In-vivo measurement of the compressive force under the coraco-acromial arch

[1, 2]Toshimasa Yanai and [3]Franz K. Fuss
[1] Chukyo University, Japan; [2] University of Otago, New Zealand; email: tyanai@life.chukyo-u.ac.jp
[3]Nanyang Technological University, Singapore; email: mfkfuss@ntu.edu.sg

INTRODUCTION

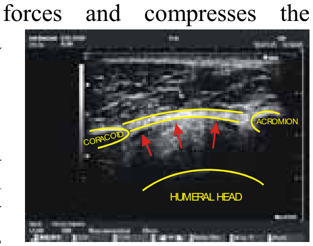
Shoulder impingement is a widely recognized mechanism of chronic shoulder pain. With this mechanism, the shoulder pathology is explained as the consequence of repeated impingement, or compression, of the subacromial structures under the coraco-acromial arch. It has not been confirmed, however, if the compressive force that impinges the subacromial structures is sufficiently large to cause micro-trauma that leads to the pathological condition. The purpose of this study was to determine in-vivo the magnitude of the compressive force developed under the coraco-acromial ligament at selected shoulder configurations.

METHODS

Five males with no history of shoulder pain volunteered to participate in this study. After having provided written informed consent, each subject was asked to actively maintain his arm in specified positions: (1) Anatomical (neutral) position, (2) 90° abduction + maximum external rotation, (3) 90° abduction + neutral rotation and (4) 90° abduction + maximum internal rotation. In addition, (5) the subject's shoulder was passively and forcibly configured to form the position for the Hawkins impingement test.

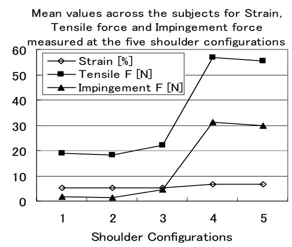
An ultrasound unit (EUB-6500, Hitachi Medico, Japan) was used to visualize and record the shape of the coraco-acromial ligament at each shoulder configuration. The probe was positioned carefully, so that the shape of the ligament's long-axis could be visualized. The contour of the upper, and also lower, surface of the coraco-acromial ligament were identified from the recorded images and digitized manually. The best-fit polynomial equation was determined to express the shape of the ligament mathematically for each shoulder configuration.

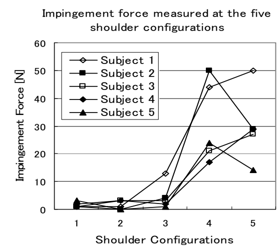
The ligament was modeled to have: (a) a uniform elastic property throughout the length between the insertions (Young's modulus = 290 MPa [2]); (b) smooth (no friction) surfaces; (c) a uniform cross-sectional area of 8 mm^2 throughout the length [2]; and (d) the length of a coraco-acromial ligament *in situ* was 5% (pre-strain) longer than the resting length of the ligament [2]. With this model and the measured length, the tensile force acting across the cross-sectional area of the ligament at its attachments and a single resultant of the distributed normal forces that caused the ligament to change its shape were determined. The latter force balances the two tensile forces and compresses the subacromial structures as a reaction (impingement force).



RESULTS

The ultrasound images showed that the coraco-acromial ligament that was flat initially at the anatomical position was pushed, and deflected, upward by the subacromial structures to form a curved shape when the arm was elevated and internally rotated. The extent of the deformation exhibited at the maximum internal rotation was found similar to that provoked at the Hawkins test position. This observation was confirmed with the determined impingement forces (below).





DISCUSSION

The study demonstrated that the impingement force developed under the coraco-acromial ligament increased with the active shoulder internal rotation and that the magnitude of the impingement force recorded during active motion attained similar values to that recorded with the Hawkins test. The first result was consistent with the in-vivo study conducted by Nobuhara [1] in which the impingement force under the coraco-acromial ligament was measured directly from 260 patients during open surgery. The second result indicates that the subacromial structures during active shoulder motions are subject to a compression at the intensity similar to the "impingement sign (localized pain)."

The validity of the present methodology was tested with a cadaveric study in which known amounts of forces applied to ten specimens of coraco-acromial ligament were compared with the corresponding forces determined with the model approach used in the present study. The correlations were found high (0.925-0.986) although the absolute values of the forces were found to involve large error due to the individual variability in the Young's modulus of the ligament. These results suggest that the present methods provide sufficient accuracy in determining the relative magnitude of impingement force and that the ligament Young's modulus needs to be individualized to improve the accuracy in determining the absolute magnitude of the impingement force. It is also important to scan the ligament immediately after the subject has moved his arm into the required shoulder position, in order to keep stress-relaxation and creep to a minimum.

REFERENCES

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ACKNOWLEDGEMENTS

This study was partially funded by the Royal Society of New Zealand, ISAT Linkages Fund (99-BRAP-09-YANA).