BJSM Online First, published on May 25, 2011 as 10.1136/bjsm.2010.077453

Quadratus lumborum asymmetry is not isolated to the dominant side in junior cricket fast bowlers

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Accepted 8 February 2011

ABSTRACT

Background and aim Bowling-side quadratus lumborum (QL) asymmetries have been previously reported on the dominant side in junior cricket fast bowlers using MRI. The aim of this study was to investigate QL asymmetry when measuring with two different methods; first using a small number of images with clear muscle borders and second using a larger number of images with less strict inclusion criteria.

Methods MRI was performed on 38 junior (14.9 years) cricket fast bowlers prior to the start of a cricket season. Each MR image slice was evaluated to determine whether the QL muscle contour was visible and was assigned an image-quality rating for inclusion in the study. The cross-sectional area of each included QL image was measured and compared with the corresponding image on the other side of the spine to determine side-to-side difference (asymmetries).

Results Using the main method of including only high-quality MR images, 25% of MR images, where QL was in the field of view, met the inclusion criteria. The mean QL asymmetry was 13%, while 55% of participants had asymmetries greater than 10%. There was no significant difference in the number of participants with dominant and non-dominant side QL asymmetry. However, there was a significant difference in the magnitude of asymmetry between the dominant side (10.5%) and non-dominant (16.4%) asymmetries. The intraclass correlation coefficient for repeated measurements of QL asymmetry for randomly selected images (18%) was excellent (ICC 0.966, 95% CI 0.89 to 0.99). Using the second measurement method, with less strict inclusion criteria for MR images, similar results on the distribution of QL asymmetry were found.

Conclusion Contrary to previous research, this study demonstrated that there was a similar distribution of QL asymmetry between the dominant and non-dominant side. The presence of only dominant side asymmetry must therefore be questioned.

Cricket fast bowling is a demanding activity involving trunk lateral flexion, extension and rotation during the delivery stride, where vertical ground reaction forces as high as six times body weight are experienced.[1] Fast-bowling kinematics and kinetics vary between bowlers and different bowling techniques. It is expected that the asymmetrical nature of the bowling technique may result in asymmetrical muscular contractions and be represented as muscle asymmetries in key muscle groups.

The significance of paraspinal muscle asymmetry has recently been highlighted with quadratus lumborum (QL) asymmetries linked to lumbar pars stress fractures in junior fast bowlers.[2–5] Asymmetry, defined as a larger cross-sectional area (CSA) of muscle on one side of the spine compared with the other side, is usually expressed as a percentage difference between sides. Engstrom *et al*[5] used MRI to investigate QL asymmetries in adolescent fast bowlers over four consecutive cricket seasons. They reported that fast bowlers had large QL asymmetries favouring the dominant (bowling arm) side of the trunk. Ranson *et al* (2008)[6] also reported bowling-side (dominant-side) asymmetries in 47% of adult fast bowlers using MRI. They defined asymmetry as a difference of greater than 10% between the dominant and non-dominant QL muscles. Hides *et al*[7] also used MRI to demonstrate that adult cricket players in all positions (bowlers, batsmen and wicket keepers), had larger dominant-side asymmetries for QL, lumbar erector spinae and multifidus.

If differences exist between sides in key muscles, then it is critical to quantify asymmetry with valid techniques of measuring muscle CSA. There is currently no universally accepted method of determining the CSA of muscles from MRI. The use of two-dimensional images to measure three-dimensional structures results in superimposition of structures.[5 8] Additional imaging issues include movement artefact and error in body alignment during imaging that may distort the CSA and therefore asymmetry measurements.

Because of these imaging issues, determining which MR images are suitable for CSA analysis is an important consideration. Previous studies investigating paraspinal muscle CSA in cricket players have used a variety of approaches.[5 7 9] Ranson *et al*[8] reported a reliable method of measuring the CSA of paraspinal muscles by determining the grey-scale range of paraspinal lean muscle compared with surrounding fat.[8] Additionally, Ranson *et al*[6] measured CSA at single spinal levels as well as the sum of all image slices available. In comparison, Engstrom *et al*[5] used muscle template profiles of MR images from consecutive years to reliably determine the fascial boundary of paraspinal muscles. Finally, Hides *et al* (2008)[7] used MR images only at the L3/4 intervertebral disc to measure the CSA of QL and other paraspinal muscles. Whist all three previous methods described have reported good reliability, there is no 'gold standard' in the measurement of paraspinal CSA using MRI.[9] Despite very good reliability being reported, there is no way of knowing the validity of the measurements made, that is, whether the measurements truly represent the target muscle.

The primary aim of this study was to examine if junior fast bowlers had dominant-side QL asymmetries similar to previous studies. The secondary aim was to quantify QL CSA using MR images using a combination of the previous techniques described above. It was hypothesised that cricket fast bowlers would have high rates of QL asymmetry towards the dominant side and that a small number of high-quality MR slices would reliably determine QL asymmetry.

METHODS

MR images of 48 junior male fast bowlers with a mean age of 14.8 years (range 12–17 years) were performed prior to the beginning of the 2002/2003 Australian cricket season as part of a larger research project. All bowlers were injury-free at the time of baseline MRI. The baseline MR images were performed at a single radiology clinic, using the same MR machine and protocol. The MR protocol implemented was identical to that used and reported by Engstrom *et al*.[2 5] The protocol involved T1-weighted 7 mm axial slices with a 7 mm gap (TR/TE 500/9.4, 19 image slices, 512×512 matrix, FOV 30×30) from T12 to L5 vertebral levels using a GE Sigma 1.5T MR machine (General Electric Medical Systems, Milwaukee, Wisconsin). Ethics approval for this project was obtained from Deakin University Human Research Ethics Committee.

The CSA of QL was measured on the axial scans. The images were analysed by a single investigator who was blind to all participants' details. The cross-sectional measurements of the QL muscle were made using imaging-analysis software (ImageJ 1.36B; National Institutes of Health). The contour of QL was outlined on each axial image slice using the magnification and freehand functions of the imaging software. The CSA was calculated on each side of the spine and at each vertebral level where the muscle could be clearly measured.

Images were rated on a four-point scale based on the clarity of the muscle boundaries and clarity of the QL muscle (table 1). The researcher who determined the image quality was blinded to the participant's details including arm dominance and injury status.

Table 1 MRI image quality scale

Image quality (0–3 points)	Definition
0/3 points	Image quality is poor, or QL is not clearly visible; cross-sectional area measurement not possible
1/3 points	QL is visible, but at least one edge of the muscle is not clear, owing to superimposing of structures
2/3 points	Image quality is good, and all edges of QL are clearly delineated from other structures, but some blurring of the edges exists
3/3 points	Image quality is very good, and QL is clearly delineated from other structures with minimal or no blurring of the edge

QL, quadratus lumborum.

High-quality images (3/3 points in table 1) had a clear muscle contour and fascial border, and were free of muscle superimposition or distortion owing to movement artefact. These images were used for the main analysis (method 1). Images in the highest two categories (2/3 and 3/3 points) were also analysed (method 2). The sum of all CSAs was used for analysis. The purpose of the second method was to act as a comparison with the method of using the highest-quality images for analysis and allow comparison with previous research. Thirty-six randomly selected images were measured twice for reliability.

Each participant required a minimum of one QL image slice of sufficient quality to be included in this study. Asymmetry for each participant was determined by dividing the CSA of QL image slices on one side by the CSA on the other side of the trunk. The magnitude of asymmetries was divided into three categories; 0–10%, 11–20% and greater than 20% asymmetry. The 0–10% category represents asymmetries that previous researchers considered as not a clinically important asymmetry.[9] These categories would also define bowlers with small side-to-side differences and those with large asymmetries, particularly as asymmetries of greater than 18% have been reported to be highly associated with lumbar spine injury in junior fast bowlers.[5]

QL was imaged between L2 and L5 vertebral levels. The characteristics of the participants using both methods described earlier are outlined in table 2. All measured slices were between the L2 and L4 vertebral levels. There were no images of sufficient quality above the L2 mid-vertebra level and below the L4/L5 disc.

Data analysis

All data were entered into a spreadsheet (Microsoft Excel 2003). The CSAs measured were summed to give the total area of the QL on each side of the vertebral column. At each imaging level on the vertebral column, the absolute difference between the dominant and non-dominant side QL muscle CSA was measured and used to calculate the percentage difference in CSA between sides. The absolute values (mm^2) and percentage difference between sides were summed to give an overall value for absolute difference and percentage difference between dominant- and non-dominant-side muscles.

The Mann–Whitney test was used to compare the magnitude of QL asymmetry between dominant- and non-dominant sides of the trunk. The Fisher exact test was used to determine the statistical significance between categorical measures of dominant and non-dominant QL asymmetries. Significance was set at $p<0.05$. Intraclass correlations were used to examine reliability. A reliability of >0.90 was considered to be reasonable.[24]

RESULTS

Using method 1, the mean CSA for all QL image slices was 611 mm^2 (SD 146.1 mm^2), and the mean total summed CSA for QL in each participant (all image slices) was 977 mm^2 (SD 515.5 mm^2). The intraclass correlation coefficient for repeated

Table 2 Participant characteristics

	N (mean age) at baseline	Excluded (n)	Paired image slices (n (%))	N (mean age) in final analysis	Image slices (n, mean (range))	Vertebral levels where quadratus lumborum was imaged
Method 1	48 (14.9 years)	10	61 (25)	38 (14.9 years)	1.6 (1–3)	L3 vertebra–L4/5 disc
Method 2	48 (14.9 years)	4	167 (53)	44 (14.8 years)	3.8 (1–8)	L2 vertebra–L4/5 disc

measurements of QL asymmetry for randomly selected images (18%) was excellent (ICC 0.966, 95% CI 0.89 to 0.99).

The mean QL asymmetry of the participants was 13.1% (range 0.6–28.8%). An asymmetry of 0–10% was the most frequent finding (table 3). Twenty-one (55%) participants had QL asymmetries greater than 10%.

The QL asymmetries were subdivided as favouring either the dominant (bowling arm) or non-dominant side of the body. There was a similar distribution of asymmetry between dominant (55%) and non-dominant (45%) sides. Asymmetry was significantly larger on the non-dominant side QL (16.4%) when compared with the dominant side (10.5%, Z=−2.07, p=0.038). Additionally, there was also a significant difference between dominant and non-dominant QL asymmetries when the data were analysed using the three categories (p=0.037, table 4).

Using measurement method 2, which included a larger number of images for analysis, similar results were obtained. The mean CSA for each image slice was 581 mm^2 (SD 146.3 mm^2), and the mean total summed CSA for QL in each participant was 2216 mm^2 (SD 966.3 mm^2). The mean QL asymmetry was 12.8% per participant, and there was no significant difference between the CSA of QL dominant (14.7%) and non-dominant (11.2%) sides. Additionally there was an equal distribution between dominant (48%) and non-dominant (52%) side asymmetries. Fifty-two per cent of participants had asymmetries greater than 10%. The majority (48%) of participants had asymmetries magnitudes of 0–10%, compared with those with 11–20% asymmetry (34%) and those with greater than 20% asymmetry (18%).

DISCUSSION

Consistent with previous research[5,7,9] QL asymmetry was a common finding in junior fast bowlers. Fifty-five per cent of young fast bowlers in this study had asymmetries greater than 10%, which is similar to the 47% of asymmetries reported by Ranson *et al* (2008) in adult fast bowlers. The mean asymmetry (13.1%) for the fast bowlers in the current study is similar to that reported by Engstrom *et al*[5] in junior fast bowlers (10.5%).

However, we found that junior fast bowlers had QL asymmetries on both the dominant and non-dominant side of the trunk. This was in contrast to Engstrom *et al*,[5] who reported that asymmetries consistently favoured the dominant side of the trunk in their group of junior fast bowlers.

There were differences in methods between the current study and that of Engstrom *et al*.[5] For example, Engstrom measured QL CSA over four consecutive years rather than a single preseason measurement used in this study. It is possible that QL may alter morphologically as the bowler matured, particularly as the participants in the current study and in Engstrom's study were aged around puberty (13–17 years).

Table 3 Magnitude of quadratus lumborum asymmetry (n (%))

Asymmetry (%)	Bowlers (n (%))
0–10	17 (44)
11–20	13 (34)
>20	8 (21)

Table 4 Asymmetry and dominance (p=0.037)

	Quadratus lumborum asymmetry		
	0–10%	11–20%	>20%
Dominant asymmetry	11	8	2
Non-dominant asymmetry	6	5	6

This study also reported that the magnitude of QL asymmetry was significantly greater on the non-dominant than the dominant side. Engstrom *et al*[5] also reported that QL asymmetries were predominantly on the dominant or bowling side of the trunk. In contrast, we found that QL asymmetries on the non-dominant side were significantly greater than the dominant side. Again, differences in methods may have contributed to the contrasting results. In particular, this study carefully excluded images where the QL muscle contours were partially obstructed or superimposed by surrounding structures, whereas Engstrom *et al*[5] facilitated measurement of all slices with muscle profile templates and multiyear measurements. The superimposition of surrounding structures and use of templates to enhance measurement may influence the results. In the current study, the iliacus muscle was regularly superimposed over QL in MR images below the L4 vertebral level and could easily be mistaken as part of QL when measuring CSA.

Additionally, bowling-technique differences between participants may be a key contributing factor to the contrasting results between the two studies, particularly as recent biomechanical research has speculated that QL activation may be related to the amount of trunk rotation, extension and side flexion during the bowling technique.[11] Bowling kinematics were not considered in either study, and it is possible that there were differences in bowling technique in the different studies, which may alter activation patterns of QL and therefore muscle CSA. Since fast bowling is an asymmetrical activity involving varying rates of trunk side-flexion and rotation,[1,12,13] and QL is a strong trunk side-flexor,[9,11] QL hypertrophy is likely. The amount of trunk side-flexion associated with fast bowling is variable between bowlers and may be dependent on the type of bowling technique.[1,14] To date, no research has investigated the relationship between bowling technique kinematics and paraspinal CSA; however, de Visser *et al*[11] used a finite-element model to demonstrate that QL asymmetry may be related to QL activation during the extreme postures adopted in the later part of the bowling technique (rotation extension and side flexion). They hypothesised that dominant-side asymmetry may protect the lumbar pars interarticularis from stress fractures in fast bowlers. Our finding that asymmetry existed on both sides suggests that this is unlikely.

This study applied a rigorous method for measurement. The results of rigorous measurement methods were similar to results found using our second method where less strict inclusion criteria were applied that therefore included a larger number of image slices for analysis. By using strict criteria for including MR images in this study (first method) we had to eliminate 75% of all MR image slices. The low number of images available for analysis resulted in a smaller total CSA per person when compared with Engstrom *et al*'s results.[5] Engstrom *et al* only included bowlers with a CSA of more than 2500 mm^2 resulting in the exclusion of one bowler from their study. The total CSA per participant in the current study was 977 mm^2, which is well below the value set by Engstrom *et al*. The use of muscle profile templates in Engstrom *et al* that projected the templates on neighbouring image to improve measurement at levels where the muscle contours were distorted or 'fuzzy' may have resulted in the difference in measures compared with the current study. In this study, images falling in these categories were excluded because measurement accuracy could not be guaranteed. Fewer image slices and smaller summed CSAs resulted, which could further explain some of the differences between the current study and that of Engstrom *et al*, but are unlikely to alter the finding of QL asymmetry on dominant and non-dominant sides.

This study also reported that the QL was most clearly measurable in the L3/L4 vertebral region. There were no MR images used in method 1 from the L1, L2 and L5 intervertebral levels. This differed from Ranson *et al* (2008), who reported QL measurements at the L1 and L4 vertebral level. Ranson *et al* used a method to measure the CSA by determining the grey-scale range of MR signal intensity of lean paraspinal muscle to differentiate muscle from surrounding bone and fat. Additionally, the participants in Ranson *et al* study were older (26 years) and skeletally mature, with more defined paraspinal musculature and possibly more fat, which may have made them easier to measure over more vertebral levels.

A consistent problem with all research involving the measurement of three-dimensional structures such as muscle, using two-dimensional MR images, is the presence of overlapping structures, making it difficult to determine the target object boundaries and can result in a partial volume averaging as the overlapping structures result in an erroneous image pixel signal. Additionally, there were problems associated with motion artefact and errors in alignment of the subject in the MR machine that may result in angulations and, therefore, distortion of structures, resulting in measurement errors. Any angulation issues would be of particular concern in this sort of project, as it involved comparison of structures from the left and right side of the trunk to assess whether asymmetries existed.

CONCLUSION

This study demonstrated that junior cricket fast bowlers have QL asymmetries on both the dominant and non-dominant sides of the body. These results were similar using two different methods for including MR images. Further research is required to compare the different methods used in this study and evaluate the validity of measuring the CSA of QL using MR images. Additionally, research comparing paraspinal asymmetries with fast bowling techniques and workloads is required to fully understand the nature of the asymmetries described in the current and previous research.

Acknowledgements The authors would like to acknowledge the support of Cricket Australia's Centre of Excellence for helping collect data that was used in this study.

Funding The project was funded by Cricket Australia through its Sports Science and Medicine Research Program.

Competing interests None.

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Ethics approval Ethics approval was provided by the Deakin University, Victoria, Australia.

Provenance and peer review Not commissioned; externally peer reviewed.

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Br J Sports Med published online May 25, 2011
doi: 10.1136/bjsm.2010.077453