ABSTRACT
The purpose of this study was to compare the effectiveness of active, passive, and proprioceptive neuromuscular facilitation (PNF) stretching techniques on improving internal rotation of the shoulder in asymptomatic individuals. From a convenience sample of college students, including individuals on a particular athletic team, 42 asymptomatic individuals volunteered to participate. A stretching intervention was implemented during which participants performed 3 shoulder stretches by either passive, active, or PNF techniques. The results revealed significant differences in range of motion (ROM) over time for internal rotation among the different stretching protocols (P < .01). However, the stretching protocol implemented, whether passive, active, or PNF, did not significantly affect ROM for internal rotation. The current findings revealed that active, passive, and PNF stretching over time can elicit increases in internal rotation within the glenohumeral joint, and these changes are apparent after 1 week of stretching intervention.

When shoulder range of motion (ROM) and injury implications are examined, internal rotation deficits are of concern.1-5 Posterior capsule tightness results in glenohumeral flexion and internal rotation restrictions. This phenomenon of glenohumeral ROM restriction results in increased anterosuperior shift or decreased posteroinferior slip of the humeral head, which commonly leads to subacromial impingement.6-7 Decreased flexibility of the posterior capsule and the infraspinatus muscle are typically observed in throwing athletes.6-9 Posterior capsule tightness is often associated with glenohumeral internal rotation deficit (GIRD), which is the loss of internal rotation compared with the contralateral side and is attributable to both bony and soft tissue changes.10

Loss of glenohumeral internal rotation may be caused by an osseous adaptation of the humerus and increased retroversion of the proximal humerus resulting in the increase in external rotation, at the expense of internal rotation.5,10-13 In addition, a loss in glenohumeral internal rotation that exceeds gains in external rotation has been associated with the soft tissue restriction of the posterior capsule.10 Through the constant repetitive nature of throwing and the susceptibility of sustaining GIRD, there is a high propensity for shoulder instability (lack of humeral head movement control), resulting in impingement.2,4,5 Stretching of the posterior capsule and posterior muscles of the glenohumeral joint has been shown to increase ROM and decrease the risk of injury to the joint if the restriction is the result of soft tissues.8,11,14-20

Along with identifying the benefits of shoulder stretching, the literature shows previously documented different stretching procedures and the corresponding effectiveness on posterior capsule tightness.5,10,21,22 In an attempt to treat GIRD, it has been recommended to incorporate posterior capsular stretching.23 If posterior capsule tightness is truly the cause of the internal rotation deficit, posterior capsule stretching should
correct the deficit as well as prevent further injury caused from the restriction. \(^4\) Loss of internal rotation caused by posterior capsular tightness is not permanent if a regular posterior capsule stretching regimen is implemented. \(^10\) In addition, the longer the stretching program is performed, the smaller the internal rotation deficit. \(^10\) When evaluating the effects of stretching regimens, a 3-year intervention has been found to yield significant improvements in the deficit, with most of the improvements occurring within years 2 and 3. \(^10\)

Approximately 90% of all throwing athletes diagnosed with posterior capsule tightness have benefited by some type of posteroinferior capsular stretching, particularly the sleeper stretch. \(^23,24\) The sleeper stretch is performed while lying on the side to be stretched, elevating the humerus to 90°, and then passively internally rotating the shoulder with the opposite arm, with or without performing scapular stabilization. However, it has also been shown that the cross-body stretch can result in significant increases in internal rotation. \(^21\) The cross-body stretch places the individual in a position where the humerus is elevated to approximately 90° of flexion and pulled across the body into horizontal adduction with the opposite arm. The disparity of the cross-body stretch is the lack of scapular stabilization while performing the stretch. \(^21\) Although the sleeper and cross-body stretches have been the primary stretches for the posterior capsule, their effectiveness has been debated. \(^21,23,24\) In addition to the type of stretch, the stretching techniques of passive, active, \(^10\) and proprioceptive neuromuscular facilitation (PNF) stretching have also been examined for effectiveness. \(^25-27\)

Deficits in internal rotation have been shown to improve from various active and passive stretching procedures. \(^23\) In addition, there has been suggestion of improvements in ROM pertaining to glenohumeral internal rotation when utilizing PNF techniques with the 2 posterior capsule stretches mentioned previously. \(^10\) Apart from the studies that have focused on improving glenohumeral internal rotation deficits, PNF utilization has been shown to be beneficial in increasing ROM, \(^28\) as well as yielding greater gains at a faster rate than that of static stretching. \(^11,16,19,20,26,28-36\) It has been reported that one repetition of PNF stretching is adequate to elicit gains in ROM, \(^37-40\) with expected changes ranging from 3° to 9°, depending on the joint. \(^37,39\) Regardless of the duration of the PNF stretching intervention, changes in ROM do occur. \(^16,41,42\)

Thus, with the literature focusing on the benefits of posterior capsular stretching, as well as different types of stretching techniques, the purpose of this study was to compare the effects of active, passive, and PNF stretching techniques over time on improving shoulder internal rotation. We hypothesized that the PNF stretching technique would elicit the greatest increase in internal rotation ROM, and these changes would be seen earlier in the stretching regimen as compared with the active and passive stretching groups.

**METHOD**

**Study Design**

An observational, repeated measures design was implemented to collect ROM data during a 4-week stretching intervention. Baseline ROM measurements were recorded on day 1 and 24 hours after the third stretching session of each week for each study participant. All measurements were collected by the primary investigator (J.H.) and recorded by an athletic training student. Range of motion measurements were collected using a digital inclinometer (Baseline Evaluation Instruments, White Plains, New York). Prior to all measurements, the digital inclinometer was calibrated per the manufacturer’s guidelines.

**Participants**

From a convenience sample of college students, including individuals on a particular athletic team, 42 individuals (8 men, 34 women; mean age, 23.4±1.4 years) volunteered to participate. Of the 42 participants, 19 were National Collegiate Athletic Association Division I softball athletes (throwers) (mean age, 20.9±1.5 years) and 24 were graduate students (nonthrowers) (mean age, 23.4±1.4 years). Participants were excluded if they had a history of shoulder injury, pain, or GIRD at the time of data collection. In addition, all participants had to be shoulder injury–free for the past 6 months. Hand dominance was determined by the throwing hand of the throwing athletes and the hand used for writing for the graduate students. Forty-one of the 42 participants were right-hand dominant. All testing protocols used in the study were approved by the university’s institutional review board. Prior to participation, the approved procedures, risks, and benefits were explained to all participants. Informed consent was obtained by the participant, and the rights of the participants were
protected according to the guidelines of the university’s institutional review board.

**Procedure**
All participants reported to the graduate athletic training education classroom laboratory for preliminary baseline glenohumeral ROM testing. All measurements were performed by the primary investigator, who had established intrarater reliability on a group of 11 participants (22 shoulders) prior to the study (intraclass correlation coefficient = 0.957; 95% confidence interval, 0.910-0.978). The primary investigator reported all scores to an athletic training student who monitored the progress. Following the protocol of Kibler et al,⁴³ the mean of 3 passive internal rotation measurements were taken with the participant’s humerus abducted to 90° in the frontal plane with the humerus parallel to the treatment table and the elbow flexed to 90° (Figure 1). The end point of internal rotation was determined through visual inspection of scapular movement accommodation. The digital inclinometer was placed on the surface at the midpoint of the anterior forearm with the digital read-out screen facing the investigator.

**Stretching Intervention**
Participants were randomly assigned, regardless of whether they were a throwing athlete or graduate student, to 1 of 3 groups (active, passive, or PNF) with each group performing 3 stretches—sleeper, cross body, and genie. The active group was given verbal instruction and feedback by the investigator while they actively performed the stretches throughout the entire intervention program. The investigator throughout the intervention stretched participants in the passive and PNF groups. All participants completed the 3 stretches for 5 repetitions of 30-second holds, for a total of 3 times per week for 4 weeks, at an intensity of 2 on a scale of 1 to 3. The stretch intensity was described on a scale of 1 to 3, with 1 = stretching sensation, 2 = intense stretch with no discomfort or pain, and 3 = intensive stretch with pain and discomfort. Initial baseline ROM measurements were taken on day 1 prior to any stretching and again at 24 hours after the third stretching session of each week throughout the 4-week period. For the entire 4 weeks, the investigator constantly monitored participant compliance. The participants were notified at the beginning of the study and at every ROM measurement day that if they did not perform the stretches 3 times per week, they would be excluded from the study. All participants were reported as compliant.

The passive cross-body stretch was performed with the participant lying supine on the treatment table, humerus abducted and elevated to 90°, and elbow flexed to 90°. The participant’s humerus was pushed at the distal end nearest the elbow into horizontal adduction toward the participant’s midline, keeping the elbow flexed and the humerus elevated with the scapula stabilized by the investigator (Figure 2). The cross-body active group performed the same stretch, and with their contralateral arm they pulled their distal humerus into horizontal adduction.

For the cross-body PNF group, participants were passively stretched to their end point for 7 seconds with the scapula stabilized; they then contracted against the investigator’s resistance for 3 seconds followed with another passive stretch by the investigator to a new end point using the contract–relax PNF technique.¹⁰ This series was repeated 3 times. Contraction by the participant was a 4/5 on manual muscle test grades, meaning that the contraction was strong enough to overcome...
gravity and some external resistance but not strong enough to push out of the stretch position. The sleeper stretch that was performed by the passive stretching group was conducted with the participant lying on the ipsilateral side of the shoulder to be stretched. Side lying allowed the participant’s weight to stabilize the scapula. The shoulder and elbow were positioned at 90° flexion; the humerus was then internally rotated by the investigator, moving it toward the table (Figure 3). The active stretching group used their contralateral limb to internally rotate the humerus, whereas the PNF group mimicked the PNF protocol repetitions as described in the cross-body stretch.

The genie stretch was performed by the passive group with the participant positioned similarly to the cross-body stretch lying supine. After the participant was lying supine on the treatment table with their humerus abducted and elevated to 90° and elbow flexed to 90° (representing the cross-body position), they began the genie stretch. From the cross-body position, participants placed their contralateral arm parallel to the arm to be stretched so that the hand of their contralateral arm was placed over the elbow of the arm to be stretched. Both palms were facing out and away from their face. Pressure was then applied to the dominant arm or arm to be stretched by the investigator in an internal rotational direction (Figure 4). The active group performed the same stretch but applying their own resistance with the contralateral arm in an internal rotational direction, whereas the PNF group repeated the protocol of the PNF groups for the sleeper and cross-body stretches.

**Statistical Analysis**

Descriptive statistics are reported as mean and standard deviation. A 2-way analysis of variance (ANOVA) with repeated measures was used to assess any differences in ROM among the different stretching groups over time. To assess for possible differences between the throwing population and nonthrowing population, a series of two-way ANOVAs with repeated measures were used for each stretch (active, passive, or PNF). A one-tailed student $t$ test was used to assess differences in baseline ROM for internal rotation between throwers and nonthrowers. Differences between baseline ROM and reported at week 4 were found for each stretch type, and the reported deltas were analyzed using a one-way ANOVA with Tukey’s post hoc analysis for pairwise comparisons when significant. Differences in ROM from baseline values for each week were analyzed using a one-way ANOVA with Tukey’s post hoc analysis for pairwise comparisons. The desired overall level of significance was $P < .05$. A Bonferroni adjustment was made due to multiple analyses, which lowered the level of significance to $P < .01$.

**RESULTS**

Due to a concern that the throwers may have responded to the intervention differently than the nonthrowers, the stretching groups were further divided into two subgroups.

No significant difference in internal rotation ROM was noted between the throwing (65.90°±19.69°; $n = 18$) and nonthrowing (73.41°±18.88°; $n = 24$) groups during baseline measurements (Figure 5). Internal rotation ROM did not significantly differ between the throwing and nonthrowing groups for those participating in the active (thrower: 27.43°±15.78°, $n = 6$; nonthrower: 24.90°±13.35°, $n = 9$; $P = .08$), passive (thrower: 37.16°±20.62°, $n = 5$; nonthrower: 38.80°±15.51°, $n = 9$; $P = .55$), or PNF (thrower: unknown).
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23.76±17.02°, n = 8; nonthrower: 21.75±17.08°, n = 6; P = .03, Cohen’s d = 15.8) stretching programs. Because no differences were found between the throwers and nonthrowers, the groups were combined for all remaining analyses.

When analyzing for differences in ROM among the different stretching groups throughout the duration of the intervention, no interaction between the type of stretch and duration of the intervention was found (P = .37). However, the duration of the stretching intervention alone did have a significant effect on ROM (P = .0001), where the average ROM for internal rotation was greater at each week following baseline. Figure 6 represents the difference (Δ) in ROM from baseline values for weeks 1 through 4 (mean and standard error). Range of motion measurements continued to increase significantly from baseline through week 3. By week 4, no further gain in ROM was observed.

When pre- and postintervention ROM were analyzed using the calculated deltas, the results showed that no one type of stretch produced a greater increase than another (active 25.91±13.87, n = 15; passive 38.21±16.72, n = 14; PNF 21.53±16.37, n = 12; P = .02, Cohen’s d = 9.2) (Figure 7).

DISCUSSION
Our results reveal that a 4-week stretching program did allow for increases in glenohumeral internal rotation ROM. Of the 3 stretching techniques implemented (active, passive, and PNF), none were deemed superior to another for ability to produce greater glenohumeral internal rotation ROM gains. As the stretching intervention progressed, so did the gains in internal rotation ROM. Data revealed that internal rotation ROM increased significantly compared with the prior week until week 4. At week 4, the increases in ROM appeared to plateau with no further gains. The 4-week stretching intervention was based on the study by McClure et al21 who also examined stretching interventions in an attempt to gain glenohumeral internal rotation. However, our study not only examined the posterior capsule stretching exercise, but it also implemented different stretching techniques.

Previous studies demonstrated that the PNF stretches that incorporate a shortening contraction of
the antagonistic muscle to lengthen the target muscle achieve greater gains in ROM. In addition, it is known that 1 repetition of PNF is sufficient to increase ROM with an expectant change in ROM from 3° to 9°, depending on the joint. Not only does the implementation of PNF stretching twice per week improve ROM, it is strongly supported that a single repetition effectively augments ROM. In our study, we increased ROM an average of 9.5° each week with the exception of week 4 when there was no further gain in ROM from week 3 over the course of the intervention time period.

It has been shown previously that a 4-week passive stretching intervention for glenohumeral internal rotation has proven beneficial in increasing ROM. As McClure et al. documented, our study also revealed that a 4-week intervention was adequate for increases in ROM. However, our study is unique because the participant population included randomly assigned asymptomatic shoulders of both throwing and nonthrowing populations; yet, similar results were achieved. It is often speculated that an intervention involving the shoulder would affect throwers versus nonthrowers differently.

Lintner et al. indicated there has not been a published study documenting that stretching programs can measurably increase internal rotation, and McClure et al. reported that it is difficult to know how high-level throwing athletes would respond due to humeral retroversion that may limit a response to a stretching intervention. Our study agrees with Davis et al., who found that a 4-week passive stretching intervention did increase ROM. However, when applied to our sample of both throwers and nonthrowers, the passive, active, and PNF techniques all showed a significant increase in ROM, but the differences among the techniques were not significant. We have identified that implementing stretching programs 3 times per week for 4 weeks can significantly increase ROM in both nonthrowing individuals and in high-level throwing athletes. In addition, our study agrees with previous studies in which implementing a stretching regimen 3 times a week for 4 weeks resulted in changes in ROM.

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