Assessment of trunk lateral flexion range of movement using a novel method in first class cricket players

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Lateral flexion, side strain, reliability, stability

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Abstract

Objectives: Lateral flexion range of movement (LF ROM) is used to assess and monitor recovery of side strain injury in athletes. This study established a reliable and pragmatic measure of LF ROM and investigated the stability of the measure over time in athletes.

Design: 1) Cross-sectional reliability study and 2) Cohort longitudinal study.

Setting: Elite cricket teams in COUNTRY-AAA and COUNTRY-BBB

Participants: Cricket players

Methods: 1) The intra- and inter-rater reliability of two methods of measuring LF ROM were assessed (distance to the floor or distance to fibular head). Ten healthy first-class cricket bowlers were tested by three experienced physiotherapists. Intra-class correlations (2,1) were calculated for absolute agreement for all 3 testers. 2) Professional cricket fast bowlers were recruited from COUNTRY-AAA and COUNTRY-BBB domestic and international competitions. Lateral flexion range of movement was measured monthly during the pre- and competitive season. A one-way repeated measures analysis of variance was performed to identify difference within the pre-season, within the competitive season, and between competitive seasons.

Main Outcome Measures: Lateral flexion range of movement towards and away from the bowling arm.

Results: Both methods had good intra- and inter-test reliability (ICC>0.84). As LF ROM to the floor was easier for clinicians it was used for the longitudinal study. Lateral flexion range of movement did not significantly alter throughout the pre- and competitive season or between seasons (p>0.05).
Conclusions: This new method of describing LF ROM demonstrates good intra- and inter-rater reliability and stability over time and can be used as an outcome measure in side-strain injury.
Introduction

Side strain injury is common in throwing and bowling athletes; with internal or external oblique, intercostal or rib muscle strains accounting for 92% of these injuries. A review of 23 major league baseball disability lists reported 393 side strain-type injuries, comprising 5% of all injuries in major league baseball over a 20 year period. Side strain injury also impacts cricket fast bowlers; and has the second highest incidence and third highest prevalence of all injury types in COUNTRY-AAA first class cricket over 18 years to 2013-14 (Figure 1).

Daily life seldom requires extremes of LF ROM. However, throwing or bowling are repetitive, strenuous and asymmetrical tasks. Three-dimensional kinematic study of professional first class bowlers has shown that the bowling action induced 30% more trunk LF ROM during the front foot phase of the delivery stride than in standing. For baseball pitchers the proposed moment of injury is the late cocking and early acceleration stages of throwing. A kinematic study showed the most demanding moment for the trunk during pitching was near the instant of front foot contact. This is the moment that maximum trunk rotation and high trunk axial acceleration was produced, implying high torque.

Diagnosis of the side strain injury is clinical, based on the mechanism of injury and localised tenderness over the lateral trunk near or over the rib cage, but clinical practices of assessment of this injury vary. Lateral flexion range of movement (LF ROM) may be the simplest and most widely used measure to quantify the severity of side strain injury. However, there is no current consensus on a reliable and feasible method of taking this measurement in the clinical setting. Several methods of measuring LF ROM of the trunk and lumbar spine have been described in both clinical and sporting populations with reliability reported to vary from poor to excellent and little consensus on the most reliable method. One review even suggesting there was no reliable way of measuring it. Further, some studies employed a single measurement method while others relied on averaging multiple measures. While some
of these methods may be viable in research, their utility is limited for the clinician where convenient and quick methods are required in practice\textsuperscript{14}.

It is essential that a reliable method of measuring LF ROM is established, and its variation in measurement during and between seasons is established before its utility as a potential predictor of injury, clinical assessment test, and predictor of prognosis and recurrence is investigated in future research. This study aimed to examine the reliability of LF ROM via two methods (measurement of finger to the floor, measurement of finger to the fibular head).

The second aim was to examine the variation in LF ROM during the pre- and competitive season, and between seasons.

Methods

Ethics approval for this study was granted by two University Human Research Ethics Committees and all participants supplied written informed consent.

Reliability

(i) Participants

Ten first class cricket players from the same COUNTRY-BBB county team (six fast bowlers, one spin bowler and three specialist batsmen (mean: age 26.8 years, height 182.7cm) attended one testing session. Five of the fast bowlers had previously sustained a side strain injury including one who underwent rib resection 5 years earlier. Participants were included if they were free of any injury that would impact training or participation in competitive matches at the time of testing. Participants had not bowled in a competitive match on the day of testing as this may have affect results. Participants were excluded if they were not participating in competitive cricket for any reason.
(ii) Test description

The participant stood side on to a flat wall without shoes, feet hip width apart, with the base of one fifth metatarsal and greater trochanter touching the wall. The arm adjacent to the wall was ab ducted overhead and the elbow comfortably flexed so that this arm was not pushing the participant away from the wall. The participant was instructed to “slowly run your fingers down the outside of your leg and reach as far as you can while continuing to look straight ahead”. The participant maintained contact with the wall at both lower limb points and kept both feet and heels flat on the floor at all times. The participant was given specific instructions and tactile feedback to keep their lateral border of foot in contact with the wall (Figure 2). The physiotherapist was near the participant’s feet to ensure that the participant complied with this instruction. The participant laterally flexed at the trunk without trunk or hip flexion or extension. The measurement was measured in both directions: towards and away from the bowling arm. Two methods of determining range of movement were performed for comparison of reliability: distance to the floor (FLR) and distance to head of fibula (FIB).

Measurements were conducted by three experienced first-class cricket team physiotherapists (13, 6, and 8 years of experience) using a retractable tape measure (Medisave Nurses Tape Measure, www.medisave.co.uk). Testing was completed in a single session to prevent time of day and activity between testing sessions potentially confounding data. Each physiotherapist tested each participant in a randomised order for both trials to enable the investigation of intra-rater reliability. Following every measurement, the measuring physiotherapist ensured that the ROM mark on the participant’s leg was completely removed using an alcohol wipe. Each measurement was taken on a separate movement, rather than multiple testers taking a measurement on the same movement. This introduces the variable of actual difference.
between movements, in addition to the reliability of the measurement technique between and within testers.

Repeated measurements in and between seasons

(i) Participants

Participants were recruited from professional cricket teams in COUNTRY-AAA and COUNTRY-BBB. Participants were included if they were aged 18 years or older and selected as a fast bowler. A total of 24 teams were invited to participate (each team had approximately 5 fast bowlers) and data were provided from 72 participants in season and 49 participants between seasons. At the commencement of data collection for each participant, their age, standing height, bowling arm and number of previous side strain injuries were recorded. Only data on injury free bowlers were included.

(ii) Measurements

The physiotherapists of each respective team recorded the ROM of participants on each occasion. Lateral flexion ROM measured from the floor was first measured 3 months prior to the start of the preseason (month -3) and repeated at intervals not exceeding 1 month until the completion of the first year of the competitive season (month 4). During years 2 and 3, the first measure was taken at the start of preseason (month -3) and repeated at intervals not exceeding 1 month until the first month of the competitive season (month 1). Measurements were taken prior to any bowling on that day. Measurement points were labelled according to their timing pre or post the commencement of each bowler’s competitive season.

(a) Within pre-season variation

Changes in ROM within pre-season were assessed with three time points. The latest measure was taken in the one month preceding the commencement of each bowler’s respective competitive season. The prior measures were taken not more than one month preceding the subsequent measure.
(b) Within competitive season variation

Changes in ROM within the competitive season were assessed with five time points. The first measure taken in the one month preceding the commencement of each bowler’s respective competitive season was used. The subsequent measures were taken not more than one month after the preceding measure.

(c) Between competitive season variation

Changes in ROM between competitive seasons were assessed with three time points. Each measure was taken in the first month of each bowler’s respective competitive season, in successive seasons.

Statistical analyses

Reliability

Reliability was calculated on a single measure basis (SPSS, IBM) to match the clinical setting where ROM is only measured once. Intra- and inter-rater reliability was calculated with the intra-class correlation (ICC) with 95% confidence intervals, standard deviation (SD), standard error of measurement (SEM) and minimum detectable change (MDC) of the measure in both directions. Reliability was reported as poor, moderate, good, or excellent based published criteria (ICC>0.5, 0.5 to 0.75, 0.75 to 0.9, >0.9, respectively)\(^27\). Standard error of the measurement indicates the amount of variability in a test due the measurement error, whereas MDC represents the smallest amount of change that represents real change beyond measurement error. Statistics were calculated for both the measurement to the head of fibula (FIB) and to the floor (FLR). Absolute agreement was chosen over consistency.

Intra- and inter-rater reliability was calculated for all 3 testers using a two-way random effects model looking for absolute agreement based on a single (first) measure of each tester.
The SEM provides an absolute index of reliability, in the same units as the measurement, therefore quantifying the precision of the scores of the test. SEM was calculated from the square root of the mean square error value generated from a one-way repeated measures ANOVA. The MDC was calculated using the formula MDC = SEM x 1.96 x √2.

Repeated measurements in and between seasons

Range of movement was measured using distance to the floor due to its ease. A lower numeral represents a larger magnitude of movement. Ranges presented are minimum to maximum. All data unless stated were normally distributed for all time points (Shapiro-Wilk significance value > 0.05). Data were analysed for seasonal variation using a one-way repeated measure analysis of variance (ANOVA). Given the asymmetrical demands of the bowling action and potentially different effect of past side strain injury on the behaviour of ROM in either direction, data for the directions towards and away from the bowling arm were considered independently. Cases in which there were any missing time points were excluded. All significance values (°) unless specified are sphericity assumed since Mauchly’s test of sphericity significance value was > 0.05. Differences in ROM between time-points were plotted on a scatterplot to highlight individual variation in LF ROM, with 95% confidence bands based on the standard error of measurement for inter-rater reliability using the floor measure.

Results

Reliability

(i) Intra-rater reliability

Intra-rater reliability for all raters were demonstrated to be good-to-excellent when measuring LF ROM to the floor or proximal fibula and both towards and away from the bowling arm (Table 1). The floor measure ICCs were marginally higher than the fibula measure for all 3 raters. The MDC for the floor measure was lower for all 3 raters when measuring LF ROM.
away from the bowling arm. There was much greater variation between the raters in MDC for
towards the bowling arm measures than away from the bowling arm.

(ii) Inter-rater reliability

Inter-rater reliability demonstrated similar ICCs for the floor measure than the fibula measure
both towards (floor 0.91, fibula 0.84) and away (floor 0.96, fibula 0.94) from the bowling
arm. The MDCs for away were almost identical for the floor and fibula measures (floor away
28mm, fibula away 27mm, floor toward 41mm, fibula toward 48mm).

Repeated measurements in and between seasons

Data were collected over a period of 3 years from the commencement of the COUNTRY-
BBB County cricket season in 2011 and the COUNTRY-AAA State cricket season in 2011-
12. There were 1,736 ROM measurements taken of 238 first class cricket fast bowlers by
physiotherapists from all 24 first class and each respective national teams from COUNTRY-
AAA and COUNTRY-BBB. Data received from national teams were distributed to the sets
for each respective bowler’s domestic first-class team. Data for bowlers who moved teams
between seasons were transferred to the team data set in which the bowler commenced the
data collection period.

(i) Within pre-season variation

There were 56 bowlers (24% of cohort, mean age 24.4 years (range: 18 to 36), mean height
188.7cm (range: 175 to 203)) from 9 teams with complete ROM data sets for 3 time points in
a single pre-season. There were 49 right arm and 7 left arm bowlers, data were analysed as
towards and away from the bowling arm to account for this. Past history of side strain injury
was provided, 22 bowlers had 1 injury, 4 bowlers had 2 injuries and 1 bowler had 3 injuries.
There was no difference in ROM, either towards or away from the bowling arm, between the
three time points, with p > 0.05 (Table 2). Eighty-four percent of measurements towards the
bowling arm and 67% of measurements away from the bowling arm varied within the 95%
confidence intervals that an individual’s ROM varied due to the systematic error of the measurement (Supp 1).

(ii) Within competitive season variation

There were 72 bowlers (30% of cohort, mean age 25.1 years (range: 18 to 39), mean standing height 187.2cm (range: 173.6 to 204)) from 13 teams with complete ROM data sets for five time points in a single competitive season. There were 61 right arm and 11 left arm bowlers. Past history of side strain injury was provided, 30 bowlers had 1 injury and 9 bowlers had 2 injuries.

There was no difference in ROM away from the bowling arm, between any of the five time points, with $p > 0.05$ (Table 3). There was a significant difference in ROM towards the bowling arm between the 5 time points. Post-hoc pairwise comparisons revealed that the ATLF ROM towards the bowling arm was statistically different between month 1 and month 4 ($p<0.01$). However, the mean difference (15.8mm) was smaller than the MDC for the ROM test. Therefore, ATLF ROM both towards and away from the bowling arm did not vary greater than measurement error from the final month of pre-season and within the competitive season. Seventy-six percent of measurements towards the bowling arm and 62% of measurements away from the bowling arm varied within the 95% confidence intervals that an individual’s ROM varied due to the systematic error of the measurement (Supp 2).

(iii) Between competitive season variation

There were 49 bowlers (21% of cohort, mean age 25.4 years (range: 18 to 37), mean standing height 188.5cm (range: 176.0 to 204)) from 14 teams with complete data sets for 3 time points being the first measure in consecutive competitive seasons. There were 42 right arm and 7 left arm bowlers. Past history of side strain injury was provided, 25 bowlers had 1 injury, 4 bowlers had 2 injuries, 1 bowler had 3 injuries and 1 bowler had 4 injuries.
There was no difference in ROM, either towards or away from the bowling arm, between the
three time points, with p > 0.05 (Table 4). Sixty-six percent of measurements towards the
bowling arm and 51% of measurements away from the bowling arm varied within the 95%
confidence intervals that an individual’s ROM varied due to the systematic error of the
measurement (Supp 3). Therefore, LF ROM taken within the first month of the competitive
season did not vary.

Discussion

This study describes a new simple and reliable method of measuring active trunk lateral
flexion (ATLF) range of movement. The reliability of previous methods have varied from
poor to excellent, with some of these methods requiring expensive and cumbersome
equipment. Further, lateral flexion ROM in professional cricket players was shown to be
consistent during the preseason, competitive season, and between seasons. Establishing the
reliability and natural variation of lateral flexion ROM is a critical step in understanding its
role in the clinical assessment, screening, and prognosis of side strain injuries in cricket and
throwing athletes.

Reliability

Lateral flexion ROM measured with this novel method has been demonstrated to have good-to-excellent intra- and inter-rater reliability. The MDC was lowest for the method to the floor
for the majority of measures. Reliability statistics were similar for the direction towards the
bowling arm than away. Indices of inter-rater reliability for towards the bowling arm were
comparable to those for intra-rater. There was greater variability for the direction away from
the bowling arm.

The levels of reliability demonstrated in this study are consistent with that of Ng (2001)\textsuperscript{17},
who used a custom built pelvic restraint device. This study suggests that the method
investigated is similarly reliable with the distinct advantages of simplicity, minimal equipment, and time, as a single measure can be completed within 30 seconds. This is important in the clinical and sporting settings when assessing a painful patient and screening a large number of players.

Side listing of the pelvis and lumbar spine is a common coupling movement with lateral flexion of the trunk and lumbar spine. A tendency to deviate in the sagittal and horizontal planes has previously been reported to reduce reliability of the measurement of LF ROM compared to sagittal movements. Standing in close proximity to, and facing, a wall was shown not to significantly improve reliability. The lack of complete pelvic fixation limiting free motion of the pelvis in terms of sagittal rotation was also noted to contribute to the poor reproducibility of computerised measuring equipment. The participant’s desire and indeed instructions to reach to maximise their ROM may also encourage flexion of the hips and spine. The novel method described overcomes the issue of side listing by insisting that the participant’s lateral foot and greater trochanter maintain contact with the wall, thus providing a physical block. The instruction for the subject to maintain their gaze straight ahead was also considered helpful and has been previously reported. This necessitates that the participant avoids cervical, and consequently, trunk and hip flexion, optimising the purity of the lateral flexion movement.

There are several strengths of the measurement method to the floor. Firstly, the measurement is an objective measure of distance that does not require the palpation of any bony landmarks. This distance is a direct measure to the floor with no skin movement under a measurement tool. The measure is non-invasive and the only equipment it requires are a wall and tape measure. The good-to-excellent reliability of the test is based on a single measure, making it very quick to implement in the clinical context. Another major strength of the measurement method is its simplicity. Two of the three testers in this study had no previous experience
using the test, receiving only a written and pictorial description and a single demonstration
prior to completing the measurements. The method has now been shown to have good-to-
excellent reliability and its SEM and MDC have been determined and can be factored into
research and clinical decisions. These are essential steps for the test to be implemented in
prospective research and clinical practice.

Variation between measurements

Range of movement did not vary during measurements 1 month apart within pre-season,
within the competitive season, or between three competitive seasons. Side strain occurs
frequently in the initial months of the season. This suggests that the increased demands of
transition from training to competition may be a contributing factor in the aetiology of the
injury.

There are implications of this research for the clinician that is managing athletes who at-risk
of sustaining side strain injuries. The lack of variation in ROM within pre and competitive
seasons and between seasons indicates that a baseline measure taken in the 3 months prior to
the commencement of the competitive season is consistent not only during the season, but
also for subsequent seasons.

This study was methodological robust with a large data set using a prospective study design.

There were good-to-excellent levels of intra- and inter-rater reliability, the measurements
were consistent with how tests are used clinically, and the participants were representative of
a clinical population. The findings provide a pragmatic and simple measurement tool that
clinicians can use both clinically and in a sporting context.

A limitation of this study was that the ATLF ROM test has not yet been shown to be reliable
in injured players, unlike the AKE and PKE tests for hamstring injury. There were also
several missing data that reduced the size of the cohorts for each analysis. However, the study
was dependent on the contributions of many physiotherapists working within the time
constraints of the first-class cricket season and measures taken more than one calendar month apart or on injured players were excluded.

In summary, this research provides clinicians with a reliable and simple way to evaluate lateral flexion range of movement in a time efficient manner. The findings may improve clinician’s measurement technique and reproducibility of lateral flexion assessment, which enables its use as a screening tool and an outcome measure after injury. Future studies could investigate the progression of lateral flexion range of movement during recovery from side strain injury and determine if it is a criterion measure for return to sport.

Conclusion

This study has demonstrated good-to-excellent intra- and inter-rater reliability of a novel method of measuring LF ROM that is simple and quick to employ in the clinical setting. It has also been demonstrated that this measurement does not vary between or during pre- or competitive seasons in a large cohort of uninjured first-class cricket fast bowlers. These findings provide a basis for future prospective research investigating LF ROM as a predictor of injury, clinical assessment test and predictor of recovery time and recurrence following side strain injury.
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| Tester | ICC (95% CI) | SEM (mm) | MDC (mm) | Mean (SD) (mm) | ICC (95% CI) | SEM (mm) | MDC (mm) | Mean (SD) (mm) |
|--------|--------------|----------|----------|----------------|--------------|----------|----------|----------------|
| 1      | 0.96 (0.8 – 0.99) | 10       | 28       | 491 (50)       | 0.95 (0.79 – 0.99) | 10       | 28       | -4 (44)        |
| 2      | 0.965 (0.87 – 0.99) | 10       | 28       | 489 (50)       | 0.938 (0.78 – 0.98) | 10       | 29       | -3 (38)        |
| 3      | 0.95 (0.82 – 0.99)  | 11       | 31       | 480 (53)       | 0.90 (0.66 – 0.97)  | 12       | 34       | -1 (38)        |

Table 1: Intra-rater reliability for measurement to floor and fibula
### Table 2: Lateral flexion ROM of 56 cricket players both away and towards the bowling arm at monthly intervals during the pre-season. No significant changes were observed.

|        | Away |     |     | Towards |     |     |
|--------|------|-----|-----|---------|-----|-----|
|        | Month -3 | Month -2 | Month -1 | Month -3 | Month -2 | Month -1 |
| Mean (mm) | 495  | 489  | 492  | 490  | 485  | 485  |
| Range a (mm) | 620 - 415 | 620 - 370 | 620 - 372 | 610 - 391 | 610 - 390 | 640 - 380 |
| SD (mm) | 49  | 56  | 50  | 51  | 55  | 54  |
Table 3: Lateral flexion ROM of 72 cricket players both away and towards the bowling arm at monthly intervals from the end of preseason (month -1) to the end of the competitive season (month 4). Post-hoc analysis revealed a statistically significant difference in ROM towards the bowling arm between month 1 and month 4.
|                | Away          |          |          | Towards       |          |          |
|----------------|---------------|----------|----------|---------------|----------|----------|
|                | Season 1      | Season 2 | Season 3 | Season 1      | Season 2 | Season 3 |
| Mean (mm)      | 495           | 488      | 483      | 476           | 485      | 478      |
| Range° (mm)    | 620 - 415     | 632 - 345| 580 - 375| 580 - 340     | 630 - 365| 580 - 380|
| SD (mm)        | 49            | 61       | 48       | 59            | 53       | 47       |

Table 4: Lateral flexion ROM of 49 cricket players both away and towards the bowling arm in the first month of each bowler’s respective competitive season, in successive seasons. No significant differences were observed.
Figure 1: Cricket fast bowling action demonstrating the jump, back-foot contact and follow-through (left to right). Left centre image demonstrates common delivery point where bowler side strain injury is likely to occur. Image courtesy of Cricket Australia.
Figure 2: Start and finishing position for testing active trunk lateral flexion (ATLF) range of movement
Supplementary 1. Individual participant differences in lateral flexion range of motion during the pre-season a) towards and b) away the bowling arm

a)

Individual participant differences in lateral trunk range of motion towards the bowling arm during the pre-season

b)

Individual participant differences in lateral trunk range of motion away from the bowling arm during the pre-season
Supplementary 2. Individual participant differences in lateral flexion range of motion during the competitive season a) towards and b) away the bowling arm

a) Individual participant differences in lateral trunk range of motion towards the bowling arm during the competitive season

b) Individual participant differences in lateral trunk range of motion away from the bowling arm during the competitive season
Supplementary 3. Individual participant differences in lateral flexion range of motion between competitive season a) towards and b) away the bowling arm

a) Individual participant differences in lateral trunk range of motion towards the bowling arm between seasons

b) Individual participant differences in lateral trunk range of motion away from the bowling arm between seasons
