의학석사 학위논문

투구 후 유소년 야구선수들의 극상근-건, 이두박건 장두 및 견관절 관절범위의 급성기 변화: 투구 후 얼마의 휴식이 필요한가?

Immediate changes and recovery of supraspinatus, long head biceps and shoulder range of motion after pitching in youth baseball players: How long is the rest needed after pitching?

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여지현

Abstract

Immediate changes and recovery of supraspinatus, long head biceps and shoulder range of motion after pitching in youth baseball players: How long is the rest needed after pitching?

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Introduction: Baseball players usually get injuries such as rotator cuff tear, SLAP lesion due to repetitive pitching since youth. However, there have been few researches regarding effects of pitching on shoulder muscles and time-based recovery of youth baseball players. The purpose of this study was to evaluate the effect of pitching on supraspinatus muscle-tendon, long head biceps tendon (LHBT) and shoulder ROM, and time-based recovery of youth baseball players using sonoelastography.

Material and Methods: Fifteen youth baseball players (mean age:

12.1 ± 3.5 yrs) were enrolled at a single institute. The thickness of supraspinatus tendon and LHBT and the strain ratios (SR) of supraspinatus muscle and tendon were measured using sonoelastography, and ROM of shoulder joint (abduction, external rotation (ER) at 90° abduction (ABER), internal rotation (IR) at 90° abduction (ABIR), horizontal adduction (HA) were measured by a bubble goniometer. Every measurement was performed on throwing shoulders before and immediate period after pitching (mean pitch count (n); 78.3 ± 13.3), 30 minutes, 24 hours, and 72 hours after pitching.

Results: At the immediate measurement after pitching, the thickness of supraspinatus tendon (before pitching, 6.64 mm; after pitching, 6.27 mm, p = 0.026), and LHBT (before pitching, 2.56 mm; after pitching; 2.26 mm, p = 0.02) were significantly decreased. Those decreases of thickness of two tendons were recovered at 72 hours after pitching. The SR of supraspinatus muscle tended to be decreased, and the SR of supraspinatus tendon tended to be increased at the immediate period after pitching, but recovered at 72 hours after-pitching. For shoulder ROM, ABER was increased (119.7° to 127.3°, p = 0.001) and HA was decreased (34.7° to 29.3°, p = 0.02) at the immediate measurement after-pitching.

Those ROMs were recovered at 72 hours (ABER; p = 0.017, HA; p = 0.04).

Conclusion: The immediate effect of pitching on supraspinatus muscle-tendon, LHBT, and shoulder ROM of youth baseball players was confirmed through the current data. These changes were recovered to pre-pitch level at 72 hours after pitching. Therefore, it is recommended to take enough rest until third day after pitching to prevent injuries of youth baseball players.

Keyword : Baseball, pitching, supraspinatus, strain ratio, sonoelastography, recovery

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Chapter 1. Introduction

1.1. Study Background

Repetitive pitching is known to cause damages to the structures of shoulder joint, such as rotator cuff tendon, long head of biceps tendon (LHBT), and labrum.[12, 19, 29] And many baseball players get injuries such as rotator cuff tear, SLAP lesion due to repetitive pitching. Those shoulder injuries are not limited to adult players but are starting from youth baseball players and also frequently found in youth baseball players.[12, 16, 20] Further, it is reported that about 20% of youth baseball players experience shoulder pain during a single baseball season.[15, 16, 20] And youth baseball players are at risk for shoulder injury and this tendency is getting worse.[7, 20]

Risk factors of shoulder injuries and diseases are not fully understood and have been rarely studied.[15] Baseball players have been subjected to repeated loads on the shoulder joints by throwing ball for long time since youth.[28] Baseball pitching places tremendous forces on glenohumeral joint and adjacent structures during pitching.[24] These pitching movements cause damage to rotator cuff, long head biceps tendon (LHBT).[12, 19, 29] Some literatures reported the rotator cuff tendon and LHBT complex injuries in shoulder joint regarding repetitive throwing. However, there are limited

researches regarding immediate changes of shoulder muscles and tendons with pitching. There are only several studies regarding immediate effect of pitching on supraspinatus muscle and LHBT in adult baseball players.[1, 10, 19]

There was a study evaluating thickness of supraspinatus and LHBT to confirm the long term effect of pitching.[19] In this study, thickness of supraspinatus and LHBT tended to be decreased after pitching. Forceful contraction and traction may cause thining of tendons. These results suggest that the thickness of supraspinatus and LHBT could be a parameter of the immediate effect of pitching.

To date, there was a study which assessed supraspinatus muscle-tendon as well as biceps tendon with sonoelastography after pitching in professional baseball pitchers.[19] The strain is one of parameters which assesses the quality or condition of human tissue.[18] Sonoelastography is an examination method which evaluates strain or elasticity of tissue.[23] Strain of tissue induced by compression is measured by sonoelastography.[9] Strain is increased in the soft tissue and is decreased in the harder thissue.[9, 19, 23] In general, muscle lesions tends to be hard and tendon lesions tend to be soft on musculoskeletal sonoelastography.[4] In addition to the studies using sonoelastography for diagnosis of musculoskeletal diseases,[4, 13, 14] there have been several studies on rotator cuff and

LHBT.[8, 18, 19, 22] It is reported that strain could be measured in qualitative or quantitative way. Lalitha et al. reported that sonoelastoraphy can be used to diagnose disease of supraspinatus tendon in qualitative way. However, there is a problem that the qualitative method has a low reproducibility of the test and can not yield objective test results. Using strain ratio, relatively objective results of strain could be obtained in quantitative way.[23]

The baseball pitchers have a characteristic range of motion (ROM) of shoulder joints, which is an important factor in understanding the thrower s shoulder.[25] There are several literatures reporting changes of range of motion (ROM) of shoulder joint were correlated with shoulder injuries. In general, the throwing shoulders reveal the decrease of internal rotation (IR) and increase of external rotation (ER) at 90° of abduction which was correlated with glenohumeral internal rotation deficit (GIRD) and throwing arm injuries.[27] Repetitive extreme forces on the throwing shoulder during pitching cause structural remodeling to the shoulder joint structures, and may be responsible for unique shoulder ROM.[3] The osseous structural change such as greater humeral retroversion begins at youth age.[26] However, we are still uncertain about the immediate effect of pitching on changes of ROM.[3] Further, there have been limited researches regarding recovery of ROM as well as changes

of muscle-tendon over time in youth baseball players.

There were several studies regarding immediate effect of pitching on shoulder ROM in adult baseball players. Kibler et al. measured shoulder ROM before and until 72 hours after pitching.[11] It was reported that external rotation was recovered at 72 hours after pitching. Reuther et al. reported that sleeper stretch reduced time course of recovery for internal rotation of shoulder joint to 2days.[21] However, there have been no research regarding immediate effect pitching on shoulder ROM in youth baseball players. In many country, the number of pitching and rest time after pitching is limited to prevent injury of throwing arm of youth baseball players. However, there is a lack of research on comprehensive research on proper rest time after pitching in youth baseball players, and these guidelines are largely based on clinical experience.

1.2. Purpose of Research

There has been no research regarding immediate effects of pitching on supraspinatus muscle-tendon, LHBT and shoulder ROM in youth baseball players. And also, there have been no research regarding time-based recovery of youth baseball players. Therefore, the purposes of this study were (1) to evaluate the immediate changes of supraspinatus muscle-tendon and LHBT, and shoulder ROM after pitching in youth baseball players and (2) to verify when those changes are restored to pre-pitching level by serial monitoring of those changes over time.

Chapter 2. Body

2.1. Materials and Methods

Participants

This study included 15 healthy male youth baseball players who were registered in a single institute of South Korea (The Baseball Academy). Institutional review board of one author's (team doctor of the academy) approved the study, and informed consent was obtained from all participants as well as guardians. The subjects had no history of throwing arm injuries and no present pain on throwing arm at the time of measurements. And all subjects were right-handed overhead throwers. The mean age was 12.1 ± 3.5 years, and the mean career was 4.1 ± 3.5 years. The other demographic characteristics are summarized in Table 1.

Table 1. Demographic characteristics of participants

Variables	Value (Mean ± SD)
Age (yr)	12.1 ± 3.5
Height (cm)	152.9 ± 12.5
Weight (kg)	52.2 ± 16.0
BMI (kg/m^2)	21.8 ± 3.5
Career (times)	4.1 ± 3.5

Parameters and timetable of measurement

The parameters measured throughout the study were (1) the

thickness of supraspinatus tendon and LHBT, (2) the strain ratio (SR) of supraspinatus muscle and tendon, and (3) shoulder ROM. Measurements were performed at the day of pitching (before pitching, immediate period after pitching and 30 minutes after pitching), 24 hours and 72 hours after pitching. All participants had a minimum of 3 days of rest before pitching day. During this measurement period of three days, all participants were instructed not to perform any baseball training including throwing and batting. However, any stretching exercises were allowed during the study period.

Raters

Two orthopaedic fellows who both had 8 years of experience as orthopedic surgeons and 2 years of experience of using sonoelastography with application to the shoulder joint. During the measurements, these two fellows made agreements for each measurement.

Pitching

The participants threw as many fastballs as possible with maximum effort at the distance of 14 meters. Between each pitching, at least 10 seconds of rest was allowed. The pitching was continued

till the participants felt any fatigue or soreness on throwing arm and the number of pitches was limited to the maximum of one hundred. Mean pitching counts of this study was 78.3 ± 13.3 (n).

Measurements

Every measurement of the current study was limited to the throwing arm which was dominant arm in every participant of the study. We measured the thickness of supraspinatus tendon and LHBT at first, and the strain ratio (SR) of supraspinatus muscle-tendon, and ROM of shoulder in order. The strain ratio was measured using a sonoelastography (Alpinion medical system, E-cube 15EX, Seoul, Korea) and the ROM using a bubble goniometer. The result of sonoelastography, which evaluates the strain of tissue, might vary according to the operator and the degree of pressure applied to the probe.[17, 19] Therefore, the strain ratio (SR) is usually used for the comparative analysis[19]; the SR is calculated by dividing the strain of the target area (area of interest; supraspinatus muscle and tendon) by the strain of reference area (subcutaneous fat), which is automatically calculated.

Thickness of supraspinatus tendon and LHBT

The thickness of supraspinatus tendon and LHBT were measured

with a 3.13 Hz linear transducer of conventional B-mode.[19] At first, participants were seated on the chair without backrest and examined in modified Crass position while measuring the thickness of supraspinatus tendon. The thickness of supraspinatus tendon (yellow dashed line) was measured between superior facet of greater tuberosity of humerus and highest curvature of supraspinatus tendon at a transverse scan (Figure 1A). After then, the thickness of LHBT was measured with arm at side. and it was measured at the point of highest thickness (yellow dashed line) at the bicipital groove in a longitudinal scan (Figure 1B). In the previous study, quantitative ultrasound measurements of thickness of supraspinatus tendon showed considerable reliability. Felx et al. reported intraclass correlation coefficients was more than 0.90.[5] Therefore, measurement of thickness using ultrasound could be regarded as reliable.

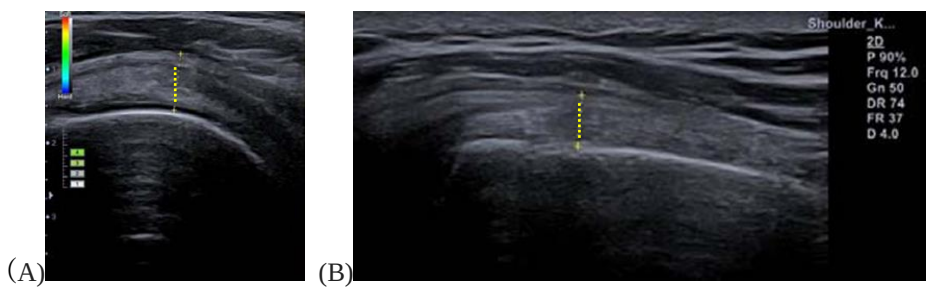


Figure 1. The measurements of thickness of supraspinatus tendon (1A) and long head of biceps tendon (1B). The yellow dotted line with closed arrows at the end indicates the thickness.

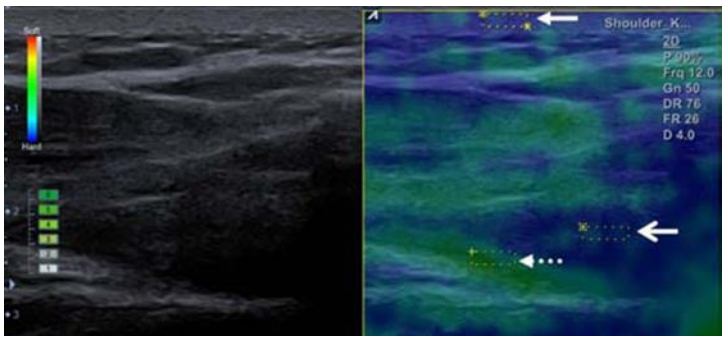
The strain ratio (SR) of supraspinatus muscle-tendon

The SR of supraspinatus muscle-tendon were measured with a 3.13 Hz linear transducer of sonoelastography. During the measurement of the SR of supraspinatus muscle, the participant is seated on a chair without backrest with placing his throwing arm on anterior aspect of ipsilateral thigh.[18, 19, 22] The examiner stands behind the participant and approaches to the posterior shoulder locating the transducer with B-mode parallel to the middle of supraspinatus muscle belly which is one finger breadth above from the scapular spine. When the trapezius and supraspinatus muscle appear on the screen and it is determined as the proper image for further measurements and the location of transducer was marked with oil-based ink on the skin for measurement during the follow-ups.

After placing the transducer perpendicular to the overlying skin at the center of supraspinatus muscle belly, the elastogram mode is activated. During the compression of supraspinatus muscle with transducer, the pressure indicator should mark over level 4 or higher, and it is meant to be a reliable image to obtain SR. The level of pressure indicator ranges from 1 to 6; Level 1 indicates to be the lowest and unreliable pressure and level 6 is the most highest and stable pressure.

The sonoelastography image is composed of 256 degrees color map. Softer tissue is expressed in red, harder tissue in blue. The yellow and green areas are defined as areas near hardness (or softness) deviated to red and blue, respectively. The SR of supraspinatus muscle was measured in the most blue area (the hardest area; the lowest elasticity) and the most red area (the softest area; the highest elasticity), respectively (Figure 2A and 2B).

(A)



(B)

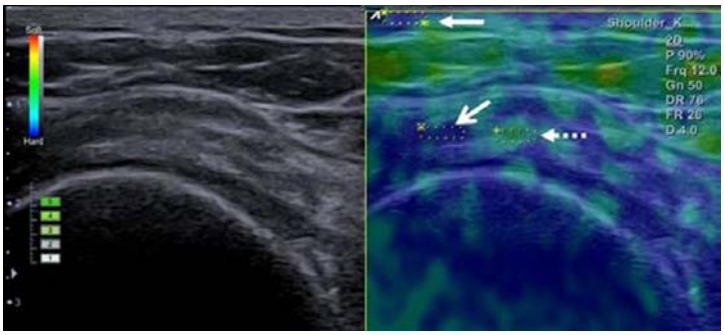


Figure 2. The measurement of strain ratio of supraspinatus muscle (2A) and supraspinatus tendon (2B). Left sided images were obtained from conventional B-mode and right sided images were obtained from elastogram mode. Closed arrow with solid line indicates the reference area (subcutaneous fat tissue), closed area with dotted line indicates the red area (softest area) and open arrow with solid line indicates the blue area (hardest area).

The subcutaneous fat tissue is selected as the reference for measuring the SR of supraspinatus muscle and tendon. The reference box which is rectangular is placed on the subcutaneous fat tissue at the sonoelastography image. The SR is calculated by dividing the strain of the target area (supraspinatus muscle and

tendon) by the strain of reference area (subcutaneous fat). After the measurement of the SR of supraspinatus muscle, the SR of supraspinatus tendon was measured in the same manner. To measure the SR of supraspinatus tendon, the participant is seated on a chair with modified Crass position. The examiner stands next to the participant and the transducer is located on short axis of supraspinatus tendon. When the supraspinatus tendon appears on the screen and the transducer is positioned properly, the location of transducer was marked with oil-based ink on the skin for further measurements during follow-ups.

Shoulder ROM

Active shoulder ROM for abduction (ABD), external rotation (ER) at 90° of abduction (ABER), internal rotation (IR) at 90° of abduction (ABIR) and horizontal adduction (HA) were measured with a bubble goniometer in supine position. In the previous study, measurements of shoulder ROM using goniometer showed considerable reliability. Fieseler et al. reported both of intraclass correlation coefficients and interrater correlation coefficients were more than 0.90.[6] Therefore, measurement of shoulder ROM using goniometer could be regarded as reliable.

Statistical analysis

Statistical analysis was performed in SPSS 22.0 (SPSS Inc., Chicago, IL). Serial changes of thickness of supraspinatus tendon and LHBT, the strain ratio of supraspinatus muscle-tendon, and shoulder ROM were analyzed by Wilcoxon signed rank test. $P < 0.05$ was considered to be statistically significant.

2.2. Results

Before pitching

The baseline values of parameters before pitching are summarized in Table 2. The thickness of supraspinatus tendon was mean 6.64 (range, 5.0 ~ 7.7) mm, and the thickness of LHBT was mean 2.56 (range, 2.1 ~ 3.3) mm. The SR of supraspinatus muscle in red area was mean 8.31 (range, 4.47 ~ 12.86), and mean 1.41 (range, 0.91 ~ 2.56) in blue area. The SR of supraspinatus tendon in red area was mean 6.10 (range, 1.31 ~ 9.26), and mean 1.02 (range, 0.25 ~ 1.73) in blue area. Regarding shoulder ROM, ABD was mean 175.3° (range, 165 ~ 180°), ABER was mean 119.7 (range, 105 ~ 135°), ABIR was mean 64.3 (range, 40 ~ 80°), and HA was mean 34.7° (range, 25 ~ 40°).

Table 2. Baseline values of the parameters before pitching

Variables	Mean (range)
Thickness (mm)	
[1]SSP tendon	6.64 (5.0−7.7)
[2]LHBT	2.56 (2.1−3.3)
Strain ratio	
SSP muscle ([3]red)	8.31 (4.47−12.86)
SSP muscle ([4]blue)	1.41 (0.91−2.56)
SSP tendon (red)	6.10 (1.31−9.26)
SSP tendon (blue)	1.02 (0.25−1.73)
Shoulder range of motion (°)	
Abduction	175.3 (165−180)
[5]ABER	119.7 (105−135)
[6]ABIR	64.3 (40−80)
Horizontal adduction	34.7 (25−40)

[1]SSP, supraspinatus; [2]LHBT. long head of biceps tendon; [3]red, red area or softest area at 256 degrees color map in sonoelastography; [4]blue, blue area or hardest area at 256 degrees color map in sonoelastography; [5]ABER, external rotation at 90° of abduction; [6]ABIR, internal rotation at 90° of abduction

Immediate changes after pitching

At the immediate period after pitching, the mean thickness of supraspinatus tendon decreased from 6.64 mm (range, 5.0−7.7 mm) to 6.27 mm (range, 5.3−7.2 mm) (p = 0.026), and that of LHBT was decreased from 2.56 mm (range, 2.1−33 mm) to 2.26 mm (range, 1.8−3.3 mm) (p = 0.021) (Figure 3). The SR of supraspinatus muscle was decreased, and that of supraspinatus tendon increased without reaching statistical significance. The SR of supraspinatus muscle in red portion was decreased from 8.31 (range, 4.47−12.86) to 7.15 (range, 4.17−9.89) (p = 0.145), and the SR of supraspinatus muscle in blue portion also decreased from 1.41 (range, 0.91−2.56) to 1.26 (range, 0.64 to 1.59) (p = 0.147). The SR of supraspinatus tendon in red portion was increased from 6.10 (range, 1.31−9.26) to 7.37 (range, 4.82−11.79) (p = 0.094), and the SR of supraspinatus tendon in blue portion also increased from 1.02 (range, 0.25−1.73) to 1.00 (range, 0.54 to 1.39) (p = 0.879). (Figure 4). For shoulder ROM, the ABER was significantly increased from 119.7° (range, 105−135°) to 127.3° (range, 115−140) (p = 0.001), and HA was significantly decreased from 34.7° (range, 25−40°) to 29.3° (range, 25−45°) after pitching (p = 0.023). ABD was decreased from 175.3° (range, 165−180°) to 174.7° (range, 160−180°) (p = 0.145) and ABIR was

decreased from 64.3° (range, 40-80°) to 59° (range, 50-70) (p = 0.142) (Figure 5).

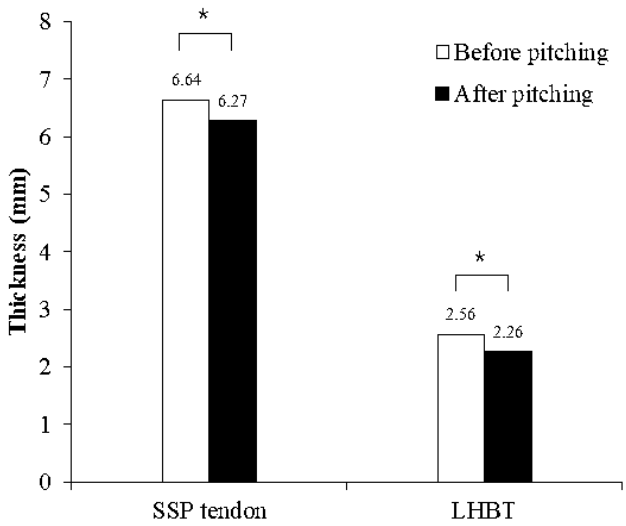


Figure 3. Immediate effect of pitching: changes of thickness of supraspinatus tendon and long head of biceps tendon at immediate after pitching; LHBT, long head o biceps tendon; SSP, supraspinatus, *p < 0.05

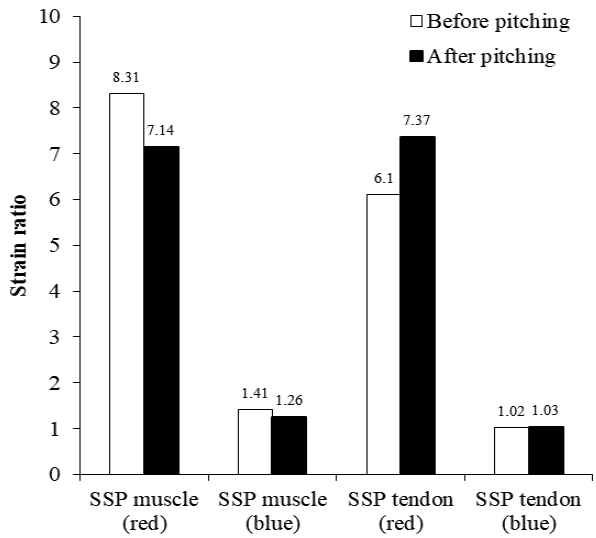


Figure 4. Immediate effect of pitching: changes of strain ratio of supraspinatus muscle and supraspinatus tendon after pitching; SSP, supraspinatus; [3]red, red area or softest area at 256 degrees color map in sonoelastography; [4]blue, blue area or hardest area at 256 degrees color map in sonoelastography

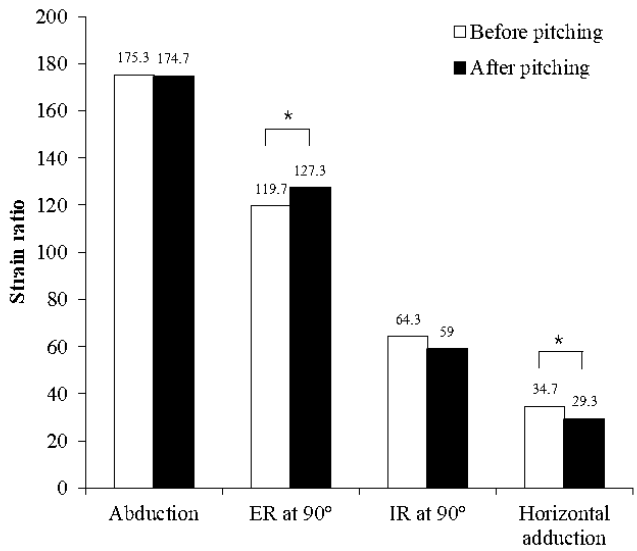


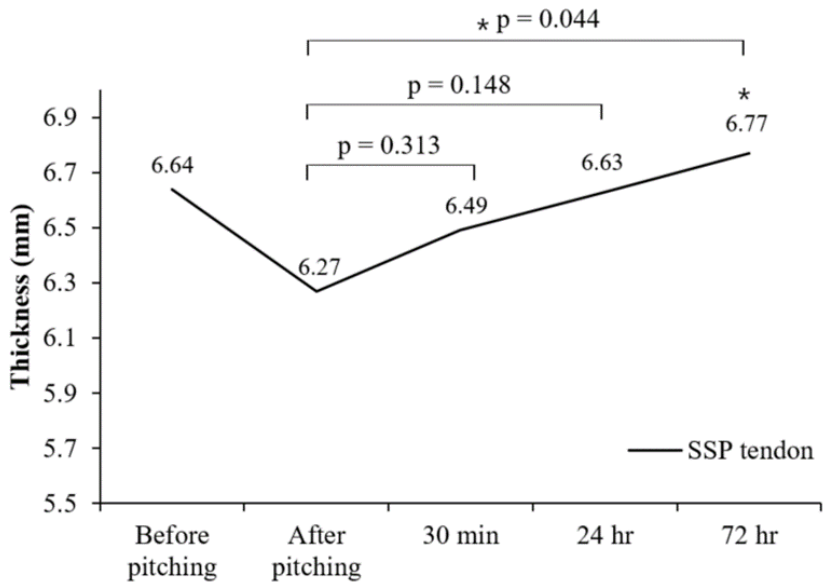
Figure 5. Immediate effect of pitching: changes of ROM; ABER, external rotation at 90° of abduction; ABIR, internal rotation at 90° of abduction (ABIR) *P < 0.05

Recovery after pitching over time (at 30 minutes, 24 hours and 72 hours after pitching)

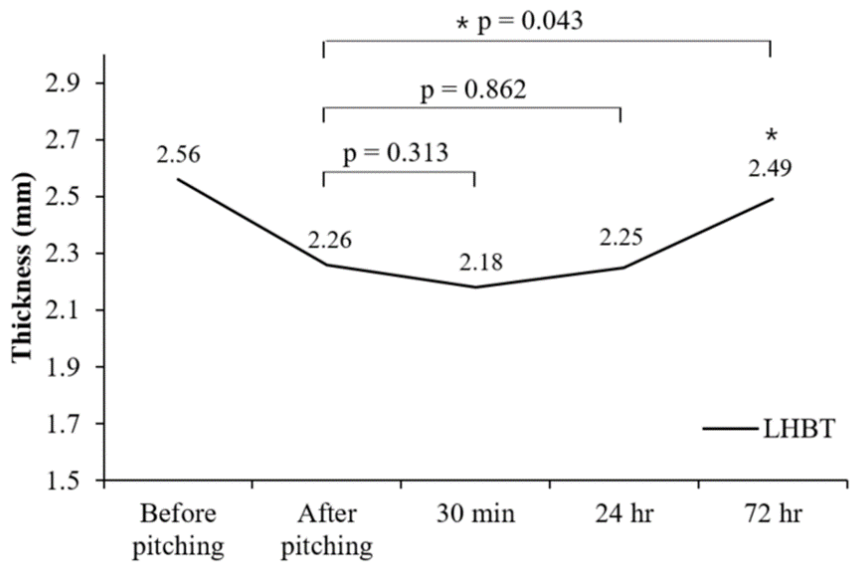
The mean thickness of supraspinatus tendon began to recover at 30 minutes after pitching (mean 6.49 mm (range, 5.2−7.7 mm), p = 0.313), and fully recovered at 72 hours after pitching (mean 6.77 mm (range, 5.5−7.8 mm), p = 0.044) (Figure 6A). The thickness of LHBT was kept decreasing at 30 minutes after pitching (mean 2.18 mm (range, 1.9−3.5 mm), p = 0.313), and turned into increase

at 24 hours after pitching (mean 2.25 mm (range, 1.8−3.5 mm), p = 0.862) to full recovery at 72 hours after pitching (mean 2.49 mm (range, 1.8 −2.8 mm), p = 0.043) (Figure 6B). The SR of red areas of supraspinatus muscle−tendon both were recovered at 72 hours, however those were not statistically significant changes compared to acute phase changes (muscle, p = 0.220; tendon, p = 0.167), further, the SR changes of supraspinatus muscle and tendon in red area over time tend to be in inverse relations each other (Figure 6C). The strain ratios of supraspinatus muscle and tendon in blue area were recovered at 72 hours after pitching however those changes were not statistically significant (muscle, p = 0.965; tendon, p = 0.955) as in the red area. (Figure 6D).

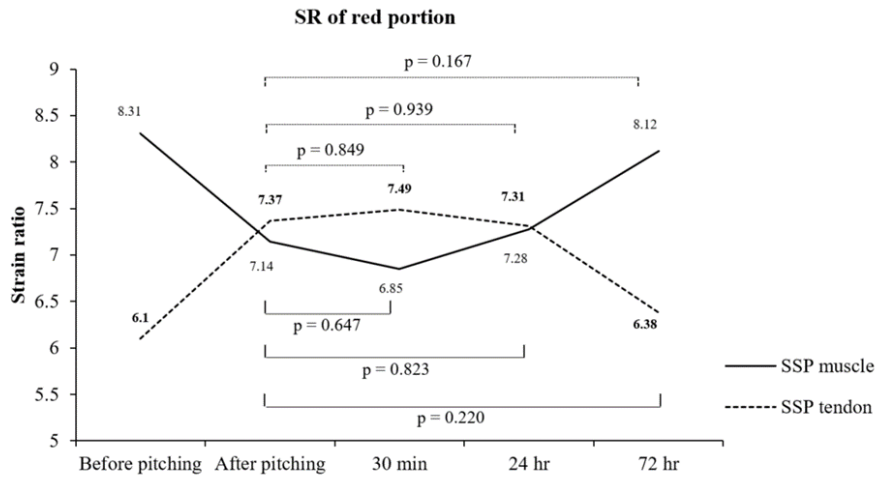
For the shoulder ROM, the increased ABER at immediate period after pitching (mean 127.3° (range, 115−140°)) was kept to be increased at 24 hours after pitching (mean 128.3° (range, 115−140°), p = 0.510) and recovered at 72 hours after pitching (mean 123.1° (115−140°), p=0.017), and the decreased HA at immediate period after pitching (mean 29.3° (range 20−45°)) was kept to be decreased at 24 hours after pitching (mean 28.7° (range, 50−70°), p= 0.849) and recovered at 72 hours after pitching (mean 33.3° (range, 25−35°), p=0.04) (Figure 6E, 6F).


* p = 0.044
p = 0.148
p = 0.313
*
6.77
6.64
6.63
6.49
6.27
Thickness (mm)
6.9
6.7
6.5
6.3
6.1
5.9
5.7
5.5
SSP tendon
Before pitching
After pitching
30 min
24 hr
72 hr

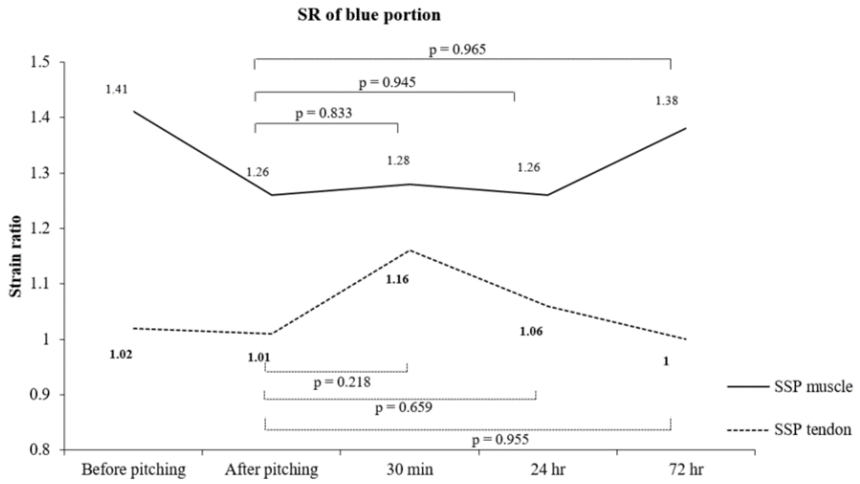
(A)


* p = 0.043
p = 0.862
p = 0.313
*
2.49
2.56
2.26
2.18
2.25
Thickness (mm)
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5
LHBT
Before pitching
After pitching
30 min
24 hr
72 hr

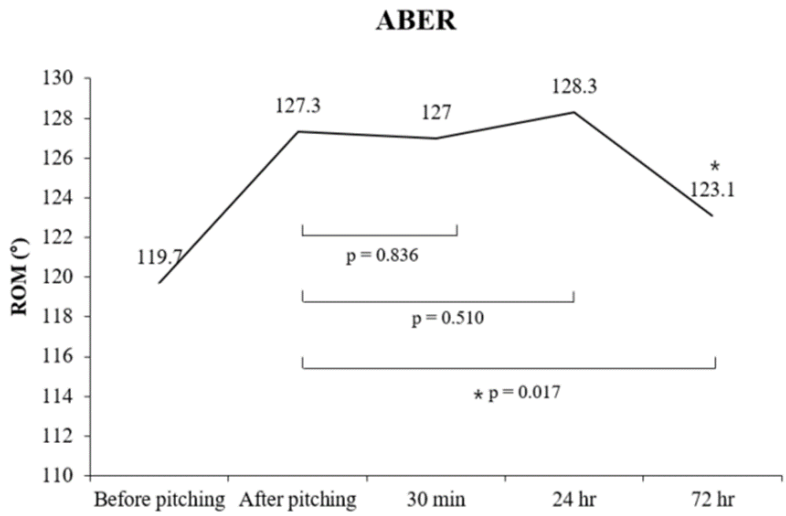
(B)


SR of red portion
Strain ratio
9
8.5
8
7.5
7
6.5
6
5.5
5
p = 0.167
p = 0.939
p = 0.849
p = 0.647
p = 0.823
p = 0.220
8.31
7.37
7.49
7.31
8.12
7.14
6.85
7.28
6.1
6.38
Before pitching
After pitching
30 min
24 hr
72 hr
SSP muscle
SSP tendon

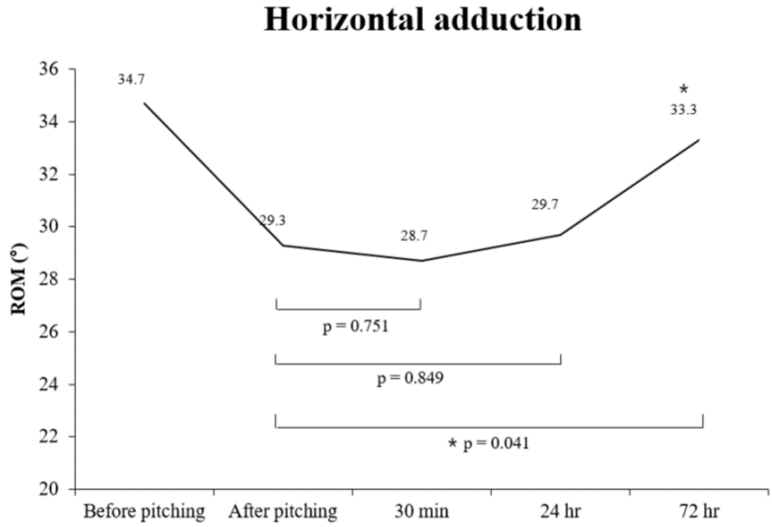
(C)


SR of blue portion
Strain ratio
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
p = 0.965
p = 0.945
p = 0.833
p = 0.218
p = 0.659
p = 0.955
1.41
1.38
1.26
1.28
1.26
1.16
1.06
1.02
1.01
1
Before pitching
After pitching
30 min
24 hr
72 hr
SSP muscle
SSP tendon

(D)



(E)



(F)

Figure 6. Recovery after pitching over time: thickness of supraspinatus (SSP) tendon (6A), thickness of long head of biceps tendon (LHBT) (6B), strain ratio (SR) of red area of supraspinatus muscle and tendon (6C), strain ratio of blue area of supraspinatus muscle and tendon (6D), external rotation at 90° of abduction(ABER), and internal rotation at 90° of

abduction (ABIR) (6E) and horizontal adduction (6F) ; LHBT, long head of biceps tendon ;SSP, supraspinatus; SR, strain ratio;,Before pitching, baseline status; After pitching, immediate after pitching; 30 min, 30 minutes after pitching; 24 hr, 24 hours after pitching; 72 hr; 72 hours after pitching

*$p<0.05$

2.3. Discussion

This study was conducted for two purposes: (1) to evaluate the immediate effect of pitching on supraspinatus muscle-tendon and LHBT, and shoulder ROM of youth baseball players using sonoelastography (2) to determine the time course for recovery of these changes due to pitching. To evaluate the immediate effect of pitching, we measured the thickness of supraspinatus tendon and LHBT, strain ratio of supraspinatus muscle-tendon, and shoulder ROM.

In current study, the thickness of supraspinatus and LHBT after pitching was significantly decreased in youth baseball players. In the line with the previous study of Oh et al. which observed the decrease of thickness of supraspinatus and LHBT after pitching in 10 professional baseball league pitchers[19]. In the previous study, those results were not statistically significant. However, in current study, we could observe that the thickness of supraspinatus tendon and LHBT at the immediate period after pitching were decreased compared to the those of baseline status in youth baseball players as well. Compared to the previous study of Oh et al., the baseline values (before pitching) were obtained at the same date of pitching in 15 youth baseball players which are apparent differences compared to the previous study[16] in which the baseline values of 10

subjects were obtained several weeks before pitching. Those differences could empower the results of negative impact of pitching on supraspinatus tendon and LHBT in the current study rather than previous one. Regarding the mechanisms of throwing, forceful contraction and traction are known to be applied on supraspinatus tendon and LHBT with repetition during pitching or throwing. [2, 12, 19, 29] Further, tensile stress on supraspinatus and LHBT is thought to be related to pull of LHBT during the cocking and/or deceleration phases of throwing [3-5,2] which is known to be contributable to the occurrence of rotator cuff disease and SLAP lesions in baseball players. The findings of acute decreases of thickness of supraspinatus tendon and LHBT after pitching in the current study might be the evidence of mechanisms of forceful contraction of supraspinatus muscle and forceful traction or tensile stress on LBHT during pitching or throwing.

Sonoelastography is the examination method which evaluates strain of tissue.[23] The strain is measured by sonoelastography using physical properties that increase the strain or elasticity in the softer soft tissue and decrease the elasticity in the harder soft tissue.[9, 19, 23] Generally, on musculoskeletal sonoelastography, muscle lesions tends to be hard and tendon lesions tend to be soft.[4] Sonoelastography is method of examining the elasticity of soft

tissues by applying pressure to the probe. In this way, the result may vary depending on the operator, and the degree of pressure applied to the probe.[17, 19] Therefore, we measured the strain ratio of soft tissue for comparative analysis.[19]

The SR of suprapinatus tendon tended to be increased after pitching. This means that elasticity or strain of the supraspinatus tendon increases after pitching which might be explained by tendinopathy known to be associated with considerable softening of intratendinous tissue.[4] Tendinopathy is usually caused by hypoxia, destruction of collagen fiber, and altered extracellular matrix. And by these mechanism, the SR increased in tendinous lesion. Meanwhile, the SR of supraspinatus muscle tended to be decreased after pitching according to the current study. This means that elasticity of the supraspinatus muscle increases after pitching. In muscle lesions, it is known that elasticity of muscle is usually decreased due to inflammation or myositis and muscle contraction.[14] The muscular contraction mechanism during pitching might have reduced the elasticity of supraspinatus muscle after pitching in this study. The results of SR decrease of supraspinatus muscle suggest that pitching also has a negative effect on the supraspinatus muscle and after-pitching management could be focused on softening of supraspinatus muscle. However, these changes of SR of

supraspinatus muscle and tendon were not statistically significant. There might be several reasons that those changes of SRs of supraspinatus muscle and tendon were not statistical significant; First, the number of participants in the current study was relatively small which might have possibility of underestimation of changes. Second, changes of SR of supraspinatus muscle and tendon after pitching may not be pathologic. One episode of pitching may have a negative effect on supraspinatus muscle and tendon, but the changes of SR would not be significant, because they were not permanent pathologic lesions of disease. Third, previously reported studies regarding SR was conducted in adult population, but the current study was conducted in youth populations and the SR in youth baseball players might reveal different characteristics because they are still in growth. Fourth, the methods of measuring SR using sonoeleastography were various and tend to be operator dependent.

ER at 90° abduction (ABER) was significantly increased, and horizontal adduction (HA) was significantly decreased at the immediate period after pitching. ABD tended to be decreased, and IR at 90° abduction (ABIR) tended to be decreased either. The baseball pitchers usually have a decreased internal rotation (IR) and increased external rotation (ER) at 90° abduction in throwing

arm.[27] There were several studies that have demonstrated simultaneous increase of ER and decrease of IR immediately after pitching in adult baseball pitchers.[11, 21] Kibler et al. examined shoulder ROM in professional pitchers before and 3 days after pitching[11] and they also observed increase of ER and decrease of IR, and those changes sustained up to 72 hours after pitching.[11, 21] Increased ER and decreased IR are known to be adaptive changes and might be advantageous in achieving an optimal shoulder position for energy storage and maximal ball speed generation.[11, 24] In line with previous studies, we could observe the similar changes of increasing ER and decreasing tendency of IR of shoulder joints at the immediate period after a single sessions of pitching which lasted till 24 hours after pitching in the current study. Interestingly, we observed the acute decrease of HA in the current study which was known to be correlated with posterior shoulder musculature contractures.

In current study, immediate changes of thickness and strain ratio were recovered to pre-pitch level 72 hours after pitching. Temporary reduction in the thickness of tendons is likely to be restored with enough rest, but persistent pitching without enough restoration may lead to irreversible changes in the tendons. And also, it was confirmed that the negative effect on SR of

supraspinatus muscle-tendon was reversible, and changes of SR is recovered by a sufficient rest. There has been no study regarding time-based recovery of thickness and strain ratio of shoulder muscle after pitching in youth baseball players. Every acute changes after pitching was recovered to the pre-pitching level at 72 hours after pitching in youth baseball players in current study. The results of recovery from immediate effect of pitching is in line with previous studies of Kibler et al., although the cohort of study is different and some of changes of shoulder ROM (IR and HA) were different. Katherine et al. reported that recovery from immediate effect of pitching regarding both increased ER and decreased IR can be promoted by sleeper stretch.[21] They insisted that daily sleeper stretch after pitching shortened the recovery period from 4 days to 2 days.[21] However, there have been no research regarding immediate effect pitching on shoulder ROM in youth baseball players. The rest time after pitching is limited to prevent injury of throwing arm of youth baseball players. However, there is a lack of research on comprehensive research on proper rest time after pitching in youth baseball players, and these guidelines are largely based on clinical experience. The results in currents study could be the evidence of duration of rest to prevent shoulder injury in youth baseball players. We might be cautious about the harms of

repetitive pitching without sufficient rest, which might cause the irreversible damage to shoulder joint structures or permanent adaptation of shoulder joint.

There are several limitations in this study. First, sample size of this study is relatively small which might bias the statistical results. Second, the baseline values as well as changes over time might be various according to the physical growth as well as the positions of subjects. Third, measurements using sonoelastography were performed only for the supraspinatus and LHBT, without evaluation of subscapularis and infraspinatus. Fourth, the measurements with less pitching count were not performed which might result in earlier recovery of acute changes less than 72 hours. Fifth, injury during pitching is not only related with shoulder muscle, but also spine, pelvis, and lower extremities. However, in current study, we evaluated only shoulder muscle. Therefore, to present a suitable rest time after pitching, further study is needed. Sixth, it is also a limitation that we did not make an evaluation of whether the subjects were sufficiently rested between the measurements. And, it would be better if the study was repeated several times to see whether the results were consistent.

However, this is the first study to evaluate the immediate effect of pitching by measuring the thickness of supraspinatus and LHBT, the

strain ratio of supraspinatus muscle and tendon using sonoelastography as well as ROM of shoulder joint of throwing arm, and to verify those recoveries over time in youth baseball players. In fact, this is the first study dealing with the recovery over time in youth baseball players.

Chapter 3. Conclusion

The immediate effect of pitching on supraspinatus muscle-tendon, LHBT, and shoulder ROM of youth baseball players was confirmed through the current data. These changes were recovered to pre-pitch level at 72 hours after pitching. Therefore, it is recommended to take enough rest until third day after pitching to prevent injuries of youth baseball players.

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국 문 초 록

배경: 야구 선수들은 유소년 시절부터 오랜 기간 동안 반복적인 투구로 인하여 회전근 개 및 상부 관절와순 전후 병변 등의 부상을 입을 가능성이 높다. 그러나, 투구가 유소년 야구 선수들의 극상근-건과 이두박건 장두에 미치는 영향을 분석한 연구, 그리고 투구 후 시간에 따른 극상근-건의 회복에 관한 연구는 부족하며, 따라서 경험적인 지도에 의해 휴식 시간이 결정된 것이 현실이다. 이에 유소년 야구 선수들에서 투구가 우세 견관절의 극상근 및 극상건, 이두박건 장두에 미치는 영향을 탄성초음파를 이용하여 알아보고, 투구 후 시간에 따른 회복 정도를 확인하고자 하였다.

대상 및 방법: 야구 학교에 등록된 15명의 유소년 야구 선수를 대상으로, 투구 전 그리고 전력으로 투구가 가능한 만큼 투구한 후(평균 78.3회), 우세 견관절의 극상근과 이두박건 장두의 두께 및 극상근-건의 탄성률(적색부, 부드러운 부위; 청색부, 단단한 부위)을 탄성 초음파(Alpinion Medical Systems, E-CUBE 15 EX)로 측정하였다. 투구가 극상근-건 및 이두박건 장두에 미치는 영향을 알아보기 위해 투구 직전 및 직후에 결과를 측정하였고, 시간에 따른 회복을 확인하기 위해 투구 30분 후, 투구 24시간 후, 72시간 후에 각각 검사하였다. 견관절 관절범위도 각 시점에 측정하여 그 변화를 비교하였다.

결과: 투구 전후 극상건의 두께는 6.64mm에서 6.27mm로 감소하였고 ($p = 0.026$), 이두박건 장두의 두께 역시 2.56mm에서 2.26mm로 투구 후 유의하게 감소하였다($p = 0.021$). 극상근의 탄성률은 투구 후 감소하였고, 극상건의 탄성률은 투구 후 증가하였으나 탄성률의 변화는 통계적으로 유의하지 않았다. 투구 전후 외회전은 119.7° 에서 127.3° 로

증가하였고(p = 0.001), 수평 내전은 34.7° 에서 29.3° 로 투구 후 유의하게 감소하였다(p = 0.023). 투구 후 시간에 따른 회복 정도는, 극상건과 이두박건의 두께는 투구 후 30분 및 24 시간째에는 투구 전 수준으로 회복되지 않았으나, 투구 72시간째 투구 전 수준으로 유의하게 회복되었다(극상건 p = 0.04; 이두박건 p = 0.04). 극상근-건의 탄성률 변화도 투구 후 72시간 째에 투구 전 수준으로 회복되는 양상을 보였으나 통계적으로 유의하지 않았다. 외회전과 수평 내전 역시 투구 후 30분 및 24 시간째에는 투구 전 수준으로 회복되지 않았으나, 투구 72시간 째 투구 전 수준으로 유의하게 회복되었다(외회전 p = 0.017; 수평 내전 p = 0.041).

결론: 투구 후 유소년 야구 선수들에서의 극상건과 이두박건 장두의 두께 감소, 극상근-건 탄성률의 증감, 관절 범위의 변화를 탄성 초음파 등으로 측정할 수 있었고, 투구로 인한 의미있는 변화가 투구 후 72시간은 지나야 투구 전 수준으로 회복되는 것을 확인할 수 있었다. 따라서 유소년 야구 선수들의 부상 예방을 위해, 투구 후 3일째까지는 충분한 휴식을 취하는 것이 좋을 것으로 판단된다.

색인 단어: 야구, 투구, 극상근, 변형률, 탄성초음파, 회복

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