-shoulder markers) and the hip axis (defined as the vector between the right and left hip markers) in their calculation of the crunch factor. Second, both of these studies adopted retrospective rather than prospective research designs, which makes it difficult to establish whether some variable other than the crunch factor was instrumental in the onset of lower back pain or whether the lumbar spine in those golfers experiencing pain was constrained to work within a much narrower range of motion.

Although the evidence supporting and refuting the crunch factor is inconclusive and further research is clearly necessary to establish its full role in the aetiology of lumbar spine pathology in golf, it remains an intuitively appealing concept that could have even greater relevance in other sports. In the next section, the potential role of the crunch factor in the aetiology of lower back injuries in cricket fast bowling is explored in light of recent research findings.

3. The Crunch Factor and its Potential Application to Cricket Fast Bowling

As of yet, the crunch factor has not been investigated in cricket fast bowlers, possibly because of a lack of awareness of its potential importance and the inherent difficulties with accurately measuring lumbar spine kinematics. In the past, sport biomechanists have typically used image-based motion analysis systems to coordinate digitize hip and shoulder joint centres from which hip and shoulder axis alignment data could be obtained.[20,21] More recently, however, the use of optoelectronic motion analysis systems has enabled additional markers to be placed on prominent landmarks pertaining to pelvis and thorax motions and more sophisticated reconstruction models have been implemented to obtain kinematic data related to lumbar spine motion.[13,22] An electromagnetic tracking device has also been used to measure the position and orientation of the lumbar spine during fast bowling.[23] Although these studies did not directly examine the crunch factor, they produced some interesting data that are related to this potentially important parameter.

In their investigation of the bowling techniques of 50 healthy professional fast bowlers from English County cricket clubs, Ranson et al.[13] showed that, although no statistically significant differences existed between 'mixed' and 'non-mixed' bowling action groups for percentage of total range of motion for contralateral flexion and ipsilateral axial rotation, the differences were only marginally non-significant (p-values were 0.07 and 0.08, respectively). Furthermore, effect size statistics revealed medium effects between groups for percentage of contralateral flexion ($d = 0.62$) and ipsilateral axial rotation ($d = 0.57$). These results were similar to those of Burnett et al.[23] who found no statistically significant differences in lower trunk kinematics for mixed and non-mixed bowlers but reported a medium sized effect ($d = 0.75$) for contralateral flexion. When considered together, the results of Ranson et al.[13] and Burnett et al.[23] appear to indicate that bowlers adopting the potentially injurious mixed technique may use a greater proportion of lower trunk range compared with those bowlers adopting the non-mixed (front-on, midway and side-on) techniques. Given that the total range of lateral flexion is effectively reduced when the lower trunk is extended and rotated to the ipsilateral side,[24] as is the case in fast bowling, it is highly plausible that the excessive contralateral flexion between front foot impact and ball release may predispose to contralateral stress-related injuries to the pars interarticularis.

Although Ranson et al.[13] did not directly measure the crunch factor, they produced data that suggest it might be an important consideration in the aetiology of lower back injuries. As shown in figure 1, peak crunch factor (the instantaneous product of contralateral flexion and ipsilateral axial rotation velocity) occurs approximately 0.05 seconds after front foot impact when ground reaction forces are known to be high, typically between 3.8–6.4 times bodyweight.[25] Although these compressive forces are somewhat less than the peak forces of 8.57 bodyweight and 8.13 bodyweight calculated by Hosea et al.[26] for

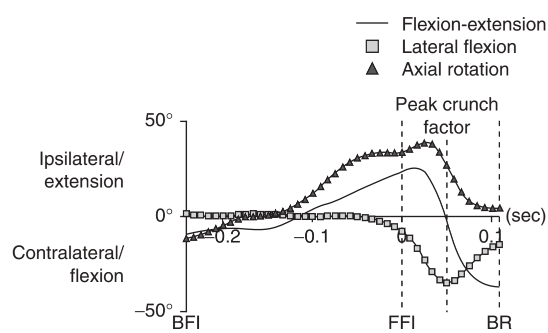

Fig. 1. A graph showing typical flexion-extension, lateral flexion and axial rotation of the lower trunk between back foot impact (BFI) and ball release (BR). Visual inspection indicates that peak contralateral flexion and peak axial rotation velocity (indicated by the gradient of the slope of the axial rotation time series) coincide at approximately 0.05 sec after front foot impact (FFI) [reproduced from Ranson et al.,[13] with permission from Taylor & Francis Group, http://www.informaworld.com].

groups of professional and amateur golfers respectively, they are arguably more significant given that peak compressive forces during the golf swing do not appear to coincide with peak crunch factor. Indeed, Hosea et al.[26] demonstrated that peak compressive forces in the lumbar spine occurred during the downswing phase of the golf swing, whereas Morgan et al.[15] showed that peak crunch factor does not occur until the impact and early follow-through phases. It could be argued, therefore, that the coincidence of peak ground reaction force and peak crunch factor during the delivery stride of fast bowling may make the crunch factor a far more dangerous entity in fast bowling. The suggestion that the crunch factor might be an important consideration certainly corresponds with the supposition of Ranson et al.[13] that the period between front foot impact and early follow-through is likely to be when the lower back is at its greatest risk of injury. Unfortunately, only data pertaining to the crunch factor for a 'typical' participant in their study was provided, thus differences between mixed and non-mixed bowlers cannot be established.

Further evidence of the stress imposed on the lumbar spine during the latter part of the delivery stride and the potential role of the crunch factor, or variant of, in the aetiology of lumbar spine injuries, was provided by Ferdinands et al.[22] In their analysis of 21 New Zealand premier club grade and above fast bowlers, they found that between front foot impact and ball release, peak axial rotation and lateral flexion kinetics (torque and power) coincided at approximately 22–23% of the phase duration (see figure 2). Compressive forces were also shown to be high during this period, with the vertical ground reaction force peaking at 27% of the phase duration. As the focus of this study was predominantly on the kinetics of lumbar spine motion during fast bowling, no corresponding kinematic time series data were provided, so making any direct observations regarding the crunch factor is impossible. However, as power is the scalar product of torque and angular velocity, it can be deduced from figure 2 that high axial rotation and lateral flexion velocities were being produced almost concurrently just after front foot impact, when ground reaction forces were reported to be high. Although, until now, the crunch factor has been defined as the instantaneous product of lateral flexion and axial rotational velocity of the lumbar spine, it might be the combination of lateral flexion velocity and axial rotational velocity of the lumbar spine that is a more potentially injurious combination. Again, as Ferdinands et al.[22] only presented their results as ensemble averages, differences in lumbar spine kinetics and kinematics between mixed and non-mixed bowlers cannot be established.

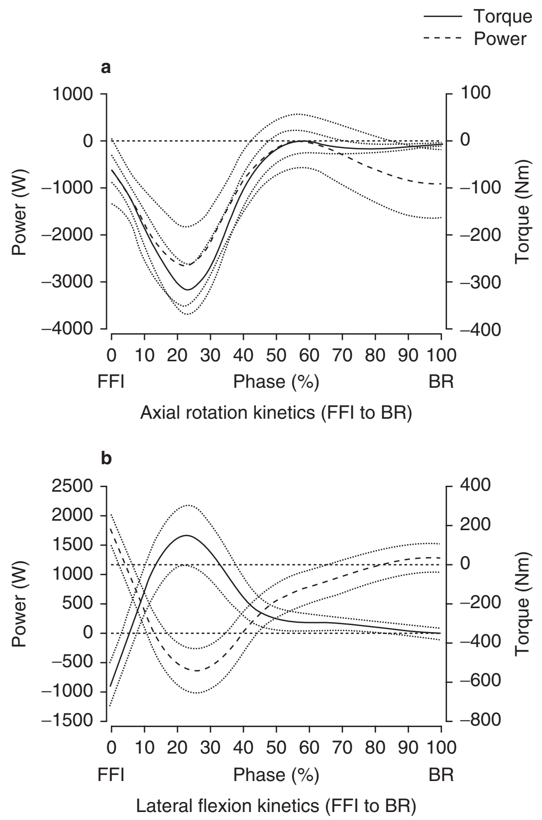

Fig. 2. Time normalized ensemble averages ±95% CI for (**a**) axial rotation kinetics; and (**b**) lateral flexion kinetics of the lumbar spine between front foot impact (FFI) and ball release (BR). Left rotation and right lateral flexion torques were defined as positive. Positive power indicates that motion was active (i.e. segment torque and angular velocity acted in the same direction and corresponded to power generation or net concentric muscle action), whereas negative power indicates that motion was controlled (i.e. segment torque and angular velocity acted in opposite directions and corresponded to power absorption or net eccentric muscle action) [reproduced from Ferdinands et al.,[22] with permission from Elsevier].

4. The Crunch Factor and its Potential Application to Other Sports

Having established that the crunch factor, or variant of, could occupy a role in the development of lumbar spine pathology in cricket fast bowling, it may also prove to be applicable to lower back injuries sustained by athletes in other sports, particularly those involving unilateral throwing and striking motions, where lower back injuries are known to be prevalent.[27,28] Atwater[29] showed that the spatial orientation of the arm at release or impact in these motor skills is determined primarily by lateral flexion of the trunk (see figure 3). Bartlett[30] and Elliott[31] also demonstrated that high end-point velocity in more distal limb segments in unilateral throwing and hitting motions is generated by a precisely timed sequence of segmental rotations originating from more proximal segments. As the flow of energy and momentum along the kinetic chain in these actions is typically initiated by a rapid rotation of the pelvis before transferring to the upper torso and limbs,[32,33] lateral trunk flexion is likely to be accompanied by high axial rotational velocity of the lower trunk, as has already been demonstrated in cricket fast bowling. Furthermore, in activities involving an approach run and subsequent front leg plant (e.g. javelin throwing), ground reaction forces at front foot impact are likely to generate

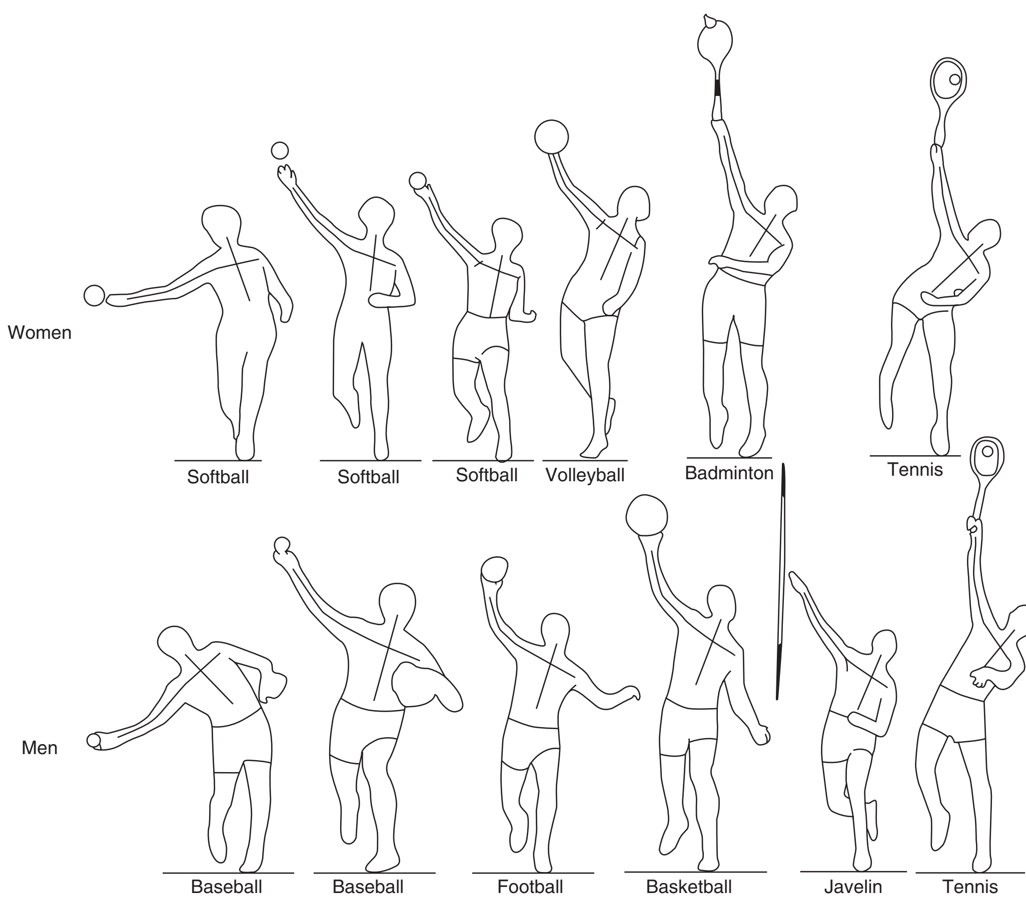

Fig. 3. The spatial orientation of the arm at release or impact in throwing and striking skills is determined primarily by lateral flexion of the trunk (reproduced from Atwater,[29] with permission from Lippincott Williams & Wilkins).

additional compression forces in the lower back at a time when compressive and shearing forces from the crunch factor are already likely to be high.

5. Conclusions

The information provided in this article suggests that the crunch factor might be instrumental in the aetiology of contralateral lumbar spine injuries and intervertebral disc degeneration in cricket fast bowlers. Further research is clearly necessary to empirically verify the role of the crunch factor in the development of lower back injuries, not only in cricket fast bowling, but also in other sports actions that involve similar lower trunk mechanics. This research would ideally be supported by modelling work, similar to that undertaken recently by de Visser et al.[34] examining the stresses imposed on bony, disc and joint structures by each direction of lower trunk motion (flexion/extension, lateral flexion and axial rotation) so that their respective contribution to injury could be identified. As motion tracking technology and modelling methods advance, the accuracy and precision of measurement of the lumbar spine will improve as will the capacity of sport biomechanists to identify injury mechanisms. The information emerging from this research could be used to direct coaching interventions, devise strength and conditioning programmes and define rehabilitation strategies.

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