THE INFLUENCE OF BASEBALL PITCHING ON THE HARDNESS OF THE FLEXOR PRONATOR MUSCLES - USING ULTRASOUND REALTIME TISSUE ELASTGRAPHY

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The purpose of this study was to examine changes of the individual hardness of the flexor - pronator muscle group after pitching. The twelve normal male volunteers who had played baseball participated in this study. One hundred pitches were performed, and the individual flexor pronator muscles hardness were analyzed using ultrasound real time tissue elastgraphy (RTE) both before and after 100 pitching. The hardness of the flexor pronator muscles were not significant different between before and after pitching. However, hardness of the most hardened muscle was significantly different between before and after pitching. Therefore RTE is useful method to manage of the pitching counts in pitchers who performed athletic rehabilitation after throwing injuries.

KEY WORDS: flexor pronator muscle, baseball, elastgraphy

INTRODUCTION: Baseball pitchers have a high risk of the elbow injuries, and of these pitching-related injuries, 25% are considered severe requiring ten or more days lost from sport.(Dick et al., 2007) It is important for baseball athletes to prevent the throwing injury, and need to be examined as a mechanism of the throwing injury. It is well known that pitching type, counts, and form are the risks of throwing injuries. Lyman, Fleisig, Andrews, and Osinski (2002) suggests that pitchers between ages 9 and 14 years should not throw breaking pitches because of an increased incidence of shoulder and elbow pain.
Increasing the intense valgus force on the medial elbow from the late cocking phase to acceralation phase of pitching is known to be lead to medial elbow pain such as Ulnar Collateral Ligament (UCL) injuries.(Leach & Miller,1987; Glousman, Barron, Jobe, Perry& Pink,1992) A large valgus force is experienced during pitching and it is increased by age; Youth pitchers experience ~28 Nm of valgus force, high-school pitchers experience ~48 Nm of valgus force, college pitchers experience ~55 Nm of valgus force, and professional players experience 64 Nm of valgus force. (Fleisig, Andrews, Dillman, & Escamilla, 1995) The UCL was found to only be able to resist ~32 Nm of valgus force. Therefore, the valgus force is experienced on not only UCL, but also flexor-pronator muscles group.
Degenerative changes in the musculotendonous region of the medial epicondyle are the result of chronic repetitive concentric and eccentric contractile loading of the flexor-pronator muscles group.(Ciccotti, Schwartz, & Ciccotti, 2004) The flexor carpi ulnaris(FCU) is the primary stabilizer, and the flexor digitorum superficialis (FDS) is a secondary stabilizer, while the pronator teres (PT) provides the least dynamic stability.(Park & Ahmad,2004) The FCU, because of its position directly over the UCL, and the FDS, with its near proximity and relatively large bulk, are the specific muscles best suited to provide medial elbow support. This is especially relevant to overhead throwing athletes who encounter extreme valgus force across the elbow during the cocking and acceleration phases of the throwing motion. (Davidson, Pink, Perry,& Jobe, 1995) Reinold et al. reported that passive range of motion is significantly decreased immediately after baseball pitching that continues to be present 24 hours after throwing.(Reinold, Wilk, Macrina, Sheheane, & Dun, et al. 2008) Therefore, it is considered that hardness of the flexor-pronator muscles group are changed by increased pitch count. However, it is unclear that increased pitch counts influences the hardness of the individual muscles.
Real-time tissue elastgraphy(RTE) can assess the hardness distribution at a specific muscle. (Drakonaki & Allen 2010). Niitsu, Michizaki, Endo, Takei, & Yanagisawa (2011) reported that the hardness of the biceps brachii muscle was significantly higher for several days after eccentric elbow flexion exercise. Thus, RTE may be able to examine hardness

changes of the muscle after pitching, and help to develop a customized pitching program for the athletes with throwing injuries.
The purpose of current study was to examine individual changes in the hardness of the flexor -pronator muscles group after pitching.

METHODS: The twelve normal male volunteers(mean age;19.8±0.8 years old, mean height; 172.7±4.2 cm, mean weight; 76.0±14.9kg) who had played a baseball more than 2 days per week, and had experienced pitcher in game since they were in high school were participated in this study. All subjects were free from throwing injuries at time of testing. This study was approved at Morinomiya University of medical sciences ethical community.
One hundred pitches were performed after warming up throwing, and all subjects were instructed to pitch the first ball at constant rhythm.
The flexor- pronator muscles hardness were analyzed using ultrasound RTE with 18 MHz linear transducer (Aplio 300, TOSHIBA co. Japan) both before and after 100 pitches.
The subject was measured RTE at supine lying with elbow 30 degrees flexion. The transducer was put on 20% proximal level of the antero-medial forearm to view the whole cross sectional area of the FCU, FDS and PT muscles, respectively. The RTE image is obtained by manual application of adequate light repetitive compression (rhythmical compression-relaxation cycle) with the transducer which was wrapped on the reference gel pad in the scan position. After scanning, rectangular regions of interest (ROI) are defined individually FCU, FDS, PT and the reference material (Fig.1). Then the each strain ratio (muscle/reference ratio) was calculated three times for each image. Lower strain ratio values implied higher hardness. The ratio of hardness change was calculated as percentage of the hardness of each muscle of each pitcher after 100 pitches to hardness of same muscle before pitches, the most hardened muscle was defined as the lowest ratio of hardness change muscle in each pitchers. The hardness of the most hardened muscle were compared before with after 100 pitches.
The reliability of the RTE were assessed using intraclass correlation coefficients (ICC), the standard error of measurement (SEM) was calculated. Those strain ratio of three muscles, and grip strength were assessed at both before and after 100 pitching, respectively using paired t-test or Wilcoxon test ($p<0.05$). The ratio of hardness changes was assessed among three muscles using ANOVA, and hardness of the most hardened muscle was compared between before and after 100 pitches using paired t-test. All statistical methods were performed using R 2.8.1.

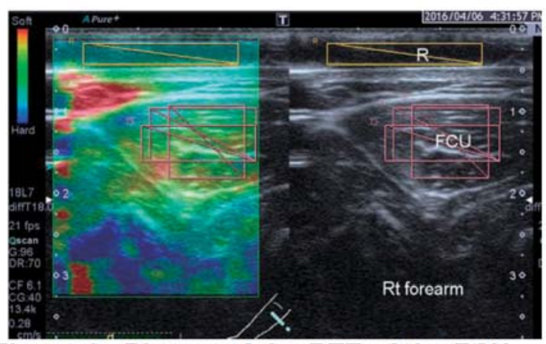

Figure 1: Picture of the RTE of the FCU.
R; reference gel pad.

RESULTS: The reliability of RTE of flexor-pronator muscles group were shown in Table 1. The ICC value of all muscles were more than 0.9. The RTE values of the FCU, FDS and PT were shown in Table 2. Hardness of all muscles were no significant difference between before and after pitching. The grip strength of after 100 pitching were no significant decreased than that of before pitching ($p<0.05$). The ratio of hardness change was no significantly different among the three muscles (Table 3). The pitchers who the most hardened muscle was the FCU were 5 pitchers, and who was the FDS, PT were 4, 3 pitchers, respectively. The Hardness of the most hardened muscle was significantly different before and after pitching (Table 4).

DISCUSSION: Collegiate pitchers average of the 96.7 ± 16.1 pitches per game and at the end of the games, approximately 18% report subjective fatigue; however there were not

Table 1 Reliability of RTE of flexor-pronator muscles

	ICC(1,3)	SEM
FCU	0.94	0.03
FDS	0.95	0.04
PT	0.98	0.03

Table2 Comparison of the RTE values of flexor-pronator muscles group and grip strength between before and after 100 pitches

	Before pitching	After 100 pitching	P value
FCU (%)	0.41±0.11	0.40±0.19	0.08
FDS (%)	0.29 (0.39-0.22)	0.23 (0.20-0.30)	0.47
PT (%)	0.27±0.13	0.33±0.24	0.31
Grip strength (kg)	37.48±8.79	37.18±8.82	0.89

FCU/FPT/GS: paired t-test, FDS: Wilcoxon test

Table 3 Comparison of the Ratio of hardness change among three muscles

	FCU	FDS	PT	P-value
Ratio of hardness change (%)	96.57±42.16	90.03±32.53	129.61±75.25	0.28

Table 4 comparison of RTE of the most hardened muscle

	Before pitching	After 100 pitching	P-value
RTE (%)	0.40±0.14	0.25±0.12	< 0.01

significant declines in velocity from the beginning to the end of the game. (Grantham, Byram, Meadows, & Ahmad, 2014) The collegiate baseball pitchers approach muscle fatigue when they throw between 105 and 135 pitches in simulated baseball game. (Escamilla, Barrentine, Fleisig, Zheng, Takada, et al. 2007) Therefore, we hypothesize that approximately 100 pitches lead to increase hardness of the flexor-pronator muscles group, and the pitchers have some problems and injuries of the upper limbs, if they cannot recover from the muscle hardness.

In this study, hardness of the three muscles were not significant decreased between before and after pitching. However, hardness of the most hardened muscle was significantly different before and after 100 pitches. There are some researches which has reported relationship individual muscle and pitching. The PT and FCR both attach to the anterior aspect of the medial epicondyle. These tendons are stretched during the acceleration phases of throwing and swinging. Thus, the PT and the FCR are most often the muscles afflicted with these alterations. (Ciccotti et al., 2004) Davidson et al.(1995) described that the FCU muscle, because of its position directly over the medial collateral ligament, and the FDS muscle, with its near proximity and relatively large bulk, are the specific muscles best suited to provide medial elbow support. This is especially relevant to overhand throwing athletes who encounter extreme valgus force across the elbow during the cocking and acceleration phases of the throwing motion. (Davidson et al.,1995) Thus, the flexor-pronator muscles are important to play a role of dynamic stabilizer of the medial elbow support, however, it is unclear which muscles play the most important role during the pitching. Our results demonstrate that even in the same pitching counts, hardness change and most hardened muscle depend on the individual. Pitching mechanics is important to prevent the throwing injuries, and it is clear that pitching biomechanics affect the degree of stress on the upper limb (Sabick, Torry, Kim & Hawkins, 2004, Sabick, Torry, Lawton & Hawkins, 2004). It has been shown that a pitcher experiences significant muscle fatigue during an individual game performance (Lyman et al. 2001), making it difficult to maintain ideal pitching mechanics. Moreover, there have been no reports documenting the stiffness changes of forearm flexor- pronator muscles during pitching. There is possibility that individual difference of the most hardened muscle depend on the pitching biomechanics. However it is impossible to analyze the individual activation of the flexor- pronator muscles during the pitching. Therefore it is useful to manage pitching counts in pitchers who performed athletic rehabilitation after throwing injuries.

A limitation of this study was that it did not investigate the morphological changes after pitching. Also further study is needed to assess the hardness of those muscles in both higher levels and a larger number of pitches.

CONCLUSION: The current study examined changes of the hardness of the flexor -pronator muscles after pitching. Hardness changes were no different before and after 100 pitches, however, hardness of the most hardened muscle was significant harder than before 100 pitches. Therefore, evaluation of the RTE for the flexor-pronator muscles after pitching may be an effective method to assess rehabilitation of throwing athletes.

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