Original Article
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Immediate Changes and Recovery of the Supraspinatus, Long Head Biceps Tendon, and Range of Motion after Pitching in Youth Baseball Players: How Much Rest Is Needed after Pitching? Sonoelastography on the Supraspinatus Muscle-Tendon and Biceps Long Head Tendon

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Background: Baseball players are subjected to repeated loads on the supraspinatus and long head biceps tendon from youth, and repetitive pitching motions can cause shoulder injuries. The purpose of this study was to evaluate the immediate changes caused by pitching in the supraspinatus muscle-tendon, long head of the bicep tendon (LHBT), and shoulder range of motion (ROM) and to verify their recovery over time in youth baseball players.

Methods: Fifteen youth baseball players (mean age, 11.5 ± 1.3 years) were enrolled. The thicknesses of the supraspinatus tendon and LHBT and the strain ratios (SRs) of supraspinatus muscle and tendon were measured by sonoelastography. ROMs of shoulder joints (abduction, external rotation at 90° of abduction [ABER], and internal rotations at 90° of abduction [ABIR]) and horizontal adduction (HA) were measured using a goniometer. All measurements were performed on the throwing shoulders before and immediately after pitching (mean pitch count, 78.3 ± 13.3) and at 30 minutes, 24 hours, and 72 hours after pitching.

Results: The thickness of supraspinatus tendon (6.64–6.27 mm, $p = 0.026$) and that of LHBT (2.56–2.26 mm, $p = 0.021$) significantly decreased immediately after pitching. The SRs of supraspinatus muscle tended to decrease, whereas SRs of supraspinatus tendon tended to increase immediately after pitching. ABER increased (119.7°–127.3°, $p = 0.001$) and HA decreased (34.7°–29.3°, $p = 0.023$) immediately after pitching. All immediate changes recovered 72 hours after pitching.

Conclusions: The immediate effects of pitching on the supraspinatus muscle-tendon, LHBT, and shoulder ROM in youth baseball players were confirmed in the current study. These changes were recovered to pre-pitch levels 72 hours after pitching. Therefore, we recommend that youth baseball players should rest for three days after pitching to minimize the risk of shoulder injury.

Keywords: *Baseball, Supraspinatus, Elasticity, Recovery, Rest*

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Repetitive pitching is known to damage structures in the shoulder joint, such as the rotator cuff tendon, the long head of the bicep tendon (LHBT), and the labrum.[1-3] Many baseball players experience injuries, such as rotator cuff tears and superior labral anterior to posterior (SLAP) lesions due to repetitive pitching. These types of shoulder injuries are not limited to adult players and are also frequently observed in youth baseball players.[1,2,4,5] Furthermore, it has been reported that about 20% of youth baseball players experience shoulder pain during a single baseball season[4-6] and that the risk of shoulder injuries among youth baseball players is increasing.[4,7]

Risk factors for shoulder injuries and diseases are not fully understood.[6] The shoulder joints of baseball players are subjected to repeated loads due to throwing baseballs from youth.[8] Baseball pitching creates tremendous forces on the glenohumeral joint and adjacent structures[9] and causes changes to the rotator cuff and LHBT.[1-3] Some studies have reported rotator cuff tendon and LHBT complex injuries in shoulder joints caused by repetitive throwing. However, research on immediate changes to shoulder muscles and tendons due to pitching is limited. Several studies have investigated the immediate effects of pitching on the supraspinatus muscle and LHBT in adult baseball players,[2,10,11] but no similar study has evaluated these effects in young baseball players. As was previously suggested, because shoulder injuries in baseball players begin from youth, research is needed on the immediate effects of pitching on the shoulder structures of young players.[4,7]

One study confirmed the long-term effects of pitching on the thicknesses of the supraspinatus and LHBT.[2] In this study, the thickness of the supraspinatus tendon and LHBT tended to decrease after pitching. Forceful contraction and traction may cause thinning of tendons. These results suggest that the thickness of supraspinatus tendon and LHBT might be a parameter of the immediate effect of pitching.

To date, one study has assessed the supraspinatus muscle-tendon, as well as long head biceps tendon, using sonoelastography after pitching in professional baseball pitchers.[2] The measurement of strain assesses the quality and condition of the human tissue.[12] Sonoelastography is an examination method, which evaluates strain or elasticity of tissue.[13] Tissue strain induced by compression can be measured by sonoelastography.[14] The principle of sonoelastography is that tissue compression produces strain (displacement) within the tissue, which is more pronounced in softer tissue than in harder tissue. Therefore, the strain is measured greater in softer tissue and lesser in harder tissue.[2,13,14] As muscle lesions usually become harder due to muscle contraction and tendon lesions become softer due to intratendinous softening, strain increases in tendon lesions and decreases in muscle lesion when measured by musculoskeletal sonoelastography.[15] In addition to the studies using sonoelastography for the diagnosis of musculoskeletal diseases,[15-17] sonoelastography has been used in several studies on the rotator cuff and LHBT.[2,12,18,19]

Baseball pitchers have a characteristic range of motion (ROM) of their shoulder joints, which is important for understanding the pitcher's shoulder.[20] In general, throwing shoulders exhibited a decrease in internal rotation (IR) and an increase in external rotation (ER) at 90° of abduction (ABD), and these changes are associated with glenohumeral IR deficits and throwing arm injuries.[10] Extremely repetitive forces on the throwing shoulder during pitching cause structural remodeling to the shoulder joint structures and may be responsible for unique shoulder ROMs in baseball players.[21] The osseous structural changes, such as greater humeral retroversion, begin in youth.[22] However, the immediate effects of pitching on the shoulder ROM in youth baseball players have not been determined.[21] Furthermore, limited research has been conducted on the recovery of the shoulder ROM or on changes of the muscle-tendon over time in youth baseball players.

Several studies have been conducted on the immediate effects of pitching on shoulder ROM in adult baseball players. Kibler et al.[23] measured shoulder ROMs before and 72 hours after pitching[23] and reported that ER had recovered 72 hours after pitching. However, no study has addressed the immediate effects of pitching on shoulder ROMs in youth baseball players, and there is a lack of comprehensive research on the proper rest time needed by youth players for safer pitching. Present guidelines are largely based on clinical experience.

Therefore, the purpose of this study was to evaluate the immediate changes caused by pitching on the supraspinatus muscle-tendon and LHBT, and shoulder ROM and to verify their recovery over time in youth baseball players.

METHODS

Participants

This study included 15 healthy, male youth baseball players who were registered at The Baseball Academy in South Korea. We conducted this study in compliance with the principles of the Declaration of Helsinki. The protocol of this study was approved by the Institutional Review Board of Myongji Hospital (IRB No. 2018-11-010), and written informed consents were obtained from all guardians. The subjects had no history of injuries or present pain in their throwing arms at the time of measurements. All subjects were right-handed overhead throwers. The mean subject age was 11.5 ± 1.3 years and mean time spent playing baseball at a competitive level (career) was 3.4 ± 1.7 years. All subjects were year-round players. Other demographic characteristics are summarized in Table 1.

Parameters and Time of Measurements

The parameters measured in this study were (1) the thickness of the supraspinatus tendon and LHBT, (2) strain ratio (SR) of supraspinatus muscle and tendon, and (3) shoulder ROM. Measurements were performed before pitching, immediately after pitching, and 30 minutes, 24 hours, and 72 hours after pitching. All participants had a minimum of 3-day rest before scheduled pitching days. During this 3-day rest period and the 3-day measurement period, participants were instructed not to perform any throwing or batting training. Furthermore, participants did not undergo any post-pitching treatments such as extracorporeal shockwave therapy (ESWT), massage, or icing. Two orthopedic fellows (JHY and KPN), each with 8 years of experience as orthopedic surgeons and 2 years of sonoelastography of the shoulder joint, conducted all measurements jointly. One fellow measured all outcomes during the entire study period and the other fellow simultaneously checked whether measurements had been made correctly. Outcomes were recorded only when the two fellows agreed on the measurements taken.

Table 1. Baseline Demographic Characteristics of Participants

Variable	Mean ± SD
Age (yr)	11.5 ± 1.3
Height (cm)	152.9 ± 12.5
Weight (kg)	52.2 ± 16.0
BMI (kg/m^2)	21.8 ± 3.5
Career (yr)	3.4 ± 1.7

SD: standard deviation, BMI: body mass index.

Pitching

The participants threw as many fastballs as possible at maximum effort at a pitching distance of 14 m. At least 10 seconds of rest was allowed between each pitch. The pitching continued until the participants felt fatigue or soreness in their throwing arms. The number of pitches was limited to a maximum of 100. The mean pitching count was 78.3 ± 13.3.

Measurements

Thickness of supraspinatus tendon and LHBT

The thickness of supraspinatus tendon and LHBT were measured using a 3.13 Hz linear transducer in conventional B-mode.[2] Participants were first seated on a chair without a backrest in the modified Crass position while the thickness of supraspinatus tendon was measured. The thickness of supraspinatus tendon (yellow dashed line in Fig. 1A) was measured between the superior facet of the greater tuberosity of the humerus and the highest curvature of the supraspinatus tendon on a transverse scan (Fig. 1A). We first moved the probe to locate the thickest portion of the supraspinatus tendon, and when the two fellows agreed, the screen was captured and the thickness of supraspinatus tendon was measured. Since the surface location at which the tendon is measured the thickest is subtly different each time, the thickest part was found again each time of measurement. Outcomes were recorded only when the two fellows agreed. After measurement of supraspinatus tendon, the thickness of LHBT was measured at the point of greatest thickness (yellow dashed line in Fig. 1B) at the bicipital groove in longitudinal scan with the participant's pitching arm at his side (Fig. 1B).

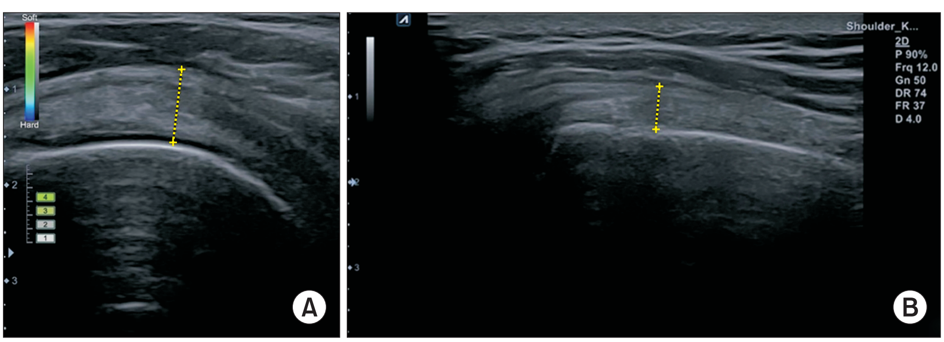

Fig. 1. Measurement of the thickness of supraspinatus tendon (A) and long head of biceps tendon (B). The yellow dotted line indicates the thickness.

SR of supraspinatus muscle-tendon

The SRs of supraspinatus muscle-tendon were measured by sonoelastography (E-cube 15EX; Alpinion Medical System, Seoul, Korea). To measure the supraspinatus muscle SR, the participant was seated on a chair without a backrest with his throwing arm placed on the anterior aspect of his ipsilateral thigh.[2,12,18] The examiner stood behind the participant, approached the posterior shoulder, and located the transducer in B-mode parallel at the middle of supraspinatus muscle belly at one fingerbreadth above the scapular spine. When the trapezius and supraspinatus muscles appeared on the screen, the measurement position was achieved and the transducer location was marked on the skin with an oil-based ink for follow-up measurements. After placing the transducer perpendicular to the overlying skin at the center of the supraspinatus muscle belly, elastogram mode was activated. During compression of the supraspinatus muscle by the transducer, a pressure indicator level of 4 or higher was used to obtain a reliable SR image. Pressure indicator levels ranged from 1 to 6, where level 1 indicates the lowest and most unreliable pressure and level 6 the highest and most stable pressure.

The sonoelastography image is composed of a 256° color map. Softer tissue is represented in red and harder tissue in blue. The SR of supraspinatus muscle was measured in the bluest area (the hardest area with the lowest elasticity) and the reddest area (the softest area with the highest elasticity) (Fig. 2). Subcutaneous fat tissue was selected as the reference for SR measurements of supraspinatus muscle and tendon, and a rectangular reference box was placed on the subcutaneous tissue in sonoelastography images. SR was defined as the strain of the target area (supraspinatus muscle and tendon) divided by strain of the reference area (subcutaneous fat). Once the target and reference areas had been selected, SR values were automatically calculated by software in sonoelastography; the monitor displayed SR values. After measuring the SR of the supraspinatus muscle, the SR of supraspinatus tendon was measured in the same manner. To measure the SR of supraspinatus tendon, the participant was seated on a chair in the modified Crass position. The examiner stood next to the participant and located the transducer on the short axis of the supraspinatus tendon. When the supraspinatus tendon appeared on the screen and the transducer was positioned properly, its location was marked on the skin with an oil-based ink for use during follow-up measurements.

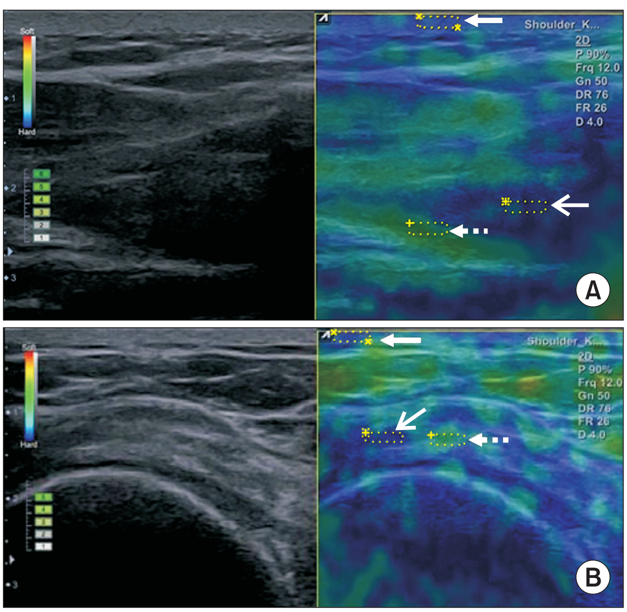

Fig. 2. Measurement of the strain ratio of the supraspinatus muscle (A) and the supraspinatus tendon (B). Left-side images were obtained from conventional B-mode, and right-side images were obtained from the elastogram mode. Closed arrows with solid lines indicate the reference area (subcutaneous fat tissue), closed areas with dotted lines indicate the red area (softest area), and open arrows with solid lines indicate the blue area (hardest area).

Shoulder ROM

The active shoulder ROMs for ABD, ER at 90° of abduction (ABER), IR at 90° of abduction (ABIR), and horizontal adduction (HA) were measured.

Statistical Analysis

Statistical analyses were performed using SPSS ver. 22.0 (SPSS Inc., Chicago, IL, USA). Serial changes in the thicknesses of supraspinatus tendon and LHBT, SRs of supraspinatus muscle-tendon, and shoulder ROMs were analyzed using the Wilcoxon signed-rank test. A $p < 0.05$ was considered to be statistically significant.

RESULTS

Before Pitching

Baseline values of parameters before pitching are summarized in Table 2.

Immediate Changes after Pitching

Immediately 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 decreased from 2.56 mm (range, 2.1–33 mm) to 2.26 mm (range, 1.8–3.3 mm) (p = 0.021) (Fig. 3). The mean SR of supraspinatus muscle decreased and that of the supraspinatus tendon increased but without reach-

Table 2. Baseline Parameters before Pitching

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

SSP: supraspinatus, LHBT: long head of the bicep tendon, red: red area (softest area) in sonoelastography, blue: blue area (hardest area) in sonoelastography, ABER: external rotation at 90° of abduction, ABIR: internal rotation at 90° of abduction.

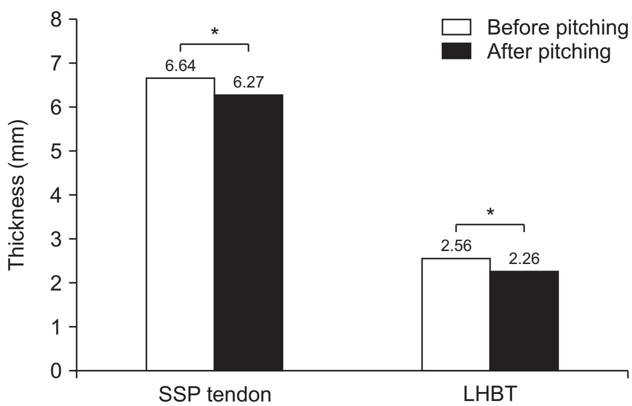

Fig. 3. Immediate effect of pitching: changes in the thickness of the supraspinatus (SSP) tendon and long head of the bicep tendon (LHBT) immediately after pitching. *$p < 0.05$.

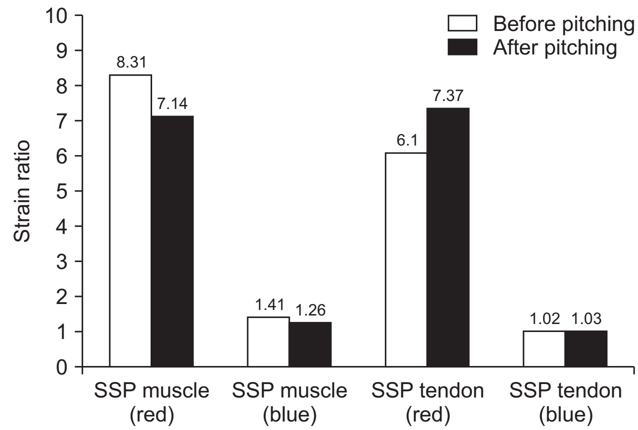

Fig. 4. Immediate effect of pitching: changes in the strain ratio of the supraspinatus (SSP) muscle and tendon. red: red area in sonoelastography, blue: blue area in sonoelastography.

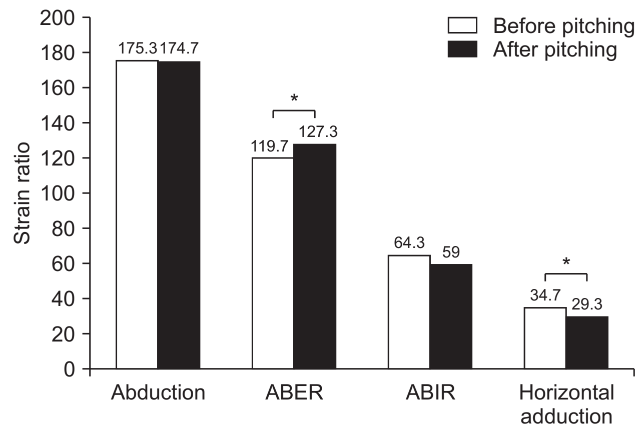

Fig. 5. Immediate effect of pitching: changes in range of motion. ABER: external rotation at 90° of abduction, ABIR: internal rotation at 90° of abduction. *$p < 0.05$.

ing statistical significance. The SR of supraspinatus muscle in the red area 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 the blue area also decreased from 1.41 (range, 0.91–2.56) to 1.26 (range, 0.64–1.59) (p = 0.147). The SR of supraspinatus tendon in the red area 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 the blue area also increased from 1.02 (range, 0.25–1.73) to 1.03 (range, 0.54–1.39) (p = 0.879) (Fig. 4). Regarding shoulder ROM measurements, ABER significantly increased from 119.7° (range, 105°–135°) to 127.3° (range, 115°–140°) (p = 0.001), and HA significantly decreased from 34.7° (range, 25–40°) to 29.3° (range, 25–45°) (p = 0.023). ABD decreased from 175.3° (range, 165°–180°) to 174.7° (range, 160°–180°, p = 0.145), and ABIR decreased from 64.3° (range, 40°–80°) to 59° (range, 50°–70°) (p = 0.142) (Fig. 5).

Recovery after Pitching over Time (at 30 Minutes, 24 Hours, and 72 Hours after Pitching)

The mean thickness of supraspinatus tendon began to recover 30 minutes after pitching (mean, 6.49 mm; range, 5.2–7.7 mm; p = 0.313), increased at 24 hours (mean, 6.63 mm; range, 5.0–8.0 mm; p = 0.148), and fully recovered at

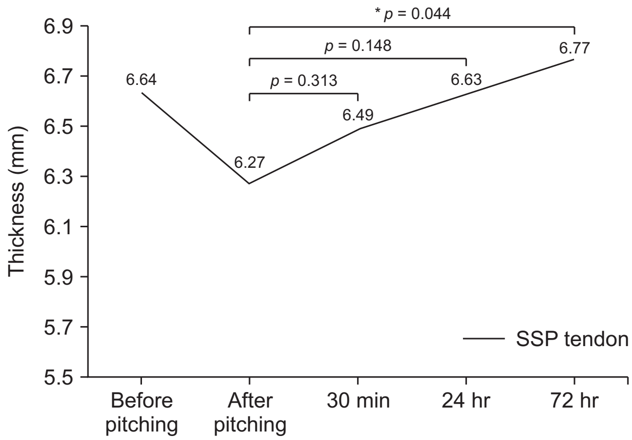

Fig. 6. Recovery after pitching over time: thickness of the supraspinatus (SSP) tendon. *$p < 0.05$.

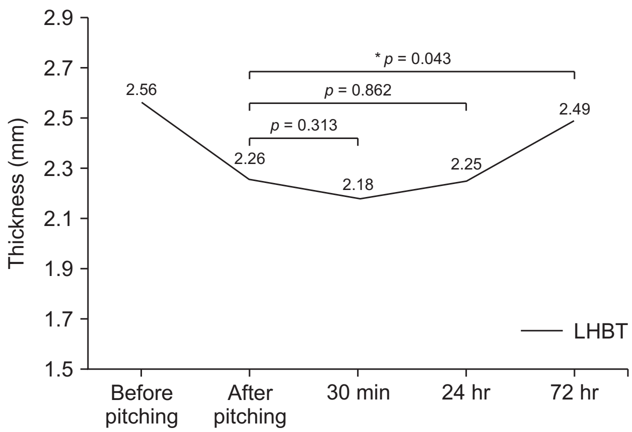

Fig. 7. Recovery after pitching over time: thickness of the long head biceps tendon (LHBT). *$p < 0.05$.

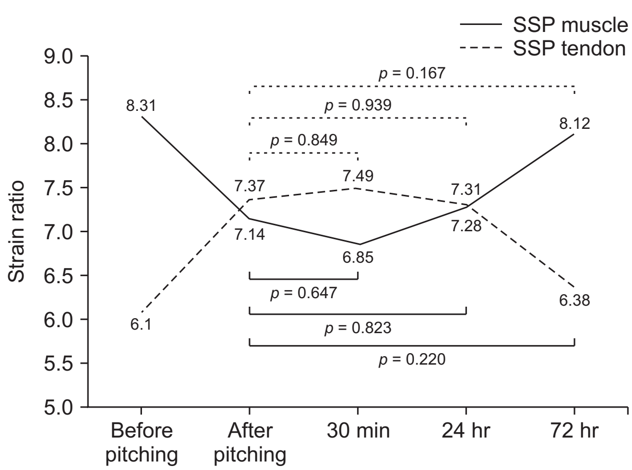

Fig. 8. Recovery after pitching over time: strain ratio of the red areas of the supraspinatus (SSP) muscle and tendon. Red area: red area in sonoelastography.

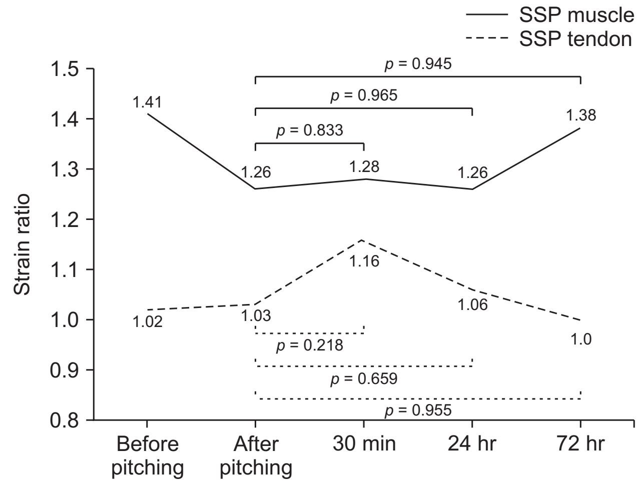

Fig. 9. Recovery after pitching over time: strain ratio of the blue areas of the supraspinatus (SSP) muscle and tendon. Blue area: blue area in sonoelastography.

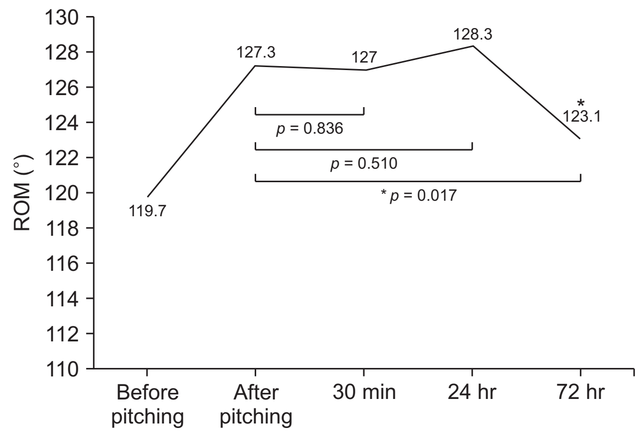

Fig. 10. Recovery after pitching over time: external rotation at 90° of abduction. ROM: range of motion. *$p < 0.05$.

72 hours (mean, 6.77 mm; range, 5.5–7.8 mm; $p = 0.044$) (Fig. 6). The thickness of the LHBT decreased 30 minutes after pitching (mean, 2.18 mm; range, 1.9–3.5 mm; $p = 0.313$), increased at 24 hours (mean, 2.25 mm; range, 1.8–3.5 mm; $p = 0.862$), and fully recovered at 72 hours (mean, 2.49 mm; range, 1.8–2.8 mm; $p = 0.043$) (Fig. 7). SRs of red areas of the supraspinatus muscle-tendon recovered at 72 hours after pitching, but changes were not statistically significant (muscle, $p = 0.220$; tendon, $p = 0.167$). SR changes of the supraspinatus muscle and tendon in red areas over time tended to be inversely related (Fig. 8). SRs of supraspinatus muscle and tendon in blue areas recovered at 72 hours, but changes were not statistically significant (muscle, $p = 0.965$; tendon, $p = 0.955$) (Fig. 9).

For shoulder ROMs, ABERs increased immediately after pitching (mean, 127.3°; range, 115°–140°) and increased further at 24 hours (mean, 128.3°; range, 115°–140°, $p = 0.510$), but recovered at 72 hours (mean, 123.1°; range, 115°–140°, $p = 0.017$) (Fig. 10). HAs decreased immediately after pitching (mean, 29.3°; range, 20°–45°), decreased further at 24 hours (mean, 28.7°; range, 50°–70°; $p = 0.849$), but also recovered at 72 hours (mean, 33.3°; range, 25°–35°; $p = 0.04$) (Fig. 11). Mean ABD values were 174.7° (range, 160°–180°) immediately after pitching, 174.3° (range, 165°–180°) at 30 minutes, 175.0° (range, 165°–180°) at 24 hours, and 173.3° (range, 165°–180°) at 72 hours. No significant ABD change was observed between time points ($p = 0.806$, $p = 0.792$, and $p = 0.262$, respectively). Mean ABIR values were 59.0° (range, 50°–70°) immediately after pitching, 62.3° (range, 50°–80°) at 30 minutes, 60.3° (range, 50°–70°) at 24 hours, and 63.3° (range, 45°–80°) at 72 hours. Like ABD changes, ABIR changes between time points were not significant ($p = 0.173$, $p = 0.512$, and $p = 0.144$, respectively).

DISCUSSION

This study was conducted for two purposes: (1) to evaluate the immediate changes caused by pitching in the supraspinatus muscle-tendon, LHBT, and shoulder ROM and (2) to verify their recovery over time in youth baseball players. To evaluate the immediate changes, we measured the thickness of supraspinatus tendon and LHBT, the SR of supraspinatus muscle-tendon, and shoulder ROM.

In the current study, the thickness of supraspinatus and LHBT after pitching were significantly decreased in youth baseball players. These results agree with those of a previous study by Oh et al.[2], who observed a decrease in the thickness of supraspinatus and LHBT after pitching in professional baseball league pitchers. These results could explain the negative impact of pitching on the supraspinatus tendon and the LHBT. Regarding the mechanisms of throwing, forceful contraction and traction are known to be applied to the supraspinatus tendon and the LHBT with repetition during pitching or throwing.[1-3,24] Furthermore, tensile stresses in the supraspinatus and LHBT are thought to be related to pull on the LHBT that occurs during the cocking and/or deceleration phases of throwing,[3-5,24] which are known to contribute to rotator cuff disease and SLAP lesions in baseball players. Findings of acute decreases in the thicknesses of supraspinatus tendon and LHBT in the current study might be explained by forceful contraction of the supraspinatus muscle and forceful traction or tensile stress on the LBHT during pitching.

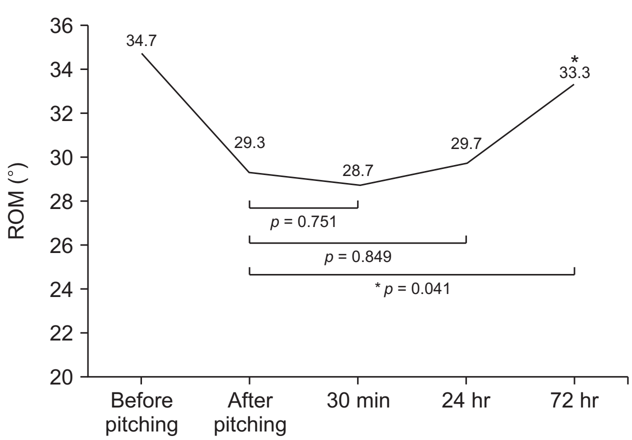

Fig. 11. Recovery after pitching over time: horizontal adduction. ROM: range of motion. *$p < 0.05$.

Sonoelastography is the examination method used to evaluate tissue strain.[13] The strain is measured by sonoelastography, which uses physical properties that the strain or elasticity increases in the softer tissue and decreases in the harder tissue.[2,13,14] Generally, muscle lesions tend to be hard and tendon lesions tend to be soft. Sonoelastography examines the elasticity of soft tissues by applying pressure to a probe. Because of this, the results may vary depending on the operator and the degree of pressure applied to the probe.[2,25] Therefore, in the current study, we measured SRs of soft tissue for comparative analysis.[2]

In the current study, we measured the immediate effect of pitching on SRs of supraspinatus muscle and tendon, but differences were not statistically significant. The SR of supraspinatus tendon tended to increase immediately after pitching. This means that the elasticity of supraspinatus tendon increased after pitching. And this might be explained by the fact that tendinopathy is associated with considerable softening of the intratendinous tissue.[15] Tendinopathy is usually caused by hypoxia, collagen fiber destruction, and extracellular matrix alterations. On the other hand, SR of supraspinatus muscle tended to decrease immediately after pitching in the current study. This means that the elasticity of the supraspinatus muscle increased after pitching. In muscle lesions, muscle elasticity usually decreased due to inflammation, myositis, and muscle contractions.[17] The muscular contraction during pitching might have reduced supraspinatus muscle elasticity after pitching. The reductions in SR observed in supraspinatus muscle suggest that pitching had a negative effect and that after-pitching management should focus on softening of the supraspinatus muscle. However, these changes in the SR of supraspinatus muscle and tendon were not statistically significant. There might be several reasons why the changes in the SRs of supraspinatus muscle and tendon were not statistically significant. First, the number of participants in the current study was relatively small, which might have underestimated the changes. Second, changes in the SR of supraspinatus muscle and tendon after pitching may not be pathologic. One episode of pitching may have a negative effect on the supraspinatus muscle and tendon, but the changes in the SR might not be significant because there were no permanent pathologic disease lesions. Third, previously reported studies regarding SRs were conducted in adult populations, but the current study was conducted in youth pitchers, who might exhibit different characteristics. Fourth, various methods for measuring SR using sonoelastography has been reported previously and they seem to be operator dependent. No standardized method is established. In the current study, we measured the SR at the reddest area and bluest area, as we described in a previous study.[2] Our technique has a potential limitation because the reddest area and bluest area change according to the location of a probe. We thought that pitching negatively affects more on the weakest or pathologic portion. The weakest portion of the supraspinatus tendon or muscle might be the bluest or reddest portion. This is why we chose to measure at the reddest and bluest portion. To reduce measurement bias, one fellow measured all outcomes during the whole study period and the other fellow simultaneously checked whether the measurements were made correctly. Outcomes were recorded only when the two fellows agreed on the measurements taken.

ABER was significantly increased, and the HA was significantly decreased immediately after pitching. The ABD tended to decrease, and the ABIR also tended to decrease. Baseball pitchers usually have a decreased IR and an increased ER at 90° ABD in their throwing arm.[10] Several studies have reported increases in ER and decreases in IR immediately after pitching in adult baseball pitchers.[23,26] Kibler et al.[23] examined the shoulder ROMs in professional pitchers before and 3 days after pitching and also observed an increase in ER and a decrease in IR, and those changes were sustained up to 72 hours after pitching.[23,26] Increased ERs and decreased IRs are known to be adaptive changes and might be advantageous in achieving a shoulder position optimal for energy storage and maximal ball speed generation.[9,23] In line with previous studies, we observed similar changes, which were an increased ER and a decreased tendency of IR of the shoulder joints, immediately after pitching. Interestingly, we also observed an immediate decrease of HA in the current study, which is known to be correlated with posterior shoulder musculature contractures.

In the current study, immediate changes in the thickness and SR recovered to pre-pitch levels at 72 hours after pitching. A temporary reduction in the thickness of tendons is likely to be restored with enough rest, but persistent pitching without enough restorative rest may lead to irreversible changes in the tendons. However, we observed the negative effect of pitching on supraspinatus muscle-tendon SR was reversible, which showed SR changes can be reversed by sufficient rest. There has been no study on the time-based recovery of the thickness and SR of the shoulder muscle after pitching in youth baseball players. In the current study, all immediate changes after pitching recovered to pre-pitching levels at 72 hours. The recovery from the immediate effects of pitching is consistent with that in a previous study by Kibler et al.[23], although cohorts and some of changes in shoulder ROMs (IR and HA) differed. Reuther et al.[26] reported that recovery of increased ER and decreased IR from the immediate effects of pitching were promoted by sleeper stretch. The authors[26] reported that a daily sleeper stretch after pitching shortened the recovery period from 4 to 2 days. However, no research has been conducted on the immediate effect of pitching on shoulder ROMs in youth baseball players. Currently, some rest time is recommended after pitching to prevent throwing arm injury in youth baseball players. However, there is a lack of comprehensive research on the adequate rest time for youth baseball players, and current guidelines are largely based on clinical experience. The results of the current study provide some evidence regarding the amount of rest required to prevent shoulder injury in youth baseball players. We stress that the awareness of the potential harm of repetitive pitching without sufficient rest as irreversible damage to shoulder joint structures and permanent adaptation of the shoulder joint is important in terms of preventing injury.

The current study has several limitations that require consideration. First, the sample size was relatively small and this may have introduced bias. Second, baseline values and changes over time might be dependent on physical growth and playing position. Third, sonoelastographic measurements were performed only for the supraspinatus and LHBT, without evaluation of the subscapularis and infraspinatus muscle-tendon. Fourth, injury during pitching is not only related to the shoulder muscle, but also to the spine, pelvis, and lower extremities. However, in the current study, we only evaluated the shoulder muscle. Therefore, to determine the suitable rest time after pitching, further study is needed. Fifth, we did not check intra- and interrater reliability of outcomes. There was a limited time permitted by guardians for us to measure the variables because the participants are youth in the current study. It took long time to finish measurements because we measured many variables such as the thickness of tendons, SR of supraspinatus muscle and tendon, and shoulder ROM at each point. The intra- and interrater reliability could not be measured because of time restriction. Especially for the tendon thickness, immediate changes in the supraspinatus tendon and LHBT tendon were 0.37 and 0.3 mm, respectively. These changes may have been smaller than intra- or interrater reliability. However, to increase reliability, two orthopedic fellows conducted measurements jointly. One fellow measured all outcomes during the entire study period and the other fellow simultaneously checked whether measurements had been made correctly. Outcomes were recorded only when the two fellows agreed on the measurements taken. Nevertheless, measurement bias should be considered when interpreting the results. Sixth, two factors caused cohort heterogeneity, namely, age and playing position. Of the 15 study subjects, 12 were elementary school players and 3 were middle school athletes. In addition, all players such as pitchers and batters were included. Their athletic abilities and tissue qualities may be different each other, which may cause the bias. All participants threw the balls at a distance of 14 meters, which is a regular distance for elementary school students. However, there were 3 middle school players in the study group, who may feel 14 meters as short to throw, because regular throwing distance for middle school baseball is 16.04 meters. There is a possibility that the results of middle school players were set low, leading to a bias in the results.

Nonetheless, this is the first study to evaluate the immediate effect of pitching by measuring the thickness of supraspinatus and LHBT and the SR of supraspinatus muscle and tendon using sonoelastography, as well as the shoulder ROMs of the throwing arm, and to verify the recovery over time in youth baseball players. In fact, this is the first study dealing with the recovery over time in youth baseball players.

The immediate effects of pitching on supraspinatus muscle-tendon, LHBT, and shoulder ROM in youth baseball players were confirmed in the current study. These changes were recovered to pre-pitch levels at 72 hours after pitching. Therefore, we recommend that youth baseball players should rest for 3 days after pitching to minimize the risk of shoulder injury.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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