BIOMECHANICAL FUNCTIONS OF LATISSIMUS DORSI MUSCLE IN BASEBALL PITCHING

Hwai-Ting Lin (1,2), Fong-Chin Su (2), Terry K.K. Koo (1), Atsushi Yokota (1), Jun Hashimoto (3), Nozomu Inoue (1), Mari Nakamura (3), Katsuya Nobuhara (3), Edmund Y.S. Chao (1)

(1) Orthopaedic Biomechanical Laboratory, Johns Hopkins University, Baltimore, MD

(2) Institute of Biomedical Engineering, National Cheng Kung University, Tainan, Taiwan

(3) Nobuhara Hospital and Institute of Biomechanics, Hyogo, Japan

INTRODUCTION

The latissimus dorsi (LD) muscle is primarily considered as an extensor and adductor of the shoulder. However, during the large range of motion required in baseball pitching, it may change its function in different positions and orientations of the humerus in reference to the trunk.

Overuse of the LD muscle especially for a baseball pitcher may affect his pitching performance [1]. It could also lead to various shoulder and back disorders in overhead sports activities among athletes and in heavy and repetitive manual tasks among industrial workers. The biomechanical function of the LD muscle involved in these strenuous activities has not been well studied.

To judge the function of the muscle, the muscle moment arm and muscle stress are probably the most important factors. In previous muscle moment arm studies, the roentgenographic method [2] or anatomic measurements using cadaver specimens [3]. These methods were restricted to static analysis in selected joint positions. van der Helm developed a three-dimensional finite element shoulder model to calculate the muscle moment arm and muscle force using a truss element [4]. Further extension of this concept by considering the continuous movement of muscle origin and insertion sites and to graphically demonstrate muscle line of action changes relative to joint anatomy during motion would be important to facilitate modeling of the musculoskeletal system for biomechanical analysis. The purpose of this study was to apply a visual interactive musculoskeletal system (VIMS) to investigate the anatomical and biomechanical roles of the LD muscle during baseball pitching and to utilize the graphic animation capacity of VIMS to visualize the model in action.

MATERIAL AND METHODS

The Qualisys Motion Capture System (Gothenburg, Sweden) was used for baseball pitching motion data collection, using a sampling rate of 500 Hz. Thirty four reflective markers were mounted on a pitcher at selected anatomical locations over the entire body. There are five local coordinate systems fixed to the key skeletal segments defined by the markers.

Since the LD muscle has broad attachment sites, it was divided into three branches: the thorax, lumbar and iliac crest branches. The muscle attachment sites were determined by analyzing the Visible Human dataset from the U.S. National Library of Medicine. To define the muscle line of action, if using only the origin and insertion points, the LD muscle would have pointed through the bone and chest wall. To alleviate this problem, intermediate points along the muscle path defined by the centroids of its cross-sectional area were used to redirect its line of action from the humerus throughout the baseball pitching cycle.

During pitching motion, scapula moves rhythmatically with the elevation of humerus. In this study, we incorporated scapula motion data [5] to consider possible interference of LD muscle line of action. Vector analysis was used to determine the muscle moment arm. The resultant moment arm of a muscle is defined as the magnitude of the position vector from the joint center to any point along the muscle line of action direction. The resultant moment arm of the LD muscle is then decomposed into three orthogonal components with respect to a humerus-fixed coordinate system, X_h, Y_h, Z_h, responsible for the abduction/adduction, flexion/extension and internal/external rotation of the humerus (Fig. 1). Using the inverse dynamic analysis and optimization technique by minimizing the sum of the squares of muscle stresses, the muscle stress of the LD muscle (thorax branch was represented the LD muscle action line) could be determined. There are five main phases of baseball pitching: these are the wind up, early and late cocking, acceleration and follow through phases. The results were analyzed according to these phases.

RESULTS

The skeletal positions corresponding to different phases of pitching motion are illustrated using the VIMS model with local coordinate system defining shoulder motion. The orientation of LD relative to the humerus varied significantly in different pitching position (Fig. 1). LD muscle is primarily an extensor muscle (in reference to Y_h) during pitching which matches with its anatomic and physiological function. The iliac crest branch of LD muscle had the largest extension moment arm from the late cocking phase through the rest of pitching cycle. All branches of the LD muscle changed from an adductor to the abductor (in reference to X_h) at the end of cocking phase and changed back to adductor at the acceleration phase. However, the internal rotation moment arm (with respect to Z_h) of LD muscle did not change significantly during pitching. Among all braches of the LD muscle, the iliac crest branch of the LD muscle had the largest internal rotation moment arm in the acceleration phase (Fig. 2). All branches of the LD muscle increased its muscle length in the cocking phase and decreased during the acceleration and follow-through phases. The LD muscle was active in the early cocking phase and reduced its activity in the late cocking phase. The LD muscle increased muscle stress in the acceleration phase and reached its maximum value just after ball release in follow through phase (Fig. 2).

DISCUSSION

The Virtual Interactive Musculoskeletal System was ideal to study the LD muscle moment arm and length change as a function of the pitching motion. It also allows visualization the LD muscle orientation to validate its relative functional contribution in reference to other muscles. Using the intermediate points to constrain the muscle line of action to accommodate the wrapping around effect improved the biomechanical model for baseball pitching and other shoulder-trunk activity analysis. The LD muscle extends eccentrically in the cocking phase to store potential energy to be transformed to power during acceleration phase in order to produce the required momentum before ball release. During cocking phase, this muscle would be elongated passively and remained relatively inactive to prevent injury caused by eccentric contraction. LD muscle is primarily an extensor and internal rotator, which provides the main driving force during baseball pitching. Although the VIMS model is generic in nature, it can be used for parametric analysis based on measured kinematics data. Same technique was used to study other muscle function in the shoulder during baseball pitching.

CONCLUSION

In summary, the LD muscle is primarily an extensor and internal rotator in the later phases of pitching motion. Its adduction/abduction function fluctuates during pitching but this is judged as the minor function of the muscle. LD muscle stores energy during cocking phase to prepare for the large acceleration required before ball release. However, the critical timing of its physiological function is important to avoid eccentric contraction injury.

ACKNOWLEDGEMENT

This study was supported by OREF, Bristol- Myers Center Grant, and Nobuhara Hospital.

REFERENCES

1. Nobuhara, K., 2001, "Its Biomechanical Function and Clinical Problems", Shoulder, Chapter 9, pp. 416, Igaku-Shoin, Tokyo.
2. Bassett, R.W., Browne, A.O., Morrey, B.F., and An, K.N., 1990, "Glenohumeral muscle force and moment mechanics in a position of shoulder instability," Journal of Biomechanics 23, pp. 405-415.
3. Kuechle D.K. et al., 1997, "Shoulder muscle moment arms during horizontal flexion and elevation," Journal of Shoulder and Elbow Surgery 6, pp. 429-439.
4. van der Helm, F.C.T., 1994, "A finite element musculoskeletal model of the shoulder mechanism," Journal of Biomechanics 27, pp. 551-569.
5. Fung M. et al., 2001, "Scapular and Clavicular Kinematics during Humeral Elevation: A Cadaver Study," Journal of Shoulder and Elbow Surgery 10, pp. 278-285.

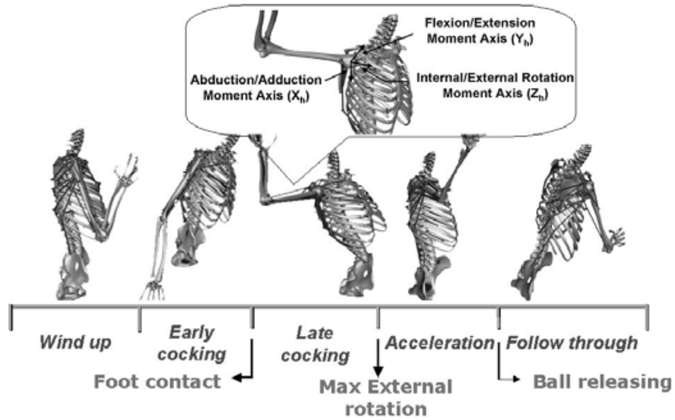

Figure1. The LD muscle direction change corresponding to different phases of pitching motion and its functional moment arm is defined based on the humerus-fixed axes.

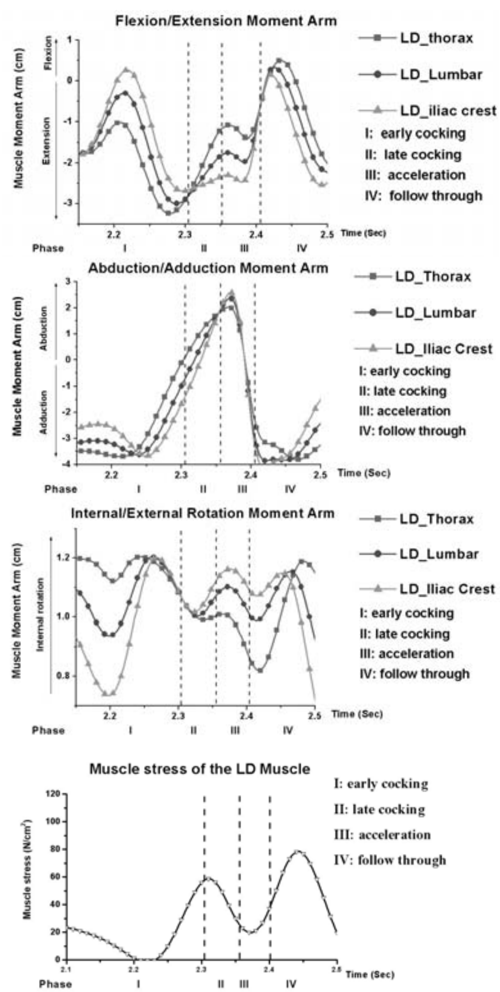

Figure 2. The LD muscle moment arms about the three reference axes fixed to the humerus and muscle stress of the LD muscle (bottom).