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Br J Sports Med 2008 42: 477-482 originally published online April 7, 2008
doi: 10.1136/bjasm.2008.046698

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Use of field-based tests to identify risk factors for injury to fast bowlers in cricket

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Accepted 26 March 2008
Published Online First
7 April 2008

ABSTRACT

Objective: To identify risk factors for injury to cricket fast bowlers using field-based tests.

Design: Prospective cohort study.

Setting: High performance Australian cricket.

Participants: Ninety-one male adolescent and adult fast bowlers (aged 12–33 years).

Assessment of risk factors: A field-based pre-participation screening, consisting of musculoskeletal, fitness and anthropometric assessments and analysis of bowling technique was undertaken. Bowlers were prospectively monitored over the 2003–4 season and bowling workload and injuries were recorded. Logistic regression was used to identify injury risk factors.

Main outcome measurement: Repetitive microtrauma injury to the trunk, back or lower limb associated with fast bowling.

Results: Two variables were identified as independent predictors of injury in the multivariate logistic regression analysis. Bowlers with hip internal rotation of $\leq 30^\circ$ on the leg ipsilateral to the bowling arm were at a significantly reduced risk of injury (OR 0.20, 95% CI 0.06 to 0.73) compared with bowlers with $>40^\circ$ of rotation. Bowlers with an ankle dorsiflexion lunge of 12.1–14.0 cm on the leg contralateral to the bowling arm were at a significantly increased risk (OR 4.03, 95% CI 1.07 to 15.21) than bowlers with a lunge of >14 cm. Bowlers with a lunge of ≤ 12 cm were also at an increased risk, but not significantly so (OR 1.38, 95% CI 0.40 to 4.84).

Conclusions: Biomechanical research is needed to investigate how these two intrinsic risk factors increase injury risk so that appropriate interventions can be developed.

bowling workload).^{14–16} Biomechanical studies of fast bowling techniques have reported bony and soft tissue lower back injuries as being more common with a mixed bowling technique than with a front-on or side-on technique.^{14 15 17} Other studies have considered the role of physical characteristics of fast bowlers^{14 15 18} and bowling workload^{14 19–22} in the aetiology of injury.

However, the use of cross-sectional and retrospective study designs has limited the ability of many previous studies to establish cause-effect relationships between putative risk factors and injury. Furthermore, some studies have relied on specialised equipment and facilities to test the bowlers, and the degree to which the testing procedures can be adopted in the cricket “real world” is unclear. This paper presents the results of a prospective cohort study using a field-based screening protocol to concurrently measure bowling workload, bowling technique and physical characteristics as risk factors for injury to adolescent and adult fast bowlers.

METHODS

Bowler recruitment

Players were selected from the male Under 13, 15, 17, 19, 23 years or state high performance squads in New South Wales and Queensland, Australia for the 2003–4 summer cricket season. Coaches identified all fast bowlers (of which there were usually 7–8) from each squad of 25–30 players. A total of 91 bowlers were recruited, and all bowlers (and a parent/guardian for those aged <18 years) provided written consent.

Pre-participation screening protocols and testing procedures

Bowlers completed a pre-participation screening assessment before the 2003–4 season. This consisted of three major components: a musculoskeletal assessment, a two-dimensional multiple plane analysis of bowling technique and a fitness and anthropometric assessment. As the majority of fast bowling injuries are to the back, trunk and lower limb,^{1 21 22} the identification of potential risk factors for these injuries was the primary focus of the screening protocol. The tests were also chosen for their ease of use in the field environment and because they did not require highly specialised equipment.

Musculoskeletal assessment

A number of tests measuring flexibility, strength and stability were conducted, with a detailed description of the procedures provided elsewhere.²³ A summary is provided in table 1.

Internationally, surveillance of cricket injuries has consistently identified fast bowlers as the players at greatest risk of injury.^{1–8} Of particular concern is the repetitive microtrauma (overuse injuries) sustained by fast bowlers, such as lumbar stress fractures, as they can prevent participation in cricket for extended periods of time and related impairments may restrict function generally. Such injuries develop gradually and are associated with the cumulative effects of microtrauma to the musculoskeletal system.^{9 10} Two distinct pathways have been proposed by which cumulative microtrauma leads to symptoms or impairments. In the first, continuous exposure to a pattern of loading and/or other factors simply exacerbates the microtrauma.^{11 12} In the second, an otherwise normal load causes failure of the structure weakened by microtrauma.¹³

It has been proposed that fast bowling repetitive microtrauma (hereafter referred to as “injury”) is related to a combination of poor technique, poor physical preparation and overuse (in terms of

Table 1 Summary of pre-participation musculoskeletal assessment of cricket fast bowlers

Screening test	Purpose of test	Procedure
Knee extension	To assess hamstring muscle length in a position of hip flexion	Range of assisted active knee extension measured (°) in a supine position with the hip of the testing leg held in 90° flexion ²⁴
Modified Thomas test (hip extension)	To assess flexibility of the hip flexors	In a supine position, the contralateral hip is held in maximal flexion with testing leg lowered towards the floor. Femur angle measured (°) relative to the horizontal ²⁵
Modified Thomas test (hip abduction)	To assess degree of hip abduction	Same as above. External rotation then added to the contralateral hip to move the anterior superior iliac spine (ASIS) of the left and right side into a parallel alignment. Femur angle measured (°) with the centre of the goniometer over the ipsilateral ASIS, with the flexible arm positioned to the opposite ASIS ²⁵
Hip internal and external rotation	To assess range of hip rotation in a neutral hip position	Prone position, with hips extended and testing knee flexed at 90°. Contralateral knee extended and line of tibia of testing leg measured (°) relative to the vertical ²⁴
Combined elevation	To assess combined thoracic extension (strength and range of motion), shoulder girdle flexion and scapula retraction	Prone position, arms outstretched, with feet, hips, chest and chin in contact with floor. Both arms raised off floor as high as possible without flexing elbows. Measured perpendicular distance (cm) from the base of the metacarpal of the thumb to the floor
Prone four point hold	To assess lower abdominal strength and endurance	Prone position, elbows flexed at 90°. Trunk raised off floor, resting on forearms and toes, holding a neutral lumbopelvic position as long as possible. Measured length of time (s) neutral position held
Bridging hold	To assess gluteal strength and endurance	Supine position, both knees flexed at 90°. Hips and pelvis raised off floor to attain a continuous alignment from the shoulder through to the hip and knee. Contralateral foot then raised off floor and, with the foot in a neutral position, knee fully extended without lowering the hips or arching the lower back. Measured length of time (s) this position held
Ankle dorsiflexion lunge	To assess range of dorsiflexion at the ankle joint and mobility in the midfoot	Tape measure fixed along floor. Foot positioned beside tape so that heel line and big toe aligned. Heel held to prevent it from lifting off the floor and subtalar joint manually locked. Lunge forward until knee touches wall. Maximum distance (cm) from great toe to the wall recorded
Calf heel raises	To assess endurance of the ankle plantar flexor muscles in a weightbearing task	Stand on one foot, rise onto ball of that foot as high as possible, then slowly lower heel while maintaining knee extension. Number of raise/lower cycles recorded

For range of motion tests, a modified goniometer was used. A spirit level was attached to one arm of the goniometer so that the degree of motion relative to the vertical could be determined. Where bilateral tests were conducted, measurements were recorded as the “bowling” and “non-bowling” sides of the body. For example, for right-handed bowlers, tests on the right side were classified as the “bowling” side. This was done so that differences between the dominant and non-dominant sides of the body could be identified.

Two-dimensional multiple plane analysis of bowling technique

The protocol incorporated various technical measurements of the fast bowling action based on those used in previous studies (table 2).

Video footage of the bowling action was captured by side-on and overhead digital cameras at 25 frames per second. The side-on camera was perpendicular to the bowling direction on the bowling side of the body (sagittal plane) and the overhead camera was placed directly above the bowling crease (transverse plane), mounted perpendicular to the floor. Both cameras were focused halfway between the popping crease and the bowling crease. Footage was analysed using the Siliconcoach video motion analysis software (Sport and Physical Education Technology Ltd, New Zealand; www.siliconcoach.com).

Bowlers wore tights and their usual training shoes and were instructed to warm up and be ready to bowl at full match pace. The testing facilities enabled the bowler to use their normal full run-up. They were asked to bowl a minimum of four legal

Table 2 Summary of pre-participation analysis of cricket fast bowling technique

Screening test	Purpose of test	Procedure
Stride length	Length of bowling delivery stride	Using side-on footage, distance (cm) measured from back of heel of back foot at BFI to back of heel of front foot at FFI. This stride length was also normalised, being expressed as a percentage of the standing height of the bowler
Front knee angle	Angle of front knee during delivery stride	Using side-on footage, angle of front knee at FFI measured using the line formed by the medial malleolus marker, medial femoral epicondyle marker and up the middle of the thigh. Angle also recorded when front knee was most flexed after FFI and prior to ball release
Height of ball release	Height of ball release	Using side-on footage, distance (cm) measured from the ground directly under the front foot to the centre of the ball in the frame of ball release. This height was also normalised, being expressed as a percentage of the standing height of the bowler
Ball speed	Ball speed at ball release	Using side-on footage, ball speed (km/h) calculated from the frame at ball release (the first frame the ball is not in contact with the hand) to one frame after ball release
Shoulder angle at BFI	Shoulder alignment at BFI	Using overhead footage, a line was drawn through the primary alignment of the acromion process at BFI. This line was continued down the pitch, parallel to the alignment of the pitch, and the angle (°) of the shoulders relative to the pitch alignment in the direction of bowling was measured
Minimum shoulder angle	Alignment of shoulders in most side-on position	Using overhead footage, the frame in which the shoulders obtained the most side-on position between BFI and ball release (usually just before FFI) was identified. The angle (°) of the shoulders relative to the pitch alignment in the direction of bowling was measured.
Shoulder counter-rotation	Rotation of shoulders to a more side-on position after BFI	This was automatically determined by subtracting the minimum shoulder angle from the shoulder angle at BFI

BFI, back foot impact (defined as the point in time when the back foot was in first full contact with the ground during the delivery stride); FFI, front foot impact (defined as the point in time when the front foot was in first full contact with the ground during the delivery stride).

Table 3 Summary of pre-participation fitness and anthropometric assessment of cricket fast bowlers

Screening test	Purpose of test	Procedure
Height	To assess height	Height (cm) recorded using a tape measure fixed to a vertical wall
Body mass	To assess body mass	Body mass (kg) recorded using electronic digital scales
Skinfolds	To assess percentage body fat	Skinfolds assessed using Harpenden calipers with all measurements (mm) taken on the right side of the body. Measurements added together to determine sum of seven skinfolds
Vertical jump	To assess peak height of a countermovement vertical jump	Countermovement vertical jump performed. Starting height (maximal reach of the bowling arm while standing) subtracted from peak jump height to determine height jumped. A yardstick jumping device was used in Queensland and a wall-mounted board was used in NSW
Overhead medicine ball throw	To assess peak distance of a standing overhead throw	Feet shoulder width apart, 3 kg medicine ball held above the head. Ball thrown forward, similar to a soccer throw-in. Maximal distance recorded (cm)
Chest medicine ball throw	To assess peak distance of a seated chest throw	Seated position on floor, legs extended, 3 kg medicine ball held against chest, with elbows bent. Elbows then extended and ball pushed forward. Maximal distance recorded (cm)
Side-on medicine ball throw	To assess peak distance of a standing side-on throw	Feet shoulder width apart facing perpendicular to direction of throw with 3 kg medicine ball held in both hands directly in front of body. Using a movement similar to a golf swing, the ball is rotated backwards then forwards to throw the ball. Maximal distance recorded (cm)
40-metre sprint	To assess maximum running speed	Time (s) to complete 40 m sprint as fast as possible recorded. Electronic timing gates were used in Queensland and handheld stopwatches were used in NSW
Yo-yo intermittent recovery test	To assess ability to repeatedly perform intervals over a prolonged period of time	This was used in place of the multistage fitness test. Two markers placed 20 m apart. An audio cassette emitted signals to control the timing of the test. The speed of test gradually increased until the participant was unable to maintain the indicated speed for two trials. Total distance (m) completed was recorded

BFI, back foot impact (defined as the point in time when the back foot was in first full contact with the ground during the delivery stride); FFI, front foot impact (defined as the point in time when the front foot was in first full contact with the ground during the delivery stride).

deliveries (front foot no-ball law) over the wicket while being filmed. For the purposes of standardised analysis, the bowler was instructed to attempt to bowl a good line and length. The fastest delivery was selected for analysis.

The following sites were marked using tape and/or a non-permanent black marker on both sides of the body to allow digitisation in Siliconcoach: acromion process, medial and lateral humeral epicondyle, ulnar and radial styloid, greater trochanter, anterior superior iliac spine, medial and lateral femoral epicondyle, medial and lateral malleolus.

Fitness and anthropometric assessment

These tests focused on body composition, strength, power and aerobic fitness and were chosen for their ease of use in the field environment because they did not require highly specialised testing equipment (table 3).

Bowling workload

All participants were asked to complete daily bowling log books of the number of training, match and warm-up deliveries bowled each day for the entire 2003–4 season. This diary was submitted weekly and entered into a central database. Unfortunately, despite regular encouragement and the successful use of log books in an earlier study,²² the workload data provided by the participants was of poor quality and incomplete. It was therefore excluded from the final analysis.

Injury surveillance

Injury was defined as a condition that affected availability for team selection in a match; and/or required surgery at any stage of the year; and/or during a match caused a team member to be absent from the field for >1 h; or caused a bowler to finish bowling due to symptoms before the end of a normal over; or prevented a bowler from being available to bowl during a match. To be eligible for inclusion, injuries must have been to the back, trunk or lower limb, and had an insidious onset associated with bowling. Unless they met any of the listed criteria, injuries that occurred during training or only affected participation in training sessions were not included.

Bowlers were asked to report any condition or injury, even if it was unrelated to cricket, in their log books. A list of the injury concerns reported by the bowlers was prepared two-weekly and given to a sports physiotherapist who contacted each bowler to determine the date, cause, site, nature and mechanism of injury as well as to determine if the injury met the inclusion criteria. Injury diagnosis was coded in a cricket-specific modification of the Orchard Sports Injury Classification System (OSICS).²⁶

Statistical analysis

All pre-participation screening, workload and injury data were entered into a central Microsoft ACCESS database and then imported to SPSS for analysis.

The main outcome measure of interest was injury (yes/no). Continuous pre-participation screening variables were categorised into approximate tertiles to improve the practical interpretation of the results. The reference group was taken to be the group with the highest tertile for a particular variable. No assumption was made as to which group was the preferred or “best” performing category.

To assess the relationship between potential risk factors and injury, logistic regression models were constructed.²⁷ Unadjusted logistic regression analyses were used to identify univariate associations between risk factors and injury. Odds ratios (ORs) were calculated relative to the reference category, as well as 95% confidence intervals (CIs) and p values. As there was a significant difference between the states (New South Wales or Queensland) for some pre-participation screening variables, the state squad from which the bowler was recruited was included as a covariate in all analyses. Variables with a p value <0.25 were selected for inclusion in the multivariate model. χ^2 tests were conducted to rule out multicollinearity between variables.²⁷

A multivariate logistic regression analysis was then undertaken using a backward likelihood ratio procedure.²⁷ The stepwise inclusion and exclusion criteria were set at p<0.10 and p<0.15, respectively. The ORs and 95% CIs were calculated after adjustment for state squad and all other variables. Associations with a p value of <0.10 were included in the final

Table 4 Risk factors for trunk, back and lower limb injury to adolescent and adult fast bowlers, adjusted for state squad

Screening test	N (% of bowlers in this category who were injured)	Univariate analysis		Multivariate analysis	
		OR (95% CI)	p Value	OR (95% CI)	p Value
Hip internal rotation (°) (B)			0.233		0.045
≤ 30	29 (27.6)	0.40 (0.12 to 1.32)		0.20 (0.06 to 0.73)	
31–40	38 (34.2)	0.45 (0.16 to 1.30)		0.36 (0.12 to 1.11)	
> 40	24 (54.2)	Ref		Ref	
Ankle dorsiflexion lunge (cm) (NB)			0.114		0.060
≤ 12.0	41 (29.3)	0.99 (0.30 to 3.25)		1.38 (0.40 to 4.84)	
12.1–14.0	29 (51.7)	2.69 (0.79 to 9.17)		4.03 (1.07 to 15.21)	
> 14.0	20 (30.0)	Ref		Ref	
Calf heel raises (B)			0.234		
≤ 15	22 (22.7)	0.41 (0.10 to 1.79)			
16–25	51 (43.1)	1.13 (0.35 to 3.68)			
> 25	17 (35.3)	Ref			
Maximum front knee angle (°)			0.193		
≤ 200	28 (35.7)	1.44 (0.43 to 4.80)			
201–220	31 (45.2)	2.96 (0.88 to 9.96)			
> 220	25 (28.0)	Ref			

B, bowling side of the body (ipsilateral to the bowling arm); CI, confidence interval; NB, non-bowling side of the body (contralateral to the bowling arm); OR, odds ratio.

model.²⁷ The goodness-of-fit of the final model was determined using the Hosmer-Lemeshow test.

RESULTS

Of the 91 participating bowlers, 72 (79.1%) were right-handed bowlers and 19 (20.9%) were left-handed bowlers. The median age was 17.8 years (range 12.3–33.1). Of these, 53 bowlers (58.2%) were adolescent (aged ≤ 18 years) and 38 (41.8%) were adults (>18 years). The age of bowlers at the time of baseline screening was investigated in the univariate analysis but was not associated with injury ($p = 0.641$) and was therefore not included in the multivariate model.

Of the 53 adolescent bowlers, 20 (37.7%) were injured compared with 17 (44.7%) of the 38 adult bowlers. The most common injuries were lumbar injuries (other than stress fractures/reactions) ($n = 10$), groin injuries ($n = 6$) and heel and achilles injuries ($n = 4$). Other included injuries were side and abdominal strains and lumbar stress fractures/reactions. Thirty-four bowlers (37.4%) reported an injury that met the criteria for inclusion in the analyses.

Four measures passed the selection criteria for inclusion in the multivariate model (table 4). Two of these were on the leg ipsilateral to the bowling arm: hip internal rotation and calf heel raises. The other two were on the leg contralateral to the bowling arm: ankle dorsiflexion lunge and maximum front knee angle. χ^2 analyses confirmed that the four variables selected for inclusion in the multivariate model were not significantly correlated and therefore all four variables were considered further. The state squad from which the bowler was recruited was also included as a covariate.

The modelling strategy identified only two variables as independent predictors of injury. Reduced hip internal rotation on the leg ipsilateral to the bowling arm (back foot landing leg in the delivery stride) was associated with a significantly decreased risk of injury, and reduced ankle dorsiflexion on the leg contralateral to the bowling arm (front foot landing leg) was associated with a significantly increased risk of injury (table 4). The lunge test was used to measure ankle dorsiflexion and hip internal rotation was measured in a prone position (as described in table 1). The Hosmer-Lemeshow statistic for goodness-of-fit showed that the data fitted the model well ($\chi^2 = 0.98$, $p = 0.995$).

DISCUSSION

This prospective cohort study of fast bowlers conducted over one summer cricket season measured a broad range of musculoskeletal, fitness, anthropometric and technique variables through a pre-participation screening. Of the 35 measures, only two were identified as independent predictors of injury. Reduced hip internal rotation on the back foot impact leg was associated with a significantly decreased risk of injury, and reduced ankle dorsiflexion on the front foot impact leg was associated with a significantly increased risk of injury.

Several studies have identified decreased ankle dorsiflexion as a risk factor for a range of injuries, including lower extremity injury to Australian footballers,²⁸ ankle injury in children,²⁹ metatarsal stress fractures in soldiers,³⁰ patellar tendon injury in volleyball players,³¹ plantar fasciitis in physiotherapy patients³² and patellofemoral pain syndrome in recreational runners.³³ A lack of ankle dorsiflexion on the front foot impact leg could relate to injury to fast bowlers in a number of ways. Tight calf musculature with a lack of ankle dorsiflexion may contribute to higher ground reaction forces at front foot impact as there is less displacement available to attenuate the impact. Compromised function of the calf muscle could increase load on the knee and patellar tendon via the closed kinetic chain.³⁴ Alternatively, it may be possible that decreased ankle dorsiflexion results in changes in both tibial and femoral alignment, which have been speculated to cause changes in optimal pelvis and lumbar spine alignment in weight bearing.³⁵

Previous studies have suggested that a lack or excessive amount of hip rotation can be a risk factor for injury. One study reported that male soldiers with exertional medial tibial pain had a significantly increased range of hip internal rotation and hip external rotation, but that female soldiers did not.³⁶ It has also been proposed that increased hip internal rotation is associated with an increased risk of non-contact knee injury.³⁷ The mechanism by which decreased hip internal rotation on the back foot impact leg is related to a decreased risk of injury is not clear, but it may be possible that increased hip internal rotation is an indicator of inadequate gluteus medius control.³⁸

Although this study has identified decreased ankle dorsiflexion and increased hip internal rotation as risk factors for injury, only further detailed biomechanical studies will be able to explain how they contribute to the internal loads in the lower

limb. It would also be of interest to investigate whether the adopted field-based screening measures of ankle dorsiflexion and hip rotation accurately reflect the movement that occurs dynamically at certain stages of the delivery, such as at front and back foot impacts.

It has been stated that injury interventions should focus on modifying the loads applied externally and internally to the body, either by reducing the loads to below relevant injury tolerance criteria or by improving the body's capacity to tolerate certain patterns of loading.³⁹ The results of this study suggest that, once a clearer understanding of the potential injury mechanisms is available, it would be worth examining how interventions to improve ankle dorsiflexion range and control of hip internal range of motion could be developed and evaluated for their effectiveness in preventing fast bowling injury.

Previous research has reported a consistent association between the mixed bowling technique and injury.^{14 15 17} However, none of the technique measures in this study were independent predictors of injury. This may be due to limitations of using a two-dimensional analysis of bowling technique, with the field-based screening protocols not providing the same level of accuracy afforded by laboratory-based tests. Alternatively, it may be possible that the high performance fast bowlers who participated in this study had already corrected any technique faults prior to the conduct of this study due to their more advanced coaching.

The major strength of this study was the prospective collection of injury data following a comprehensive field-based pre-participation screening. As a cricket physiotherapist consulted with each injured bowler to confirm the symptoms associated with the reported injuries, more accurate injury data was collected than studies relying solely on the bowlers' self-reported recall. Although this study focused on injuries that were attributable to fast bowling, it is possible that the pathogenesis of some of the included injuries is related to other causes, including incomplete recovery from previous injury.

There has been some debate in the literature as to whether all musculoskeletal tissues are subject to unrecovered deformation as a result of repetitive loading. There is evidence to support the role of cumulative microtrauma in the aetiology of injuries to bone,^{12 40 41} cartilage,¹² tendon and ligament,^{10 12 42} but the relationship with muscle strain injuries is not so well understood. Hence, it is acknowledged that the aetiology of the injuries sustained by fast bowlers is complex and that the role of cumulative trauma is not clearly established for all musculoskeletal tissues, particularly muscle.

A potential limitation of this study is the inclusion of a diverse range of musculoskeletal injuries across a range of bowler ages. The risk factors and mechanisms for these injuries will not necessarily be universal, and this may have contributed to only a limited number of significant independent risk factors for injury being identified.²⁸ Future research that monitors a larger cohort of bowlers over a longer period is needed to provide sufficient power to identify age-specific risk factors for specific injury types or categories.

Unfortunately, we were not able to include bowling workload data in the multivariate analyses because of the poor capture of this data. This is in contrast to a previous study of adolescent fast bowlers²² which successfully used the same bowling workload log books. It would be worth considering other methods for recording bowling workload data that may increase compliance, such as interactive web-based submission or mandatory reporting to squad coaches.

A reliability assessment of all tests included in the pre-participation screening protocol was conducted, with the results relating to the musculoskeletal protocol being described in detail elsewhere.²³ All musculoskeletal tests had excellent intra-observer reliability, the only exception being the bridging hold test. However, the inter-observer reliability was not as high. All of the tests in the fitness and technique protocols demonstrated excellent intra- and inter-observer reliability. There was a significant difference between the states (New South Wales and Queensland) for some pre-participation screening variables and therefore the state squad from which the bowler was recruited was included as a covariate in all analyses. These differences may be due to differing interpretations of the screening protocols (even though detailed standardised protocols were developed) or poor reliability of some tests used.

With respect to the tests assessing hip internal rotation and ankle dorsiflexion, the ankle dorsiflexion lunge test demonstrated excellent inter-observer reliability (intraclass correlation coefficient (ICC) = 0.96) and intra-observer reliability (ICC = 0.98).²³ While the intra-observer reliability of the hip internal rotation test was also excellent (ICC = 0.94), the inter-observer reliability was very low (ICC = 0.30), which may have influenced these results. It may be possible that some other measures not identified as risk factors were also limited by poor reliability. Alternative field-based tests for some musculoskeletal measures should be evaluated for their intra- and inter-observer reliability and considered for inclusion in future research.

CONCLUSIONS

This study contributes to the international body of knowledge of risk factors for repetitive microtrauma injury to cricket fast bowlers by identifying two independent risk factors for injury: decreased range of ankle dorsiflexion on the leg contralateral to the bowling arm and increased range of hip internal rotation on the leg ipsilateral to the bowling arm. These findings should be

What is already known on this topic

- ▶ Fast bowlers have been identified as the cricket players at the greatest injury risk, with repetitive microtrauma injuries being of particular concern.
- ▶ Bowling technique, physical preparation and bowling workload have been proposed as injury risk factors.
- ▶ However, many previous studies are limited by the use of specialised equipment and facilities, and the degree to which the testing procedures can be adopted in the cricket "real world" is unclear.

What this study adds

- ▶ A field-based screening protocol was used to concurrently investigate measures of bowling workload, technique and physical characteristics as injury risk factors for adolescent and adult fast bowlers.
- ▶ Increased hip internal rotation and reduced ankle dorsiflexion were identified as independent predictors of trunk, back and lower limb repetitive microtrauma injury.
- ▶ This study identifies priority areas for further biomechanical research to investigate how these two intrinsic risk factors contribute to internal loading and increased injury risk.

the focus of future biomechanical research to investigate how these factors increase injury risk so that appropriate interventions can be developed.

Acknowledgements: The authors acknowledge the valuable contributions of Danny Redrup, Ben Williams, Richard Done, Marc Portus and Andrew Hayden, and thank the participating bowlers and the staff of Cricket NSW and Queensland Cricket including the coaches, physiotherapists, strength and conditioning coaches, performance analysts and other High Performance staff who assisted with this study.

Funding: This project was funded by Cricket Australia. RD was supported by an NHMRC Public Health PhD scholarship during the data collection and analysis phase, and by an NHMRC Population Health Capacity Building Grant in Injury Prevention, Trauma and Rehabilitation during the reporting and publication phase. CF was supported by an NHMRC Principal Research Fellowship.

Competing interests: None.

Ethics approval: The project was approved by the University of New South Wales Human Research Ethics Committee.

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