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A Randomized and Blinded Study for the Treatment of Glenohumeral Internal Rotation Range of Motion Restriction: The Prone-Passive Stretching Technique

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Background: Prior research has focused on specific interventions to reduce the symptoms of glenohumeral internal rotation deficit (GIRD) and posterior glenohumeral (GH) tightness; however, clinicians often utilize a prone stretching technique instead for which a lack of evidence exists to support the use of. **Hypothesis:** Improvements in GH Internal rotation (IR) range of motion (ROM) will be greater in a group of overhead athletes using a prone-passive stretching technique than for overhead athletes using a cross-body stretching technique. **Design**: Randomized and blinded comparative research study **Methods:** 34 asymptomatic overhead athletes exhibiting ≥ 10° of GH IR deficit randomly received either 12 prone-passive (n=17) or cross-body (n=17) stretching treatments for the deficit over a consecutive 28 day period. Measures of IR and external rotation (ER) for both the dominant and non-dominant shoulders were taken with a modified digital inclinometer before and after participants underwent 12 treatments over a consecutive 28-day period in either the prone-passive or cross-body group. **Results**: Analysis revealed increased dominant shoulder IR ROM and total motion, whereas IR deficit decreased for both groups, but no group differences. Gain scores for the prone-passive and cross-body respectively: IR ROM (13.23° ± 7.78°, 8.47° ± 8.71°), IR deficit (-12.64° ± 11.49°, -9.13 ± 8.33°), and total motion (14.81° ± 11.27°, 9.97° ± 11.99°). **Conclusion**: The prone-passive stretching technique is as effective as the cross-body technique at improving IR ROM, IR deficit, and total motion in the shoulder joint in participants with IR deficit. **Clinical Relevance:** Accounting for IR deficits in the overhead athlete shoulder is effectively managed through both clinician-assisted and self-stretching techniques. Clinicians treating overhead athletes with greater limitations in IR ROM may find the prone-passive technique advantageous when compared to the cross-body technique.

Key Words: *shoulder, GIRD, stretching, overhead athletes*

Introduction

Internal rotation (IR) of the glenohumeral (GH) joint becomes limited in the dominant shoulder of many overhead athletes. Left unchecked restrictions to IR range of motion (ROM) lead to GH impingement and labral pathologies, which often translates to loss of normal upper extremity function.[1-3] Substantial prior evidence exists in regard to the prevalence of GIRD in professional baseball players.[7, 8] In addition, Meister et al.[9] demonstrated the prevalence of IR ROM changes in youth baseball athletes as young as eight years old. Recently, Shanley and colleagues[4] observed a 4-6 times greater risk of injury in baseball pitchers with restricted IR, and, an increased risk of upper extremity injury as the degree of IR restriction progressed.[5] In a study of professional baseball pitchers with IR restriction, Wilk et al.[6] noted a twofold rate of upper extremity injuries.

Clinicians often prescribe a stretching treatment to counter restrictions in the dominant shoulder, including restrictions that affect the GH joint, such as glenohumeral internal rotation deficit (GIRD) or posterior shoulder tightness (PST). Multiple studies have demonstrated the effectiveness of stretching techniques and their usefulness in prevention or treatment of these conditions.[10-12] The cross-body stretching technique, a commonly used technique, has previously shown to be effective at improving IR ROM when compared to the sleeper stretch. McClure et al.[10] compared the cross body technique to the sleeper stretch and though findings were not statistically significant, greater improvements in IR ROM were found in the cross body group.[10] Manske et al.[13] compared the cross body technique to posterior joint mobilizations plus the cross body technique and found similar improvements in IR ROM for both treatments. In light of similar findings,[1,9,14] the purpose of this study was to investigate the *prone-passive stretching technique*, as explained in this paper, by comparing treatment effects on IR ROM to the *cross body stretching technique*. This study is the first to investigate the effectiveness of the prone- passive stretching technique.

Stretching the shoulder of an overhead athlete is often necessary for the treatment of GIRD or PST. GIRD or PST commonly affects the dominant shoulder and is characterized by a decrease in IR ROM. This has been described as a shift towards dominant shoulder external rotation (ER) ROM compared to the non-dominant shoulder,[1] whereby total motion (IR+ER) remains the same in both shoulders.[6, 16] Disagreement exists in the literature regarding the causation of GIRD. Soft tissue contracture is the likely cause in these conditions affecting overhead athletes, specifically contracture of the posterior GH capsule and/or posterior musculature as a result of repetitive stress.[6, 17-19] Knowledge of different stretching techniques is important for both patient and clinician. Tissue location and type respond differently to specific alterations in lines of applied stress provided by either the torsional or tensile forces of a stretching technique.[19]

The prone-passive stretching technique discussed in this report is an adaptation of the modified internal rotation stretching technique previously described by Johansen et al.[15] Johansen and colleagues described the treatment as an effective method for stretching IR while accounting for movement at the scapulo-thoracic articulation in order to focus on GH structures that restrict IR ROM. The method presented in this paper has been adjusted from the previously referenced modified technique in order to accommodate patients exhibiting moderate to significantly restricted IR ROM (≥ 15°). The difference with the prone passive-technique is with a clinician applying force to maintain an appropriate level of stretching rather than a bolster method of sustaining the end point. This adjustment allows the treating clinician more control of the intended effects. That is, sustaining and progressing passive torsional forces at the end point of IR. This may be especially effective in patients with a significant unilateral IR deficit, such as overhead athletes.

The hypothesis was IR ROM improvements will be greater for a group of overhead athletes using the prone-passive stretching technique than for overhead athletes using the cross-body stretching technique.

Methods

Participants and Design. 113 volunteers were screened for a ≥ 10° IR deficit between dominant and non-dominant shoulders of which 35 met the inclusion criteria for the IR deficit threshold. Additional inclusion criteria included being on a current roster for a sponsored college or university athletic team, or a recreational overhead dominant sport program, and self-reporting as healthy with no history of shoulder injury or surgery in the prior year. Participants were excluded from participation if shoulder pain and recent injury or surgery were reported.

Before participation all participants signed an informed consent form, completed a shoulder medical history and demographics survey, and were informed of potential benefits and/or side effects of performing IR shoulder stretching. This study was approved by the local Institutional Review Board. Participants reported sports participation as: Baseball (n = 15), softball (n = 9), recreational athletes in club sports which included volleyball and tennis or a combination of both (n = 8), and swimming (n = 2). None of the participants reported having current shoulder pain on a self-reported medical history. Participants were observed out of their competitive season to avoid the acute effects of repetitive stress on the shoulder. In addition, participants were not involved in any other IR shoulder stretching program.

Stretching group was a between-participant independent variable in this study. One participant in the prone-passive group did not complete the study for unknown reasons. 34 participants that met the threshold for a unilateral internal ROM difference were randomly assigned to treatment groups using computer generated randomized coding: prone-passive stretching or cross-body stretching. Unilateral IR and ER ROM were measured at the beginning of the study and again at the end of the study; therefore, time was a repeated-measures independent variable. Thus, this was a 2 (Group: prone-passive versus cross-body) x 2 (pretest versus posttest) design. This study evaluated the effect of the prone-passive and cross-body stretching techniques on IR ROM of the GH joint. GH rotation ROM was the dependent variable in this study.

Measurement and Procedures. Four measures were analyzed in this study. Passive internal and external ROM was measured for the dominant and the non-dominant shoulder. Measurements were performed using a digital inclinometer (GX products digital inclinometer: Hong Kong, China), which has been found useful in prior studies that evaluated ROM.[20-22] To manage standardization of measurements a 0.125" x 1.5" x 6.5" industrial grade steel plate was attached to the magnetic bottom of the inclinometer, which was affixed to the outer surface of a flat, medium-sized, soccer shin guard (Vizari: Paramount, CA, USA); see figure 1.

Figure 1. Modified digital inclinometer

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Pretest and posttest measurements of GH ROM using this device were performed by the same trained research assistant to allow for blinding of the tester and investigators to group and measurements. Pretest and posttest measurements were taken with the participant in the supine position, on the same treatment table, with the GH joint abducted to 90° and the elbow flexed to 90°. This position has previously been demonstrated as an appropriate measure of ROM with the scapulo-thoracic articulation immobilized against the table surface.[23, 24] The modified inclinometer was fastened securely to the forearm, using the ulnar styloid and olecranon process as bony landmarks to centrally position the apparatus on the extremity. Manske et al.[13] utilized a similar measurement technique to measure shoulder rotation. Prior to observing measurements, the tester passively rotated the extremity through a complete IR and ER motion to help the participant relax and become accustomed to the testing motion and endpoints of motion.

A 0.5" section of medium density memory foam (Econoline Industries: LaPlume, CA, USA) was placed between the humerus and treatment table. This was performed for two reasons: 1. the foam elevates the humeral head to perpendicular alignment on the glenoid fossa, and 2. the memory foam allows the upper arm to rotate freely while keeping the desired alignment of the elbow and shoulder at 90°. The forearm was secured by the tester in a vertical position of GH neutral, and then passively moved in external and internal motion with one hand on the participant's wrist and another stabilizing the elbow. The end range of GH motion was identified when a firm endpoint was noted, and/or when compensatory movement caused by the scapula flexing forward on the thorax was observed in the shoulder girdle by the tester; see figure 2. The tester recorded the measurement once the end range of motion was established and held for approximately three seconds. Using this passive technique helps remove the possibility of muscle insufficiency in cases of asymptomatic muscle shortening or lengthening as a cause of motion difference or compensatory joint movement in the scapulo-thoracic region.

Pretest measurements were taken no sooner than 24 hours prior to the initial stretching intervention and posttest measurements were taken no later than 48 hours after the final intervention session was completed. Measurements were taken three times for both internal and external ROM for pretest and posttest. The average of the three measures were computed and used as the key outcome variables in the study.

Figure 2. Internal (top) and external (bottom) ROM measurement technique with attention to arm abducted to 90° and observation of accessory movements of the GH joint.

Reliability. To verify the reliability of the techniques to measure rotation, a pilot study was conducted with 22 participants. Previously recommended intra-class correlations were used to assess the reliability of the measures.[25, 26] Measures were compared across two independent raters and found excellent inter-rater reliability (ICC ranged from .83 and .91 across raters for the measures). Moreover, measures were compared across time for an individual rater and found excellent test-retest reliability (ICC ranged from .93 to .96 across times for the measures).

Intervention. Participants in the cross-body group, (figure 3), were given instructions with picture demonstrations and the principal investigator also explained and demonstrated this technique to each participant by elevating the arm to 90° then using the non-dominant arm to pull the dominant arm across the body while keeping the dominant arm in an elevated position. This explanation is similar to prior investigation of the cross-body technique.[10, 13] All participants were advised to stretch to the point of normal stretch sensation, which has been described as mild discomfort.[10] For this stretch, the participant statically holds the cross-body position for thirty seconds for a total of five repetitions three times per week.

Figure 3. Prone-passive (top) with specific emphasis on GH joint abducted to 90° and right hand stabilizing scapulo-thoracic movement while clinician's left hand passively internally rotates extremity; cross body (bottom) technique.

The prone-passive stretching technique is similar to a technique described by Johansen et al.[15], however, modifications to this technique were made to accommodate participants exhibiting restricted ROM. The prone-passive technique requires a clinician to perform the stretch.

The prone-passive stretching technique was conducted by a trained and proficient research assistant. The stretch was repeated a total of five times during each session and passively held for 30 seconds each time three times per week. Participants were given up to a minute break between each stretch. Specific attention to GH endpoints, shoulder and elbow alignment, discomfort, and any compensatory movements of the shoulder girdle were monitored during the administration of the stretch. To standardize treatment between groups, *all* study participants were asked to perform stretches three times per week over a 28-day period for a total of 12 separate sessions. Treatment sessions were recorded by self-stretch participants and the research assistant working with the prone-passive group participants to monitor adherence to the requirements for this study.

Description of the Prone-Passive Stretching Technique:

The steps for performing this technique are as follows:

1. Patient is positioned prone with the involved upper extremity in a freely movable position on the side of a treatment table

2. With the elbow bent to 90° the clinician passively abducts the glenohumeral joint to 90°. The upper extremity should be in a neutral position as seen in Figure 3, with specific emphasis on maintaining the humeral head in perpendicular alignment to the glenoid. The upper arm should now be depressed to the table. In some cases the upper arm may need to be off of the table to reduce friction inhibiting passive rotation.

3. The clinician passively stabilizes the scapula by pressing the lower portion of the scapula toward the thorax with the free hand. While doing this the clinician's forearm is placed on the patient's upper arm to help maintain perpendicular alignment of the upper arm. This will be necessary as the arm is now passively internally rotated by the clinician to a firm end point. This position is held 30 seconds and repeated five times with a gradual, yet tolerable stretch applied by the clinician.

Results

Prior to examining dependent variables groups were evaluated for similarity. The prone-passive and cross-body groups (prone-passive N=17, cross-body N=17) did not differ in mean age, $t(32) = .66$, $p = 0.52$; years of overhead sports participation, $t(32) = .99$, $p = 0.33$; gender, $\chi^2(1) = .12$, $p = 0.73$. The groups were similar and descriptive statistics for the variables are reported in *Tables 1-2*.

Table 1. Participant Descriptives for Prone-Passive and Cross-Body groups

Group	Male	Female	Age	Age Range	Left Shoulder	Right Shoulder
Prone-Passive	9	8	20.64 (3.34)	18-29	2	17
Cross-Body	10	7	20.05 (1.56)	18-29	4	11
Total	19	15	20.35 (2.58)	18-29	6	28

Note: Age reported as mean (standard deviation)

Table 2. Participation by Sport and Total Years of Experience in the Respective Sport

Group	Baseball	Softball	Recreational	Swimming	Years of Experience
Prone-Passive	6	5	5	1	13.17 (3.72)
Cross-Body	9	4	3	1	12.94 (3.91)
Total	15	9	8	2	13.06 (3.76)

Note: Years of Experience reported as mean (standard deviation)

The effects of Group and Time were analyzed using a 2 (prone-passive versus cross-body) x 2 (pre-test versus post-test) analysis of variance (ANOVA). A separate ANOVA was conducted for each of the dependent variables. Measurements are reported in *Table 3*. While differences were observed within groups from pre-test to post-test, between group interactions were not significant. Dominant IR ROM analysis exhibited a moderate to strong effect size, reported as partial eta squared, while IR deficit and total motion exhibited a moderate effect.

Dominant IR was greater at posttest than at pretest for both groups, $F(1, 32) = 58.16$, $p < .001$, partial eta squared = .65 and the groups were similar, $F(1, 32) = 1.42$, $p = 0.10$. The interaction between groups was not significant, $F(1, 32) = 2.81$, $p = 0.10$. *Non-Dominant IR* did not differ from posttest to pretest, $F(1, 32) < 1$, $p = .983$ and the groups were similar, $F(1, 32) < 1$, $p = 0.45$. The interaction between groups was not significant, $F(1, 32) < 1$, $p = 0.64$.

Dominant ER did not differ from pretest to posttest, $F(1, 32) = 1.46$, $p = 0.24$ and the groups were similar, $F(1, 32) < 1$, $p = 0.39$. The interaction between groups was not significant, $F(1, 32) < 1$, $p = 0.97$. *Non-Dominant ER* did not differ from pretest to posttest, $F(1, 32) < 1$, $p = 0.58$ and the groups did not differ, $F(1, 32) < 1$, $p = 0.86$. The interaction was not significant between groups, $F(1, 32) < 1$, $p = 0.82$.

IR Deficit decreased from pretest to posttest for both groups, $F(1, 32) = 40.00$, $p < .001$, partial eta squared = .56 and the groups were similar, $F(1, 32) < 1$, $p = 0.38$. The interaction between groups was not significant, $F(1, 32) = 1.04$, $p = 0.32$.

Total Motion in the dominant arm increased from pretest to posttest for both groups, $F(1, 32) = 38.66$, $p < .001$, partial eta squared = .55 and the groups were similar, $F(1, 32) = 2.15$, $p = 0.15$. The interaction was not significant, $F(1, 32) = 1.49$, $p = 0.23$.

Table 3. Pre- and Post- Test Measurements for all Measurements by group

Measurement	Test	Prone-Passive	Cross-Body
Dom IR ROM	Pre	60.36 (13.58)	58.42 (7.23)
	Post	73.60 (12.79)	66.89 (10.62)
Non Dom IR ROM	Pre	77.58 (11.76)	75.44 (7.40)
	Post	78.18 (15.03)	74.78 (9.29)
Dom ER ROM	Pre	109.86 (8.98)	107.18 (12.25)
	Post	111.45 (7.48)	108.67 (9.92)
Non Dom ER ROM	Pre	99.45 (9.10)	100.07 (6.92)
	Post	100.10 (7.42)	100.34 (5.99)
IR Deficit ROM	Pre	17.22 (6.76)	17.02 (3.63)
	Post	4.58 (8.70)	7.89 (8.33)
Dominant Total Motion	Pre	170.22 (14.11)	165.60 (12.73)
	Post	185.05 (14.79)	175.57 (18.48)

Note: Means (Standard Deviation) in degrees
Dom = Dominant Shoulder
Non Dom = Non-Dominant Shoulder

Discussion

The study demonstrates a previously untested prone-passive stretching technique is at least as effective as the cross-body technique at improving shoulder internal rotation, internal rotation deficit, and total motion in an overhead athlete population; the investigation did not demonstrate, with statistical significance, that one technique is more effective than the other.

Similar to previous studies,[10, 13] clinical significance may be inferred due to the improvements in IR ROM noticed in the prone-passive group compared to the cross-body subjects. However, this study did not utilize a true control group as compared to McClure and colleagues[10]. Instead, this study compared a previously untested technique to a previously tested method. The IR deficit threshold for inclusion in this study was asymptomatic participants with ≥ 10°, which has been utilized in each of the previously mentioned studies. This allows for a minimal amount of deficit, yet an appreciable difference whereby participants are not harboring underlying pathology. Potentially confounding injury variables are minimized using this inclusion process. However, analysis of both asymptomatic groups revealed a pre-test mean IR deficit at just over 17°.

Participants were asked to perform 12 stretching sessions over a 28-day period. Excellent adherence was reported over this timeline. However, self-reporting in the cross-body stretching group could have potentially lead to less improvement in IR ROM as compared to the prone-passive group in this study. Creep theory of collagenous tissue emphasizes the importance of repeated stretching or, more simply, movement within soft tissue in order to maintain elasticity.[29] This theory can be thought of as a change in length proportional to the amount of strain applied over time. An interesting observation was noted by the research assistant providing the prone-passive stretching technique in this study as improvements to IR ROM were noticed after only 4-6 treatment sessions in the prone-passive group. An explanation for this occurrence would be the acute stretch response which has been demonstrated in many other studies investigating IR ROM restriction response to a single stretching treatment.[2, 11] Participants in the prone-passive group were not treated on a daily basis; rather, treatment was administered three times per week. Even with multiple days in between sessions, the research assistant noticed a reduction to the previously encountered soft tissue limitations to IR ROM within the first 2 weeks of the prone-passive stretching program. While this observation was not measured or substantiated, this response to treatment may imply a shorter creep response, leading to the suggestion that a reduced number of treatments are needed to elicit improvement in IR ROM at the shoulder joint. This same phenomenon would also suggest a rather rapid reversal in tissue elongation in the absence of maintenance stretching. Future study should consider investigation over a shorter timeline, or fewer intervention sessions.

Different Views on Total Motion in an IR Deficit Sample

Prior studies describe a concomitant increase in external rotation (ER) when limitations to IR exist, with total motion remaining normal compared to the non-dominant shoulder. Others refer to this relationship as a shift toward ER.[8, 16, 27] This explanation leads to the assumption that total motion remains the same even with a decrease in IR. Pre- and post-measurements of total motion in this study do not fully support this assumption; rather, in this study, total motion was improved in the dominant shoulder after treatment for unilateral IR deficit. Increased IR was observed in the prone-passive group compared to the cross-body participants in this study, while ER remained unchanged regardless of treatment. The total motion concept states that an equal amount of IR and ER exists in the dominant and non-dominant shoulders, even in cases of GIRD.[8] The observation in this study may suggest there is a difference in the degree of total motion when IR ROM has been improved, producing an increased total motion in an individual with IR deficit. This finding is similar to what McClure et al. observed,[10] however Manske et al.[13] did note subtle changes in dominant ER ROM. The observation leads one to speculate that dominant shoulder total motion may be increased in healthy, non-GIRD overhead athletes compared to the non-dominant shoulder. These findings may support the belief that soft tissue contracture, developed over time in the posterior shoulder musculature, leads to GIRD and/or posterior shoulder tightness (PST). An increased total motion may be advantageous to the overhead athlete by allowing for greater force production and throwing velocity.

Recent evidence suggests humeral retroversion is correlated to change in IR ROM in professional baseball pitchers, whereby osseous adaptation of the glenoid compromise normal shoulder rotation.[3, 28] These adaptations could also lead to patho-mechanical changes during the overhead throw, creating similar posterior shoulder contractures as mentioned previously in this article. However, future research should investigate the indication for stretching those exhibiting osseous changes in the glenoid.

Limitations

Statistical significance in this study was not observed, most likely due to insufficient sample size (n=34). This limitation is similar to those reported previously which utilized a similar experimental design whereby researchers explained the difficulty in recruiting enough asymptomatic participants with unilateral IR deficit.[10, 13] Future studies should attempt to include a larger number of participants with GIRD. While both stretching groups reported adherence to treatment parameters, as is often observed in self-treatment, the self-stretching cross body group participants may have demonstrated less treatment exposure than those in the clinician guided prone-passive group.

Implications

The prone-passive stretching technique, like other stretches used to improve or maintain normal shoulder IR ROM, is a useful manual therapy tool when treating overhead athletes that exhibit IR restriction. This technique may be particularly useful when working with patients that have a higher degree of IR limitation. The abducted position in the prone-passive stretch, compared to other GH IR stretching positions, allows for greater capsular and muscle twisting because the motion occurring in the shoulder girdle occurs in both the sagittal and frontal planes.[30] In addition, it has been suggested that the torsional stresses applied to the soft tissue structures of the GH joint may impart greater elongation of the tissue than tensile forces alone.[31] Further, a prior cadaveric manipulation study demonstrated greater elongation of posterior GH capsule tissue using a strain gauge during torsional stretching techniques.[19]

The prone-passive stretching technique may also be advantageous when treating the symptomatic shoulder. For example, when the forward flexed position of the sleeper stretch creates a decreased sub-acromial space, which could increase inflammation when treating an athlete with sub-acromial impingement. The prone nature of the prone-passive stretch can easily be sequenced with other prone positioned therapeutic exercises or manual therapies for the posterior shoulder while allowing the clinician to closely observe and stabilize the scapulo-thoracic articulation.

Patient adherence to a self-stretching technique treatment plan can be an impediment to restoring adequate IR ROM. Clinician assisted stretching may present adherence issues too, as resources required of the patient, including time and money, often become a barrier to receiving treatment.

Conclusion

The prone-passive stretching technique, when performed by a trained clinician, is at least as effective as the cross-body technique at improving glenohumeral internal rotation in an asymptomatic IR deficit overhead athlete sample. The cross-body technique has previously shown to be effective at treating GIRD.[10] This is the first empirical evidence to support use of the prone technique when treating a patient population with GIRD and/or PST. Studying a larger patient population of baseball athletes, whom often exhibit greater degrees of GIRD, may have affected the statistical outcomes observed with the prone technique in this study. The prone-passive stretching technique may be a valuable tool for a clinician treating GIRD. The results of this study support the recommendation that IR stretching be part of a consistent maintenance program for overhead athletes in the hope that risk of injuries are decreased.

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