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ORIGINAL ARTICLE

Anatomic study and electromyographic analysis of the teres minor muscle

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Background: The teres minor muscle is a focused topic on the treatment of massive rotator cuff tears and reverse total shoulder arthroplasty. Its precise anatomy and function have not been completely investigated. The purposes of this study were to anatomically investigate the muscle and analyze electromyographic (EMG) activities during shoulder motion.
Methods: This anatomic study used 20 shoulders from deceased donors (mean age, 75.0 years). EMG data were recorded from 10 healthy volunteers (mean age, 21.7 years) during flexion, abduction, and external rotations at 0° of abduction, at 90° of abduction, and at 90° of flexion in their dominant arms synchronized with a computerized 3-dimensional motion analysis system.
Results: The muscle in all specimens consisted of 2 distinct muscular bundles: the upper and lower portions. The upper portion attached to the round area of the greater tuberosity, and the lower portion inserted into the linear shaped area. Both portions were independent in their origins, insertions, and innervation. The muscle engaged force during each shoulder motion. EMG activities of abduction and the 3 forms of external rotation were similar. Maximal voluntary contraction in the 3 forms of external rotation was 32% in maximum external rotation in the neutral position, 25% in flexion, and 40% in abduction.
Conclusions: The teres minor consists of independent upper and lower portions. The muscle engages force in all ranges of 5 shoulder motions, and maximum external rotation in abduction is a reliable method to evaluate potential activity of the muscle.
Level of evidence: Basic Science Study; Anatomy and Kinesiology

Keywords: Teres minor muscle; anatomy; superior portion; lower portion; electromyography; flexion; abduction; external rotation

Participants provided informed written consent. The anatomic study used specimens with full consent for study, and the Koriyama Institute of Health Sciences Internal Review Board approved the electromyographic study (R14-07).

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The rotator cuff muscles act to stabilize the shoulder joint, additionally contributing to external and internal rotation of the humeral head to the glenoid cavity. In particular, the teres minor muscle, located on the posteroinferior border of the shoulder joint, cooperates with the infraspinatus as an

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external rotator and depressor of the humerus.[27,30] At greater than 60° of abduction, the infraspinatus no longer has a significant external rotational moment arm, and the teres minor becomes the predominant external rotator.[21]

The teres minor is an important external rotator muscle in patients with rotator cuff tears in which the supraspinatus, infraspinatus, and subscapularis tendons are most commonly injured; however, the importance of the teres minor is not fully appreciated. The function of the teres minor becomes more important in large or massive tears of the rotator cuff, especially those involving the infraspinatus.[10] Atrophy of the teres minor, which is identified in 3.2% of patients with rotator cuff tears, jeopardizes the clinical outcome of latissimus dorsi tendon transfer or reverse shoulder arthroplasty in patients with massive rotator cuff tears.[3,7,19] Isolated teres minor atrophy has been identified using magnetic resonance imaging as occurring in 3% of patients with shoulder pain[9,25] and also associates with axillary nerve palsy such as quadrilateral space syndrome, anterior shoulder dislocation, and inferior humeral head osteophyte.[9,20]

The muscle attaches proximally to the lateral border of the scapula and distally to the greater tubercle of the humerus. The morphologic and functional capacity of the teres minor has received clinical attention; however, few authors have investigated the anatomy of the muscle substance, the insertion to the humerus, and the innervated nerve.[8,16,26,28] Therefore, the precise anatomy and function of the teres minor are not completely identified and understood. The purposes of this study were, firstly, to investigate macroscopically and microscopically the muscle substance, including the intramuscular tendon, the humeral insertion, and innervated nerves; and secondly, to analyze electromyographic (EMG) activity during flexion, abduction, and 3 forms of external rotation of the shoulder joint.

Materials and methods

Cadaveric study of the teres minor muscle and the axillary nerve

The study used 20 shoulders from 10 deceased donors (8 men and 2 women; mean age, 75.0 years). The cadavers were fixed in 8% formalin and preserved in 30% ethanol. The entire scapula and the proximal one-third of the humerus and clavicle, with soft tissues, were obtained by cutting the humerus and clavicle. The skin, the subcutaneous tissues, and the deltoid muscle were removed from the shoulder. After the acromion was resected, the connective tissues overlying and adjacent the infraspinatus and teres minor were removed. The study excluded shoulders with severe degenerative changes or rotator cuff tears. The composition of the muscle bundles of the teres minor and innervation of the muscle were macroscopically investigated in 16 specimens.

Four shoulders from 4 cadavers were used for microscopic study. The muscular tendinous junction to the insertion to the humerus was removed en bloc, after fixation in 8% formalin and decalcification, and was embedded in paraffin and serially sectioned at 5 µm in the transverse plane. The Masson trichrome staining technique was used to investigate the intramuscular tendon.

EMG study of the teres minor

The participants in this study were 10 healthy male volunteers (mean age, 21.7 ± 2.8 years), who did not often participate in sports activities and with no previous shoulder pain or a medical history of shoulder disorders. Each subject was informed of the details of the study and provided signed consent before participation. Intramuscular fine wires were prepared using the method previously reported.[22] Two sterile 50-µm-diameter wires coated with Teflon (DuPont, Wilmington, DE, USA) were inserted into the muscle belly of the teres minor using a 25-gauge hypodermic needle in 90° of abduction and a neutral rotation position of the shoulder joint, as guided with ultrasonography.[23]

EMG signals were recorded during flexion, abduction, and external rotations at 0° of abduction, at 90° of abduction, and at 90° of flexion in the subjects' dominant arms, and this was synchronized with a computerized 3-dimensional motion analysis system (MAC 3D System; Motion Analysis Corp., Santa Rosa, CA, USA). This system used 10 synchronized infrared cameras placed circumferentially around the participants and allowed for the capture of data at 50 Hz. Before the measurement session was recorded, all participants randomly flexed, abducted, and externally rotated their dominant arms 3 times to learn the expected motions.

Motion data were analyzed using KineAnalyzer system software (Kissei Comtec Co., Nagano, Japan).[31] EMG signals were recorded with a telemetry EMG system (MQ-Air; Marq-Medical, Farum, Denmark) and analyzed with Bimutus 2 analysis software (Kissei Comtec Co.). The signals were band-pass filtered at 10 to 1000 Hz, sampled at 1000 Hz, and stored for further analysis.

All participants were positioned in the optimal 5 muscle-testing positions recommended by Hislop and Montgomery.[12] Muscle forces were measured with a dynamometer to determine 100% of maximal voluntary isometric contraction (MVIC) for each participant in the following positions: 90° of flexion and abduction; the neutral position in adduction of the shoulder joint; maximum external rotation with the arm in 90° of external rotation in 90° of abduction, and 90° of external rotation in 90° of flexion. After this, EMGs were recorded for 10 seconds at 50% of MVIC (50% of muscle force) for each position. EMG data for each 15° increment of integrated EMG (IEMG) of the teres minor were obtained. The percentage of IEMG (%IEMG) for each 15° increment for 1 second was calculated from the average figures for each second for each 50% MVIC for all subjects.

Statistical analysis

Mean IEMG results for flexion and abduction from 0° to 150° were compared with Wilcoxon matched pairs signed ranks test and the mean IEMG results for the 3 forms of external rotation during 0° and 75° with the Kruskal-Wallis test. The Friedman test was used to compare %IEMG for each 15° increment for flexion and abduction and for each external rotation. Statistical analyses were performed using SPSS 22.0 J software (SPSS Japan Inc., Tokyo, Japan). Statistical significance was defined as $P < .05$.