Systematic Review

Are stretches effective in the prevention and treatment of glenohumeral internal rotation deficit?

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Background: Shoulder injuries are well documented in overhead throwing athletes and glenohumeral internal rotation deficit (GIRD) has been identified in this population. There is evidence to suggest that GIRD and pain or pathology may be linked. Stretches are a common treatment to increase range of movement and have been advocated as a treatment to reduce GIRD.
Objectives: To review the efficacy of stretches on reducing GIRD.
Methods: A systematic literature search of Ovid MEDLINE (R), AMED, EMBASE, and CINAHL for studies investigating the efficacy of stretches alone on GIRD was performed from database inception to July 2011.
Results: Six studies met the inclusion criteria, all of which investigated the efficacy of stretches on glenohumeral internal rotation as a preventative measure for asymptomatic subjects. A variety of stretching interventions were utilized, ranging from single stretches to multiple position stretching programs, with different follow-up periods. Although all studies demonstrated reduced GIRD after stretching, four of the studies report changes within or only just above the standard error of measurement. The data suggested that stretching over a period of weeks, rather than a single session, demonstrated the greatest reduction in GIRD. All studies were either cohorts or clinical trials, only one of which included a no treatment and stretching group, similar at baseline. There was evidence from this study to suggest that stretching in one direction was superior to another.
Conclusions: There is weak evidence to suggest that stretches may be effective in reducing GIRD in subjects with asymptomatic shoulder pain.

Keywords: GIRD, Physical therapy, Shoulder, Shoulder pain, Stretch

Background

Shoulder pain is a common and often persistent musculoskeletal problem affecting all ages. A review of shoulder disorders estimated that the one year prevalence in the general adult population ranges between 20 and 51%.[1] This was based on two self-administered questionnaires. A later systematic review of 18 studies reported a 1-year prevalence of between 5 and 47% and a lifetime prevalence of between 7 and 67%.[2] There is evidence to suggest that glenohumeral internal rotation deficit (GIRD) and shoulder pain and/or pathology may be linked in the overhead athlete.[3–7] In a prospective cohort of 122 baseball pitchers, 40 players presented with GIRD and were almost twice as likely to receive a shoulder injury requiring time off play than those without GIRD.[7] An earlier case controlled study of 11 baseball throwers with confirmed pathological internal impingement demonstrated a significantly greater GIRD than 11 matched control throwers ($P=0.03$).[5] A series of 124 baseball pitchers with symptomatic type 2 superior labrum anterior to posterior (SLAP) lesions observed arthroscopically, on average demonstrated a preoperative GIRD of 53° in their throwing shoulder.[3] GIRD has also been linked to pain in tennis and cricket players.[4,8] Internal rotation deficits have been observed in the dominant arm of tennis players and linked to internal impingement.[6,8–10]

Shoulder pain is often attributed to SLAP tears or pathological internal impingement. The latter is defined as pinching of the under surface of the rotator cuff tendons between the humeral head and the posterosuperior glenoid labrum during the late

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cocking phase of throwing.[11] While the aetiology of SLAP and internal impingement remain unclear, Burkhart and Morgan propose that pathomechanical restriction of the posteroinferior capsule may be responsible.[3] This causes loss of internal rotation during abduction (GIRD) and secondary gains in external rotation. Subsequent increased anterior and superior translation of the humeral head during shoulder elevation may cause impingement against the posterosuperior glenoid labrum.[12,13]

The cause of GIRD has yet to be determined in the symptomatic population. Some authors have attributed the pathoetiology to soft tissue changes, including tightness of the posterior capsule or posterior muscle shortening caused by repetitive microtrauma during an overhead throw.[3,14–19] Osseous adaptations have also been implicated. These include increased humeral retroversion and structural changes to the proximal humeral growth plate.[20–22] It is unclear whether GIRD results from short tissue changes, osseous changes or a combination of both.

GIRD is defined as 'the loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder'.[3] Theoretically, a healthy shoulder should have equal rotation bilaterally or 180° combined internal and external rotation.[23] However, a thrower's shoulder typically demonstrates gains in external rotation at the expense of internal rotation.[19] Wilk *et al.*[24] noted in a study of 372 baseball players, that their pitching arm exhibited approximately 7° greater external rotation and 7° less internal rotation than their non-throwing shoulder. Wilk *et al.*[24] refer to the 'total motion concept', whereby the total rotation in the throwing shoulder is within 5° of the non-throwing shoulder although proportions of internal and external rotation may differ between sides. GIRD is often measured with a goniometer, when the elbow is flexed and the shoulder is abducted to 90° and then internally rotated.[23] GIRD is considered to be the difference in internal rotation, as geometrically measured by a goniometer or inclinometer, between the dominant and non-dominant shoulder.

Bilateral differences in range of internal and external rotation have been demonstrated to increase with age and with years of participation in sports with overhead throwing.[25,26] This increase in GIRD may go some way to explain the increase in prevalence of shoulder injuries with age and period of play observed by Oberlander *et al.*[27]

Burkhart *et al.*[3] suggest that GIRD is a loss of ≥20° of internal rotation in the throwing shoulder compared with the non-throwing shoulder which may increase the risk of shoulder injury. Wilk *et al.*[7] found that pitchers who had a total range of movement deficit of over 5° had a higher injury rate than those with a smaller deficit. Consequently, it could be argued a reduction in GIRD may prevent injury and improve pain and function.

Stretching has been demonstrated to be an effective treatment for increasing range of movement at many joints.[28,29] To manage and prevent injuries associated with GIRD, stretches of the posterior shoulder have been advocated with the intention of minimizing GIRD.[3,30] Cadaveric studies have demonstrated that stretches commonly employed to treat GIRD have an effect on the posterior shoulder capsule and posterior aspect of the rotator cuff and posterior deltoid.[31,32] However, it is important to evaluate the efficacy of stretches and to identify which is the most beneficial. The aim of this literature review is to evaluate the efficacy of physiological stretches, auto or therapist applied, in reducing GIRD in symptomatic and asymptomatic shoulders.

Methods

Eligibility criteria

Primary studies published in English, which measured GIRD before and after one or more glenohumeral internal rotation stretches alone on human participants with or without shoulder pain or pathology were included in the review. The stretch could range between one treatment session and a prolonged programme. Management strategies which included additional therapy techniques were excluded. Animal and cadaver studies and single subject case reports were excluded.

MEDLINE, AMED, EMBASE, and CINAHL were searched from inception to November 2010 using indexing, text terms, and Boolean operators. Results received were combined and duplicates removed. The full MEDLINE search strategy is presented in Table 1. The same search was updated in July 2011 and 107 new articles were obtained, 84 when duplicates were removed. One new study met the eligibility criteria. Two investigators independently evaluated all identified titles and abstracts against the predefined eligibility criteria. Full texts of any articles which appeared to potentially satisfy the eligibility criteria were obtained and again screened independently by two reviewers for inclusion. If disagreement arose in study eligibility, and a consensus could not be reached, any disagreement was to be settled by an adjudicator. An adjudicator was not required. Reference lists of selected articles were also searched by hand.

Literature Search Results

The selection process for included articles is demonstrated in Fig. 1. Of 1233 citations identified, six articles, describing six studies met the inclusion criteria.[33–38] These are summarized in Tables 2–4. All studies explored the efficacy of stretches on glenohumeral internal rotation as a preventative

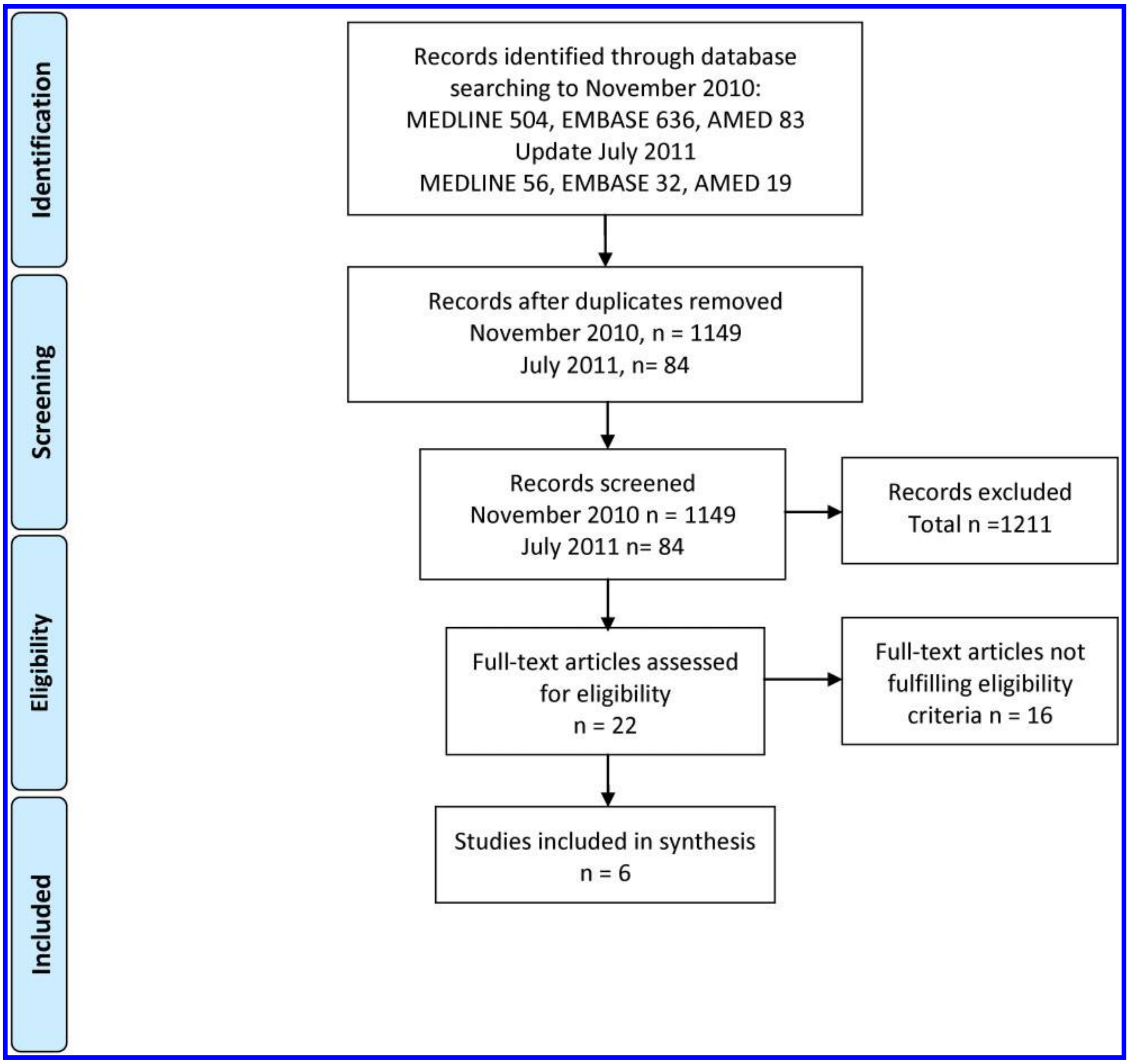

Figure 1 Article selection process.

measure. One further study was excluded, because in addition to stretches, manual mobilizations, scapula stabilization and external rotation strengthening exercises were employed and may have affected the results.[39]

A variety of study designs were utilized; only two employed random group allocation and blinding of assessor to group allocation,[33,34] one determined the appropriate sample size using a power calculation,[34]

Table 1 Ovid MEDLINE (R) search strategy

1. (shoulder$ or gleno-humer$ or scapulo-humer$ or humero-scapul$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
2. shoulder pain/or shoulder impingement syndrome/
3. Shoulder/
4. Shoulder Joint/
5. (contract$ or tight$ or stiff$ or flexibil$ or throw$ or athlet$).mp.
6. (posterior adj capsul$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
7. (internal adj rotat$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
8. contracture.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
9. Muscle Stretching Exercises/
10. stretch$.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
11. exercise therapy/or motion therapy, continuous passive/or muscle stretching exercises/
12. physical therapy modalities/or exercise therapy/
13. 1 or 2 or 3 or 4
14. 5 or 6 or 7 or 8
15. 9 or 10 or 11 or 12
16. 13 and 14 and 15

Table 2 Population characteristics

Study	Subject details (mean age±SD)	Intervention groups	Control	Shoulder stretched
McClure *et al.*[33]	Gp 1+2: 30 asymptomatic students >10° GIRD Control: 24 asymptomatic students <10° GIRD Gp 1: 6M 9F, 3 overhead sports participants, age 23.5±1.7 Gp 2: 4M 11F, 3 overhead sports participants, age 22.9±1.5 Control: 10M 14F, 5 overhead sports participants, age 23.5±1.8	Gp 1: sleeper stretch Gp 2: cross-body stretch	Control Gp and contralateral shoulder No treatment	Shoulder with most GIRD
Moore *et al.*[34]	61 asymptomatic national collegiate Athletic Association Division 1 baseball players Gp 1: n=19, age 19.5±1.0 Gp 2: n=22, age 20.4±1.1 Control: n=20, age 19.8±1.1	Gp 1: horizontal abduction MET Gp 2: external rotation MET	No treatment	Dominant
Launder *et al.*[35]	Gp 1: 33 asymptomatic National Collegiate Division 1 baseball players (15 pitchers, 18 position players), age 19.8±1.3 Gp 2: 33 physically active males, age 20.1±0.6	Gp 1: sleeper stretch	Gp 2: no treatment	Dominant
Lintner *et al.*[36]	81 asymptomatic male professional baseball pitchers, age 18–38 (age distribution between groups not described) Gp 1: 42 pitchers Gp 2: 39 pitchers	Gp 1: stretching program >3 years Gp 2: stretching program <3 years	No control	Dominant
Sauers *et al.*[37]	30 asymptomatic male collegiate baseball players, age 20±1.2	Stretching program on throwing shoulder	Contralateral shoulder No treatment	Throwing arm
Oyama *et al.*[38]	15 male collegiate baseball players, age 20.40±1.35 (Age distribution between groups not described)	Gp 1: horizontal cross-arm Gp 2: sleeper stretch 90° Gp 3: sleeper stretch 45°	No control	Throwing arm

Note: M=male. F=female, MET=muscle energy technique, GIRD=glenohumeral internal rotation deficit, Gp=group.

Table 3 Treatment

Study	Stretch and position	Stretch duration (seconds)	Rest (seconds)	Repetition total	Intervention period	Approach	End of stretch
McClure *et al.*[33]	1. Sleeper stretch: side lying, shoulder+elbow 90° flexion 2. Cross-body stretch: horizontal adduction	30	N/D	5	Daily stretches for 4 weeks	Passive, self performed	'Mild discomfort'
Moore *et al.*[34]	MET horizontal abduction MET external rotation	30	N/D	3	1 treatment	25% max isometric hold of antagonist, then PT applied	'To the first barrier of motion'
Launder *et al.*[35]	Sleeper stretch: side lying, shoulder+ elbow 90° flexion, lat scapular on table	30	30	3	1 treatment	Passive, PT assisted	'End range'
Lintner *et al.*[36]	Houston Astros program: 5 positions	3	N/D	3	Daily stretches for 3 years	Passive, PT assisted, and active	N/D
Sauers *et al.*[37]	Fauls routine: 12 positions	7	0	10	1 treatment	Passive, PT assisted	'Comfortable stretch'
Oyama *et al.*[38]	1. Horizontal cross-arm stretch: border of scapula against wall, horizontal adduction. 2. Sleeper stretch 90: shoulder+elbow flexed to 90° 3. Sleeper stretch 45°–45°: shoulder flexion	30	30	3	1 treatment	Passive, self performed	When 'stretch was felt'

Note: N/D=not documented, PT=physiotherapist, MET=muscle energy technique.

and two carried out a retrospective power calculation which indicated that they were underpowered.[33,35] Justification for sample size was not documented in the other three studies.[36–38]

Characteristics of participants are illustrated in Table 2, all of whom were asymptomatic. In five of the studies, the mean age ranged from 19 to 24 years,[33–35,37,38] and in one age ranged from 18 to 38 years.[36] Five studies included baseball players,[34–38] and one included a variety of non-athletic and athletic students.[33] Four studies compared a stretching group with a control group, which was comprised of participants that had received no treatment,[33–35] or the contralateral shoulder of the same subjects.[33,37] One study did not use a comparison or control group,[38] and one compared two groups who had been applying the same stretch routine but for different intervention periods.[36]

A variety of stretching interventions were employed (Table 3). Four studies employed just one stretch per group,[33–35,38] whereas the other two used multiple position stretching programs.[36,37] Three studies used a clinician to apply the stretches to each subject,[35–37] two were performed by the participants themselves,[33,38] and the remaining used both.[34] A variety of follow-up periods were implemented. Moore *et al.*,[34] Laudner *et al.*,[35] Sauers *et al.*,[37] and Oyama *et al.*[38] analysed the immediate effects of stretching after one intervention. The remaining studies analysed more long term adaption of glenohumeral internal rotation by following up 4 weeks[33] and 3 years[36] after daily stretching. It is more likely that longer intervention periods will show greater improvements in GIRD.

Table 4 shows that all subjects receiving stretches reported gains in internal rotation, ranging from 3.1° (Ref. 35) to 20°.[33] The two studies which presented standard deviation in mean change data indicated large variations from the mean.[34,38]

Stretching compared to no treatment (different subjects)

Three studies compared stretching in one or more groups (total $n=104$) with a control group (total $n=77$) receiving no treatment.[33–35] Laudner *et al.* documented a statistically significant ($P<0.005$) but clinically small (mean 3.1°) reduction in GIRD after just one treatment but no significant difference in the control group.[35] Over a 4-week period, McClure

Table 4 Glenohumeral internal rotation changes

Study	Stretch	IR pre-intervention (°) (mea±SD)	IR post-intervention (°) (mea±SD)	Change at glenohumeral joint (°)	*P* value between pre/post-intervention	*P* value between groups
McClure *et al.*[33]	Stretch 1	48.2±8.8	60.6±10.4	12.4*	N/D	0.586 (gp 1+ control gp) <0.001 (gp 1+ control side)
	Stretch 2	46.6±11.5	66.6±15.9	20*	N/D	0.009 (gp 2+ control gp) <0.001 (gp 2+ control side)
	Control	52.5±9.5	58.3±8.8	5.8*	N/D	–
Moore *et al.*[34]	Stretch 1 Habd	43.5±10.1	47.7±11.7	4.2±5.3	>0.05	MET Abd and control *P*=0.03
	Stretch 2 ER	44.5±8.6	44.7±8.6	0.2±6.3	>0.05	
	Control	50.7±11.3	50.5±12.1	−0.2±4.0	>0.05	MET Abd and MET ER *P*=0.02 In favour of Abd MET ER and control *P* >0.05
Launder *et al.*[35]	Stretch 1	43.8±9.5	46.9±9.8	3.1	0.003	N/D
	Control	43.1±7.9	42.7±7.9	0.4	0.62	
Lintner *et al.*[36]	1	N/D	74.3±N/D	N/D	N/D	<0.01
	2	N/D	55.2±N/D	N/D	N/D	
Sauers *et al.*[37]	Stretch	49.4±11.6	55.8±11.7	6.4	<0.05	N/D
	Control	56.4±13.9	57.9±13.5	1.5	N/D	
Oyama *et al.*[38]	Stretch 1	36.7±11.1	41.1±10.5	4.4±5.6	<0.001	N/D
	Stretch 2	38.6±10.6	42.5±8.9	3.8±4.8		
	Stretch 3	35.4±11.6	40.0±11.4	4.6±5.5		

Note: N/D=not documented, IR=internal rotation, ER=external rotation, SD=standard deviation, Habd=horizontal abduction, MET=muscle energy technique, Abd=abduction, gp=group. *Reviewer's calculations.

et al.[33] reported a 12.4 and 20° reduction in GIRD from the sleeper and cross-body stretch respectively (reviewer's calculations from data presented) and a 5.8° reduction in the control group. Over a single treatment, Moore *et al.*[34] reported greater gains using the horizontal adduction muscle energy technique (mean 4.2°) in comparison with the control group (mean −0.2°). No significant differences were reported between the external rotation muscle energy technique (mean 0.2°), in comparison with the control group (mean −0.2°).

Stretching compared to no treatment (same subjects)

Two studies used a same subject design (total n=60) to compare changes in GIRD between shoulders; one shoulder received the stretch(es) and the other shoulder did not.[33,37] Sauers *et al.*[37] report an improvement of 6.4° ($P<0.05$) after just one application of the Faul's routine but less than 1.5° of improvement in the contralateral or control shoulder. McClure *et al.*[33] report an improvement of between 3 and 8° in the control shoulders of subjects receiving the sleeper and cross-body stretch respectively. This was less than the improvement gained in the stretched shoulders resulting in a statistically significant difference between sides ($P<0.005$). The control shoulders in the study by McClure *et al.*[33] achieved greater improvements than the stretched shoulders in Sauer's study.[37]

Different stretches

Three studies compared two or more different types of stretch between different groups of participants (total n=86).[33,34,38] All groups demonstrated improvements in the range of internal rotation after treatment apart from those receiving the external rotation muscle energy technique.[34] These improvements were of the greatest magnitude in the study by McClure *et al.*,[33] whose subjects underwent 4 weeks of stretches as opposed to just one stretching session in the other studies (see Table 4). Although there was a greater observable improvement in internal rotation following the cross-body stretch, in comparison with the sleeper group in the McClure *et al.* study,[33] the difference was not statistically significant. Moore *et al.*[34] demonstrated the only statistically significant difference in internal rotation gain between their stretching groups, although the difference was just 4°. The small magnitude of change in internal rotation in the Oyama *et al.*[38] and Moore *et al.*[34] studies may be reflective of the single treatment session.

Lintner *et al.*[36] compared two groups of subjects, one of which had performed daily stretches for more than 3 years previously and the other of which had performed stretches 'for less than 3 years'. No prestretch data was available. The group stretching for over 3 years demonstrated a statistically significant greater range of internal rotation, in comparison to the group who had performed stretches for less than 3 years (mean difference 19.1°, $P<0.01$).

Study Design

Design factors may have influenced results. Recruitment was either convenience,[33,34] or details were not stated. Three of the five studies used an intervention and control group(s),[33–35] only two of which were randomized.[33,34] Random group allocation reduces selection bias. McClure *et al.*[33] randomized participants with a 10° GIRD between two stretching groups. Participants with less than 10° GIRD were assigned to the control group. Therefore, it could be argued that stretches were given to participants who had more potential to gain increased range of internal rotation. Consequently, this may have biased results in favour of the intervention groups rather than the control.

In addition to a control group, McClure *et al.*[33] also used the contralateral shoulder as a comparison to the affected shoulder. Sauers *et al.*[37] also used a same-subject design. However, the control shoulders in these studies did not demonstrate the same degree of GIRD as the experimental shoulder. Again, this may have biased results in favour of the intervention groups rather than the control.

Lintner *et al.*[36] undertook a cross-sectional observational study to compare characteristics of two groups of pitchers at one point in time. However, this single contact renders it difficult to separate cause from effect; therefore, it is unknown whether the observed differences in range of internal rotation between groups are due to the stretching programme or other factors. Details of group allocation were not documented.

Sample

All participants were asymptomatic. Participants with a history of shoulder surgery or recent injury were excluded from all studies. Five studies included baseball players.[34–38] Moore *et al.*,[34] Laudner *et al.*,[35] Sauers *et al.*,[37] and Oyama *et al.*[38] included players of any position, whereas Lintner *et al.*[36] included pitchers, possibly representing those more susceptible to repetitive throwing injuries.[40] One study included college students, only a small proportion of whom were overhead sports players and therefore potentially more characteristic of the general population.[33]

Only Moore *et al.*[34] carried out a power calculation prior to data collection, which ensured a large enough sample size to detect statistically significant changes between the groups. Retrospective analysis by McClure *et al.*[33] and Laudner *et al.*[35] indicated that their studies were underpowered. This increased the likelihood of a type II error, in which it could be concluded that the stretch is statistically no more effective than another stretch or control, when a larger sample size would demonstrate that it is.

Blinding

Only three studies appeared to have blinded their assessors.[33,34,37] McClure *et al.*[33] and Moore *et al.*[34] blinded their assessors to group allocation, and Sauers *et al.*[37] to measurement values. Blinding of assessors to group allocation is important to reduce the risk of observational bias.

Intervention

Four studies performed just one session of stretches.[34,35,37,38] Although these resulted in increased range of internal rotation, this was smaller in magnitude than the gains reported after four weeks of stretches in the study by McClure *et al.*[33] These preliminary data may suggest that longer periods of stretching may be necessary for greater gains in internal rotation.

Only one of three studies demonstrated superiority of one type of stretch over another although the clinical significance of such a small difference (mean 4°) is unknown.[34] There was otherwise no clear trend indicating one aspect of stretching was more effective than another. For example, although clinicians performed the stretches in three studies,[35–37] and participants performed them independently in two,[33,38] and there was a combined approach in another,[34] the stretch duration and number of repetitions differed between studies. Heterogeneity between stretch procedures therefore renders comparison inappropriate.

Reliability of Outcome Measurements

Recent interest in detecting and treating internal rotation deficits has necessitated the development of reliable methods to measure isolated passive glenohumeral rotational motion. All six studies required the patient to lie supine with 90° shoulder abduction and 90° elbow flexion in order to measure GIRD.[33–38] Scapular stabilization has been demonstrated to isolate movement to the glenohumeral joint.[41] Five of the six studies used this method.[34–38] However, it has been suggested that scapular stabilization may not be necessary if the limit of passive internal rotation is defined as the point at which the scapula visually begins to lift from the examining table.[9] This method was used by McClure *et al.*[33] Comparisons of unstabilized, stabilized, and visual inspection methods of measuring shoulder internal rotation show both the visual inspection and scapular stabilized techniques exhibit equally acceptable reliability.[42] The visual inspection method actually exhibited marginally higher intraclass coefficient values and has the added advantage of being able to be performed by a single operator.

Instrumentation for measuring GIRD included digital display inclinometers,[34,35,38] non-digital incremental display inclinometers,[33] bubble level goniometry,[36] and standard goniometry.[37] Non-digital readings were displayed in one degree increments. The accuracy of the non-digital read out inclinometers and goniometers used in these three studies was not stated. Although research has indicated that goniometers may be accurate to 3°, this may differ between different sized instruments.[43] Moore *et al.*,[34] Laudner *et al.*,[35] and Oyama *et al.*[38] used digital inclinometers, the latter stating that the tool is reported as accurate to 0.1° by the manufacturers.

Reliability of goniometric shoulder internal rotation measurement is variable with reported intra-rater reliability generally better than inter-rater values. Measurements taken through goniometers are limited by errors in bony landmarks and visual reading — the latter of which will also affect non-digital display inclinometers. Digital inclinometers are reported to be a reproducible alternative. Authors of the included studies report intra-class coefficients for inter-rater reliability of 0.98 for digital inclinometers,[34,35] and 0.75–0.84 for non-digital inclinometers.[33] None of the included studies stated inter-rater agreement. Mullaney *et al.*[44] compared standard goniometry to digital inclinometer in determining the reliability of measuring shoulder range of motion in 20 patients aged 18–79 years. They concluded that reliability estimates for both methods were similar. However, there was a systematic bias in which readings from the digital inclinometer were 3–5° greater than those of the standard goniometer. This suggests that comparisons between studies which use a variation of measurement tools, and report figures barely above the minimal detectable change (MDC) should be made with some caution.

When assessing changes in internal rotation it is important to determine the MDC, that is, which part of the measurement is due to actual change rather than measurement error in the goniometer or inclinometer. Kolber *et al.*,[45] using a bubble inclinometer, calculated that a change of greater than or equal to 4° is necessary for clinicians and researchers to be 90% certain that the change is not due to inertial variability or measurement error. In contrast to the supine positioning of subjects in the studies of this review, Kolber *et al.*'s measurements were taken with subjects in prone and transferability to the supine position may be limited. Moore *et al.*[34] detected an MDC of closer to 5° in the supine position. Authors of the included studies for this review stated standard errors of measurements of 2°,[35] 3.28°,[34] 4.3–5.6°.[33] The changes in GIRD for four of the studies are within,[34,35,38] or only just above the standard errors of measurements,[37] calculated by McClure *et al.*[33] In addition, consideration must be given to the minimal important clinical difference; that is the smallest difference which may be beneficial for the patient.[46] While all studies demonstrated statistically significant improvements in GIRD for subjects undergoing stretches, the clinical significance of these is unclear.

Discussion

The six studies included within this review all indicated that stretches reduce GIRD. Of the five studies presenting change data,[33–35,37,38] the one study that applied stretches over a period of weeks rather than in one single session, demonstrated the greatest reduction in GIRD.[33] One study, which presented end mean data only, suggested that 3 years of stretching was more effective than less than 3 years.[36]

Shoulders receiving a stretch, demonstrated greater improvements in the range of internal rotation than the control shoulders; whether this be in the same subjects or different groups. There is currently no evidence to suggest that clinician performed stretches or self performed stretches are superior. Self-stretch treatments are easily employed by the patient and low in cost whereas programs that require therapists to provide the stretch are more costly and less time efficient.

Methodological factors need to be considered when interpreting these results and applying them to clinical practice. Several studies may have been underpowered and this may have produced a type II error, indicating for example no difference between various types of stretching when in fact a larger sample size may have demonstrated alternative results. The one study that was adequately powered and randomized comparable subjects at baseline did show a statistically significant difference between stretching techniques, and between one of the stretching techniques and a control group.[34]

The greatest magnitude of effect was reported in studies with a longer term follow-up period.[33,36] Neither of the longer term follow-up trials used digital inclinometers which have been reported to bias towards higher readings than standard goniometry.[44] It is therefore unlikely that different measurement tools are responsible for the differences in magnitude between studies. Inter-rater reliability may be a factor and is not reported within any of the studies. It is worthy of note that the control group receiving no treatment in one of the longer term studies,[33] achieved a greater mean reduction in GIRD than the subjects in the stretching groups within three other studies.[34,35,38] It is not possible to say with any certainly why such variation occurred between studies; this may be attributable to true difference or procedural differences.

The magnitude of difference before and after stretching is small and although reported as statistically significant in a number of reports, only exceeds the MDC reported by Moore *et al.* (4.6°),[34] in two of the five studies.[33,37] The clinically important difference has yet to be ascertained. Wilk *et al.*[7] investigated the relationship between GIRD and total range of movement to injury rate, and found that 27% of pitchers with a total range of movement deficit greater than 5° were more likely to be injured than those with a smaller deficit. In addition, although not statistically significant, pitchers with GIRD were almost twice as likely to develop a shoulder injury. Therefore, it could be reasoned that even small reductions in GIRD may improve total range of movement and be considered clinically important. However, more research is needed to verify this.

The exact mechanisms by which stretches produce a reduction in GIRD is as yet only theoretical. Stretches are unlikely to change osseous adaptations/humeral retroversion and certainly not in the timeframe of the follow-up periods presented in this review. The posterior glenohumeral capsule has been implicated and arthroscopic release of the posterior capsule demonstrated to produce an increase in glenohumeral internal rotation and a reduction in shoulder pain associated with throwing.[47–49] The small changes in GIRD reported immediately following one episode of stretching could be attributed to creep and hysteresis in the posterior capsule. Knowledge of the duration of any changes in GIRD beyond the immediate post-treatment period would also help to develop our understanding of the possible structures responsible.

Alternatively muscles posterior to the shoulder including the posterior cuff and posterior fibres of deltoid may be responsible for posterior shoulder tightness. Inhibition of these muscles via stretching would account for the more immediate effects observed from just one treatment. Both McClure *et al.*[33] and Moore *et al.*[34] demonstrated greater improvements in GIRD following techniques with a focus on increasing horizontal adduction (cross-body stretch and muscle energy techniques to release the horizontal abductors) than internal rotation (sleeper stretch and muscle energy techniques to release the external rotators). Differences were minimal between these same techniques in the Oyama *et al.* study.[38] Cadaveric studies have demonstrated that at 60° shoulder elevation the posterior deltoid is under greatest strain during horizontal adduction and the inferior fibres of infraspinatus under greatest strain during internal rotation.[50] These positions are similar to the cross-body and sleeper stretch respectively. The greater efficacy of muscle energy techniques inducing relaxation in the horizontal shoulder abductors in comparison with the external rotators,[34] suggests that the more superficial rather than deeper posterior cuff muscles may be contributing to GIRD. Electromyography is needed to investigate this hypothesis further.

A combination of mechanisms may be responsible for posterior shoulder tightness. Humeral retroversion in the dominant shoulders has been demonstrated as a likely adaptive mechanism in the throwing shoulder of baseball pitchers.[20–22] Stretching, at least in the short term, is unlikely to be an effective treatment strategy for subjects in whom this is the dominant mechanism. Longer term physiological stretches are required to produce anything but temporary post-treatment improvement in GIRD, if the posterior capsule is implicated. A case series of patients with posterior capsular restriction undergoing arthroscopic release demonstrated extensive adhesions in the fascia surrounding the glenohumeral external rotators suggesting a combination of soft tissues may be involved. Consideration should be given to the various pathomechanics which may be contributing to GIRD increase when determining the appropriate duration and frequency of stretch that is, at least theoretically, required for this condition.

Clinical Relevance

All six papers focused on injury prevention for asymptomatic athletes with GIRD. Therefore, the results cannot be generalized to symptomatic patients. The efficacy of stretches alone as a treatment rather than prevention, from our search of published material, does not appear to have been investigated. The effect of changes in GIRD on pain and dysfunction in symptomatic shoulders can only, as yet, be hypothesized.

The incidence of future shoulder pain following reduction of GIRD was not investigated in any of the included studies. Prospective long term follow-up over a recorded period of time from baseline did not take place in any of the studies; therefore, the duration of any improvements in internal rotation is unknown.

Conclusion

Previous studies have identified a possible link between GIRD and shoulder pain, although cause and effect has yet to be demonstrated. The evidence available focuses on internal rotation to reduce GIRD rather than treat shoulder pain and dysfunction. The results of this review suggest that stretches may be effective in reducing GIRD in asymptomatic subjects, but study design, methodological issues, and clinical significance of the results limit the confidence that can be placed in these results. More research is needed, in particular randomized controlled trials, with allocation concealment, blinded assessors and in which participants have an equal chance of being allocated to the stretching or control group. This would be of clinical value for asymptomatic subjects in which GIRD is the outcome and symptomatic subjects in which pain, function and GIRD are outcome measures.

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