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ORIGINAL ARTICLE

Changes in shoulder joint function due to differences in care after pitching

Yuichi Jyumonji, and Eiki Tsushima

Abstract

Objective: Icing is the most common care method for Japanese baseball players to prevent secondary tissue damage. However, because of reports that icing causes decrease in muscle strength and reduction in training effect, currently there is no standard post-pitching care. The purpose of this study was to longitudinally investigate whether different post-pitching care methods are associated with different effects on shoulder joint function.

Method: Aerobic exercise, stretch training, and icing were administered, at intervals of more than a week, to nine high school baseball pitchers after each of them pitched 100 throws. A comparative study was performed by measuring shoulder joint function after pitching, after care completion, and at 24 hours, 48 hours, and 72 hours post pitching.

Results: Significant differences were observed in shoulder rotation range of motion and external rotation muscle strength due to differences in care. Icing was the most selected care method in the questionnaire survey as well.

Conclusion: Depending on differences in post-pitching care, the shoulder joint function changes. Awareness about changes in shoulder joint function due to different care methods will help prevent pitching disorders through the selection of appropriate care depending on circumstances such as pitching day intervals.

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Key words: Baseball; pitching disorder; post-pitching care; high school student.

1. Introduction

About 40% of baseball players in Japan develop throwing shoulder disorder during one season[1,2]. The repeated action of throwing causes reduction in the range of motion and the external-to-internal ratio of rotator muscle strength in the shoulder joint in baseball players[3-5], which can cause the onset of throwing shoulder disorder[6,7]. Accordingly, for pitchers throwing a large number of pitches, physical care after pitching is important. Aerobic exercise, stretch training, and icing of the shoulder effective primary means of physical care. Aerobic exercise improves arterial function[8,9], and has been reported to enables getting rid of fatigue early by increasing blood flow through exercise after strenuous physical activities. Light-load exercises performed in stretch training increase blood flow in soft tissues[10,11]. Of the possible care methods, icing of the shoulder joint is most often undertaken. Icing after pitching prevents secondary tissue damage by reducing hyperemia, bleeding, and swelling through effectively lowering blood flow and capillary permeability[12-14]. However, icing after pitching also has disadvantages such as decreasing muscle strength and reducing training effect[15,16]. Therefore, there is no standard method for post-pitching care in Japan, where about 80% of professional baseball players, but only 40% high-school baseball players, use icing[16-18]. Moreover, there is no elucidative report on comparison of associated effects.

Furthermore, among the studies on the effect of icing on shoulder joint function, cross-sectional studies have confirmed the immediate effect, longitudinal studies have considered the effect only up to day one post pitching[16-19], and no study on the long-term effect has been reported

Graduate School of Health Sciences, Hirosaki University

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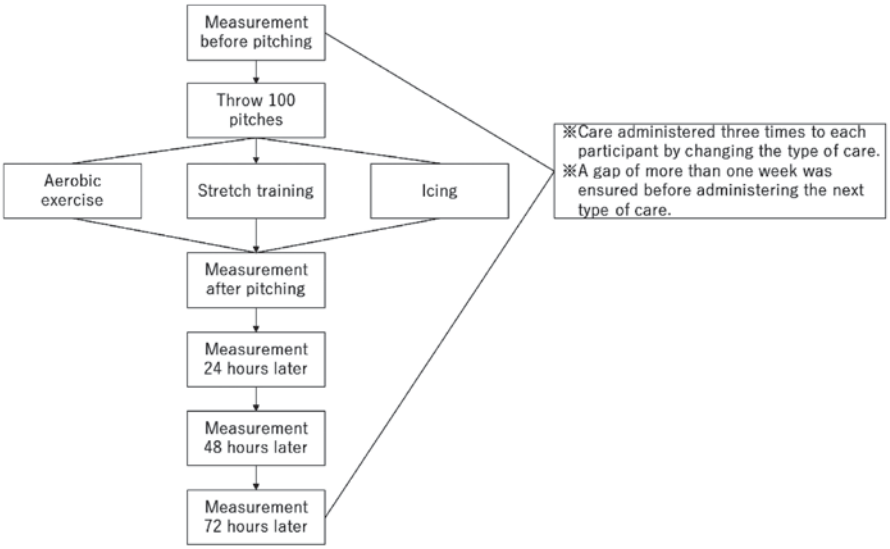


Figure 1 Measurement flow

yet.

This study aimed to investigate which care method, among aerobic exercise, stretch training, and icing, is effective in improving shoulder joint function. A longitudinal study was undertaken as knowledge about effective care will help select the most effective care method for recovery of shoulder joint function after pitching.

2. Method

The subjects were members of the baseball team in a high school. The purpose of the study was adequately explained and written consent was obtained from the subjects.

Nine 3rd year (12th grade) male students (all aged 17–18 years), who had experience of pitching and were continuing with pitching practice, were selected for the study. Individuals who were unable to pitch on the day of the measurement because of shoulder pain, who had history of operation in the throwing side shoulder, and for whom measurement was not possible on the scheduled day, were excluded.

The study was conducted with approval (No.: 2020-021) from the ethics review committee of the Graduate School of Health Sciences, Hirosaki University.

2.1 Intervention

After warm-up, subjects' shoulder joint function was measured and then, they were asked to play catch for 30~50 times. Thereafter, the subjects pitched more than 100 throws applying more than 80% of their strength as per own judgement. Next, they performed light-load playing catch for about 10 minutes.

Thereafter, using a lottery drawing for the type of care, with A for aerobic exercise, B for stretch training, and C for icing, the subjects were assigned to respective care groups. The shoulder joint function measurements were repeated after completion of care, at 24 hours, 48 hours, and 72 hours (Fig. 1). Also, in order to minimize the influence of temperature etc., the same plan was not done on the same day.

Considering the limit on number of throws for each subject, a gap of more than one week was ensured before administering the next care, and subjects were asked not to participate in any pitching practice during that period.

2.1.1 Aerobic exercise

The subjects ran around the playground

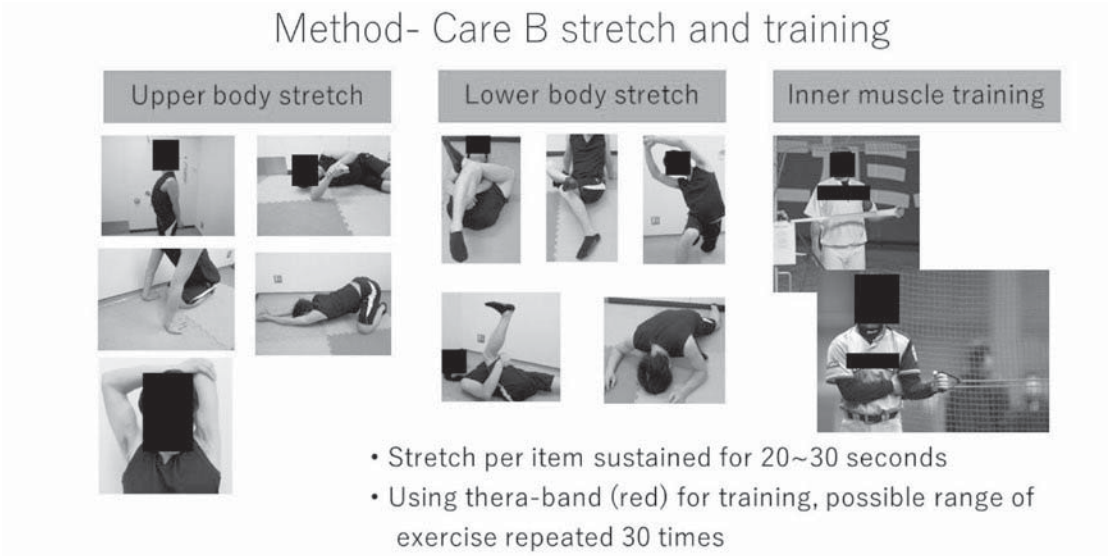


Figure 2 Stretch and training

perimeter (about 500 m) for 20 minutes, at a speed that allowed breathing easily.

2.1.2 Stretch training

The subjects trained according to a pamphlet illustrating the procedure of stretching and inner muscle training (Fig. 2). Static stretching involved performing each stretch item (10 items) for 20~30 seconds. For the shoulder joint inner muscle training (left and right, seven items), red thera-band (Sakai Medical Co. Ltd.) was used to perform each item 30 times. The subjects performed the stretching and inner muscle training for 20 minutes.

2.1.3 Icing

Icing was administered for 20 minutes using icing bag (M SLJD1904, MIZUNO Corp.) and icing supporter (1GJYA22100, MIZUNO Corp.).

2.2 Measurement of shoulder joint function

2.2.1 Shoulder joint range of motion

Both acromions, humeral medial epicondyle, humeral lateral epicondyle, olecranon, and radial styloid apophysis were marked, using oil-based black ink marker.

Horizonal flexion test (HFT) (Fig. 3a) and combined abduction test (CAT) (Fig. 3b) were undertaken following the original test method[19]. The subjects were asked to lie in supine position on the bed, and the measurements were performed using images captured with a digital camera (GZ-E565, 2.29 million pixels, JVCKENWOOD Corp.) placed perpendicular to the respective measurement planes—horizontal plane (head side) for HFT, frontal plane for CAT, and sagittal plane for secondary external rotation (external rotation) and secondary internal rotation (internal rotation) (Figs. 3c and 3d).

The measurements were performed using image editing software (ImageJ Ver 1.51, NIH, freeware). The angle between the upper arm and the line connecting both acromions on the horizontal plane image for HFT, the angle between the vertical line at the acromion and the upper arm on the frontal plane image for CAT, and the angle between the forearm and the line that intersects at right angles with the vertical line passing through the acromion on the sagittal plane for external and internal rotations, were recorded[20].

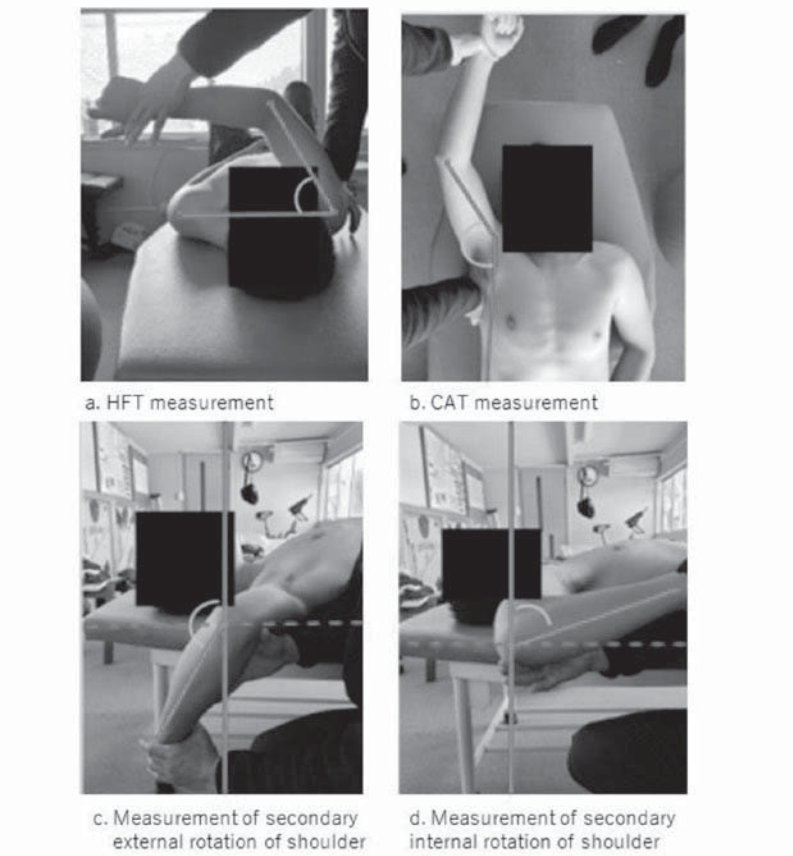


Figure 3 Method - Measurement of shoulder joint range of motion

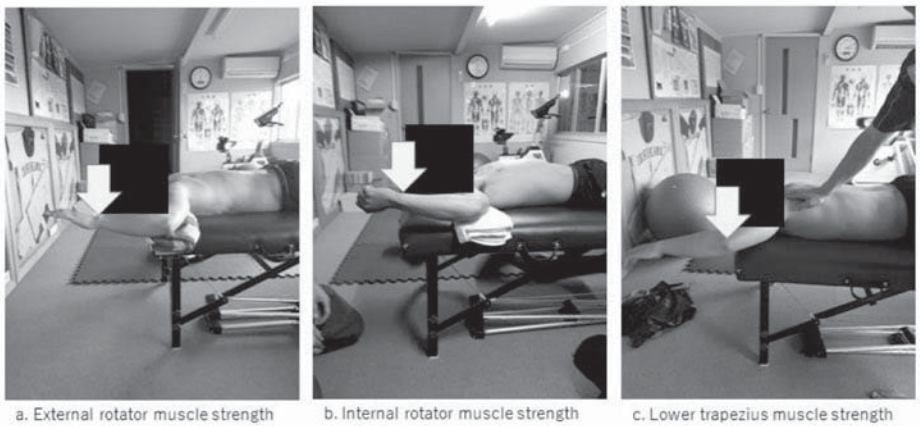
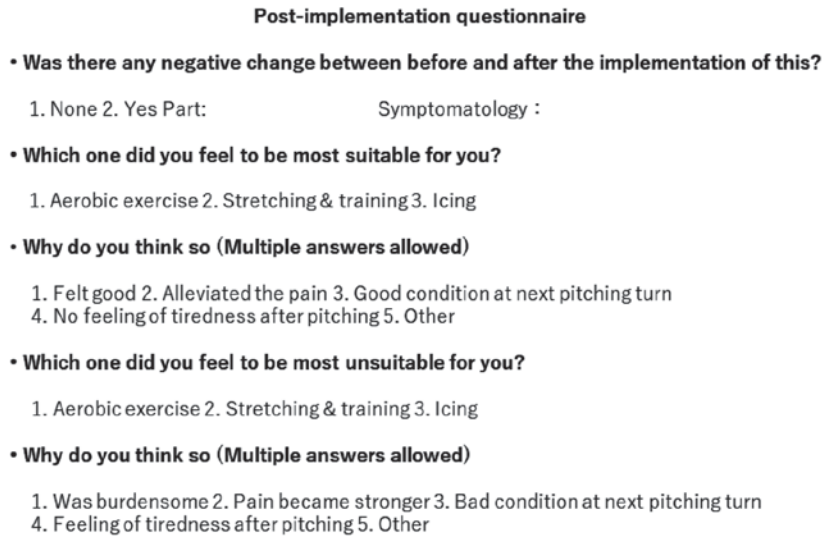


Figure 4 Method - Limb position for shoulder rotator muscle strength measurement

2.2.2 Shoulder rotator muscle strength

Shoulder rotator muscle strength was measured using a hand-held dynamometer (Mobii MM-100, Minato Medical Science Co. Ltd.) [21,22]. For the external rotation, muscle strength was in the prone position (Fig. 4a), and for internal rotation, in the supine position (Fig. 4b), with the shoulder joint and elbow joint in the 90° flexion position. The examiner applied resistance to the distal forearm and measured isometric muscle strength with a break test. Careful attention was given to prevent occurrence of


Post-implementation questionnaire

- **Was there any negative change between before and after the implementation of this?**

  1. None 2. Yes Part: Symptomatology :

- **Which one did you feel to be most suitable for you?**

  1. Aerobic exercise 2. Stretching & training 3. Icing

- **Why do you think so (Multiple answers allowed)**

  1. Felt good 2. Alleviated the pain 3. Good condition at next pitching turn
  4. No feeling of tiredness after pitching 5. Other

- **Which one did you feel to be most unsuitable for you?**

  1. Aerobic exercise 2. Stretching & training 3. Icing

- **Why do you think so (Multiple answers allowed)**

  1. Was burdensome 2. Pain became stronger 3. Bad condition at next pitching turn
  4. Feeling of tiredness after pitching 5. Other

Figure 5 Questionnaire

compensatory movements. Both the internal and external rotator muscle strengths were measured twice.

The rotator cuff provides dynamic stability between the humeral head and the glenoid cavity, and as a characteristic of baseball players, the intra-shoulder muscle strength on the pitching side is significantly increased compared to the non-pitching side, which reduces the external-to-internal rotator muscle strength ratio (E/I ratio). Consequently, shoulder joint balance declines, and may influence pitching disorder onset[21-23]. Accordingly, the E/I ratio for the pitching side was calculated.

2.2.3 Lower trapezius muscle strength

With the subject in a prone position, shoulder joint at 120° abduction, elbow joint in extended position (Fig. 4c), and the hand-held dynamometer fixed to the distal back of the forearm of the examiner, the maximum isometric muscle strength was measured using break test. The measurements were taken twice.

2.3 Questionnaire survey

A questionnaire survey was conducted after the measurements to verify the subjective effects of care (Fig. 5).

2.4 Statistical analysis

After completing the measurements three times, the differences in the groups were compared using multiple comparison procedure, after performing analysis of variance. For the multiple comparison procedure, using the results of Shapiro-Wilk test, paired t-test (Welch's correction in case of significant difference observed in test for homoscedasticity) was performed when the null hypothesis was not rejectable for both the groups, and Wilcoxon test was performed when it was judged that at least one group with $p<0.05$ did not have normal distribution. Holm method was applied to adjust the p values thus obtained. This statistical analysis was performed using R 4.0.2 (CRAN, freeware).

3. Results

3.1 Comparison of changes in shoulder joint function

3.1.1 HFT (Table 1a)

For day one post pitching, significant differences ($p<0.05$) were observed among the groups. For days two and three post pitching, no significant

Table 1. Comparison of changes in shoulder rotation range of motion

*p<0.05

	Post care	1day later	2days later	3days later
A	−4.80±10.92	−2.01±6.71	−4.24±13.00	−1.02±3.80
B	1.88±10.36	−3.79±6.85	−1.19±8.96	−0.47±9.84
C	−4.51±8.14	−18.79±15.22	−2.03±13.06	−1.90±10.73

a. HFT(°)

	Post care	1day later	2days later	3days later
A	−6.29±10.49	−13.13±13.52	−7.59±15.19	0.62±10.84
B	−1.41±6.16	−4.81±9.87	−3.73±9.38	−0.32±5.77
C	−5.46±9.03	−8.28±9.17	0.97±4.63	3.18±3.36

b. CAT(°)

	Post care	1day later	2days later	3days later
A	1.10±2.46	−0.78±4.92	3.28±8.36	5.54±6.17
B	4.87±3.93	−1.57±7.93	3.17±3.56	7.52±5.65
C	−6.19±7.48	−7.37±13.30	1.79±6.81	4.48±6.43

c. External rotation range of motion(°)

	Post care	1day later	2days later	3days later
A	−0.72±3.96	−5.32±5.75	−7.61±5.70	−5.72±3.63
B	0.47±6.50	−1.57±7.93	2.48±6.02	5.07±6.84
C	−6.98±6.93	−7.37±13.30	−8.59±7.39	−3.51±7.19

d. Internal rotation range of motion(°)

a. Comparison of changes in HFT
b. Comparison of changes in CAT
c. Comparison of external rotation range of motion
d. Comparison of internal rotation range of motion

differences were observed for A, B, and C.

3.1.2 CAT (Table 1b)

Significant differences were not observed at any of the time points.

3.1.3 Shoulder external rotation range of motion (Table 1c)

Significant differences were observed among the groups ($p<0.05$). For A and B, compared to before pitching, shoulder external rotation range of motion increased after post-pitching care. For C (icing), the range of motion decreased after care. For days one, two, and three post pitching, no significant differences were observed among the groups.

3.1.4 Shoulder internal rotation range of motion (Table 1d)

Significant differences ($p<0.05$) after care were observed between B and C. For days two and three, but not day one, significant differences were observed among A, B, and C post pitching.

3.1.5 Shoulder external rotator muscle strength (Table 2a)

Significant differences ($p<0.05$) were observed, between A and B for day one post pitching, and between A and C on days two and three post pitching. No significant differences were observed between groups after care.

3.1.6 Shoulder internal rotator muscle strength (Table 2b)

Significant differences ($p<0.05$) were observed, between B and C after care, and between A and B, and between B and C on days two and three post pitching.

Table 2. Comparison of changes in shoulder muscle strength

*p<0.05

	Post care	1day later	2days later	3days later
A	−2.57±2.00	−2.87±2.02	−0.83±2.59	1.07±2.95
B	−0.29±3.62	1.37±3.77	3.03±5.11	3.33±5.69
C	−3.01±2.88	−2.04±2.07	3.36±3.14	4.92±3.36

a. External rotator muscle strength (kgf)

	Post care	1day later	2days later	3days later
A	0.40±1.31	0.97±4.72	3.52±2.79	2.58±3.45
B	1.21±3.47	1.77±3.70	3.83±3.56	3.56±3.84
C	−1.14±3.76	1.26±4.67	4.22±4.71	4.54±5.09

b. Internal rotator muscle strength (kgf)

	Post care	1day later	2days later	3days later
A	−0.15±0.08	−0.15±0.16	−0.15±0.09	−0.04±0.10
B	−0.07±0.27	0.02±0.32	−0.02±0.22	0.01±0.16
C	−0.11±0.18	−0.15±0.19	0.00±0.15	0.03±0.12

c. E/I ratio

	Post care	1day later	2days later	3days later
A	−1.74±1.84	−1.61±2.81	0.06±3.61	1.44±3.46
B	−0.04±3.38	1.48±3.65	1.84±4.77	2.72±3.49
C	−1.75±4.28	−1.79±5.06	2.29±5.46	2.67±4.71

d. Lower trapezius muscle strength (kgf)

a. Comparison of changes in external rotator muscle strength
b. Comparison of changes in internal rotator muscle strength
c. Comparison of changes in E/I ratio
d. Comparison of changes in lower trapezius muscle strength

3.1.7 E/I ratio (Table 2c)

Significant differences ($p<0.05$) were observed between A and B after care, and between B and C for day one post pitching.

3.1.8 Lower trapezius muscle strength (Table 2d)

No significant differences were observed between groups at any time point.

3.2 Questionnaire survey

Of the nine participants, seven reported that icing was personally considered most suitable. The reasons cited were “felt good” and “alleviated the pain.” Aerobic exercise was cited as the most unsuitable (eight out of nine participants). The reasons cited were “felt physically tired after care” and “tiring” (Table 3).

4. Discussion

4.1 Changes in shoulder rotation range of motion

Aerobic exercise improves arterial function[8,9] and extensibility of soft tissues increasing the shoulder rotation range of motion[24-26], but in the aerobic exercise group, compared to the stretch training group, range of motion other than external rotation range of motion after care decreased, and the internal rotation range of motion on days two and three post pitching showed significant decrease. Icing is known to prevent secondary damage to tissues[12-14]; however, Kubo et al.[27], in a study on extensibility of tissue, reported that post passive stretching after cooling, no change in extensibility of muscle fascicle, tendon, and aponeurosis was observed. Suggesting that, like the aerobic exercise group, the effect of pitching load was strong in the icing group. In contrast, stretching after pitching

Table 3. Questionnaire results

The number in the table represent the number of people

Number of persons	A	B	C
Which one did you feel to be most suitable for you?	1	1	7
[Reason] felt good	0	1	7
[Reason] alleviated the pain	0	1	7
[Reason] good condition at next pitching turn	1	1	5
[Reason] no feeling of tiredness after pitching	0	0	4
[Other] none			
Which one did you feel to be most unsuitable for you?	8	0	1
[Reason] was burdensome	4	0	1
[Reason] pain became stronger	0	0	0
[Reason] bad condition at next pitching turn	1	0	0
[Reason] feeling of tiredness after pitching	6	0	1
[Other] A: Tiring 6, Felt hot 5 (Persons)			

A. Aerobic exercise
B. Stretching and training
C. Icing

imparts sustained extension to muscle and soft tissues, increasing the blood supply to the soft tissues, thereby improving the extensibility of soft tissues[10,11], and therefore, in the stretch training group, the internal rotation range of motion on day two and day three post pitching showed significant increase.

During large baseball tournaments, usually there is an interval of two to three days between games, and for high schools with fewer baseball club members, the same pitcher takes multiple turns of pitching nearly at same intervals. Looking at the shoulder rotation range of motion, although no significant differences between groups were observed in HFT, CAT, and external rotation range of motion on day two onwards post pitching, internal rotation range of motion showed significant increase in the stretch training group.

4.2 Change in shoulder muscle strength

It has been reported that the muscles around the shoulder joint have an E/I ratio of 0.8 or more[21-23,28], control the anterior movement of the head of the humerus during the late cocking phase[28] and the accelerated phase[29,30] maintain the afferent position with respect to the glenoid fossa.

Our study results indicate significant differences in external rotator muscle strength and E/I ratio due to differences in post-pitching care. Like the shoulder rotation range of motion, the likely reason is the difference in effect between care meant for the whole body and localized care for only a part of the body.

Up to day one post pitching, the icing group did not exhibit any significant difference in external rotator muscle strength, but on days two and three post pitching, it exhibited significant increase compared to the aerobic exercise group. Icing inhibits formation of heat shock protein and decreases the effects of transient training[15,16]. This is the likely cause for reduction in external rotator muscle strength in the icing group up to day one post pitching. It is likely that the pain due muscular pain after pitching had affected the improvement in external rotator muscle strength day two onwards post pitching. Icing was the most favored post-pitching care in the questionnaire survey, with seven out of nine participants reporting that they felt the pain reduction effect. There are two types of muscle—acute and delayed onset; delayed onset muscle soreness (DOMS) induces reduction not only in muscle strength but also in motivation[31]. According to Nosaka et al.[32], DOMS usually emerges 8–24 hours after exercise, reaching its

peak during 24–72 hours. We believe that administering icing after pitching reduced the pain due to DOMS, affecting the muscle strength.

4.3 Limitations of the study

The study has some limitations. True circumstances involving pitching in a game, including aspects such as the psychological stress of the pitcher, could not be exactly reproduced. In addition, blood flow measurements could not be taken. Thus, future research should involve the utilization of diagnostic imaging devices.

5. Conclusion

The findings of this study show that shoulder joint function changes depending on the differences in care administered after pitching. We believe that awareness about the changes in shoulder joint function due to different care methods will help prevent pitching disorders through selection of appropriate care depending on circumstances such as pitching day intervals.

Conflicts of interest

We have no conflict of interest to declare.

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