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Reciprocal inhibition improves posterior shoulder tightness and shoulder range of motion in youth baseball players

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Background: The aim of this study was to evaluate the efficacy of reciprocal inhibition for posterior shoulder tightness (PST), internal rotation at 90° abduction (ABIR) limitation, and subacromial impingement in elementary and junior high school baseball players.
Methods: The present study included 290 elementary school and junior high school baseball players who were members of an organized baseball team and attended a medical checkup in 2014. Seventeen participants were excluded because they were left-handed. We applied a sit-up exercise as a tool of reciprocal inhibition to all participants. Before and after the sit-up exercise, we evaluated the shoulder range of motion (ROM) in external rotation at 90° abduction (ABER), ABIR, and horizontal flexion (HF) in both shoulders and the prevalence of subacromial impingement in the dominant shoulder. We defined PST as a ≧15°decrease in the HF angle of the dominant shoulder in comparison to the nondominant shoulder before the sit-up exercise and divided participants into two groups (the PST group and the non-PST groups). An independent *t*-test was performed to compare the shoulder ROM, and a chi-squared test was performed to compare the prevalence of subacromial impingement between the two groups. A dependent *t*-test was performed to compare intragroup changes in the shoulder ROM. The McNemar test was performed to compare intragroup changes in the prevalence of subacromial impingement.
Results: Fifty-six of 273 participants had PST in the initial examination. The initial examination revealed that the ROM of ABIR and HF in the dominant shoulder were significantly lower in the PST group than those in the non-PST group, whereas the ROM of ABER and total arc were significantly higher in the PST group. The prevalence of subacromial impingement in the PST group was significantly higher than that in the non-PST group. The sit-up exercise improved ABER, ABIR, total arc, HF, and the prevalence of subacromial impingement in both groups. However, the amount of ROM change did not differ between the two groups for any parameter with the exception of HF.
Conclusion: The presence of PST affects the prevalence of subacromial impingement but was not related to the loss of ABIR or the prevalence of pathological glenohumeral internal rotation deficit. The sit-up exercise, as reciprocal inhibition, can transiently improve the prevalence of subacromial impingement via the improvement of PST.

Takagishi et al reported that 17.7% of elementary school baseball players and 28.0% of junior high school baseball players experience shoulder or elbow pain within one year.[27,28] The diagnosis of causes of shoulder or elbow pain is limited, and some are diagnosed with little league shoulder or from X-rays, ultrasound scans, or magnetic resonance images showing osteochondritis dissecans. As these imaging examinations cannot detect the functional disorder that occurs before anatomical failure, we have to carefully detect functional problems as a risk factor for shoulder and elbow injury.

The glenohumeral internal rotation deficit (GIRD) is a well-known condition as a prestage of anatomical failure, especially in overhead sports players.[17,30] Regarding this condition, we have

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reported that decreased internal rotation is a risk factor for shoulder and elbow injury in high school baseball pitchers.[25] The cause of GIRD is thought to be not only the difference of humeral retroversion between dominant and nondominant shoulders but also the tightness of soft tissue connected to the shoulder joint.[13] Hibberd et al reported that the side-to-side difference in humeral retroversion and age-related GIRD increases with age.[6] They concluded that the major factor of GIRD is the difference in humeral retroversion.[6] However, their study also revealed that the side-to-side difference in humeral retroversion had not yet grown very large in junior high school players.[6] On the other hand, other reports have shown that the posterior shoulder tightness (PST) is related to GIRD.[23] Furthermore, a recent study showed posterior rotator-cuff tightness,[2] not capsular contracture, contributes to PST, and this idea is supported by studies showing that GIRD can improve after a single throwing exposure.[11,22] Thus, PST may have a marked influence on GIRD through junior high school age and may be a modifiable muscular factor.

Regarding the skeletal muscle tightness and its control, "reciprocal inhibition" is a well-known physiological phenomenon.[1,3,9,21] This phenomenon is observed between two muscles, which act antagonistically when one muscle contracts and the other muscle relaxes via the spinal reflex pathways. Reciprocal inhibition has been well investigated in the elbow, wrist, and ankle joint.[1,3,9,21] In the shoulder joint, although the muscles that act antagonistically with the posterior shoulder muscles were not clarified, Iwahori et al reported that sit-up exercise could improve horizontal flexion (HF) and internal rotation at 90° abduction (ABIR) in high school baseball players.[7] Thus, in the present study, the authors hypothesized that sit-up exercises can improve the shoulder rotational ROM by improving the PST.

The present study investigated the efficacy of reciprocal inhibition for PST, the shoulder ROM, and subacromial impingement and evaluated the relationship between these factors in elementary and junior high school baseball players.

Materials and methods

Subjects

This study was approved by the institutional review board of Gunma University Hospital (approval no. 1003). The subjects were elementary school and junior high school baseball players who attended a medical checkup in 2014. All participants were male and were members of an organized baseball team. The mean age of the participants was 11.4 years (range: 7 to 15 years). No participants had shoulder or elbow pain, and we excluded left-handed participants from the study subject because a previous study reported that the differences in the glenohumeral external rotation angle and humeral retroversion angle were significantly smaller in left-handed pitchers at a young age.[29] Participants were randomly assigned to a physical examination that included an impingement test and ROM measurement in each shoulder performed by three certified orthopedic surgeons (T.I., H.S., and D.S.) who had over 15 years of experience as a shoulder specialist.

Impingement test

Examiner performed shoulder impingement tests in the dominant shoulder, including the Neer test and Kennedy-Hawkins test, which is performed in the sitting position.[5,19] In the present study, the impingement test was judged as positive if the participants complained about pain in their shoulder during either test.

Measurement of shoulder ROM

The intrarater validity and reliability of ROM measurements by a digital protractor have been established in a previous study.[25] We used a digital protractor (iGaging, Los Angeles, CA). Participants lay in the supine position on an examination bed with their shoulder and elbow in 90° of abduction and flexion, respectively. The starting position consisted of placing the forearm approximately perpendicular to the floor, so that the hand was directed upward toward the ceiling. Examiners performed ROM measurement according to the method of a previous report.[26] From this position (0° of rotation), the examiner passively rotated the shoulder while stabilizing the scapula. The end range of rotation was defined as the cessation of rotation or appreciation of scapular movement. The range of external rotation at 90° abduction (ABER) and that of ABIR were measured, and the sum of these ranges was calculated as a total arc.

Evaluation of PST

In the present study, the HF angle was used to evaluate PST. Previous reports have revealed that the measurement of the ROM of HF was a reliable method[18,31] and that the ROM of HF was significantly lower in the dominant shoulder.[14,17] Participants lay in the supine position on a standard bed with their shoulder and elbow in 90° of flexion, respectively. From this position, the examiner passively flexed the shoulder horizontally while pressing the scapula to the medial side to prevent the abduction of the scapula. Using a digital protractor, examiners measured the angle between the upper arm and a line perpendicular to the ground as the HF angle.

Sit-up exercise and remeasurement

After the first examination of the ROM and impingement test, all participants underwent a single sit-up exercise. The sit-up exercise was performed according to the method of a previous report,[7] by elevating the body trunk approximately 30° from the examination bed and maintaining the posture for 10 seconds (Fig. 1). Immediately after the sit-up exercise, impingement tests and the measurement of the ROM were reperformed by the same examiner.

Statistical analyses

All statistical analyses were performed with the SPSS (version 25.0) software program (IBM, Armonk, NY, USA). Briefly, we defined PST according to the definition of a previous study,[15] as having a decreased HF angle of more than 15° in the dominant shoulder compared to the nondominant shoulder before the sit-up exercise, and divide participants into two groups (PST group and non-PST group). We also defined pathological GIRD as a $\geqq 18°$ decrease in ABIR of the dominant shoulder in comparison to the nondominant shoulder, according to a previous report.[8] The intergroup comparison of the shoulder ROM was performed with an independent *t*-test, and the intragroup comparison was performed with a dependent *t*-test. Similarly, the intergroup comparison of the prevalence of PST, GIRD, and the impingement sign was performed with a chi-squared test, and the intragroup comparison was performed with the McNemar test. The primary endpoint of the present study was to investigate the effect of sit-up exercise, such as reciprocal inhibition on shoulder ROM and subacromial impingement. The secondary endpoint was to investigate the group differences in ROM limitations and subacromial impingement in elementary and junior high school baseball players.

Figure 1 The sit-up exercise method. Participants elevate the body trunk by approximately 30° from the examination bed for 10 seconds.

Results

A total of 290 participants were included in the present study; 17 were excluded because they were left-handed. Of the remaining 273 participants, the prevalence of PST before the sit-up exercise was 20.2% (56 of 273 participants). The ROM of ABIR in the dominant shoulder were significantly lower in the PST group than those in the non-PST group (39.9° and 45.3°, $P = .005$). On the other hand, the ROM of ABER and the total arc in the dominant shoulder in the PST group were significantly higher than those in the non-PST group (128.3° and 115.2°, $P < .01$; 168.2° and 160.4°, $P = .002$, respectively) (Table I). The rate of impingement sign positivity in the PST group was significantly higher than that in the non-PST group (28.6% and 11.5%, $P = .002$), whereas the rate of GIRD positivity did not differ between the two groups (19.6% and 23.0%, $P = .364$) (Table I).

After the sit-up exercise, all ROMs (ABER, ABIR, total arc, and HF) in the dominant shoulder improved significantly in both the PST (128.3° to 130.6°, $P = .012$; 39.9° to 43.7°, $P = .002$; 168.2° to 174.2°, $P = .016$; and 14.2° to 31.4°, $P < .01$) and non-PST groups (115.2° to 117.4°, $P < .01$; 45.3° to 49.1°, $P < .01$; 160.4° to 166.5°, $P < .01$; and 20.3° to 26.0°, $P < .01$) (Table I). The amount of ROM change in ABER, ABIR, and the total arc did not differ between the two groups (2.3° and 2.2°, $P = .931$; 3.8° and 3.9°, $P = .944$; 6.1° and 6.1°, $P = .999$). In contrast, the amount of ROM change in HF was significantly higher in the PST group than that in the non-PST group (17.2° and 5.7°, $P < .01$).

The rate of impingement sign positivity improved significantly by 11.5% to 3.6% in the non-PST group ($P < .01$) and 28.6% to 10.7% in the PST group ($P = .002$). In contrast, the prevalence of GIRD did not change in both groups (19.6% to 21.4%, $P = 1.000$; 23.0% to 20.7%, $P = .542$).

After the sit-up exercise, ABIR in the dominant shoulder in the PST group was still significantly lower than those in the non-PST group (43.7° and 49.1°, $P = .004$) (Table I). ABER, total arc, and HF in the PST group were significantly higher than those in the non-PST group (130.6° and 117.4°, $P < .01$; 174.2° and 166.5°, $P = .004$; 31.4° and 26.0°, $P < .01$). Differences of ROM between the dominant and nondominant shoulders were not significantly different in ABER (9.1° and 8.0°, $P = .935$), ABIR (-8.6° and -8.2°, $P = .219$), or total arc (0.5° and 0.1°, $P = .256$). The rate of impingement sign positivity in the PST group was significantly higher than that in the non-PST group (10.7% and 3.6%, $P = .002$), and the prevalence of GIRD did not differ markedly between the two groups (21.4% and 20.7%, $P = .520$).

Discussion

The most important finding in the present study was that the sit-up exercise could improve shoulder rotational ROMs, especially HF, and subacromial impingement via reciprocal inhibition between the abdominal muscles and posterior shoulder muscles. To the best of our knowledge, this is the first study to provide evidence that the abdominal muscles and posterior shoulder muscles have an agonist-antagonist relationship in elementary and junior high school baseball players. This evidence may help evaluate whether or not posterior shoulder muscle tightness is related to PST, which is a critical factor in shoulder injuries, such as superior labrum anterior and posterior lesion[17] and pathological internal impingement.[16]

GIRD is a well-known shoulder condition associated with overhead sports, and previous studies have reported that GIRD exists not only in high school and college baseball players but also in elementary school and junior high school baseball players.[6,10] GIRD is thought to result from not only the difference in humeral retroversion between the dominant and nondominant shoulders[30] but also from PST in the dominant shoulder.[23] Hibberd et al reported that the side-to-side difference in humeral retroversion increases with age[6] and concluded that age-related increases in GIRD are due to bony changes. Their results also revealed that this side-to-side difference in humeral retroversion remained relatively low up to junior high school age.[6] Based on these results, we suspected that the influence of humeral retroversion on GIRD up to junior high school student might be lower than that in older age. Therefore, the present study focused on the relationship between PST and ROM limitations in elementary and junior high school baseball players. In our study, the initial examination revealed a decreased ABIR in the dominant shoulder in the PST group. However, the differences in the ABIR between the dominant and nondominant shoulders and the prevalence of pathological GIRD defined by generally accepted criteria[8] (≧18° loss of ABIR in the dominant shoulder) did not differ markedly between the groups. These results suggested that the influence of PST on the loss of ABIR was limited in the elementary and junior high school baseball players. In contrast, the initial examination also revealed an increased ABER and total arc in the dominant shoulder in the PST

Table I
ROM changes and rate of impingement and GIRD positivity in pre and post sit-up exercise.

Variables	Before sit-up				After sit-up				Intragroup comparison		Changes (post-pre)		
	Total	PST group	Non-PST group	Intergroup	Total	PST group	Non-PST group	Intergroup	Pre vs. post		PST group	Non-PST group	Intergroup
	(n = 273)	(n = 56)	(n = 217)	*P* value	(n = 273)	(n = 56)	(n = 217)	*P* value	PST group	Non-PST group	(n = 56)	(n = 217)	*P* value
Age (yr)	11.4 ± 1.4	11.4 ± 1.3	11.5 ± 1.5	.649					*P* value				
ABER (degree)	117.9 ± 11.9	128.3 ± 10.1	115.2 ± 10.8	.000*	120.1 ± 12.0	130.6 ± 11.3	117.4 ± 10.7	.000*	.012*	.000*	2.3 ± 6.5	2.2 ± 6.9	.931
Difference in ABER (degree)	8.0 ± 8.9	8.1 ± 9.1	8.0 ± 8.8	.935	8.2 ± 8.8	9.1 ± 10.9	8.0 ± 8.2	.935					
ABIR (degree)	44.1 ± 12.7	39.9 ± 12.3	45.3 ± 12.6	.005*	47.9 ± 12.7	43.7 ± 11.6	49.1 ± 12.8	.004*	.002*	.000*	3.8 ± 8.9	3.9 ± 8.8	.944
Difference in ABIR (degree)	−8.6 ± 12.5	−10.4 ± 11.9	−8.1 ± 12.7	.219	−8.3 ± 11.6	−8.6 ± 11.6	−8.2 ± 11.6	.219					
Total arc (degree)	162.0 ± 17.0	168.2 ± 16.5	160.4 ± 16.9	.002*	168.0 ± 16.8	174.2 ± 16.4	166.5 ± 16.5	.004*	.016*	.000*	6.1 ± 11.6	6.1 ± 12.2	.999
Difference in total arc (degree)	−0.5 ± 12.9	−2.3 ± 11.4	−0.1 ± 13.3	.256	−0.0 ± 11.8	0.5 ± 11.6	−0.1 ± 11.9	.256					
HF (degree)	19.1 ± 9.7	14.2 ± 13.3	20.3 ± 8.2	.002*	27.1 ± 10.3	31.4 ± 13.6	26.0 ± 9.0	.007*	.000*	.000*	17.2 ± 9.8	5.7 ± 7.0	.000*
Difference in HF (degree)	−6.5 ± 13.6	−28.3 ± 11.6	−0.9 ± 6.6	.000*	−1.6 ± 8.7	−10.0 ± 10.0	0.6 ± 6.8	.000*					
Impingement (Y/N)	41/232	16/40	25/192	.002*	14/259	6/50	8/209	.002*	.002*	.000*			
GIRD (Y/N)	61/212	11/45	50/167	.364	57/216	12/44	45/172	.520	1.000	.542			

ABER, abduction and external rotation; *ABIR*, abduction and internal rotation; *HF*, horizontal lexion; *GIRD*, glenohumeral internal roation deficit; *PST*, posterior shoulder tightness; *ROM*, range of motion; *SD*, standard deviation.
Data were shown by mean ± SD.
*Statistical significance was set at $P < .05$.

group. Laudner et al[12] reported that the PST was associated with anterior glenohumeral laxity among professional baseball pitchers. Grossman et al[4] investigated the relationship between PST and anterior glenohumeral laxity using a cadaveric model, and their results suggested that throwing athletes with PST may develop increased anterior glenohumeral laxity as a protective adaptation. Given these results, the increased ABER in the PST group may have been derived from this mechanical adaptation.

Regarding skeletal muscle tightness and its control, reciprocal inhibition is a well-known physiological phenomenon that occurs between two muscles that act antagonistically.[1,3,9,21] To date, the clinical application of reciprocal inhibition has been reported in relation to the elbow and ankle joint.[3,9] Blazevich et al reported that 3-week plantar flexor stretch training resulted in the improvement of ankle dorsiflexion and the inhibition of neural activity in the soleus and gastrocnemius muscle.[3] Katz et al reported that electrical motor nerve stimulation of the agonist muscle inhibited Hoffman's reflex wave of the antagonist muscle.[9] On the other hand, Iwahori et al reported that the sit-up exercise results in the improvement of HF and ABIR in the dominant shoulder in high school baseball players and suggested that the abdominal muscle is a part of the antagonistic muscle to the posterior muscles of the shoulder joint.[7] In the present study, sit-up exercise helped improve the PST and rotational ROM in both groups, and the effect on improving the PST was more significant in the PST group than in the non-PST group. These results suggest that abdominal muscles and posterior shoulder muscles may have an agonist-antagonist relationship in elementary and junior high school baseball players. In contrast, despite the significant improvement in the HF in the PST group, the amount of ABIR changes during the sit-up exercise did not differ markedly between the two groups. These results suggest that the improvement in PST derived from sit-up exercises as reciprocal inhibition may be an independent factor influencing ABIR changes in elementary and junior high school baseball players.

Generally, subacromial impingement comes from “structural impingement” and “functional impingement.” Structural impingement is due to the narrowing of the subacromial space caused by the hyperplasia of the bone or soft tissue that occurs based on inflammation.[20] On the other hand, functional impingement occurs due to PST. Previous reports have shown that PST causes anterosuperior displacement of the humeral head during shoulder elevation.[13,20,24] In the present study, the PST group showed a significantly higher rate of impingement sign than the non-PST group before the sit-up exercise. Although the rate of impingement positivity in each group decreased significantly after the sit-up exercise, this rate was still significantly higher in the PST group than that in the non-PST group after the sit-up exercise. These results suggested that PST is a critical factor for subacromial impingement in elementary and junior high school baseball players. Furthermore, the fact that the rate of impingement positivity decreased with improvement in PST suggests that because PST is a modifiable muscular factor, subacromial impingement in this study population is more likely functional than structural. Thus, the examination of PST and sit-up exercise can identify the presence of functional impingement. When residual impingement is seen even after the sit-up exercise, the physician should perform a detailed examination including an imaging examination.

The present study was associated with some limitations. First, the examiners were not blinded to the dominance of the shoulder. Examiners may have been biased by knowing the dominance of the shoulder. Second, because all the measurements in the present study were performed once by examiners, there was potential bias due to measurement errors. Third, because the second measurement of shoulder ROM and impingement were performed immediately after the sit-up exercise, the duration of the effect of the

sit-up exercise is unknown. Fourth, despite the present study and previous study[7] confirming the effect of the sit-up exercise on shoulder ROM as an actual phenomenon, the detailed mechanism underlying the improvement of glenohumeral ROM and the link between the abdominal muscles and shoulder muscles remains unclear. Further studies are needed to resolve these limitations.

Conclusion

The results of the present study showed that some elementary and junior high school baseball players have PST in their dominant shoulder. The presence of PST affects the prevalence of subacromial impingement but was not related to the loss of ABIR or the prevalence of pathological GIRD. The sit-up exercise can improve the prevalence of subacromial impingement via the improvement of PST.

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