Long Biceps Tendon: Normal Position, Shape, and Orientation in Its Groove in Neutral Position and External and Internal Rotation

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Purpose:
To characterize the position, shape, and orientation of the long biceps tendon (LBT) on transverse magnetic resonance (MR) images acquired in neutral position and in maximal external and internal rotation of the shoulder in asymptomatic volunteers.

Materials and Methods:
Informed consent was obtained from all volunteers for this institutional review board–approved study. Fifty-three asymptomatic volunteers (mean age, 33 years; age range, 21–58 years) were included. The position of the LBT with respect to the bicipital groove was measured by two musculoskeletal radiologists on three levels along the bicipital groove on axial MR images in neutral position and in external and internal rotation of the shoulder. The shape of the LBT was classified as round, oval, flat, or comma shaped, and the orientation of the LBT was measured.

Results:
The position of the LBT changed significantly at the entrance into the bicipital groove in the mediolateral and anteroposterior directions (P < .01). The changes of LBT position in external rotation and internal rotation compared with the neutral position were markedly small (< 1.5 mm). Medial eccentricity of the LBT was greatest in the neutral shoulder position at all measurement levels. Differences in LBT shape and orientation were found between the neutral position and external or internal rotation and between the three measurement levels.

Conclusion:
The position of the LBT is only slightly dependent on shoulder rotation. LBT eccentricity is maximal in the neutral position. Rotational misplacement during image acquisition does not increase LBT eccentricity.

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The tendon of the long head of the biceps brachii muscle—the long biceps tendon (LBT)—attaches at its anchor to the superior glenoid tubercle (1). From this position, it courses intraarticularly to the entrance of the bicipital groove between the major and lesser tubercles of the proximal humerus, runs caudally inside the groove, and eventually leaves the groove to end in the proximal musculotendinous junction (2,3). Along its intraarticular course, the LBT is suspended by the coracohumeral ligament, the superior glenohumeral ligament, and the pulley fibers, which arise from the aforementioned ligaments and the subscapularis tendon (4–10). Additionally, it may be stabilized by a variety of sporadic developmental interconnections with the joint capsule, ranging from the aforementioned ligaments and the subscapularis tendon (4–10). Installation of these ligamentous structures is responsible for medial dislocation of the shoulder in asymptomatic volunteers.

Advances in Knowledge

- The position of the long biceps tendon (LBT) in the intertubercular groove is only slightly dependent on rotation in the shoulder joint.
- The eccentricity of the LBT in the intertubercular groove is maximal in the neutral position.

Implication for Patient Care

- The external or internal rotation position of the humerus does not increase LBT eccentricity and should not lead to false-positive diagnosis of an LBT subluxation or dislocation.

Obtain the same amount of right and left shoulders and the same amount of shoulders of the dominant and nondominant sides, if possible. Because of a preponderance of right-handed volunteers, however, this was not entirely possible.

MR Imaging

Two 1.5-T MR imaging systems (Avanto or Espree; Siemens Medical Solutions, Erlangen, Germany) were used with a dedicated four-element shoulder array coil.

The shoulder was imaged in neutral position with the arm flanking the body and the thumb pointing up. First, the standard protocol for shoulder examinations at our institution was performed. This protocol consisted of a coronal fat-saturated intermediate-weighted turbo spin-echo sequence (repetition time msec/echo time msec, 3000/13; field of view, 16 × 16 cm; matrix, 512 × 512 pixels; number of signals acquired, one; section thickness, 4 mm; and echo train length, seven), a coronal fat-saturated T2-weighted turbo spin-echo sequence (3130/72; field of view, 16 × 16 cm; matrix, 512 × 512 pixels; number of signals acquired, one; section thickness, 4 mm; and echo train length, 11), a sagittal non–fat-saturated T1-weighted turbo spin-echo sequence (525/12; field of view, 16 × 16 cm; matrix, 512 × 512 pixels; number of signals acquired, one; section thickness, 4 mm; and echo train length, 11).

Materials and Methods

The institutional review board of the University of Zurich approved this study, and informed consent was obtained from all volunteers.

Volunteers

Fifty-three asymptomatic volunteers (mean age, 33 years; age range, 21–58 years) were included in the study. There were 23 men (mean age, 34 years; age range, 21–56 years) and 30 women (mean age, 33 years; age range, 21–58 years). The volunteers had never experienced shoulder pain, could not recall shoulder trauma, had not undergone shoulder surgery of any kind, and reported no limitation in range of motion in the shoulder joint during daily activity. Twenty-nine right and 24 left shoulders were examined. Twenty-four shoulders were of the dominant side, and 29 were of the nondominant side. For the first volunteer, the shoulder to image was determined randomly. For the following volunteers, the shoulder to image was chosen so that we could obtain the same amount of right and left shoulders and the same amount of shoulders of the dominant and nondominant sides, if possible.

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Abbreviations: ICC = intraclass correlation coefficient
LBT = long biceps tendon

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Guarantor of integrity of entire study, F.M.B.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, F.M.B., T.J.D., C.W.A.P.; clinical studies, F.M.B., T.J.D., B.J., C.W.A.P.; statistical analysis, F.M.B., C.W.A.P.; and manuscript editing, all authors
Potential conflicts of interest are listed at the end of this article.
Volunteers with lesions or any kind of degenerative changes to the rotator cuff tendons, coracohumeral ligament, superior glenohumeral ligament, and/or pulley fibers would have been excluded from the study. However, no volunteers had to be excluded.

The LBT was evaluated by two independent musculoskeletal radiologists (F.M.B. [reader 1] and T.J.D. [reader 2, with 2 years of experience in musculoskeletal radiology]) at three levels of the bicipital groove (superior, middle, and inferior) with the shoulder in neutral position, in external rotation, and in internal rotation. The superior level, at the entrance of the LBT into the bicipital groove, was defined as being shown on the most superior image that included the subscapularis tendon; the inferior level, where the LBT exited from the bicipital groove, was defined as being shown on the most inferior image that included the subscapularis tendon; and the middle level represented the midway point between those levels (Fig 1). All three levels and all three positions were evaluated at the same time in a standardized order: first, on the images obtained in neutral position, then, on the images obtained in maximal external rotation, and finally, on the images obtained in maximal internal rotation.

**Position.**—The position of the center of the LBT was evaluated with respect to the bicipital groove. The center of the LBT was defined as the point in the middle of the LBT (Fig 2). In flat or comma-shaped tendons, the center of the LBT was defined as the point in the middle of the LBT on a line drawn perpendicular to the greatest tendon diameter (Fig 1). The distance from the center of the LBT to a reference line connecting the anterior contours of the greater and lesser tubercles was measured (Fig 2). This measurement quantified the LBT position in the anteroposterior direction; a positive measurement indicated that the LBT was located outside the bicipital groove, and a negative measurement indicated how deep the LBT was located in the bicipital groove.

**Measurements and Evaluations on MR Images**

All MR images were evaluated by a musculoskeletal radiologist (F.M.B., with 5 years of experience in musculoskeletal radiology) before the measurements. Volunteers with lesions or any kind of degenerative changes to the rotator cuff tendons, coracohumeral ligament, superior glenohumeral ligament, and/or pulley fibers would have been excluded from the study. However, no volunteers had to be excluded.

The LBT was evaluated by two independent musculoskeletal radiologists (F.M.B. [reader 1] and T.J.D. [reader 2, with 2 years of experience in musculoskeletal radiology]) at three levels of the bicipital groove (superior, middle, and inferior) with the shoulder in neutral position, in external rotation, and in internal rotation. The superior level, at the entrance of the LBT into the bicipital groove, was defined as being shown on the most superior image that included the subscapularis tendon; the inferior level, where the LBT exited from the bicipital groove, was defined as being shown on the most inferior image that included the subscapularis tendon; and the middle level represented the midway point between those levels (Fig 1). All three levels and all three positions were evaluated at the same time in a standardized order: first, on the images obtained in neutral position, then, on the images obtained in maximal external rotation, and finally, on the images obtained in maximal internal rotation.

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So that we could evaluate the position of the LBT in the mediolateral
direction, a perpendicular line to the above-mentioned reference line (Fig 2) was drawn through the deepest point of the bicipital groove. The distance of the center of the LBT to this line was determined (Fig 2); a positive measurement indicated a position of the LBT medial to the deepest point of the bicipital groove, and a negative measurement indicated a position of the LBT lateral to the deepest point of the bicipital groove.

Any changes in the position of the LBT in the neutral position and in external and internal rotation of the shoulder were then determined at the three measurement levels.

Shape.—The cross-sectional shape of the LBT was categorized as round, oval, flat, or comma shaped (Fig 3). For a round LBT, the cross-sectional area was a circle with equal perpendicular diameters. For an oval LBT, the dimension of the smallest cross-sectional tendon diameter was greater than (but not equal to) half of the greatest tendon diameter. For a flat LBT, the smallest cross-sectional tendon diameter was smaller than half of the greatest diameter, and the lateral and medial contours of the tendon were rounded and obtusely angled. For a comma-shaped LBT, the same criteria applied as for a flat LBT, but the medial contour of the tendon was pointed and acutely angled.

Orientation.—The angle of the direction of the greatest LBT diameter with respect to the previously described reference line drawn between the anterior contour of the major and lesser tubercles was defined as the LBT orientation (Figs 4, 5). The orientation of the LBT along its course in the bicipital groove, as well as any changes in its orientation during external and internal rotation of the shoulder, were then described at the three measurement levels.

Statistical Analysis
Because LBT position and orientation are continuous variables and LBT shape is categoric, interreader agreement was quantified by calculating the intraclass correlation coefficient (ICC) for the evaluation of the biceps tendon position and orientation, and the weighted \( \kappa \) statistic was used to determine interreader agreement of the evaluation of the biceps tendon shape. The Wilcoxon signed-rank test was used to find significant differences in LBT position, shape, and orientation at the different measurement levels and in the different positions of the shoulder. Statistical software (PASW, version 18; SPSS, Chicago, Ill) was used. \( P < .05 \) was considered to indicate a significant difference.

Results

Position
The position of the LBT changed significantly in both directions (anteroposterior and mediolateral) from the neutral position to external rotation and from the neutral position to internal rotation.
In all joint positions (neutral, external rotation, and internal rotation), there was a significant difference in LBT shape between the superior and middle levels (Table 3). For readers 1 and 2, respectively, for the neutral position, \( P = .002 \) and .002; for external rotation, \( P = .003 \) and < .001; and for internal rotation, \( P = .010 \) and .003. The same applied to the difference in LBT shape between the middle and inferior levels. For readers 1 and 2, respectively, for the neutral position, \( P = .001 \) and .009; for external rotation, \( P = .001 \) and .002; and for internal rotation, \( P < .001 \) and < .001. More results of LBT shape classification are provided in Table 3.

**Shape**

At the superior level, the LBT was flat to comma shaped in almost all volunteers independent of the shoulder position. At the middle level, the LBT was flat to comma shaped, whereas in external rotation, the tendon had an oval shape at times. At the inferior level, the LBT was predominantly oval to flat, except in internal rotation, when there was a tendency for it to be round or oval in shape.

Interreader agreement was substantial (ICC > 0.6) to almost perfect (ICC > 0.8) and highly significant (\( P < .005 \)), except for those measurements at the superior level in internal rotation and at the inferior level in the neutral position in the anteroposterior direction. Detailed results are provided in Table 2.

Surprisingly, LBT eccentricity in the mediolateral direction was most pronounced in the neutral position and was less pronounced in external rotation and internal rotation at all measurement levels.

In neutral position of the shoulder joint, the averaged (between readers 1 and 2) position of the LBT was 2 mm medial to the deepest point of the bicipital groove at the superior level, 1.7 mm medial to the deepest point of the bicipital groove at the middle level, and 1.4 mm medial to the deepest point of the bicipital groove at the inferior level.

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However, the changes in LBT position in external rotation and internal rotation compared with its position at neutral were markedly small (Fig 6). On the superior and middle measurement levels, these differences were all less than 1 mm for both readers; on the inferior measurement level, they were less than 1.5 mm.

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Interreader agreement was moderate (weighted $\kappa > 0.5$) to substantial (weighted $\kappa > 0.6$). Specifically, weighted $\kappa$ values were as follows: 0.72 for external rotation, 0.72 for the neutral position, and 0.71 for internal rotation at the superior level; 0.81 for external rotation, 0.73 for the neutral position, and 0.62 for internal rotation at the middle level; and 0.68 for external rotation, 0.53 for the neutral position, and 0.59 for internal rotation at the inferior level.

Orientation

In all shoulder joint positions, the differences in LBT orientation between the measurements at the superior and middle levels and between the middle and inferior levels were both highly significant ($P < 0.001$), except for the comparison of measurements in external rotation between the superior and middle levels (reader 1: $P = .192$; reader 2: $P = .167$) and for the comparison of measurements in internal rotation between the middle and inferior levels (reader 1: $P = .206$; reader 2: $P = .920$).

Compared with the orientation of the LBT in neutral position, the orientation of the LBT changed significantly ($P < .001$) in external and internal rotation of the shoulder at the middle and inferior levels but not at the superior measurement level (Table 1).

Results concerning the interreader agreement of the LBT orientation measurements are provided in Table 4. Interreader agreement was mostly statistically significant ($P < .05$) and was substantial to almost perfect. Except at the superior level, there was no significant interreader agreement in internal rotation.

Discussion

Our data describe the physiologic position, shape, and orientation of the LBT in the neutral position, in external rotation, and in internal rotation of the shoulder.

In our volunteers, the position of the LBT in the bicipital groove was slightly dependent on the rotation of the shoulder. The changes in LBT position in external and internal rotation compared with the neutral position were less than 1.5 mm at all measurements levels. Surprisingly, medial eccentricity of the LBT was greatest in the neutral position of the shoulder joint at all measurement levels. Therefore, rotational misplacement in the shoulder joint at the time of image acquisition does not increase LBT eccentricity to the medial side and should not lead to erroneously diagnosed LBT subluxation or dislocation.

Superiorly, the LBT was situated eccentrically in the mediolateral direction with respect to the bicipital groove, irrespective of the shoulder joint position. With regard to the normal LBT position in the mediolateral direction at the entrance of the bicipital groove, physiologic values were found to be −1.0 to 7.5 mm medial to the deepest point of the bicipital groove. Because of this wide variability, a far medial LBT position of 8 mm medial to the deepest point of the bicipital groove would be required if the diagnosis of LBT subluxation was being considered. However, because our data are based on measurements in healthy volunteers, we cannot provide criteria to diagnose LBT instability but emphasize the variability of the LBT position in physiologic conditions.

The shape and orientation of the LBT changed depending on the level of...
Table 1

<table>
<thead>
<tr>
<th>Position and Orientation of LBT in Different Rotational Positions of the Humerus</th>
<th>Superior Level</th>
<th>Middle Level</th>
<th>Inferior Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External</td>
<td>Internal</td>
<td>P-Value for</td>
</tr>
<tr>
<td>Reader 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mediolateral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7 ± 1.32</td>
<td>2.1 ± 1.21</td>
<td>1.3 ± 1.09</td>
<td>.002</td>
</tr>
<tr>
<td>(0.0–7.0)</td>
<td>(0.0–6.0)</td>
<td>(1.0 To 4.0)</td>
<td></td>
</tr>
<tr>
<td>Anteroposterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 ± 1.08</td>
<td>1.6 ± 1.12</td>
<td>2.0 ± 1.18</td>
<td>.002</td>
</tr>
<tr>
<td>(–1.0 To 1.0)</td>
<td>(–1.0 To 1.0)</td>
<td>(1.0 To 4.0)</td>
<td></td>
</tr>
<tr>
<td>LBT orientation</td>
<td>41 ± 8.41</td>
<td>44 ± 8.71</td>
<td>46 ± 6.19</td>
</tr>
<tr>
<td>(degrees)</td>
<td>(8–75)</td>
<td>(8–75)</td>
<td>(23–70)</td>
</tr>
<tr>
<td>Reader 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mediolateral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6 ± 1.47</td>
<td>2.0 ± 1.55</td>
<td>1.2 ± 1.38</td>
<td>.026</td>
</tr>
<tr>
<td>(1.0 To 1.0)</td>
<td>(1.0 To 3.0)</td>
<td>(1.0 To 4.0)</td>
<td></td>
</tr>
<tr>
<td>Anteroposterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0 ± 1.22</td>
<td>1.2 ± 1.08</td>
<td>1.6 ± 1.43</td>
<td>.004</td>
</tr>
<tr>
<td>(–1.0 To 1.0)</td>
<td>(–1.0 To 4.0)</td>
<td>(–1.0 To 4.0)</td>
<td></td>
</tr>
</tbody>
</table>

Note.—Data are means ± standard deviations, with ranges in parentheses. P-values were calculated with the Wilcoxon signed-rank test.
Spritzer et al (28) examined a small group of nine patients with arthroscopically proven LBT instability (average age, 42 years) and compared MR imaging findings with those in a small control group of 10 patients (average age, 47 years) with shoulder disease that was different from LBT instability. The authors concluded that “in the clinical setting of pain or symptoms referable to the biceps, the presence of a flat, degenerated biceps tendon perched on the lesser tubercle with an obtusely angled bicipital groove should raise the suspicion of instability of the long head of the biceps tendon.” Our data, although partly in agreement with these findings, indicate that a flat LBT perched on the lesser tubercle can also be seen in the neutral position or with external rotation of the shoulder in
Surprisingly, the LBT was more centered in external rotation of the shoulder joint. The data acquired for this study do not allow for an explanation of this finding. It seems that an uninjured asymptomatic persons, suggesting that this position and shape of the LBT can be physiologic (Fig 7). Table 3

<table>
<thead>
<tr>
<th>Shape of 52 LBTs in Different Rotational Positions of the Humerus</th>
<th>Superior Level</th>
<th>Middle Level</th>
<th>Inferior Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reader and Shape</td>
<td>External Rotation Change Neutral Change Internal Rotation</td>
<td>External Rotation Change Neutral Change Internal Rotation</td>
<td>External Rotation Change Neutral Change Internal Rotation</td>
</tr>
<tr>
<td>Reader 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oval</td>
<td>2 (4)</td>
<td>3 (6)</td>
<td>4 (8)</td>
</tr>
<tr>
<td>Flat</td>
<td>20 (39)</td>
<td>25 (48)</td>
<td>26 (50)</td>
</tr>
<tr>
<td>Comma shaped</td>
<td>28 (54)</td>
<td>24 (46)</td>
<td>22 (42)</td>
</tr>
<tr>
<td>Reader 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oval</td>
<td>2 (4)</td>
<td>3 (6)</td>
<td>4 (8)</td>
</tr>
<tr>
<td>Flat</td>
<td>21 (40)</td>
<td>24 (46)</td>
<td>18 (35)</td>
</tr>
<tr>
<td>Comma shaped</td>
<td>27 (52)</td>
<td>26 (50)</td>
<td>31 (60)</td>
</tr>
</tbody>
</table>

Table 4

<table>
<thead>
<tr>
<th>Interreader Agreement for Evaluation of LBT Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position and Level</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Superior</td>
</tr>
<tr>
<td>Middle</td>
</tr>
<tr>
<td>Inferior</td>
</tr>
</tbody>
</table>

Note.—Data are numbers of tendons, with percentages in parentheses and P values (calculated with the Wilcoxon signed-rank test) in brackets. Change = numbers of tendons that changed their shape between the position to the left and the position to the right (external rotation vs neutral, neutral vs internal rotation).
pulley system and rotator cuff tendons center the LBT better in external rotation of the shoulder joint than in the neutral position.

There were some limitations of this study. The position, shape, and orientation of the LBT in asymptomatic volunteers with no degenerative changes on MR images are described. Despite the evaluation of the suspension of the LBT to the best of our knowledge, it is still possible that a volunteer had minor degeneration of these structures. Because there was no control group consisting of patients with proven LBT instability, it was not possible to identify reliable criteria for LBT instability.

In conclusion, the position of the LBT is only slightly dependent on shoulder rotation. LBT eccentricity is maximal in the neutral position. Rotational misplacement during image acquisition does not increase LBT eccentricity and should not lead to erroneously diagnosed LBT subluxation or dislocation.

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References