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SciVerse ScienceDirect
Journal of Sport and Health Science 3 (2014) 60–63
www.jshs.org.cn

Original article

Effects of latissimus dorsi length on shoulder flexion in canoeists, swimmers, rugby players, and controls

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Received 23 October 2012; revised 14 November 2012; accepted 24 December 2012

Abstract

Background: Shoulder flexion requires an optimal length of the latissimus dorsi muscle in order to allow full lateral rotation of the humerus and upward scapular rotation. If shoulder flexion (in an externally rotated position) is restricted, this may predispose the individual to shoulder pathology. Sports such as swimming and canoeing have increased shoulder injuries and require high levels of latissimus dorsi muscle activity, which may create muscle hypertrophy and increased stiffness, resulting in a loss of muscle length. The objective of this study was to investigate if differences are present in shoulder flexion in internally and externally rotated positions across different sports (swimming, canoeing, and rugby) and a non-sporting control group.

Methods: One hundred subjects (40 physically active controls, 25 professional Rugby Union players, 20 elite, national-level canoeists (slalom), and 15 elite, national-level swimmers) participated in this study. Shoulder flexion range of motion was measured using a standard goniometer, with the arm elevated in either full external or internal rotation.

Results: A significant difference in shoulder flexion range was observed between canoeists and swimmers, canoeists and controls, rugby players and canoeists, rugby players and swimmers, and controls and swimmers in the external rotation position ($p < 0.017$), but not between controls and rugby players ($p = 0.12$). For the internal rotation position, swimmers significantly differed from canoeists, rugby players, and controls ($p < 0.017$), but there were no significant differences between rugby players, canoeists, and controls ($p > 0.07$).

Conclusion: This study found that the length of the latissimus dorsi differs between sports and controls in accordance with the specific physical demands of their sport.

Keywords: Flexibility; Latissimus dorsi; Measurement; Sport specificity

1. Introduction

Overhead sports such as tennis, cricket, and swimming require extreme ranges of motion (ROMs) from the shoulder, and the optimal performance of these athletes requires a balance between mobility and stability in the shoulder joint. Several authors have suggested that suboptimal shoulder performance in the form of poor upper quadrant posture, muscle imbalances and improper motion may cause or perpetuate sub-acromial impingement syndrome, internal shoulder impingement, rotator cuff pathology, and several other shoulder pathologies.[1–3]

Swimming is a popular recreational and professional sport, and the shoulder joint has been reported as being the most vulnerable area to injury while swimming.[4–7] Shoulder injury incidence rates in competitive swimmers range from 23% to 38% of participants[8] with 90% of elite swimmers reporting at

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Peer review under responsibility of Shanghai University of Sport

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jshs.2013.01.004

least one incidence of shoulder pain.[9] Richardson[10] estimated that during a training year, a competitive swimmer makes 1.32 million strokes per arm. The cause of the painful shoulder in swimmers can be attributed to a myriad of stroke flaws. It has been reported that most swimming injuries are due to repetitive microtrauma and overuse, with many of these injuries actually due to faulty technique.[6,7] Repeated microtrauma (overuse) and subsequent pain and tissue injury to the supporting tissues (such as the rotator cuff and long head of biceps tendon) around the shoulder also lead to poor performance.

The canoeing literature is more limited with less epidemiological data, but what little has been reported indicates that shoulder injuries are common.[1,11] In this case, the repeated paddling action is hypothesized to be responsible for overuse injuries such as rotator cuff tendinitis and subacromial impingement.[5] In common with swimming, these problems may be related to the sport-specific demands of increased shoulder range of movement, increased internal rotation and adduction strength, and prolonged shoulder-intensive training.[11]

Several studies have shown that athletes engaged in overhead sports demonstrate increased external rotation with a concomitant loss of internal rotation.[12,13] Warner et al.[12] found that anterior instability was associated with excessive external rotation and decreased internal rotation, which could then be related to the development of secondary impingement syndrome, but this study was in overhead throwing athletes. Ellenbecker et al.[13] reported similar findings in tennis players. However, this situation might not be applicable to swimming and canoeing. As Weldon and Richardson[14] reported, most shoulder pain is caused by instability, which in turn is related to the sport-specific demands of increased shoulder range of movement, increased internal rotation and adduction strength, and prolonged shoulder-intensive training. The shoulder flexion ROM is critical to both swimming[15] and canoeing in order to provide maximum available reach prior when delivering shoulder extension, adduction, and internal rotation to produce greater motive force in the water. This motion requires the latissimus dorsi to generate a significant proportion of the force required.[8,16] The constant loading of the latissimus dorsi with repetitive training will produce muscle hypertrophy, but will also likely result in increased muscular stiffness and resistance to elongation.[17] Shoulder flexion requires an optimal length of the latissimus dorsi muscle in order to allow for full lateral rotation of the humerus and upward scapular rotation (maintaining the optimal subacromial space between the greater tuberosity and the acromion), thus preventing impingement during elevation. If shoulder flexion (in an externally rotated position) was restricted due to decreased latissimus dorsi length, then this may predispose the individual to shoulder pathology.

Sports-related injuries to the shoulder are common both in terms of the intrinsic patho-anatomical and histological changes, and unique in terms of the set of mechanical circumstances which created the tissue stresses to cause the injury.[18] One of the factors common to shoulder injury is changes in the range of movement/motion, and clinical range of motion/movement (ROM) assessment is often implemented to objectively evaluate shoulder complex excursion.[2] However, the factors responsible for these alterations in ROM are not completely understood at present, and this phenomenon has been suggested to potentially arise from functional adaptations that permit greater ROMs for the purposes of executing various sports-related tasks, such as overhead throwing.[5] This study aims to compare the ranges of movement of the latissimus dorsi muscle between sports which predominantly use the latissimus dorsi versus a non-sporting control group and a non-overhead sporting group with high incidence of shoulder injuries (rugby) in order to assess whether there were specific, functional differences in the latissimus dorsi length between these groups. The objective of the study is therefore to assess if any differences are present in the shoulder flexion range in an internally and externally rotated position respectively, across three different sports (swimming, canoeing, and rugby) and a non-sporting control group. The hypothesis of this study is that there would be a difference in the latissimus dorsi length between the groups, which would correspond to the functional activity of the shoulder related to the mechanism of their sports.

2. Materials and methods

2.1. Subjects

One hundred subjects (40 physically active controls, 25 professional Rugby Union players, 20 elite, national-level canoeists (slalom), and 15 elite, national-level swimmers) participated in this study. All subjects were male and age matched, with age of 24.5 ± 3.7 years (mean ± SD) (range 19−30 years). All subjects were free of shoulder pain at the time of the study and in the previous 2 months, and none of the participants had significant shoulder pathology (requiring missing training or competition) in the previous 6 months. All subjects gave their written informed consent, and the study was approved by the University Research Ethics Committee.

2.2. Procedures

Shoulder flexion range of movement was measured using a 360° goniometer (Physiomed, Manchester, UK). The measurements took place under two conditions: shoulder internal rotation (IR) and shoulder held in full external rotation (ER) with the subject supine with the knees flexed to 90° and the hips flexed to 45° and feet flat (Fig. 1). Whilst flexing the shoulder, the pelvis was held in full posterior rotation, and this position was monitored using a pressure biofeedback unit. The second test position (full ER) was used to measure the fully lengthened position of latissimus dorsi muscle.[19]

The shoulder was passively flexed by the same examiner in all cases, and the end of range was defined as firm resistance to movement. For the internally and externally rotated positions, the examiner held the shoulder in the respective position prior to flexion, and maintained the position to the end of the available range.

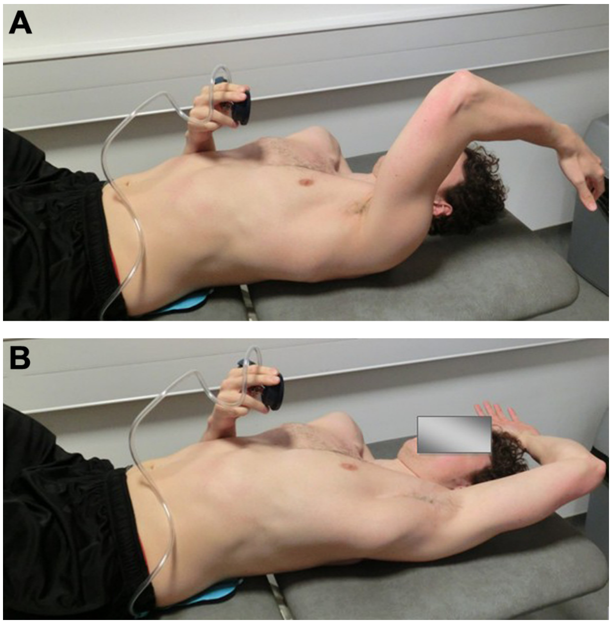

Fig. 1. Image of shoulder position for measurement: (A) in full external rotation; (B) in full internal rotation.

The measurements were performed three times for each side, and the mean score was used for further analysis.

2.3. Statistical analysis

The data were analyzed using the statistical software package SPSS 15.0 (SPSS Inc., Chicago, IL, USA). Differences in shoulder flexion range of movement between externally and internally rotated positions were analyzed with a factorial analysis of variance (ANOVA) using a mixed model with one between subject factor (sport) and two within subject factors: rotation position (internal and external) and side (left or right). The critical α level was 0.05. Paired t tests were used to evaluate specific differences, and Bonferroni corrections were applied.

The intra-tester reliability of the measurement technique was assessed by repeating the measurements (shoulder flexion in internal and external rotation) on one shoulder in 10 subjects from the control group, and the intraclass correlation (3,1) and standard error of measurement (SEM) were then calculated, and showed excellent reliability ($r = 0.9$, $p < 0.01$, SEM confidence interval (95%) $= 1.2-1.8°$).

3. Results

There were no statistically significant differences in the range of movement for either external or internal rotation ($p = 0.78$) between sides across all groups. The left and right side data from the each of the three groups were therefore pooled for all further analyses, and a Kolmogorov Smirmov test demonstrated that the pooled data were normally distributed.

The results of the study are shown in Table 1. Analyses of the results using the factorial ANOVA showed that the sport factor had a significant effect on range of movement ($p = 0.03$), as did the position of rotation ($p = 0.001$). The interaction of sport and position had no significant effect on range of movement ($p = 0.34$). Therefore, although the individual sports appeared to have different ranges of movement which differed with shoulder position (internal or external rotation), the relationship between the two positions as defined by the interaction remained fairly constant regardless of the sport. Paired t tests (with Bonferroni corrections) revealed a significant difference between canoeists and swimmers, canoeists and controls, rugby players and canoeists, rugby players and swimmers, controls and swimmers in the ER position ($p < 0.017$), but not controls and rugby players ($p = 0.12$). For the IR position, the swimmers differed significantly from the canoeists, rugby players, and controls ($p < 0.017$), but there were no significant differences between the rugby players, canoeists, and controls ($p > 0.07$).

Table 1
Mean ± SD for flexion range of movement with the shoulder in internal rotation (degrees) for all groups.

	Internal rotation	External rotation
Rugby players		
Left	165.5 ± 6.4[a]	145.0 ± 7.6[b,c]
Right	165.0 ± 7.6[a]	141.5 ± 9.7[b,c]
Swimmers		
Left	177.3 ± 10.6	127.9 ± 19.7[b]
Right	176.5 ± 11.1	124.5 ± 19.6[b]
Canoeists		
Left	159.0 ± 12.1[a]	103.3 ± 12.0
Right	163.0 ± 10.2[a]	108.2 ± 12.2
Controls		
Left	165.4 ± 11.0[a]	145.0 ± 22.3[b,c]
Right	167.0 ± 12.8[a]	147.2 ± 21.1[b,c]

Note: In all cases the differences between left and right were non-significant ($p > 0.05$).

[a] Significantly different from swimmers ($p < 0.017$), paired t test.

[b] Significantly different from canoeists ($p < 0.017$), paired t test.

[c] Significantly different from swimmers ($p < 0.017$), paired t test.

4. Discussion

This study found that the length of the latissimus dorsi muscle differed between athletes and controls in accordance with the specific physical demands of their sport. When compared to the control group, the range of flexion in internal rotation was significantly greater for the swimmers, reduced for the canoeists and similar for rugby players. This is likely to be a result of the specificity of the movements within the sport. The canoeists, rugby players, and non-sporting controls had no significant differences between their shoulder flexion ranges with the humerus internally rotated, whereas swimmers had a superior range. This finding is not unexpected because of the nature of the sport, and the arm position required (flexion/medial rotation) at the point of entry into the water for the majority of swim strokes plus the repetition of these strokes have resulted in a task-specific increased range of motion.[20] Biomechanical three-dimensional analysis of freestyle swimming supports the idea that adequate shoulder rotation range is necessary to swim with the correct technique, and to avert shoulder impingement.[11]

Assessments of shoulder flexion in external rotation revealed that when compared to the non-sporting controls, the swimmers and canoeists had significantly reduced ranges of movement, and the rugby players had a slight but not significant reduction in range as compared to the control group. This would indicate that the latissimus dorsi was least flexible in the canoeists followed by the swimmers, with rugby players and controls showing similar levels of flexibility. These findings are likely to reflect the specific nature of their individual sports, with both canoeing and swimming requiring considerable levels of activity in the latissimus dorsi in order to generate movement relative to the water.[20,21] Electromyographic studies have shown that during canoeing, the major muscle working during the pulling phase of the stroke was the latissimus dorsi.[16] During freestyle swimming, Pink and Jobe[20] used fine-needle electromyography to show the latissimus dorsi fires in concert with the subscapularis from the mid pull-through until the beginning of the recovery phase, as the arm exits the water.

The nature of the force of latissimus dorsi muscle contraction between canoeing and swimming is very different, and may significantly influence the muscle length, and hence the findings of this study. In order to control the canoe against fast moving water, the contraction of the latissimus dorsi is likely to be either isometric or relatively small concentric-eccentric contractions, all of high force. This is likely to provide considerable stimulus for muscle hypertrophy, and also for muscle stiffness (resistance to elongation) to develop within the latissimus dorsi to manage the high forces involved in controlling the canoe. The canoeist also has to control longer lever arms over which the force has to be generated, because of the presence of the paddle. In contrast, the lower resistance offered by the water during swimming and the large-range, low-force, concentric contractions required would develop less stimulus for muscle hypertrophy and stiffness as compared to canoeing. One possible explanation for this could be due to the passive resistance produced by the non-contractile elements of the musculo-tendinous unit of the muscle due to the relative sizes of the cross sectional area of the muscle. These elements represent a major contributing factor to the passive length-tension relationship of the muscle, and may comprise the elastic filaments and gap filaments spanning each half sarcomere, as well as the extensible protein titin, which is thought to be one important source of passive tension in muscle.[17]

This study only examined this relationship in male subjects, and thus these findings cannot be generalized across genders. Similarly, all of the sports participants were from elite populations engaged in full time training, and it is not known if these findings can transfer to recreational participants in the same sports.

5. Conclusion

The length of latissimus dorsi differs between canoeists, rugby players, swimmers, and controls in accordance with the specific physical demands of their sport on the latissimus dorsi muscle. This needs to be taken into consideration when screening and rehabilitating these athletes.

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