A SYSTEMATIC REVIEW OF THE EFFECTIVENESS OF ECCENTRIC STRENGTH TRAINING IN THE PREVENTION OF HAMSTRING MUSCLE STRAINS IN OTHERWISE HEALTHY INDIVIDUALS

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ABSTRACT

Background. Hamstring strains are the most common soft-tissue injury observed in recreational and athletic activities, yet no consensus exists regarding appropriate primary and secondary strategies to prevent these strains. Eccentric exercise has been reported to reduce the incidence of hamstring strains but its role has not been clearly defined.

Objective. The objective of this systematic review was to determine the effectiveness of eccentric exercise in preventing hamstring strains.

Data Sources. Online databases, including MEDLINE, PubMed, CINAHL, PEDro, SPORTDiscus, EMBASE, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, and Web of Science were searched for relevant articles. Each database was searched from the earliest date to July 2007.

Study Selection. Selection criteria included diagnosis of hamstring strain, otherwise healthy individuals, and at least one group receiving an eccentric exercise intervention. Seven articles {three randomized controlled trials (RCTs) and four cohort studies} met the inclusion criteria.

Data Extraction. Data were extracted using a customized form. Methodological rigor of included studies was assessed using the PEDro scale and Oxford Centre for Evidence-based Medicine Levels of Evidence.

Data Synthesis. Studies were grouped by eccentric exercise intervention protocol: hamstring lowers, isokinetic strengthening, and other strengthening. A best-evidence synthesis of pooled data was qualitatively summarized.

Conclusions. Findings suggest that eccentric training is effective in primary and secondary prevention of hamstring strains. Study heterogeneity and poor methodological rigor limit the ability to provide clinical recommendations. Further RCTs are needed to support the use of eccentric training protocols in the prevention of hamstring strains.

Key Words: eccentric; hamstring strain; prevention

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INTRODUCTION

Hamstring strains are the most prevalent soft-tissue injury in recreational and sports activities that involve sprinting, jumping, and kicking.[1-3] Strains to this muscle group remain a primary concern for rehabilitation professionals as they result in a debilitating injury characterized by acute loss of functional performance, prolonged periods of recovery, and subsequent increased incidence of recurrence.[4] A recent review indicated hamstring injuries have the highest recurrence rates in sports, ranging from 12-31%.[4]

A muscle strain is defined as an excessive stretch, which leads to muscle fiber damage and disrupts the integrity of related vascular and connective tissue structures.[5,6] A muscle is commonly strained or torn during rapid acceleration or deceleration movements. A strain can be classified into grades from mild to severe to reflect injury severity. A mild (first degree) strain involves damage to a small number of muscle fibers and localized pain without loss of strength. A clear loss of strength coupled with pain reproduced on resistance is indicative of a moderate (second degree) strain. A severe (third degree) strain corresponds with complete rupture of the muscle and loss of strength and function.[7]

The hamstring muscle group is at increased risk for strains due to its anatomical configuration. The hamstrings are composed of three muscles - semitendinosus, semimembranosus, and biceps femoris - forming a triad in the posterior compartment of the thigh. The musculotendinous junction of the biceps femoris is the most common site of strain.[4,8] A rapid phase change of muscle contraction from eccentric to concentric has been suggested as the underlying mechanism for hamstring strains.[5] Eccentric contractions are characterized by active lengthening of muscle fibers, in which the force of contraction increases as the speed of contraction increases. Conversely, concentric contractions involve the shortening of muscle fibers and an inverse relationship between the force and speed of contraction. For example, during gait, the bi-articular arrangement of the hamstring muscles across the hip and knee allow the hamstrings to work eccentrically during late swing to decelerate the lower leg and control knee extension. A concentric contraction follows to initiate hip extension prior to heel strike. Hamstrings are maximally loaded and lengthened during this rapid phase change.[3]

In addition to clinical investigations into the biomechanical predisposition of hamstring strains, retrospective studies have focused on the identification of other etiologic factors which may predict the occurrence of hamstring strains.[4] Intrinsic risk factors for hamstring muscle strains include older age,[9-11] ethnicity,[12] previous injury,[9,12,13] lumbopelvic instability,[14] decreased hamstring flexibility,[10,15] and reduced strength.[1,15,16] Other potential intrinsic risk factors include sex,[17,18] decreased angle of peak torque,[19] and agonist-antagonist muscle imbalance.[20] Extrinsic factors such as fatigue,[21] lack of warm-up,[22] and inadequate preseason training[23] have also been associated with increased risk of hamstring strains. However, research suggests the most significant predictor of hamstring injury is a history of previous strain to the muscle.[12,24] The direct influence of risk factors remains inconclusive as investigations do not provide strong evidence to support their individual or collective effect on development of hamstring strains.

Despite the high prevalence and subsequent high incidence of recurrent hamstring strains, there is a lack of consensus with respect to appropriate primary and secondary prevention strategies. Primary prevention is defined as an intervention that prevents the occurrence of an initial injury, while secondary prevention is an intervention that prevents the recurrence of subsequent or further injury.[25] Identification of valid and reliable prevention strategies is essential to reduce the incidence of injury and direct current rehabilitation efforts.[6]

The protective effect of muscle strengthening on the occurrence of hamstring strains has been reported in the literature;[3,6] however, the preventative role of eccentric exercise has not been clearly defined. Muscle adaptation is mode specific, with eccentric training increasing eccentric strength.[26] Hamstring strains commonly occur during the eccentric phase of a muscle contraction,[5,27-30] therefore, overloading these muscles with eccentric training could potentially serve to prevent hamstring strains.

Subsequent bouts of eccentric muscle overloading have demonstrated a cumulative protective effect against further exercise-induced damage.[31] This "repeated bout effect" causes a shift in the length-tension curve, such that peak tension is generated at longer muscle lengths.[27,32-34] Research suggests that sarcomeres are added in series following eccentric loading.[27] Given the length-dependent nature of muscle damage in hamstring strains near end range, this structural adaptation optimizes the angle of peak torque to reduce the risk for potential injury.[3,6]

Eccentric exercise has the potential to result in delayed onset muscle soreness (DOMS),[35] which needs to be differentiated from muscle strain. Delayed onset muscle soreness is clinically characterized by muscle soreness, stiffness, inflammation, and loss of function peaking one to three days after unaccustomed exercise.[36] With DOMS, repeated bouts of exercise result in progressively less tissue damage and soreness.[37] In comparison, muscle strain is characterized by immediate acute pain, and exercise too soon after strain can lead to a more disabling injury.[7]

A preliminary search of the literature found that no systematic reviews currently exist investigating the benefit of eccentric training on the primary and secondary prevention of hamstring strains. Thus, the objective of this systematic review is to evaluate the existing evidence to determine effectiveness of eccentric exercise on primary and secondary prevention of hamstring muscle strains.

Movement of the ankle may result in a reduction in foot volume secondary to a muscle pumping action moving fluid out of the area.[26] Results of this study may help health care practitioners prescribe a more appropriate exercise mode when addressing the cardiovascular health of the active geriatric individuals.

METHODS

The Question

This systematic review was undertaken to determine if eccentric strength training was effective in the prevention of hamstring strains in otherwise healthy individuals. Studies included were those in which the subjects underwent an eccentric strength training intervention for the primary or secondary prevention of hamstring strains. When appropriate, comparisons were made between groups receiving eccentric strength training and groups receiving alternative interventions. The primary outcome measure of interest was incidence of hamstring strains, which included first-time muscle strains and strain recurrences. The secondary outcome measure was the severity of hamstring strain.

Search Strategy

Electronic databases searched for the purpose of this systematic review included: MEDLINE, PubMed, EMBASE, CINAHL, the Cochrane Central Register of Controlled Trials, the Cochrane Database of Systematic Reviews, SPORTDiscus, PEDro, and Web of Science. In addition, reference lists of all studies included in the review, additional articles published by leading authors in this area of research, and other relevant academic journals were hand searched. Grey literature resources were also hand searched, including: CIRRIE Database of International Rehabilitation Research, NARIC's REHABDATA Literature Databases, and Critically Appraised Topics. Grey literature materials are not formally published in regularly accessible, peer-reviewed journals or indexed in major electronic databases. Common formats of grey literature include: works in progress, unpublished theses, statistical reports, and conference proceedings. All databases were searched from the earliest date to March 2007 to ensure the comprehensive identification of all relevant publications. The search was limited to articles in English or French.

The search began with the identification of MeSH terms referring to hamstring strains. These MeSH terms were "exploded" in all databases in order to tailor the search terms to each specific database. Databases were searched using MeSH terms and keywords such as: "athletic injuries," "sprains and strains," "leg injuries," AND "hamstring," "semimembranosus," "semitendinosus," 'biceps femoris," AND "eccentric."

Study Selection

A list of citations was accrued from the database searches and assessed for eligibility by two independent reviewers. Citations must have included: 1) "strain" or "injury" AND 2) one of "hamstring," "eccentric," "prevention," "exercise," or "training," or some variation thereof. Reviewers selected citations they deemed eligible, and abstracts were obtained for any citations selected by at least one reviewer. Abstracts were evaluated for eligibility by two independent reviewers based on predetermined selection criteria. Study selection criteria included: diagnosis of hamstring strain (any grade), otherwise healthy individuals, and at least one group receiving eccentric exercise intervention. Full text articles were retrieved for all abstracts deemed eligible by at least one reviewer. When an abstract was not available, the full text article was retrieved. Finally, full text articles were evaluated by two independent reviewers using a customized article screening form. Reviewers discussed their decisions and reached a consensus regarding whether or not to include each full text article. If two reviewers were unable to reach a consensus, a third reviewer evaluated the full text article and made a final tie-break decision.

Search Results

Results of the overall search strategy are summarized in Figure 1. An initial 354 primary articles were identified for potential inclusion. Of these articles, 259 were excluded after citation screening, leaving 95 citations. For the remaining 95 citations, abstracts were obtained and screened for eligibility. Seventy-four abstracts were excluded in the second phase of screening, leaving 21 eligible full text articles. Some reasons for abstract exclusion included: lack of eccentric training intervention, no report of hamstring strains, and limitation in study design (i.e., a review article). Of the 21 full text articles included in the final phase of screening, a further 16 were excluded. Reasons for exclusion included: lack of specified eccentric exercise intervention (n = 12) and lack of reported hamstring strain incidence or severity (n = 4). Studies were not excluded on the basis of study design. In total, five full text articles were included after the systematic review of the literature. Following hand searching of relevant journals and recent grey literature searches, two additional articles were subjected to the same process and deemed eligible for inclusion, for a total of seven included full text articles. Of the seven included full text articles, three were randomized controlled trials (RCTs). The RCTs are prospective trials in which eligible participants are randomly assigned to one or more treatment groups or a control group. The remaining four articles were cohort studies which followed groups of individuals and examined the relationship between an intervention (eccentric strengthening) and the incidence of the outcome of interest (hamstring strain) in study participants.

Table 1. *PEDro scores and inter-rater reliability*

Article	Rater	2	3	4	5	6	7	8	9	10	11	Consensus Score	Kappa Value
Arnason et al.[28]	Rater 1	n	n	n	n	n	n	n	n	y	n*	2	.615
	Rater 2	n	n	n	n	n	n	n	n	y	y		
Askling et al.[30]	Rater 1	y	n	y	n	n	n	y	y	y	y	6	.800
	Rater 2	y	n	y	n	n	n	y	y	y	n*		
Brooks et al.[2]	Rater 1	n	n	y	n	n	n	y	y	y	y	5	.800
	Rater 2	n	n	y	n	n	n	y	y	n*	y		
Croisier et al.[1]	Rater 1	n	n	n	n	n	n	y	n	n	y	2	1.000
	Rater 2	n	n	n	n	n	n	y	n	n	y		
Gabbe et al.[39]	Rater 1	y	y	y	n	n	y	n	y	y	y	7	1.000
	Rater 2	y	y	y	n	n	y	n	y	y	y		
Queiros Da Silva et al.[40]	Rater 1	n	n	n	n	n	n	y	y	n	n	2	1.000
	Rater 2	n	n	n	n	n	n	y	y	n	n		
Sherry and Best.[14]	Rater 1	y	y	y	n	n	n	y	y	y	y	7	1.000
	Rater 2	y	y	y	n	n	n	y	y	y	y		

* = consensus reached by changing this score

Data Extraction and Synthesis

Using a customized data extraction form, two independent reviewers extracted data regarding subject characteristics, type of eccentric intervention and controls, study design, and results. Discrepancies were resolved by discussion between the two reviewers. If additional study information was required prior to determining eligibility, the primary author was contacted via e-mail. Pertinent data were qualitatively summarized in both text and tabular forms.

Quality Assessment

The Physiotherapy Evidence Database (PEDro) Scale was used by two independent reviewers to assess the methodological quality of each included full text article.[38] A third reviewer acted as a tie-breaker when necessary. The PEDro Scale is scored out of ten with a single point awarded when a specified criterion is met.[38] Criteria evaluated include: random allocation, concealed allocation, baseline similarity, blinding, reported outcome measures, intention to treat analysis, statistical comparisons, and measures of variability.[38] Table 1 summarizes the quality assessment scores of included full text articles. Of the seven included full text articles, three were randomized controlled trials (RCTs) with PEDro scores ranging from 6 to 7. Scores greater than 6 are considered strong evidence.[38] The remaining four articles were cohort studies and achieved PEDro scores ranging from 2 to 5. The average kappa value for inter-rater reliability of PEDro scores was 0.89 (range 0.62 to 1.00), indicating strong agreement between reviewers.

Methodological rigor of included articles was also evaluated using Oxford Centre for Evidence-based Medicine Levels of Evidence.[39] Levels of evidence categorizations ranged from 2b to 4, where 2b represented individual cohort studies or low quality RCTs and 4 represented case-series, poor quality cohort, and case-control studies.[39] Results of this analysis are summarized in Table 2.

RESULTS

A summary of included studies is displayed in Table 3. A concise summary of results is available in Table 4. A lack of similar methodologies negated a quantitative meta-analysis of results. The seven included studies were grouped by eccentric intervention type: "hamstring lowers" protocol (n = 3), isokinetic strengthening protocol (n = 2), and other strengthening protocols (n = 2). A best-evidence synthesis of pooled data is qualitatively described below.

Table 2. *Oxford centre for evidence-based medicine levels of evidence*

Article	Level of Evidence
Arnason et al[28]	4
Askling et al[30]	2b
Brooks et al[2]	4
Croisier et al[1]	4
Gabbe et al[29]	2b
Queiros Da Silva et al[40]	4
Sherry and Best[14]	2b

Effect of Eccentric Exercise - "Hamstring Lowers" Protocol

Three studies (two cohorts, one RCT) examined the effects of eccentric exercise, using a "hamstring lowers" protocol, on the prevention of hamstring muscle strain injuries and their severity.[2,28,29] The "hamstring lowers" protocol involved participants kneeling on the floor with upright trunk perpendicular to floor *(Figure 2)*. Feet were supported under a low bench or held by a partner. Arms were kept folded across chest and body was lowered forward. Participants lowered their body until they were no longer able to hold the position, at which point the participant was allowed to relax and use their arms to catch themselves as they reached the floor.[26,27] This protocol was employed in conjunction with other conservative treatments including stretching, combined eccentric and concentric strengthening exercises, and range of motion of the lumbar spine.

Arnason et al[9] examined the effect of eccentric "hamstring lowers" and contract-relax proprioceptive neuromuscular facilitation (PNF) stretching on incidence (i.e., number of hamstring strains) and severity (i.e., duration of absence from play) of hamstring strains in male soccer players from top Icelandic and Norwegian soccer leagues during the 1999 to 2002 soccer seasons. Participants completed one of three interventions, which included combinations of warm-up PNF stretching, PNF flexibility exercises, and eccentric strength training. Results from the intervention teams were compared to results from baseline seasons (1999 and 2000) and to control teams. Control teams did not partake in the intervention programs during the 2001 and 2002 soccer seasons. Incidence of hamstring strains in the "hamstring lowers" group was less compared to baseline seasons among intervention teams. Differences in injury severity and re-injury rates, however, were not statistically significant between baseline seasons amongst intervention teams. When compared to control teams (0.62 $\pm$ 0.05 hamstring strains per 1000 player hours), the overall incidence of hamstring strains was 65% lower in the "hamstring lowers" group (0.22 $\pm$ 0.6 hamstring strains per 1000 player hours). However, the severity of injury and re-injury rates were not significantly different between "hamstring lowers" and control groups.

Brooks et al[2] examined the effectiveness of "hamstring lowers" and hamstring stretching on

Table 3. *Summary of included studies*

Author & Study Design	Prevention	Participants	Groups	Intervention	Results
Arnason et al. [28] Cohort (prospective)	Combined 1˚ & 2˚ Prevention	Icelandic and Norwegian elite league male soccer teams (elite)	Warm-up stretching, flexibility, strength training n=8 teams (age: not reported)	Warm-up stretching of hamstrings using contract-relax Warm-up: throughout entire season before each training session and game Flexibility for hamstrings based on partner contract-relax stretching Flexibility: after training 3x/week during preseason, 1-2x/week during competitive season Eccentric strength training using "hamstring lowers" Eccentric: 5-week intro period, 3 sets of 12, 10, 8 reps; during preseason 3x/week, during competitive season 1-2x/week	Incidence of hamstring muscle strain Eccentric training: Overall incidence of hamstring strains was 65% lower compared to control* (0.22 ± 0.06 vs. 0.62 ± 0.05; RR 0.35; 95% CI 0.19-0.62, p<0.001). Incidence of hamstring strains was lower compared to baseline (RR 0.42 [0.21-0.84], p=0.009). Flexibility training: No significant difference was found in the incidence of hamstring strains between intervention and control (0.54 ± 0.12 vs. 0.35 ± 0.10; relative risk 1.53; 95% CI 0.76-3.08, p=0.22) No difference in re-injury rates between "hamstring lowers" group compared to control and baseline. Severity of hamstring muscle strain No difference in injury severity between "hamstring lowers" group compared to control. Injuries in the "hamstring lowers" group were less severe compared to baseline.
			Warm-up stretching, strength training n=11 teams (age: not reported)		
			Warm-up stretching, flexibility n=7 teams (age: not reported)		
Askling et al. [30] RCT	Combined 1˚ & 2˚ Prevention	Premier league male soccer players from Sweden (elite)	Training group n=15 (age: 24±2.6 yrs)	General training & eccentric hamstring strength training using YoYo Flywheel ergometer General training not described Eccentric: 4 sets x 8 reps; 16 sessions over 10 weeks	Incidence of hamstring muscle strain Incidence of hamstring strains decreased in trained group (3/15) when compared to control group (10/15).
			Control group n=15 (age: 26±3.6 yrs)	General training General training not described	
Brooks et al. [2] Cohort (prospective)	Combined 1˚ & 2˚ Prevention	Professional male rugby players in the English Premiership rugby union club (elite)	Strengthening (S) n=148 (age: 25.5±4.1 yrs)	Regular concentric & eccentric hamstring strengthening Strength: 1.2 sessions/wk; 3.6 sets x 8.2 reps (Exercises not described)	Incidence of hamstring muscle strain S: 1.1 (95% CI 0.74-1.4) injuries/1000 player hours; 26% proportion of recurrences SS: 0.59 (95% CI 0.34-0.84) injuries/1000 player hours; 28%

			Strengthening & stretching (SS) n=144 (age: 25.8±4.0 yrs)	Regular concentric & eccentric hamstring strengthening and static stretching Strength: 1.8 sessions/wk; 3.3 sets x 7.5 reps Flexibility: 2.6 sessions/wk; 2.8 sets held 25 seconds (Exercises not described)	injuries/1000 player hours; 28% proportion of recurrences SSN: 0.39 (95% CI 0.25-0.54) injuries/1000 player hours; 15% proportion of recurrences Severity of hamstring muscle strain S: Mean 17 (95% CI 13-23) days lost per injury SS: Mean 21 (95% CI 12-30) days lost per injury SSN: Mean 14 (95% CI 9-19) days lost per injury
			Strengthening, stretching and Nordic† strengthening n=200 (age: 25.4±4.1 yrs)	Regular concentric & eccentric hamstring strengthening, static stretching and eccentric strength training using “hamstring lowers” Strength: 1.3 sessions/wk; 3.0 sets x 7.5 reps Flexibility: 1.8 sessions/wk; 2.6 sets x 28 reps Eccentric: 1.3 sessions/wk; 2.8 sets x 6.7 reps (Exercises not described)	
Croisier et al.[1] Cohort (prospective)	2° Prevention	National or international male soccer, track & field, martial arts athletes (elite)	n=18 (age: 25±8 yrs)	Initial individualized isokinetic concentric, eccentric, or combined eccentric and concentric programs 10-30 sessions; 3x/week, 4-8 reps at 30° or $120^\circ s^{-1}$ Followed by 12-month standardized maintenance program, including manual muscle strengthening and static stretching	Incidence of hamstring muscle strain No participants sustained a hamstring strain after return to their respective sports for 12 months. Pain of initial hamstring muscle strain Before rehabilitation, pain VAS was 5.9 ± 1.1. On return to activity pain VAS was 0.9 ± 0.6. Intervention significantly reduced pain at $P < 0.001$.
Gabbe et al.[29] RCT	Combined 1° & 2° Prevention	Senior or reserve grade male team from VAFA 2004 (competitive)	Eccentric strengthening n=114 (age: 23.4; range 18.0-35.0 yrs)	Controlled hamstring lowers 5 sessions/12 weeks; 12 sets x 6 reps	Incidence of hamstring muscle strain Intervention group not at decreased risk for hamstring injury when intention to treat was analyzed (RR 1.2, 95% CI 0.5-2.8) Of participants who completed at least two training sessions, 4% of the eccentric strengthening group and 13.2% of stretching and ROM exercise group sustained a hamstring strain (RR 0.3, 95% CI 0.1-1.4; p=0.098)
			Stretching and ROM exercises n=106 (age: 23.9; range 17.4-36.0 yrs)	Static stretching Gastrocnemius, hip flexors, hamstrings stretches held for 30 seconds; lumbar spine stretch held for 15 seconds.	

Queiros Da Silva et al. [40] Cohort (prospective)	2° Prevention	Male athletes with previous hamstring strain (unspecified level of competition)	n=8 (age: 25±8 yrs)	Eccentric hamstrings using a Cybex® isokinetic dynamometer and classical kinesiotherapy Isokinetic training: 10-14 sessions over 38-52 days, 2x/wk minimum 4 sets x 8 reps (5°/xec); 5 sets x 8 reps (10°/xec); 6 sets x 8 reps (15°/xec)	Incidence of hamstring muscle strain recurrence During the 8-month follow-up, there were no recurrent hamstring injuries reported.
Sherry and Best[14] RCT (prospective)	2° Prevention	Male and female athletes with acute hamstring strain (unspecified level of competition)	Stretch and Strength (STST) n=11(9 male, 2 female) (age: 24.3±12.4 yrs) 1° strain (n=7) 2° strain (n=4)	Static stretching, isolated progressive hamstring resistance exercise (including eccentric "foot catches"), and icing Mean duration=33.3 days	Incidence of hamstring muscle strain STST: 6/11 injured within 2 weeks PATS: 0/13 injured within 2 weeks STST: 7/11 injured within 1 year PATS: 1/13 injured within 1 year
			Progressive agility and trunk stabilization (PATS) n=13(9 male, 4 female) (age: 23.2±11.1 yrs) 1° strain (n=5) 2° strain (n=8)	Progressive agility and trunk stabilization exercises and icing Mean duration=18.8 days	

reducing incidence (i.e., number of injuries per player hours) and severity (i.e., number of days lost per injury) of hamstring muscle strains in 546 professional rugby players. One hundered and forty-eight players were in the strengthening group, 144 players in the conventional strengthening and stretching group, and 200 players in the intervention group, which combined conventional strengthening and stretching with "hamstring lowers." The incidence of hamstring strains in the intervention group (0.39 injuries per 1000 player hours) was reported as significantly lower than in the strengthening group (1.1 injuries per 1000 player hours) and the conventional strengthening and stretching group (0.59 injuries per 1000 players). Although a difference in hamstring strain severity existed across the three training groups, this difference was not significant.

Gabbe et al[29] examined the effect of eccentric muscle strengthening on the prevention of hamstring strains in 220 male football players from the Victorian Amateur Football Association. Participants in this Oxford level 2b RCT were divided into two groups: eccentric strengthening ("hamstring lowers"), and stretching and range of motion. A high number of dropouts were reported in this study. Results of the intention to treat analysis suggested the eccentric strengthening group was not at decreased risk for hamstring strains. However, amongst players who completed at least two training sessions, a trend existed towards a protective effect from eccentric strengthening. Incidence of hamstring strains in the eccentric strengthening group and in the stretching and range of motion group was 4% and 13.2%, respectively.

Effect of Eccentric Exercise - Isokinetic Strengthening Protocol

Two prospective cohort studies investigated the incidence of hamstring strains following eccentric exercise using isokinetic strengthening protocols. Croisier et al[1] observed the recurrence of hamstring muscle strains in 26 male athletes with pre-existing unilateral strains. Participants' baseline isokinetic profiles of hamstring and quadriceps muscle function were assessed on a Kintrex 500® dynamometer (Puidoux, Switzerland) before individualized rehabilitation programs were prescribed. Rehabilitation programs involved isokinetic eccentric exercise using the same dynamometer. During the 12-month follow-up period, no participants sustained a clinically diagnosed recurrent hamstring strain. Initial injury severity (i.e., rating of muscle pain and discomfort on a 10-point visual analogue scale) decreased from 5.9 $\pm$ 1.1 points pre-intervention to 0.9 $\pm$ 0.6 post-intervention ($p < 0.001$) and remained constant for 12 months.

A more recent study by Queiros Da Silva et al[40] explored the use of eccentric exercise using an isokinetic strengthening protocol with a Cybex® Medway, MA isokinetic dynamometer coupled with "classical kinesiotherapy" (i.e., cryotherapy, "physiotherapy," non-steroidal anti-inflammatories, deep transverse massage, progressive passive musculotendinous stretching, manual eccentric exercise, and proprioception exercises) for the secondary prevention of thigh muscle injuries. Of the eight participants with hamstring strains, none sustained a recurrent strain during the 8-month follow-up period post-intervention.

Table 4. *Summary of results*

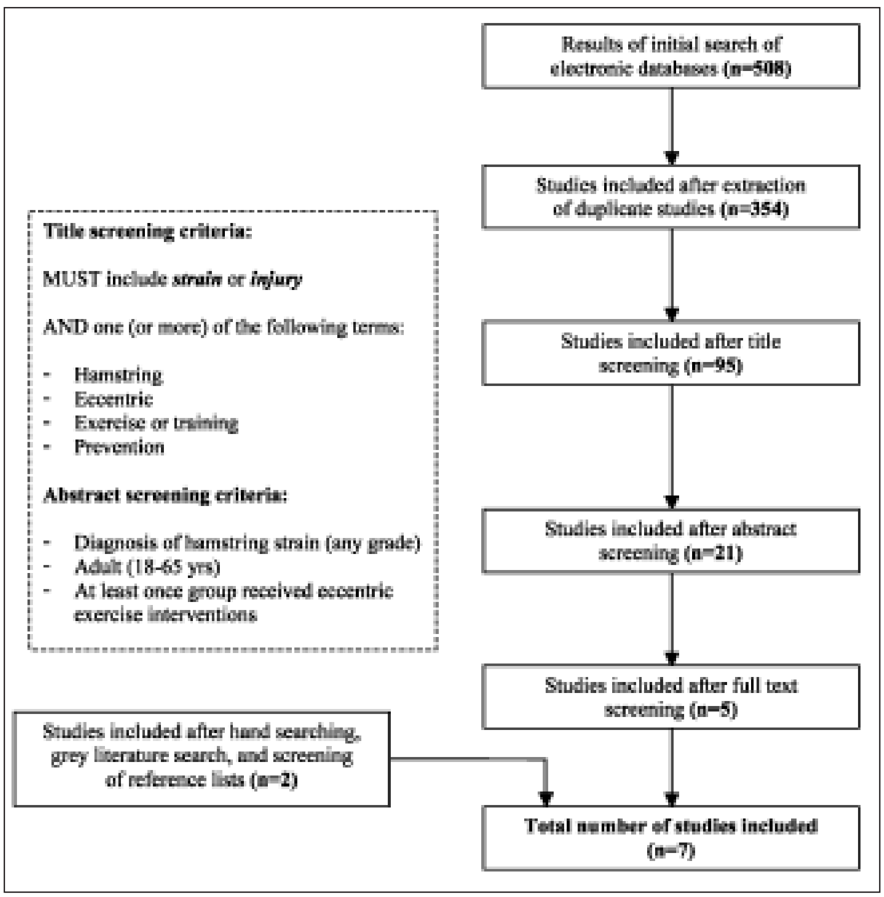
AUTHOR (YEAR)	PREVENTION	INCIDENCE	SEVERITY
"Hamstring Lowers"			
Arnason et al.[28]	1° and 2°	↓*	No difference
Gabbe et al.[29]	1° and 2°	↓	
Brooks et al.[3]	1° and 2°	↓	No difference
Isokinetic Strengthening			
Croisier et al.[1]	2°	Ø†	
Queiros Da Silva et al.[40]	2°	Ø	
Other Strengthening			
Askling et al.[30]	1° and 2°	↓	
Sherry Best[14]	2°	↑‡	

*↓ decreased incidence of hamstring strain in eccentric group(s) vs. other intervention groups

†Ø no recurrent hamstring strains after eccentric intervention

‡↑ increased incidence of hamstring strain recurrence in eccentric group vs. other intervention

Figure 1. *Search strategy results.*



Effect of Eccentric Exercise - Other Strengthening Protocols

Two RCTs investigated the use of other eccentric exercise strengthening protocols on the incidence of hamstring strains. Askling et al[30] examined the effects of pre-season overloading using a YoYo™ flywheel ergometer (Stockholm Germany) on incidence of hamstring muscle strains in 30 Swedish elite male soccer players. As described in Askling et al,[3] rotation of the flywheel was initiated with a concentric contraction of the hamstrings. An eccentric contraction of the hamstring muscle group was subsequently required to decelerate the movement of the flywheel. Eccentric overloading of the hamstrings required the performance of an eccentric contraction over a smaller angular displacement. The training group completed general training combined with concentric and eccentric hamstring strength training using a YoYo™ flywheel ergometer, while the control group completed general training only. Results showed a decreased incidence of hamstring strains in trained ($n = 3$) compared to control ($n = 10$) groups. Six of the 13 participants who sustained a hamstring strain reported a previous hamstring injury. Of these participants, two were in the training group and four in the control group.

Figure 2. *"Hamstring lowers."*

In 2004, Sherry Best[14] examined the effectiveness of two rehabilitation protocols. Stretching and strengthening (STST, n = 11) were compared to progressive agility and trunk stability (PATS, n = 13) in 24 male and female subjects with acute hamstring strains. Eccentric strengthening (STST group) for the hamstring muscles was performed using "standing foot catches." "Standing foot catches" were performed by having participants stand on one leg parallel to a wall and simulate the swing phase of walking or running *(Figure 3)*.[14] Participants contracted their quadriceps muscle to perform a rapid knee kick. Eccentric loading of the hamstring occurred when participants "caught" or stopped the lower leg from reaching full extension by eccentrically contracting their hamstrings.[14] Hamstring strain recurrence was significantly lower for athletes in the PATS group when compared to the STST group at 16 days after return to sport. At one year following return to sport, one additional participant in each group sustained a hamstring strain.

Adverse Effects and Dropouts

Intervention-related muscle soreness was reported during the initial phases of training in three of the seven included studies.[28-30] The majority of subjects in Askling et al[30] (n = 11/15) reported muscle soreness lasting 1-3 days after training sessions. A large dropout rate was observed across all training groups in the Gabbe et al[29] study. With the primary reason for non-compliance, reported by players, being DOMS.[29] Less than half of participants (46.8%) completed at least two of the five training sessions, and less than 10% completed all required sessions over the 12-week period. Adherence in the eccentric strengthening group was lower than in the stretching and range of motion group.[29] Arnason et al[28] reported that DOMS was also the principle factor underlying the dropout of one team. This team opted not to follow the prescribed "hamstring lowers" protocol and adopted a program that was much more intensive.

Other reasons for non-adherence reported in the included studies were unrelated to study design. One participant in the Croisier et al[1] study was excluded following lack of improvement in his isokinetic strength profile following nerve compression related to ectopic calcification. In Sherry Best,[14] four participants did not complete the prescribed training for reasons unrelated to the intervention (e.g., death in a motor vehicle accident).

Diagnosis of Hamstring Strain

The methodology employed to diagnose hamstring strains varied amongst included studies *(Table 5)*. In all seven included studies, sport clinicians (i.e. physiotherapists and other medical personnel) completed the assessment and diagnosis of hamstring strains.[1,2,14,28-30,40] Criteria for clinical diagnoses included tenderness on palpation of the musculotendinous junction, pain with isometric contraction, mechanism of injury that resulted in sudden onset of posterior thigh pain, limitation of activities, and pain with stretching.[2,14, 28-30,40]

DISCUSSION

After a thorough review of the literature, seven studies were included and qualitatively analyzed in the systematic review, including cohort studies and RCTs with Oxford Centre for Evidence-based Medicine Levels of Evidence ranging from 2b to 4. Due to this low level of evidence,[39] limited support exists for the use of "hamstring lowers," isokinetic exercises, and other eccentric strengthening exercises as effective training protocols to reduce the incidence and subsequent recurrence of hamstring strains.

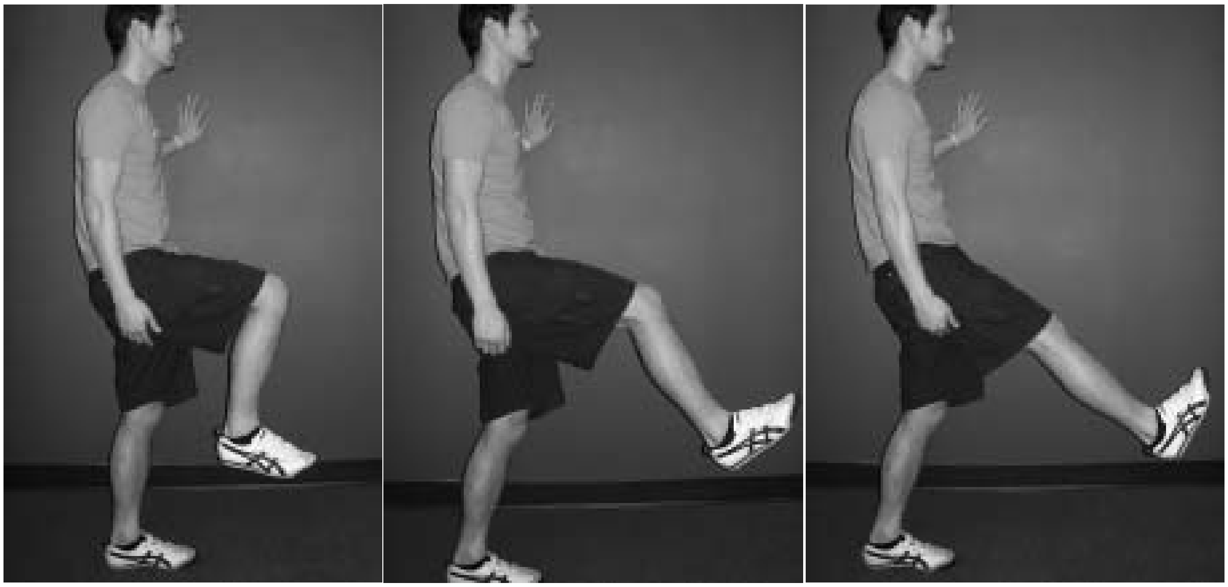


Figure 3. *Simulated swing phase of walking.*

Effect of Eccentric Exercise - "Hamstring Lowers" Protocol

Three included studies [2,28,29] examined effects of eccentric exercise using "hamstring lowers" protocols, in conjunction with other conservative treatments (e.g., stretching, combined eccentric and concentric strengthening exercises, and range of motion of the lumbar spine), on the prevention of hamstring strains and reduction of their severity. The prospective cohort studies showed a lower incidence of hamstring strains with eccentric training, but no significant difference in severity of injury.[2,28] Conversely, the RCT by Gabbe et al[29] found that the "hamstring lowers" group was not at decreased risk for hamstring strains following intention to treat analysis. However, participants in this intervention group who completed at least two training sessions sustained fewer hamstring injuries.

These three studies included competitive to elite level athletes.[2,28,29] In the study of male Premier League soccer players, Askling et al[30] contended that care should be taken when extrapolating findings from elite athletes as they train at a higher intensity and frequency than recreational athletes, and may therefore be at greater risk for hamstring injury.[30,41] Moreover, they argued that significant findings of a protective effect in elite athletes are more remarkable and robust since these athletes are typically closer to a theoretical ceiling effect for eccentric strength gains. Furthermore, Heidt et al[41] suggest the risk of injury may actually increase with progressively higher levels of play.

Poor adherence and high dropout rates plagued two of the three "hamstring lowers" studies.[28,29] Gabbe et al[29] attributed their high dropout rate to participants' subjective responses to DOMS. Arnason et al[28] noted none of the teams that performed the progression of "hamstring lowers" as prescribed, complained of DOMS. However, one team employed a more intensive training protocol than prescribed and consequently incurred considerable DOMS and dropped out of the study.[28] Gabbe et al[29] followed a "hamstring lowers" protocol as described in Brockett et al:[27] 12 sets of 6 repetitions, with 10 seconds of rest between repetitions and 2-3 minutes of rest between sets, in five sessions over a 12-week period. Conversely, Arnason et al[26] followed a protocol proposed by Mjolsnes et al.[26] This protocol involved a 5-week introductory period, increasing from two sets of five repetitions one time in the first week, to three sets of 8-10 repetitions three times per week by the end of the fourth week.[26] Thereafter, participants performed three sets of 8-12 repetitions three times per week for weeks 5-10.[26] It stands to reason that the progressive nature of the program suggested by Mjolsnes et al,[26] which incorporated a lower intensity introductory period, may explain why fewer participants reported DOMS in the Arnason et al[26] study compared to Gabbe et al.[29]

Based on the low level of evidence and paucity of published "hamstring lowers" studies, these results should be interpreted cautiously. While the included studies suggest that "hamstring lowers" appear to provide a clinically useful and inexpensive means of loading the hamstring muscles eccentrically to help protect against strain, none of the three studies adequately controlled for concurrent training methods (e.g., combined stretching and strength training). Consequently, it is impossible to isolate the effects of the "hamstring lowers" protocols. Thus, additional research isolating "hamstring lowers" from other interventions needs to be conducted in order to draw any definitive conclusions with respect to their effectiveness in the primary and secondary prevention of hamstring strains.

Table 5. *Criteria for hamstring strain diagnosis*

Criteria	Arnason et al.[28]	Askling et al.[30]	Brooks et al.[3]	Croisier et al.[1]	Gabbe et al.[29]	Queiros Da Silva et al.[40]	Sherry Best[14]	Total
Tenderness on palpation		x			x	x	x	4
Pain with isometric contraction		x			x	x	x	4
Pain with stretching		x			x	x		3
Known mechanism of injury	x				x		x	3
Limitation of activities	x	x	x				x	4

Effect of Eccentric Exercise - Isokinetic Strengthening

Two studies investigated the use of isokinetic eccentric strengthening for preventing recurrent hamstring strains - both showed protective effects. No participants in the Croisier et al[1] study examining male athletes sustained a hamstring strain during the first 12 months after returning to sport, and rehabilitation seemed to be successful in reducing self-reports of muscle pain and discomfort. Likewise, during a six-to-nine month follow-up period in the Queiros Da Silva et al[40] study of athletes, no recurrent hamstring strains were reported.

Both of the foregoing studies were prospective cohort studies with no control groups. In addition, they incorporated isokinetic eccentric strengthening in conjunction with other interventions. As a result, data need to be interpreted with caution. Due to weak study design, it is unclear exactly how much protection against recurrent hamstring strains was due to isokinetic eccentric strengthening and how much was due to other factors. Possibly, other physiotherapy interventions used in these studies (i.e., concentric strengthening and stretching of the quadriceps and hamstring muscles, trans-cutaneous electrical nerve stimulation, "kinesiotherapy," and sport specific activities) contributed to the observed protection against recurrent hamstring strains. Another limitation of both studies was small sample size, leading to a lack of precision to provide reliable answers to the questions investigated by reducing the likelihood of observing any significant effect. As well, neither study conducted follow-up beyond one year, so longer term outcomes are not known.

Despite the inherent limitations and lack of supporting evidence in these studies, both Croisier et al[1] and Queiros Da Silva et al[40] recommended that eccentric exercise should be included in the rehabilitation of hamstring strains to help prevent recurrent strains. More specifically, Croisier et al[1] concluded that persistence of muscle strength abnormalities may give rise to recurrent hamstring strains and pain, and that "classic rehabilitation" may be improved by including individualized isokinetic eccentric strengthening exercises.

Results of these two studies suggest that adequate warm-up followed by isokinetic eccentric strengthening at low velocities (5-30°/second) is necessary to avoid DOMS.[1,40] However, without an established means of differentiating muscle strain from DOMS, it is not possible to distinguish hamstring strain and DOMS from these results. Treatment should be progressed by increasing eccentric velocity, and should ideally be performed three times per week, which is in agreement with Cotte,[42] in order to minimize time to return to sport.[1,40] Isokinetic eccentric strength values can also be used to determine when return to sport is appropriate. Both studies agreed that bilateral strength differences should be no less than 5% before returning to competition. This 5% value has been repeatedly cited in the literature[1,21,43,44] since it is believed that hamstring strength deficits are a risk factor for strain.[1,11,16,44,45]

Due to study limitations (i.e., no control groups, isokinetic strengthening not examined in isolation, and small sample sizes), these protocols and recommendations must be interpreted carefully. Additional high-level research examining primary prevention and involving larger sample sizes is needed. Also, incorporating better controls, such as isokinetic eccentric strengthening in isolation compared with no exercise, concentric exercise or stretching, is necessary to accurately assess the degree to which hamstring strain incidence may be decreased using isokinetic eccentric training.

Effect of Eccentric Exercise - Other Strengthening Protocols

Two RCTs included in the systematic review utilized other eccentric strengthening protocols.[14,30] Using a YoYo™ flywheel ergometer, Askling et al[30] examined the effects of pre-season hamstring strengthening, incorporating concentric and eccentric overload, on the occurrence and severity of hamstring strains in elite Swedish male soccer players. The eccentric training group had a significantly lower number of injuries compared to the control group. The results of this study suggest a pre-season eccentric strengthening program may reduce the incidence of hamstring strains. One major limitation of the Askling et al[30] study was the inability to differentiate between the concentric and eccentric phases of the YoYo™ flywheel ergometer exercise. Therefore, the effects of eccentric training in isolation are unknown. Also, the small sample size may have decreased the reliability of the reported results by reducing its power to detect small size effects. It should also be noted that participants involved in the study were all elite male athletes. As previously discussed, research has suggested that elite level athletes may be at greater risk for hamstring injury,[41] thus limiting the extrapolation of these results to other populations.

Sherry Best[14] investigated the effectiveness of two different rehabilitation programs for the secondary prevention of hamstring strains. This study demonstrated that a rehabilitation program consisting of progressive agility and trunk stabilization (PATS) exercises was significantly more effective than a program of hamstring stretching and concentric-eccentric strengthening (STST). Of note, the interventions in both the PATS and STST groups incorporated multiple training modes. The use of agility training, which involved considerable eccentric loading through stopping and starting, was not identified as a specific eccentric intervention, which may be a confounding factor explaining why the PATS group sustained fewer hamstring strains. Furthermore, no attempt was made to measure trunk stability, making it difficult to determine the extent that trunk stabilization had on preventing hamstring strains. A small sample size and lack of therapist blinding also reduced the methodological rigor of this study. Because of the limitations in these two studies, it is not possible to affirmatively support the use of other eccentric strengthening protocols in hamstring strain prevention.

Additionally, Sherry Best[14] were the only investigators to include both male and female participants. Numerous studies have shown sex differences in muscle response to eccentric exercise.[17,18,46,47] For example, MacIntyre et al[47] found sex differences in severity of DOMS, muscle torque, and inflammatory markers following eccentric exercise. Therefore, eccentric training protocols designed to prevent hamstring strains may have to be modified to address these sex differences. It is imperative that the results of studies utilizing only male participants not be generalized to females. Furthermore, the effect of sex differences on the incidence of hamstring strains following eccentric training should be investigated in more rigorous controlled trials.

Adverse Effects and Dropouts

As previously discussed, YoYo™ flywheel ergometry and "hamstring lowers" both resulted in increased participant dropout due to occurrence of muscles soreness and DOMS.[28-30] The lack of adherence to eccentric training protocols and subsequent adverse effects reported in Arnason et al,[28] Gabbe et al,[29] and Askling et al,[30] may restrict the implementation of these protocols in clinical settings. However, it is interesting to note the eccentric isokinetic intervention used in the Croisier et al[1] study seemed to decrease the severity of initial injury.

Diagnosis of Hamstring Strains

Hamstring strains are typically diagnosed through clinical examination by a team physician or physical therapist.[5,48] Verrall et al[7] confirmed that the common clinical features of hamstring strains are sudden onset associated with running or acceleration, pain, posterior thigh tenderness, and pain on resisted muscle contraction. Other clinical features include loss of function and pain provocation with range of motion.[5,48] Therefore, it can be assumed that clinical assessment was an appropriate method to diagnose hamstring strains in the seven included studies.

CONCLUSION

Previous investigations show improvements in the structural integrity and performance of the hamstring muscles with eccentric training.[3,6,27] Although authors of these studies advocated the use of eccentric exercise to prevent hamstring strains, limited evidence exists to support its use. A lack of high-level trials impedes the ability to effectively generalize these findings to the clinical settings.

The studies included in this review varied in methodological rigor, population, sample size, and most notably, type of eccentric intervention. While the interventions varied in their prescription, no studies examined the effect of eccentric training in isolation. The coupling of eccentric training with other interventions may have limited, or conversely enhanced, the observed effects of eccentric training on the incidence and severity of hamstring strains. Thus, results of the included studies must be interpreted with caution.

In summary, seven studies were included in this review following a comprehensive appraisal of the available literature. This limited number of relevant articles highlights the need for future well-designed randomized controlled trials to conclusively evaluate the effectiveness of eccentric training in the prevention of hamstring muscle strains. Until more evidence becomes available, concrete recommendations to support or counter the use of eccentric training protocols for the primary and secondary prevention of hamstring strains cannot be made.

REFERENCES

1. Croisier JL, Forthomme B, Namurois MH, et al. Hamstring muscle strain recurrence and strength performance disorders. *Am J Sports Med.* 2002; 30:199-203.
2. Brooks JH, Fuller CW, Kemp SP, et al. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med.* 2006; 34:1297-1306.
3. Proske U, Morgan DL, Brockett CL, et al. Identifying athletes at risk of hamstring strains and how to protect them. *Clin Exp Pharmacol Physiol.* 2004; 31:546-550.
4. Petersen J, Holmich P. Evidence based prevention of hamstring injuries in sport. *Br J Sports Med.* 2005; 39:319-323.
5. Hoskins W, Pollard H. The management of hamstring injury–part 1: Issues in diagnosis. *Man Ther.* 2005; 10:96-107.
6. Hoskins W, Pollard H. Hamstring injury management–part 2: Treatment. *Man Ther.* 2005; 10:180-190.
7. Verrall GM, Slavotinek JP, Barnes PG, et al. Diagnostic and prognostic value of clinical findings in 83 athletes with posterior thigh injury: Comparison of clinical findings with magnetic resonance imaging documentation of hamstring muscle strain. *Am J Sports Med.* 2003; 31:969-973.
8. Thelen DG, Chumanov ES, Sherry MA, et al. Neuromusculoskeletal models provide insights into the mechanisms and rehabilitation of hamstring strains. *Exerc Sport Sci Rev.* 2006; 34:135-141.
9. Arnason A, Sigurdsson SB, Gudmundson A, et al. Risk factors for injuries in football. *Am J Sports Med.* 2004; 29: 300-303.
10. Gabbe BJ, Finch CF, Bennell KL, et al. Risk factors for hamstring injuries in community level Australian football. *Br J Sports Med.* 2005; 39:106-110.
11. Orchard J, Steet E, Walker C, et al. Hamstring muscle strain injury caused by isokinetic testing. *Clin J Sport Med.* 2001; 11:274-276.
12. Verrall GM, Slavotinek JP, Barnes PG, et al. Clinical risk factors for hamstring muscle strain injury: A prospective study with correlation of injury by magnetic resonance imaging. *Br J Sports Med.* 2001; 35:435-9; discussion 440.
13. Drezner JA. Practical management: Hamstring muscle injuries. *Clin J Sports Med.* 2003; 13:48-52.
14. Sherry Best TM. A comparison of two rehabilitation programs in the treatment of acute hamstring strains. *J Orthop Sports Phys Ther.* 2004; 34:116-125.
15. Orchard JW, Marsden J, Lord S, et al. Pre-season hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *Am J Sports Med.* 1997; 25:81-85.
16. Yamamoto T. Relationship between hamstring strains and leg muscle strength. A follow up study of collegiate track and field athletes. *J Sports Med Phys Fitness.* 1993; 33: 194-199.
17. MacIntyre DL, Reid WD, Lyster DM, et al. Different effects of strenuous eccentric exercise on the accumulation of neutrophils in muscle in women and men. *Eur J Appl Physiol.* 2000; 81:47-53.
18. Stupka N, Lowther S, Chorneyko K, et al. Gender differences in muscle inflammation after eccentric exercise. *J Appl Physiol.* 2000; 89:2325-2332.
19. Brockett CL, Morgan DL, Proske U. Predicting hamstring strain injury in elite athletes. *Med Sci Sports Exerc.* 2004; 36:379-387.
20. Aagaard P, Simonsen EB, Magnusson SP, et al. A new concept for isokinetic hamstring: Quadriceps muscle strength ratio. *Am J Sports Med.* 1998; 26:231-237.
21. Croisier JL. Factors associated with recurrent hamstring injuries. *Sports Med.* 2004; 34:681-695.

22. Dvorak J, Junge A, Chomiak J, et al. Risk factor analysis for injuries in football players. Possibilities for a prevention program. *Am J Sports Med.* 2000; 28:S69-74.

23. Verrall GM, Slavotinek JP, Barnes PJ. The effect of sports specific training on reducing the incidence of hamstring injuries in professional Australian rules football players. *Br J Sports Med.* 2005; 39:363-368.

24. Bennell K, Wajswelner H, Lew P, et al. Isokinetic strength testing does not predict hamstring injury in Australian rules footballers. *Br J Sports Med.* 1998; 32:309-314.

25. Brukner P, Khan K. *Clinical Sports Medicine.* 3rd ed. Columbus, OH: McGraw-Hill Companies; 2001.

26. Mjolsnes R, Arnason A, Osthagen T, et al. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand J Med Sci Sports.* 2004;14:311-317.

27. Brockett CL, Morgan DL, Proske U. Human hamstring muscles adapt to eccentric exercise by changing optimum length. *Med Sci Sports Exerc.* 2001; 33:783-790.

28. Arnason A, Andersen TE, Holme I, et al. Prevention of hamstring strains in elite soccer: An intervention study. *Scand J Med Sci Sports.* 2007.

29. Gabbe BJ, Branson R, Bennell KL. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian football. *J Sci Med Sport.* 2006;9:103-109.

30. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports.* 2003; 13:244-250.

31. Clarkson PM, Tremblay I. Exercise-induced muscle damage, repair, and adaptation in humans. *J Appl Physiol.* 1988; 65:1-6.

32. Jones C, Allen T, Talbot J, et al. Changes in the mechanical properties of human and amphibian muscle after eccentric exercise. *Eur J Appl Physiol Occup Physiol.* 1997; 76:21-31.

33. Child RB, Saxton JM, Donnelly AE. Comparison of eccentric knee extensor muscle actions at two muscle lengths on indices of damage and angle-specific force production in humans. *J Sports Sci.* 1998; 16:301-308.

34. Whitehead NP, Allen TJ, Morgan DL, et al. Damage to human muscle from eccentric exercise after training with concentric exercise. *J Physiol.* 1998; 512:615-620.

35. Faulkner JA, Brooks SV, Opiteck JA. Injury to skeletal muscle fibers during contractions: Conditions of occurrence and prevention. *Phys Ther.* 1993;73:911-921.

36. Blais C,Jr, Rouleau JL, Brown NJ, et al. Serum metabolism of bradykinin and des-Arg9-bradykinin in patients with angiotensin-converting enzyme inhibitor-associated angioedema. *Immunopharmacology.* 1999; 43:293-302.

37. Szymanski DJ. Recommendations for the avoidance of delayed-onset muscle soreness. *J Strength Cond Res.* 2001; 23:7-13.

38. Centre for Evidence-Based Physiotherapy. Physiotherapy Evidence Database (PEDro) Scale. Available at: http://www.pedro.fhs.usyd.edu.au/scale_item.html. Accessed Aug, 2007.

39. Phillips B, Ball C, Sackett D, et al. Oxford centre for evidence-based medicine levels of evidence. Available at: http://mcw.edu/display /Oxford_Levels.pdf. Accessed Aug, 2006.

40. Queiros Da Silva C, Cotte T, Vicard L, et al. Interest of eccentric isokinetic exercises in cases of calcanean tendinosis and thigh muscular injuries: Prospective study results. *Isokinetics Exerc Sci.* 2005; 13:39-44.

41. Heidt RS,Jr, Sweeterman LM, Carlonas RL, et al. Avoidance of soccer injuries with preseason conditioning. *Am J Sports Med.* 2000; 28:659-662.

42. Cotte T. Journees sur l'isocinetisme en medecine du sport, organisees par la societe MEDIMEX. Isocinetisme et Reeducation. Lyon, France: 2003.

43. Clanton TO, Coupe KJ. Hamstring strains in athletes: Diagnosis and treatment. *J Am Acad Orthop Surg.* 1998; 6: 237-248.

44. Heiser TM, Weber J, Sullivan G, et al. Prophylaxis and management of hamstring muscle injuries in intercollegiate football players. *Am J Sports Med.* 1984;12:368-370.

45. Jonhagen S, Nemeth G, Eriksson E. Hamstring injuries in sprinters. The role of concentric and eccentric hamstring muscle strength and flexibility. *Am J Sports Med.* 1994; 22: 262-266.

46. Stupka N, Tarnopolsky MA, Yardley NJ, et al. Cellular adaptation to repeated eccentric exercise-induced muscle damage. *J Appl Physiol.* 2001; 91:1669-1678.

47. MacIntyre DL, Reid WD, Lyster DM, et al. Presence of WBC, decreased strength, and delayed soreness in muscle after eccentric exercise. *J Appl Physiol.* 1996;80:1006-1013.

48. Schneider-Kolsky ME, Hoving JL, Warren P, et al. A comparison between clinical assessment and magnetic resonance imaging of acute hamstring injuries. *Am J Sports Med.* 2006;34:1008-1015.

ORIGINAL RESEARCH

GLENOHUMERAL JOINT RANGE OF MOTION IN ELITE MALE GOLFERS: A PILOT STUDY

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ABSTRACT

Background. Shoulder injuries account for up to 17% of all golf related musculoskeletal injuries. One cause may be the repetitive stresses applied to the lead shoulder during the backswing and follow-through phases, which may contribute to the frequency of these injuries. The "elite" golfer may be predisposed to developing a shoulder injury based upon the reported adaptations to the glenohumeral joint.

Objective. To examine and compare bilateral glenohumeral joint rotational range of motion in elite golfers using standard goniometric procedures.

Methods. Twenty-four "elite" male golfers were recruited for this study. Glenohumeral internal (IR) and external rotation (ER) passive range of motion was measured bilaterally at 90° of abduction using a standard universal goniometer. Paired t-tests were utilized to statistically compare the rotational range of motion patterns between the lead and the trailing shoulder.

Results. No statistical differences existed between each shoulder for mean IR or mean ER measures. This finding was consistent throughout different age groups. External rotation measurements were greater than IR measurements in both extremities.

Discussion and Conclusion. Unlike other sports requiring repetitive shoulder function, the "elite" golfers sampled in this pilot investigation did not demonstrate a unique passive range of motion pattern between the lead and trailing shoulders. Factors, including subjects' age, may have confounded the findings. Further studies are warranted utilizing cohorts of golfers with matching age and skill levels. Additional shoulder range of motion measures should be evaluated.

Key Words: golf, passive shoulder range of motion, glenohumeral joint, shoulder injuries

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INTRODUCTION

People of all ages and skill levels play golf worldwide.[1-3] For a golfer to improve to the level of an elite player, a combination of natural athletic ability and dedicated practice is required.[4] To stay at the top of one's game, an elite golfer will routinely practice daily for hours on end.[4] Competitive golfers may perform up to 2000 swings each week.[5] Due to the high volume of swings performed during practice and in competition golfers are at risk of developing overuse injuries.[5-18]

Shoulder injuries have been shown to account for 8% to 17.6% of all golf injuries.[6,12-15] Injuries to the shoulder rank 3rd behind injuries to the low back and the left wrist in professional male golfers.[6,13] For male amateur golfers shoulder injuries rank 4th following injuries to the low back, the elbow, and the hand and wrist.[4,16]

Figure 1: *Backswing Phase of the Golf Swing*

The modern golf swing consists of five phases: the takeaway, the backswing, the downswing, acceleration, and follow-through.[8] It has been proposed that the repetitive stresses applied during the backswing and follow-through phases contribute to the development of golf related overuse injuries.[17] The lead shoulder (the left shoulder for the right hand dominant golfer) tends to experience more injuries than the trailing shoulder.[7-9,11] Impingement, rotator cuff disease, acromioclavicular joint pain, acromioclavicular osteoarthritis, and distal clavicular osteolysis have been reported in the golfer's lead shoulder.[4,8,18] Golfers may also be at risk for developing posterior glenohumeral instability.[7,9]

Posterior Glenohumeral Instability in Golfers

Posterior shoulder instability occurs less frequently than anterior shoulder instability accounting for only 2% to 12% of all glenohumeral instability cases.[19-21] Traumatic and repetitive overuse mechanisms for the development of posterior shoulder instability have been reported in the literature.[19,20,22,23] In contact sports, the mechanism for traumatic posterior shoulder instability is the result of a force directed toward the flexed, adducted, and internally rotated arm.[20,24] Posterior shoulder instability may also be the result of attenuation of the posterior shoulder structures through repetitive mechanisms.[19,25]

Two investigations have reported the presence of posterior shoulder instability in "elite" golfers.[7,9] Hovis et al[7] retrospectively reviewed eight cases of golfers who were experiencing pain in the lead shoulder. Each "elite" golfer (handicap of 5 or less) reported experiencing pain and "a sense of instability at the top of the backswing *(Figure 1)* when their lead arm was fully adducted across the body."[7] A diagnosis of posterior glenohumeral instability was established in each golfer's lead shoulder with six of the eight also receiving a secondary diagnosis of subacromial impingement.[7] Mallon and Colosimo[9] published a retrospective review of 35 cases of shoulder injury in "elite" golfers. Each golfer was defined as either being a professional or a competitive golfer with a handicap of 3 or less.[9] The lead shoulder was involved in 34 of the 35 cases with 12% of the patients experiencing posterior glenohumeral subluxation.[9]

Glenohumeral Joint Range of Motion Patterns in Overhead Athletes

Overhead athletes present with unique rotational range of motion (ROM) patterns.[26-32] For example, javelin throwers and collegiate water-polo players tend to have significantly greater external rotation (ER) motion in their dominant (throwing) arm than their nondominant arm.[28,29] Ellenbecker et al[26] found elite junior tennis players demonstrate significantly less internal rotation (IR) motion with the dominant extremity. Range of motion patterns of the glenohumeral joint have been extensively researched in baseball pitchers.[27,30,32-41] Baseball pitchers typically demonstrate increased passive ER range of motion that is significantly greater in the dominant throwing arm and significantly less passive IR range of motion in the throwing shoulder as compared with the contralateral side.[27,30,32,36,38,39] It has been proposed that the repetitive stresses to the shoulder experienced by the overhead athlete may lead to attenuation of the anterior shoulder capsule and ligaments.[39,40] While this may be the case in many of the aforementioned sports, recent published reports suggest that osseous adaptations may play a significant role in the ROM presentations in the baseball pitcher.[32,33,34,37,41]

For some overhead athletes the extremes of glenohumeral joint motion that occur during overhead sports activities increase their risk of injury to the shoulder.[40,42] Appreciating the unique ROM patterns in competitive athletes may assist sports medicine professionals when developing injury prevention strength training programs and rehabilitation strategies for the injured athlete.[43] While golf specific rehabilitation programs have been published in the literature, a paucity of injury prevention programs exist.[42,44] Unfortunately, published reports of conservative treatment programs for golfer's with a diagnosis of posterior shoulder instability has only helped to return a minority of athletes successfully back to sport.[7,9] In response to failed conservative treatments physicians have prescribed nonsteroidal medication, injected the shoulder with steroids, and performed surgery to help return golfers back to sport.[7,9]

Pathomechanics of the Golf Swing

Previous reports have suggested that the biomechanics of the golf swing may contribute to the development of posterior shoulder instability.[7,9] During the backswing phase, the golfer's lead shoulder elevates and horizontally adducts *(Figure 1)*. Mitchell et al[45] found that the lead shoulder horizontally adducts during the golf swing upwards of 126° ± 7°.[45] It is plausible that attenuation of the posterior structures of the lead shoulder may occur in response to performing a high volume of golf swings.

Hovis et al[7] proposed that the development of posterior instability in elite golfers is a result of two factors: serratus anterior muscle fatigue and repetitive internal shoulder rotational forces created by subscapularis muscle activity.[7] Kao et al[46] utilizing dynamic electromyography and cinematography found that the serratus anterior muscle on the lead arm side is active during the entire swing[8,46] Due to this fact, the serratus anterior muscle on the lead arm side is believed to be at risk of muscular fatigue during practice or competition.[7,8,46] Muscular fatigue of the serratus anterior (or other scapular muscles) will affect the normal biomechanical relationship between the scapula and the humerus.[7,46-48] Alterations to scapular position may impair the ability of the external rotators of the shoulder to provide stability at the glenohumeral joint.[48] Hovis et al[7] propose that continuing to play golf, in the presence of scapular muscular fatigue, will allow the subscapularis muscle to impart an internal rotation stress to the shoulder contributing to the attenuation of the posterior shoulder.

The purpose of this pilot study was to compare the passive rotational ROM patterns of the glenohumeral joint in the trailing (dominant) and lead (nondominant) shoulders in a group of elite golfers. To the date, the rotational range of motion patterns of the glenohumeral joint have not been studied in the elite golfer.

METHODS

Subjects

Twenty-four right hand dominant male golfers with a handicap of 5 or less (mean = 2.13; SD = 1.43) volunteered to participate in the study. The golfers, ranging in age from 24 to 57 years (mean = 39.67; SD = 9.78), were recruited at the Oregon Golf Association course in Woodburn, Oregon on June 3rd, 2006. A golfer was excluded from participation in the study if he had a handicap greater than 5, if he was experiencing a current episode of shoulder pain, or had a previous history of a traumatic shoulder injury or a surgical procedure to either shoulder. None of the subjects who volunteered were excluded. The Institutional Review Board of Pacific University approved this study prior to data collection; informed consent was obtained from each subject.

Procedure

The lead examiner, blinded to the lead shoulder of each golfer, performed all measurements. Range of motion testing was performed in a manner similar to other studies investigating range of motion patterns in athletic populations.[27,30] Subjects were asked to lie in a supine position on a portable physical therapy treatment table. The shoulder was positioned in 90° of shoulder abduction with the elbow flexed to 90° and the forearm in a neutral position. Range of motion measurements were recorded using a standard universal goniometer. The axis of the goniometer was placed at the olecranon process with the stationary arm directed vertically and the moving arm aligned with the ulna.

Starting from a position of neutral shoulder rotation, the subject's extremity was passively externally rotated with slight overpressure added at the end range to appreciate the end feel.[49] The end feel, as defined by Cyriax,[50] is the sensation experienced by the examiner at the terminal ROM during passive motion testing.[49,50] Scapula stabilization was maintained through manual contacts on the anterior shoulder and from the weight of the subject's body against the table. Once the limit of ER motion was achieved, the angle was measured. Passive internal rotation was performed in a similar manner with the tester internally rotating the extremity with a stabilizing force manually applied to the coracoid and anterior shoulder in order to prevent scapular movement. Three measurements were recorded for both IR and ER with means calculated for each.

Intrarater reliability was established prior to data collection. Passive shoulder external and internal rotation ROM was measured bilaterally in five elite-level golfers with 48 hours between the two tests. An intraclass correlation coefficient (ICC 3,3) and standard error of measurement (SEM) were used to quantify the test-retest reliability of both measurement procedures. Intrarater reliability was found to be very good; the ICC for measuring ER was .99 with a SEM of .28° and .99 for IR with a SEM of .53°.

Data Analysis

Data was analyzed comparing the golfer's lead and trailing shoulders as well as the total rotation range of motion. Additional analysis was performed by dividing the golfers into two groups by age: group 1 (24-39 years) and group 2 (40+ years).[45] Paired t-tests were used to analyze the passive range of motion for lead and trailing shoulders and total rotation range of motion. The alpha level was set at 0.05.

RESULTS

Tables 1-3 present the passive range of motion measures for the entire group of elite golfers and by each age category. No significant differences existed between the lead and the trailing shoulders for either IR or ER passive ROM for the entire cohort or within each individual group. In addition, no significant difference for total rotation ROM existed between extremities for the entire group or within each individual group.

In general, ER passive ROM measurements were greater than internal rotation measurements in both extremities *(Table 1)*. This relationship (ER > IR) was consistent throughout each age group *(Table 2-3)*.

Table 1. *Shoulder Passive Range of Motion Measurements for the 24 Male Elite Golfers. The right arm was the dominant (trailing) arm in all of the golfers. All PROM measurements recorded in degrees. NS = not significant.*

	Mean	SD	*p* Value	t value	Significance
External Rotation					
Trailing Arm	91.04°	7.85°	$p = .466$	t = .74	NS
Lead Arm	90.32°	6.54°			
Internal Rotation					
Trailing Arm	50.11°	9.34°	$p = .334$	t = -0.99	NS
Lead Arm	51.76°	10.40°			
Total Rotation Range of Motion					
Trailing Arm	141.15°	10.87°	$p = .61$	t = -0.53	NS
Lead Arm	142.08°	13.67°			

DISCUSSION

If "elite" level golfers had an increased risk of posterior glenohumeral instability, it was thought that a statistically significant difference in either ER or IR motion between the lead and the trailing shoulder would be found. The results of this study demonstrate that within this sample of "elite" golfers, no significant difference existed between the lead and the trailing shoulder for either glenohumeral ER or IR passive ROM.

Several challenges were faced in attempting to research the "elite" golfer including subject recruit-

Table 2. *Shoulder Passive Range of Motion Measurements for Male Golfers Age Range 24 to 39 Years (n = 13). The right arm was the dominant (trailing) arm in all of the golfers. All PROM measurements recorded in degrees. NS = not significant.*

	Mean	SD	*p* Value	t ratio	Significance
External Rotation					
Trailing Arm	90.36°	7.84°	*p* = .575	0.58	NS
Lead Arm	89.69°	5.43°			
Internal Rotation					
Trailing Arm	53.29°	8.73°	*p* = .362	-0.95	NS
Lead Arm	55.21°	10.97°			
Total Rotational Range of Motion					
Trailing Arm	143.63°	12.00°	*p* = .60	-0.54	NS
Lead Arm	144.90°	14.53°			

Table 3. *Shoulder Passive Range of Motion Measurements for Male Golfers Age Range 40 Years or Older (n = 11) The right arm was the dominant (trailing) arm in all of the golfers. All PROM measurements recorded in degrees. NS = not significant.*

	Mean	SD	*p* Value	t ratio	Significance
External Rotation					
Trailing Arm	91.85°	8.17°	*p* = .653	0.46	NS
Lead Arm	91.06°	7.86°			
Internal Rotation					
Trailing Arm	46.37°	9.00°	*p* = .654	-0.46	NS
Lead Arm	47.69°	8.42°			
Total Rotational Range of Motion					
Trailing Arm	138.22°	9.01°	*p* = .853	-0.19	NS
Lead Arm	138.76°	12.40°			

ment and selecting which shoulder motions to measure. The first challenge encountered was recruiting a high number of "elite" golfers with a 5 or lower handicap. Team sports provide researchers a large subject population in a central location to test at one time. Unlike team sports, golf is an individual sport (except at the high school or collegiate level), allowing the golfer to practice and play whenever or wherever one chooses. This obviously increases the challenge of locating the target population.

Several options were discussed for obtaining our target population including recruiting golfers from local colleges, recruiting local golf professionals, and recruiting members from a local course. The greater Portland, Oregon region is devoid of NCAA division I universities, but has numerous smaller division III colleges. While golfers at these schools were readily accessible, their skill level consistently fell short of the "elite" definition (as defined in literature by Hovis et al[7] as 5 or below). In addition, many of the division III collegiate golfers were unaware of their handicap level. Measuring the ROM of local golf professionals appeared to be a means to recruit subjects, but this endeavor would have been a too time intensive. Recruitment of golfers during one session at the Oregon Golf Association course was decided. Based upon professional contacts, it was determined that golfers at the Oregon Golf Association course would meet the inclusion criteria. Twenty four golfers participated in this study. Despite the limited time commitment to testing, some golfers declined participation. The subject population, based upon handicap level, is similar to those reported by Mallon et al[9] and Hovis et al.[7]

The second challenge encountered was in deciding how many passive shoulder motions to measure. The initial goal for this study was to collect passive

ROM measurements bilaterally for shoulder ER, IR, and horizontal adduction. Based upon where and how to conduct the study, it was decided to only measure glenohumeral ER and IR for this pilot investigation. These measurements can be performed quickly with minimal positional changes and minimal equipment requirements. It was believed that conducting the horizontal adduction measures might affect the recruitment potential of volunteers due to the time requirements associated with the positional changes and additional measurements. Adequate testing environment (space, equipment, and staff) to appropriately perform the horizontal adduction measurements would also have been a challenge.[51]

Future research is suggested to build upon this investigation by testing bilateral glenohumeral rotation ROM patterns as well as horizontal adduction. Recruiting subjects from the professional ranks, NCAA division I schools, and from the American Junior Golf Association is also suggested. Reported ROM patterns observed in golfers may be the result of age specific changes versus sport related adaptations. Compared to other team and individual sports, golf can be "picked up" with participants achieving success (low handicap) at any age. Range of motion patterns observed in the 30-, 40- or 50-year old "elite" golfer may be due to sport or occupational pursuits from an earlier age. Range of motion patterns should also be investigated in junior and collegiate aged golfers, excluding those who had previous participation in overhead sports. If unique ROM patterns were identified in these populations then subsequent longitudinal testing should be conducted.

CONCLUSION

This study was an initial investigation of the anthropometric characteristics of the shoulders in "elite" golfers. The results demonstrated no statistical difference between extremities for each rotation pattern. Further testing is warranted to measure additional shoulder measures in specific "elite" golfer samples. A comprehensive appreciation of the golfers' shoulder may lead to advances in injury prevention training strategies and rehabilitation programs.

REFERENCES

1. Nicholas JJ, Reidy M, Oleske DM. An epidemiologic survey of injury in golfers. *J Sport Rehabil.* 1998; 7: 112-121.
2. Stover C, Stoltz J. Golf for the senior player. *Clin Sports Med.* 1996; 15: 163-178.
3. Hetu FE, Christie CA, Faigenbaum AD. Effects of conditioning on physical fitness and club head speed in mature golfers. *Percept Mot Skills.* 1998; 86: 811-815.
4. Theriault G, Lachance P. Golf injuries: An overiew. *Sports Med.* 1998; 26: 43-57.
5. Jobe FW, Pink MM. Shoulder pain in golf. *Clin Sports Med.* 1996; 15: 55-63.
6. Gosheger G, Liem D, Ludwig K, et al. Injuries and overuse syndromes in golf. *Am J Sports Med.* 2003; 31: 438-443.
7. Hovis WD, Dean MT, Mallon WJ, et al. Posterior instability of the shoulder with secondary impingement in elite golfers. *Am J Sports Med.* 2002; 30: 886-890.
8. Kim DH, Millett PJ, Warner JJ, et al. Shoulder injuries in golf. *Am J Sports Med.* 2004; 32: 1324-1330.
9. Mallon WJ, Colosimo AJ. Acromioclavicular joint injury in competitive golfers. *J South Orthop Assoc.* 1995; 4: 277-282.
10. McCarroll JR. Overuse injuries of the upper extremity in golf. *Clin Sports Med.* 2001; 20: 469-479.
11. Parziale JR, Mallon WJ. Golf injuries and rehabilitation. *Phys Med Rehabil Clin N Am.* 2006; 17: 589-607.
12. McHardy A, Pollard H, Luo K. One-year follow-up study on golf injuries in Australian amateur golfers. *Am J Sports Med.* 2007; 35: 1354-1360.
13. McCarroll JR, Gioe TG. Professional golfers and the price they pay. *Phys Sportsmed.* 1982; 10: 54-70.
14. Batt ME. A survey of golf injuries in amateur golfers. *Br J Sports Med.* 1992; 26: 63-65.
15. McCarroll JR, Retting AC, Shelbourne KD. Injuries in the amateur golfer. *Phys Sports Med.* 1990; 18: 122-126.
16. McCarroll JR. The frequency of golf injuries. *Clin Sports Med.* 1996; 15: 1-7.
17. Adlington GS. Proper swing technique and biomechanics of golf. *Clin Sports Med.* 1996; 15: 9-26.
18. McHardy A, Pollard H, Luo K. Golf injuries: A review of the literature. *Sports Med.* 2006; 36: 171-187.
19. Antoniou J, Harryman DT 2nd. Posterior instability. *Orthop Clin North Am.* 2001; 32: 463-473.
20. Bottoni CR, Franks BR, Moore JH, et al. Operative stabilization of posterior shoulder instability. *Am J Sports Med.* 2005; 33: 996-1002.
21. Millett PJ, Clavert P, Hatch GF, et al. Recurrent posterior shoulder instability. *J Am Acad Orthop Surg.* 2006; 14: 464-476.

22. Pollock RG, Bigliani LU. Recurrent posterior shoulder instability: diagnosis and treatment. *Clin Orthop Rel Res.* 1993: 291: 85-96.

23. Tibone JE, Bradley JP. The treatment of posterior subluxation in athletes. *Clin Orthop Rel Res.* 1993: 291: 124-137.

24. Mair SD, Zarzour RH, Speer KP. Posterior labral injury in contact athletes. *Am J Sports Med.* 1998; 26: 753-758.

25. Bahk M, Keyurapan E, Tasaki A, et al. Laxity testing of the shoulder: a review. *Am J Sports Med.* 2007: 35: 131-144.

26. Ellenbecker TS, Roetert EP, Piorkowski PA, et al. Glenohumeral joint internal and external rotation range of motion in elite junior tennis players. *J Orthop Sports Phys Ther.* 1996; 24: 336-341.

27. Donatelli R, Ellenbecker TS, Ekedahl SR, et al. Assessment of shoulder strength in professional baseball pitchers. *J Orthop Sports Phys Ther.* 2000; 30: 544-551.

28. Herrington L. Glenohumeral joint: Internal and external rotation range of motion in javelin throwers. *Br J Sports Med.* 1998; 32:226-228.

29. Witwer A, Sauers E. Clinical measures of shoulder mobility in college water-polo players. *J Sport Rehabil.* 2006; 15: 45-57.

30. Ellenbecker TS, Roetert EP, Bailie DS, et al. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Med Sci Sports Exerc.* 2002; 34: 2052-2056.

31. Kibler WB, Chandler TJ, Livingston BP, et al. Shoulder range of motion in elite tennis players. Effect of age and years of tournament play. *Am J Sports Med.* 1996; 24: 279-285.

32. Borsa PA, Dover GC, Wilk KE, et al. Glenohumeral range of motion and stiffness in professional baseball pitchers. *Med Sci Sports Exerc.* 2006; 38: 21-26.

33. Borsa PA, Wilk KE, Jacobson JA, et al. Correlation of range of motion and glenohumeral translation in professional baseball pitchers. *Am J Sports Med.* 2005; 33: 1392-1399.

34. Crockett HC, Gross LB, Wilk KE, et al. Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *Am J Sports Med.* 2002; 30: 20-26.

35. Crawford SD, Sauers EL. Glenohumeral joint laxity and stiffness in the functional throwing position of high school baseball pitchers. *J Athl Train.* 2006; 41: 52-59.

36. Downar JM, Sauers EL. Clinical measures of shoulder mobility in the professional baseball player. *J Athl Train.* 2005; 40:23-29.

37. Osbahr DC, Cannon DL, Speer KP. Retroversion of the humerus in the throwing shoulder of college baseball pitchers. *Am J Sports Med.* 2002; 30: 347-353.

38. Baltaci G, Johnson R, Kohl H 3rd. Shoulder range of motion characteristics in collegiate baseball players. *J Sports Med Phys Fitness.* 2001; 41:236-242.

39. Bigliani LU, Codd TP, Connor PM, et al. Shoulder motion and laxity in the professional baseball player. *Am J Sports Med.* 1997; 25: 609-613.

40. Meister K, Day T, Horodyski M, et al. Rotational motion changes in the glenohumeral joint of the adolescent/Little League baseball player. *Am J Sports Med.* 2005; 33:693-698.

41. Reagan KM, Meister K, Horodyski MB, et al. Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *Am J Sports Med.* 2002; 30: 354-360.

42. Wilk KE, Meister K, Andrews JR. Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med.* 2002; 30: 136-151.

43. Greene JJ, McGuine TA, Leverson G, et al. Anthropometric and performance measures for high school basketball players. *J Athl Train.* 1998; 33: 229-232.

44. Reinold MM, Wilk KE, Reed J, et al. Interval sports programs. Guidelines for baseball, tennis, and golf. *J Orthop Sports Phys Ther.* 2002; 32: 293-298.

45. Mitchell K, Banks S, Morgan D, et al. Shoulder motions during the golf swing in male amateur golfers. *J Orthop Sports Phys Ther.* 2003; 33: 196-203.

46. Kao JT, Pink M, Jobe FW, et al. Electromyographic analysis of the scapular muscles during a golf swing. *Am J Sports Med.* 1995; 23: 19-23.

47. Tsai N-T, McClure PW, Karduna AR. Effects of muscle fatigue on 3-dimensional scapular kinematics. *Arch Phys Med Rehabil.* 2003; 84: 1000-1005.

48. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998; 26: 325-337.

49. Chesworth BM, MacDermid JC, Roth JH, et al. Movement diagram and "end-feel" reliability when measuring passive lateral rotation of the shoulder in patients with shoulder pathology. *Phys Ther.* 1998; 78: 593-601.

50. Cyriax J. *Textbook of Orthopaedic Medicine, Volume 1: Diagnosis of Soft Tissue Lesions.* 6th ed. London, England: Bailliere Tindall; 1975: 76-77.

51. Tyler TF, Roy T, Nicholas SJ, Gleim GW. Reliability and validity of a new method of measuring posterior shoulder tightness. *J Orthop Sports Phys Ther.* 1999; 29:262-274.

ORIGINAL RESEARCH

CONCENTRIC INTERNAL AND ECCENTRIC EXTERNAL FATIGUE RESISTANC OF THE SHOULDER ROTATOR MUSCLES IN FEMALE TENNIS PLAYERS

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ABSTRACT

Background. Shoulder muscle imbalance is a potential shoulder injury risk factor in athletes performing overhead sports. While normative functional peak strength of concentric external to concentric internal shoulder muscle fatigue data is available, comparisons of functional eccentric external to concentric internal shoulder rotator muscle fatigue resistance, which impacts muscle imbalance throughout the duration of play, have not been studied in this population.

Objectives. To assess fatigue resistance of the internal and external shoulder rotator muscles in female tennis players.

Methods. Fifteen female collegiate tennis players were tested bilaterally for shoulder concentric internal and eccentric external peak torque production throughout 20 maximal repetitions on a Kin-Com isokinetic dynamometer. Twelve t - tests were conducted to evaluate for differences in peak torque, relative fatigue ratios, and functional peak torque ratios between extremities and mode of activation during the first, as well as, last five repetitions that were conducted.

Results. Non-dominant concentric internal and eccentric external peak torque production significantly decreased throughout the twenty repetitions. Neither dominant concentric internal peak torque decrements and eccentric peak torque decrements were not significantly different across the twenty contractions.

These changes in peak torque upon subsequent repetitions resulted in relative fatigue ratios of dominant eccentric external rotation that were significantly greater than non-dominant eccentric external rotation. Relative fatigue ratios of dominant concentric internal rotation did not differ from non-dominant concentric internal rotation.

Conclusions. The data suggest that eccentrically activated external shoulder rotator muscles could possibly adapt to overhead activities by becoming more fatigue resistant.

Key Words: muscular fatigue, muscle imbalance, injury risk factor

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INTRODUCTION

Shoulder muscle imbalance, indicated by a low external to internal shoulder rotator muscle strength ratio, has been observed in patients with glenohumeral joint instability and impingement[1,2] and is considered to be a shoulder injury risk factor for athletes performing overhead activities.[3] Early studies on amateur, elite junior, as well as professional tennis players have isokinetically assessed the shoulder rotator musculature concentrically, showing that shoulder muscle imbalance often occurs as the result of an adaptation to frequent overhead motions, which causes greater increases in concentric internal rotator strength than in concentric external rotator strength.[4-7]

While assessment of concentric internal and concentric external shoulder rotator strength provided early isokinetic normative values, researchers increasingly acknowledged the need to test the strength of the external shoulder rotator musculature eccentrically, which is the dominant mode of activation of the external shoulder rotator muscles during overhead motions.[8] McCarrick and Kemp[9] showed that while mean peak torque of the internal rotator muscles was similar when tested eccentrically as compared to concentrically, eccentric external rotation mean peak torque was significantly greater as compared to concentric external rotation mean peak torque. Consequently, functional muscle eccentric external to concentric internal rotation strength ratios were found to be significantly greater than concentric external to concentric internal strength ratios in athletes performing overhead activities. Data by Noffal[10] further supported these findings leading to the suggestion that functional eccentric assessments of the external rotation muscles rather than concentric assessment might be a better identifier of possible muscular imbalance. Normative data of eccentric and concentric peak strength of internal and external rotation, as well as functional ratios have since been published for various groups of athletes. Results vary depending on sex, angular velocity, range of motion and testing position, as well as the type of athletic involvement of the subjects.[8,10-15]

In contrast to the growing body of normative peak strength data, very few studies have attempted to assess isokinetic muscular fatigue of the shoulder internal and external rotator musculature.[4,16,17] Chandler et al,[4] as well as Ellenbecker and Roetert16 assessed concentric internal and concentric external fatigue of the shoulder rotator muscles and found that concentrically activated external rotator muscles fatigue faster than concentrically activated internal rotator muscles. These authors suggested that shoulder muscle imbalances increase upon prolonged activity, thereby, potentially increasing the risk of injury to the athlete throughout the duration of play.

Furthermore, only one study is currently available that assessed relative fatigue of eccentrically activated external shoulder rotator muscles on athletes who did not perform overhead activities.[17] Similar to the studies that assessed concentric external shoulder rotator muscle fatigue, the study by Mullaney and McHugh[17] showed no significant difference in fatigue of the concentrically activated internal rotator muscles versus eccentrically activated external rotator muscles in athletes participating in recreational sports. Data on eccentric fatigue of the external rotator muscles in comparison to concentric internal rotator muscle fatigue in athletes performing overhead activities, however, was not reported. Since such a functional fatigue ratio potentially provides a better indicator of the change in shoulder muscle imbalance throughout the duration of play and, hence, is a potential predictor for sustaining shoulder injuries, normative data on functional relative fatigue ratios in athletes performing overhead activities are warranted. The purpose of this study was to assess the effects of fatigue on concentric internal and eccentric external shoulder rotation strength in a group of female collegiate tennis players.

METHODS

Subjects

Fifteen collegiate Division II and National Association of Intercollegiate Athletics tennis players without a history of previous shoulder injury were recruited for this study *(Table 1)*. All subjects completed a brief personal history form including age, years played, and arm used to serve. Weight and height measurements were also recorded. The study was approved by the Institutional Review Board of Indiana at the University of Pennsylvania. Informed consent was obtained and the rights of all subjects were protected prior to and after the data collection process.

Assessing Isokinetic Shoulder Strength

Assessment of muscular strength was conducted using the Kin-Com AP Muscle Testing System (Chattecx Corp., Hixson, Tennessee). Testing employed maximum contractions during concentric internal and eccentric external shoulder rotation. An angular velocity of 120°/second was selected to minimize variance as well as to reduce the risk of injury to the subjects.[18,19] The subjects completed 10 submaximal contractions to familiarize themselves with the procedure and to aid in a specific neuromuscular warm-up.

Throughout the assessment, the subjects were seated without the legs touching the ground and the trunk secured to the chair. To approximate shoulder and elbow positioning throughout an actual overhead motion and in accordance with previous studies, the shoulder was abducted to 90° and the elbow was flexed to 90°.[6,7,11,20] The elbow was then secured in a custom-made support. The range of motion completed during the test was between 90° external rotation and 30° internal rotation. While the external range of motion stop was chosen based on prior studies,[11,21] the internal range of motion stop was chosen based on established passive range of motion limits that were as low as 30° of internal rotation for some of the subjects. Hence, greater internal rotation range of motion stops during isokinetic testing as employed in prior studies[7,11,21] would have increased the risk of injury to the subjects and were, consequently, avoided. Imitating the sequence of muscle involvement in a serve, concentric internal rotation was decided upon to always be tested first, immediately followed by eccentric external rotation. Each subject performed 20 maximal contractions during the test. To calculate a relative fatigue ratio, the total peak torque produced in the last five repetitions was divided by the total peak torque produced throughout the first five repetitions.

TABLE 1. Subjects demographics (n=15)

Subject	Mean ± SD	Range
Age	19.5 ± 1.5	18 – 23
Years Played	7.0 ± 3.3	4 – 16
Weight [kg]	67.2 ± 13.4	49.1 – 98.4
Height [cm]	164.1 ± 6.5	152 – 179
BMI* [kg/m^2]	24.9 ± 4.4	19.8 – 36.6

* body mass index

Data Analysis

Means (± standard deviations) of isokinetic peak torque on the dominant and non-dominant extremity were calculated for each condition. Twelve t - tests were conducted to evaluate for differences in peak torque, relative fatigue ratios, and functional peak torque ratios between extremities and mode of activation during the first, as well as last five repetitions that were conducted. A Bonferroni adjustment was used to correct for the multiple comparisons. Originally, the data were considered significantly different at the 0.05 level if the p value was less than 0.05 / 12 = 0.00416 within any of the subsets.

Table 2. Mean concentric internal rotation and eccentric external rotation peak torques, and eccentric external to concentric internal peak torque ratios, of the dominant and non-dominant extremity during the first and last five repetitions.

	D		ND	
Peak Torque [Nm]	Mean ± S.D.	Range	Mean ± S.D.	Range
IR 1 – 5	13.98 ± 3.05	8.51 – 18.48	15.58 ± 2.78	10.12 – 20.46
IR 15 – 20	12.18 ± 2.80	7.36 – 17.25	12.75 ± 1.75	10.40 – 16.80
ER 1 – 5	15.42 ± 4.46	8.51 – 26.62	17.78 ± 2.94	13.20 – 25.52
ER 15 – 20	15.15 ± 4.41	8.80 – 27.50	14.57 ± 2.48	10.08 – 18.04
ER / IR Ratio 1 – 5	1.11 ± 0.24	0.70 – 1.73	1.19 ± 0.41	0.78 – 2.50
ER / IR Ratio 15 – 20	1.27 ± 0.37	0.75 – 0.37	1.17 ± 0.25	0.80 – 1.48

D = dominant extremity, ND = non-dominant extremity, IR = concentric internal rotation, ER = eccentric external rotation

RESULTS

Peak Torque Protection

The results of eccentric external and concentric internal isokinetic peak torque on the dominant and non-dominant extremity are summarized in Table 2. The data of the following t-test discussion are provided in Table 3.

Subjects showed a tendency to reach a lower peak torque during eccentric external rotation on the dominant extremity (15.42 ± 4.46) than on the non-dominant extremity (17.78 ± 2.94; t = 2.946; df = 14, p = 0.0053) but the difference was not significant. Concentric internal rotation peak torque was not significantly different between extremities (dominant internal rotation 13.98 ± 3.05; non-dominant internal rotation 15.58 ± 2.78; t = 1.464; df = 14, p = 0.0826).

Throughout the twenty repetitions, concentric internal and eccentric external peak torque production on the non-dominant extremity significantly decreased ($p \leq 0.008$). Concentric internal peak torque decrements on the dominant extremity were not significant (Mean ± standard deviation: dominant internal rotation 1-5 = 13.98 ± 3.05, dominant internal rotation 15-20 = 12.08 ± 2.80; p = 0.0092), and dominant eccentric external peak torque did not significantly change upon subsequent repetitions, as well (dominant external rotation 1-5 = 15.42 ± 4.46. dominant external rotation 15-20 = 15.15 ± 4.41; p = 0.3444).

Table 3. *t-test evaluations of peak torque, relative fatigue ratios and functional peak torque ratios between extremities and mode of activation during the first and last five repetitions that were conducted*

Measurement		t stat	p
Peak Torque			
DER 1-5	NDER 1-5	2.946	.0053
DIR 1-5	NDIR 1-5	1.464	.0826
DIR 1-5	DIR 15-20	2.670	.0092
NDIR 1-5	NDIR 15-20	3.900	.0008*
DER 1-5	NDER 15-20	.0409	.3444
NDER 1-5	NDER 15 -20	4.954	.0002*
Relative Fatigue Ratios (15-20 / 1-5)			
DIR	NDIR	0.590	.2822
DER	NDER	3.151	.0035*
DIR	DER	2.387	.0158
NDIR	NDER	0.210	.4184
Functional Peak Torque Ratios (Eccentric External/Concentric Internal)			
D 1 - 5	D 15 - 20	2.515	.0124
ND 1 - 5	ND 15 -20	0.257	.4005

* Significant difference at p< 0.00416

DIR = dominant internal rotation, DER = dominant external rotation, NDIR = non-dominant internal rotation, NDER = non-dominant external rotation, * = eccentric external contractions, † = concentric external contractions).

Relative Fatigue Ratios and Functional Peak Torque Ratios

While the relative fatigue ratios for concentric internal rotation of the dominant extremity (88.78 ± 20.03) were not significantly different from the relative fatigue ratios for concentric internal rotation on the non-dominant extremity (84.08 ± 18.13; t = 0.590; df = 14, p = 0.2822), relative fatigue ratios for eccentric external rotation on the dominant extremity (100.48 ± 21.76) were significantly less than relative fatigue ratios for eccentric external rotation on the non-dominant extremity (82.71 ± 13.25; t = 3.151; df = 14; p = 0.0035). Additionally, dominant extremity eccentric external rotation peak torque (100.48 ± 21.76) showed a tendency to decrease less than concentric internal rotation peak torque (88.78 ± 20.03; t = 2.387; df = 14; p = 0.0158). Decrements in eccentric external rotation peak torque on the non-dominant extremity (82.71 ± 13.25) were not significantly different from decrements in concentric internal rotation peak torque (84.08 ± 18.13; t = 0.210; df = 14; p = 0.4184). As a result, eccentric external rotation to concentric internal rotation peak torque ratios on the dominant extremity during the last five repetitions tended to increase from 1.11 ± 0.24 to 1.27 ± 0.37 (t = 2.515; df = 14; p = 0.0124) whereas eccentric external to concentric internal rotation peak torque ratios on the non-dominant extremity did not change (non-dominant external rotation / internal rotation Ratio 15-20: 1.17 ± 0.25; non-dominant external rotation / internal rotation Ratio 1-5: 1.19 ± 0.41; t = 0.257; df = 14; p = 0.4005).

DISCUSSION

The subjects in this study exhibited weakness of eccentric external rotation on the dominant extremity compared to the non-dominant extremity. This weakness is in accordance with findings of previous studies on eccentric external peak torque differences between the dominant and non-dominant extremity in athletes performing overhead activities and is thought to be an adaptation to frequent overhead motions.[10,22] Increased concentric internal peak torque in the dominant extremity, another common adaptation to frequent overhead motions,[6,10] was not observed in this study. Conversely, athletes in this study tended to display increased fatigue resistance of the eccentrically activated external rotator muscles compared to the concentrically activated internal rotator muscles on the dominant extremity. Moreover, fatigue resistance of the eccentrically activated external rotator muscles on the dominant extremity was significantly increased as compared to the non-dominant extremity.

The present study is the first available study to observe greater fatigue resistance of the eccentrically activated external rotator muscles of the dominant extremity in athletes performing overhead activities and stands in contrast to previous findings on fatigue resistance of the shoulder rotator muscles.[4,16,17] Previous studies by Ellenbecker et al[16] and Chandler et al,[4] however, differed from this study as their assessment employed concentric instead of eccentric contractions of the external rotator muscles as well as several other varying parameters of angular velocity and range of motion being assessed.

Employing concentric external contractions at an angular velocity of 300°/sec, the study by Ellenbecker et al[16] demonstrated decreased fatigue resistance of the concentrically activated external rotator muscles as compared to the concentrically activated internal rotator muscles. Furthermore, no difference in concentric external fatigue resistance of the contralateral extremity was observed.[16] Similarly, the study by Chandler et al[4] which assessed fatigue of the shoulder rotator muscles on the dominant extremity only, also employed concentric contractions of the external rotator muscles at an angular velocity of 300°/sec. That particular study observed no difference in fatigability between the concentrically activated external and internal rotator muscles.

The only available study on fatigue resistance of concentrically activated internal rotator muscles together with eccentrically activated external rotator muscles by Mullaney et al[17] focuses on a group of 10 non-athletes. In that study, fatigue resistance was determined by the change in peak torque between the first and last five of a total of 32 repetitions at an angular velocity of 120°/sec. Like Ellenbecker et al[16] and Chandler et al,[4] Mullaney et al[17] did not observe a significant difference in fatigue of the eccentrically activated external rotator muscles versus the concentrically activated internal rotator muscles. Since Mullaney et al[17] accessed the dominant extremity only, no statements could be made regarding fatigue resistance of the eccentrically activated external rotator muscles on the dominant as compared to the non-dominant extremity.

Considering that fatigue ratios for concentric internal rotation in the present study were similar to those observed in prior studies, the authors hypothesize that the greater relative fatigue ratios for eccentric external rotation observed in this study were primarily due to the eccentric instead of concentric mode of activation of the external rotator muscles, rather than varying ranges of motion, angular velocities, or positioning of the body. This hypothesis is supported by previous studies that showed that muscular adaptations are contraction specific. McCarrick et al[9] for example, showed that mean peak torque of the external rotator muscles is increased after a 12 week resistance training program if tested eccentrically but not if tested concentrically. Based on this finding, as well as the present data, the authors suggest that eccentric fatigue measures instead of concentric fatigue measures of the external rotator muscles might provide rehabilitation professionals with further functional data of shoulder muscle fatigue relevant to athletes performing overhead activities.

Furthermore, the authors hypothesize that the difference in fatigue of the eccentrically activated external rotator muscles on the dominant extremity observed in this study compared to the study by Mullaney et al[22] could be attributed to specific adaptations of the shoulder rotator musculature in response to frequent overhead motions among the present group of tennis players versus the group of non-athletes studied by Mullaney et al.[22] Such an eccentric external rotation fatigue resistance in these athletes performing overhead activities would be in accordance with previously reported data on eccentric fatigue resistance of the knee extensors, plantarflexor and the dorsiflexor muscles. Tesch et al[23] showed a 34 - 47 % decrement in strength during 96 concentric contractions of the knee extensors without any fatigue occurring during 96 eccentric contractions. Hortobagyi et al[24] found fatigue of the plantarflexors during 50 maximal isometric and concentric contractions to be 41% and 32%, respectively, but found no change in force during 50 eccentric contractions. Eccentric fatigue resistance was also observed in dorsiflexsors with a strength decrement of 31.6 % during concentric contractions but only 23.8% during eccentric contractions.[25] All of these cases of eccentric fatigue resistance have been found in the lower extremity and concern segments that are trained in daily activities such as walking, jogging, or biking. Eccentric fatigue resistance could be hypothesized to be an adaptation to regular eccentric activation of a given muscle, suggesting that it might also be a prevalent adaptation in athletes performing overhead activities which is absent in athletes who do not perform overhead activities.

Assuming that the present data provides an accurate reference of functional muscle fatigue during repetitive overhead motions, the authors make the following conclusions. First, since muscle fatigue of the eccentrically activated external rotator muscles have not been found to be greater than muscle fatigue of the concentrically activated internal rotator muscles, perhaps, muscle balance is not exacerbated throughout repetitive overhead motions, and appears that no need exists for further exercises to improve fatigue resistance of the external rotator muscles in healthy athletes. Second, peak torque muscle strength imbalance assessments during only a few repetitions can potentially be used to assess a healthy athlete's possible risk of injury due to muscle imbalance without having to consider a potentially increased risk due to differential fatigue throughout prolonged overhead activities. Finally, increased fatigue resistance of the eccentrically activated external rotator muscles might be an adaptation to frequent overhead activities that protects the athlete performing overhead activities from overuse injuries to the shoulder. More research is warranted regarding the role of increased fatigue resistance of the eccentrically activated external rotator muscles in injury prevention. Potentially, athletes returning to overhead activities after shoulder injury could benefit from specific strength training to increase fatigue resistance of the eccentrically activated external rotator muscles. Lastly, testing of relative fatigue ratios of concentric internal and eccentric external rotator strength could possibly be applied to evaluate a rehabilitating athlete's readiness to return to the sport.

CONCLUSION

Contrary to previous studies, this study was the first to show increased fatigue resistance of the eccentrically activated external shoulder rotator muscles in adult and uninjured athletes performing overhead activities. The authors hypothesize that this adaptation might protect athletes performing overhead activities from sustaining overuse shoulder injuries. Athletes returning to play after injury might benefit from specific strength training exercises to increase fatigue resistance of the eccentrically activated external rotator musculature. Isokinetic testing of fatigue resistance of the shoulder rotator musculature might also be useful to determine an athlete's readiness to return to competition.

REFERENCES

1. Leroux J-L, Codine P, Thomas E, et al. Isokinetic evaluation of rotational strength in normal shoulders and shoulders with impingement syndrome. *Clin Orthop Relat Res.* 1993;304:108-115.
2. Warner JJ, Micheli LJ, Arslanian LE, et al. Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. *Am J Sports Med.* 1990;18:366-375.
3. Wang H-K, Cochrane T. Mobility impairment, muscle imbalance, muscle weakness, scapular asymmetry and shoulder injury in elite volleyball athletes. *J Sports Med Phys Fitness.* 2001;41:403-410.
4. Chandler TJ, Kibler WB, Stracener EC, et al. Shoulder strength, power, and endurance in college tennis players. *Am J Sports Med.* 1992;20:455-458.
5. Ellenbecker TS, Roetert EP. Age specific isokinetic gleno humeral internal and external rotation strength in elite junior tennis players. *J Sci Med Sport.* 2003;6:63-70.
6. Kraemer WJ, Triplett NT, Fry AC, et al. An in-depth sports medicine profile of women college players. *J Sport Reh.* 1995;4:79-98.
7. Stanley A, McGann R, Hall J, et al. Shoulder strength and range of motion in female amateur-league tennis players. *J Orthop Sports Phys Ther.* 2004;34:402-409.
8. Nirschl R, Sobel J. Tennis. In: Reider B, ed. *Sports Medicine: The School-age Athlete.* Philadelphia, PA: Saunders; 1996:729-729.
9. McCarrick MJ, Kemp JG. The effect of strength training and reduced training on rotator cuff musculature. *Clin Biomech.* 2000;15 Suppl 1:S42-45.
10. Noffal GJ. Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers. *Am J Sports Med.* 2003;31:537-541.
11. Ellenbecker TS, Roetert EP. Testing isokinetic muscular fatigue of shoulder internal and external rotation in elite junior tennis players. J Orthop Sports Phys Ther. 1999; 29:275-281.
12. Forthomme B, Croisier J–L, Ciccarone G, et al. Factors correlated with volleyball spike velocity. *Am J Sports Med.* 2005;33:1513-1519.
13. Ng GYF, Lam PCW. A study of antagonist/agonist isokinetic work ratios of shoulder rotators in men who play badminton. *J Orthop Sports Phys Ther.* 2002;32:399-404.
14. Wang H-K, Macfarlane A, Cochrane T. Isokinetic performance and shoulder mobility in elite volleyball athletes from the United Kingdom. *Br J Sports Med.* 2000;34:39-43.
15. Yildiz Y, Aydin T, Sekir U, et al. Shoulder terminal range eccentric antagonist/concentric agonist strength ratios in overhead athletes. *Scand J Med Sci Sports.* 2006;16:174-180.
16. Ellenbecker TS, Roetert EP. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. J Sci Med Sport. 2003;6:63-70.
17. Mullaney MJ, McHugh MP. Concentric and eccentric muscle fatigue of the shoulder rotators. *Int J Sports Med.* 2006;27:725-729.
18. Dvir Z. *Isokinetics: Muscle Testing, Interpretation and Clinical Applications.* Edinburgh:Churchill Livingstone;1995.
19. Mayer F, Horstmann T, Baeurle W, et al. Diagnostics with isokinetic devices in shoulder measurements—potentials and limits. *Isokinet Exerc Sci.* 2001;9:19-25.
20. Treiber FA, Lott J, Duncan J, et al. Effects of Theraband® and lightweight dumbbell training on shoulder rotation torque and serve performance in college tennis players. *Am J Sports Med.* 1998;26:510-515.
21. Moncrief SA, Lau JD, Gale JR, Scott SA. Effect of rotator cuff exercise on humeral rotation torque in healthy individuals. *J Strength Cond Res.* 2002;16:262-270.
22. Mulligan IJ, Biddington WB, Barnhart BD, Ellenbecker TS. Isokinetic profile of shoulder internal and external rotators of high school aged baseball pitchers. *J Strength Cond Res*. 2004;18:861-866.
23. Tesch PA, Dudley GA, Duvoisin MR, Hather BM, et al. Force and EMG signal patterns during repeated bouts of concentric or eccentric muscle actions. *Acta Physiol Scand.* 1990;138:263-271.
24. Hortobagyi T, Tracy J, Hamilton G, Lambert J. Fatigue effects on muscle excitability. *Int J Sports Med.* 1996; 17:409-414.
25. Pasquet B, Carpentier A, Duchateau J, Hainaut K. Muscle fatigue during concentric and eccentric contractions. *Muscle Nerve.* 2000;23:1727-1735.

ORIGINAL RESEARCH

DESCRIPTIVE REPORT OF SHOULDER RANGE OF MOTION AND ROTATIONAL STRENGTH SIX AND 12 WEEKS FOLLOWING ARTHROSCOPIC SUPERIOR LABRAL REPAIR

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ABSTRACT

Objectives. To measure short-term post surgery glenohumeral internal and external rotation strength, shoulder range of motion (ROM), and subjective self-report ratings following arthroscopic superior labral (SLAP) repair.

Background. Physical therapists provide rehabilitation for patients following arthroscopic repair of the superior labrum. Little research has been published regarding the short-term results of this procedure while the patient is typically under the direct care of the physical therapist.

Methods. Charts from 39 patients (7 females and 32 males) with a mean age of 43.4 $\pm$14.9 years following SLAP repair were reviewed. All patients underwent rehabilitation by the same therapist using a standardized protocol and were operated on and referred by the same orthopaedic surgeon. Retrospective chart review was performed to obtain descriptive profiles of shoulder ROM at 6 and 12 weeks post surgery and isokinetically documented internal and external rotation strength 12 weeks post surgery.

Results. At 12 weeks post-surgery, involved shoulder flexion, abduction, and external rotation active ROM values were 2-6 degrees greater than the contralateral, non-involved extremity. Isokinetic internal and external rotation strength deficits of 7-11% were found as compared to the uninjured extremity. Patients completed the self-report section of the Modified American Shoulder Elbow Surgeons Rating Scale and scored a mean of 37/45 points.

Conclusion. The results of this study provide objective data for both glenohumeral joint ROM and rotator cuff strength following superior labral repair at time points during which the patient is under the direct care of the physical therapist. These results show a nearly complete return of active ROM and muscular strength following repair of the superior labrum and post-operative physical therapy.

Key Words: glenohumeral joint, labrum, rehabilitation

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INTRODUCTION

The glenoid labrum serves several important functions including deepening the glenoid fossa to enhance the concavity and serving as the attachment for the glenohumeral capsular ligaments. Injury to the labrum can compromise the concavity compression phenomena by as much as 50%.[1] Individuals with increased capsular laxity and generalized joint hypermobility have increased humeral head translation which can subject the labrum to increased shear forces.[2] In the athlete performing overhead throwing, large anteriorly directed translational forces are present at levels up to 50% of body weight during arm acceleration of the throwing motion with the arm in 90 degrees of abduction and external rotation.[3] This repeated translation of the humeral head against and over the glenoid labrum can lead to labral injury. Labral injury can occur as either tearing or as actual detachment from the glenoid and can occur in virtually any location around the circumference of the glenoid fossa. Two of the most common areas for labral detachment encountered by physical therapists in orthopaedic and sports rehabilitation are the Bankart and SLAP lesion. In 1906, Perthes[4] was the first to describe the presence of a detachment of the anterior inferior labrum in patients with recurrent anterior instability. Bankart[5,6] initially described a method for surgically repairing this lesion that now bears his name.

In addition to labral detachment in the anterior inferior aspect of the glenohumeral joint, similar labral detachment can occur in the superior aspect of the labrum and have been defined as superior labrum anterior posterior, (SLAP) lesions. Snyder et al[7] classified superior labral injuries into four main types. Type I shows labral degenerative changes and fraying at the edges, but no distinct avulsion. Type II are the most commonly reported superior labral injuries[8] and have been described as complete labral detachment from anterosuperior to posterosuperior glenoid rim with instability of the biceps long head tendon noted. Morgan et al[8] have further sub-classified the type II superior labral lesion into type II anterior, type II posterior and type II anterior and posterior. Of significance is the increased (three times more) likelihood of type II posterior SLAP lesions in athletes that throw, as well as the finding of the Jobe subluxation relocation test as the most accurate and valuable test to identify the type II posterior lesion.[8] Type II anterior SLAP lesions are most commonly associated with trauma and are less likely to be found in athletes performing overhead activities. A type III labral injury involves the displacement of the free margin of the labrum into the joint in a bucket-handle type fashion with no instability of the biceps long head tendon noted. A type IV labral lesion is similar to a type III lesion with a bucket handle displacement of the glenoid labrum, however, a type IV lesion involves a partial rupture in the direction of its fibers of the the biceps long head tendon.[7]

Consequences of a superior labral injury include significant losses in the static stability of the human shoulder.[9] Cheng and Karzel[9] demonstrated the important role the superior labrum and biceps anchor play in glenohumeral joint stability by experimentally creating a SLAP lesion between the 10 and 2 o'clock positions in cadaveric shoulders. They found 11 to 19% decreases in the glenohumeral joints ability to withstand rotational force, as well as 100 to 120% increases in strain on the anterior band of the inferior glenohumeral ligament after a SLAP lesion. These changes demonstrate a significant increase in the load on the capsular ligaments in the presence of superior labral injury.

Arthroscopic surgical repair of the detached superior labral lesion has evolved from the use of bioabsorbable tacs[10] to the use of direct suture techniques using suture anchors.[11,12] Cadaveric research has shown that increases in glenohumeral translation created with experimentally induced labral detachment are only partially restored during repair of the human labrum.[13] Patients are referred to physical therapy following arthroscopic SLAP repair to restore both range of motion and important muscular strength to provide dynamic stabilization following the repair.

The purpose of this descriptive study was to objectively measure and report shoulder range of motion (ROM) and muscular strength following arthroscopic SLAP repair the results of the study will show the effectiveness of rehabilitation using a standardized rehabilitation protocol.

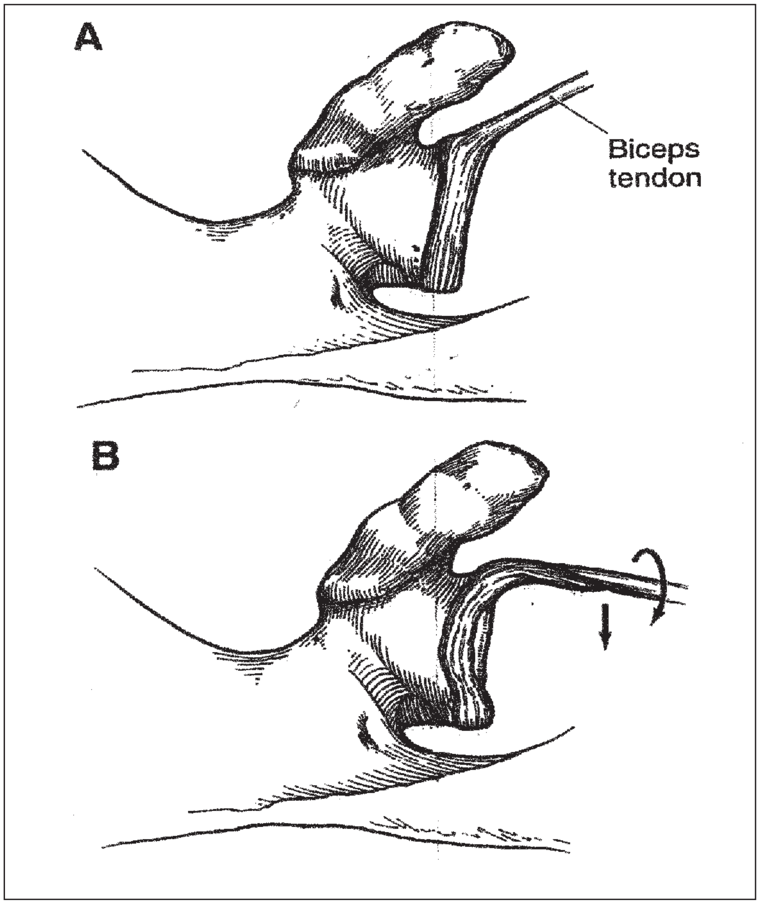
METHODS

Patients

A retrospective review was undertaken of patients who underwent arthroscopic SLAP repair and were referred to Physiotherapy Associates Scottsdale Sports Clinic over a three year period (2003-2006) for rehabilitation by the senior author (TE) using a standard rehabilitation protocol for rehabilitation following superior labral repair *(Appendix)*. Subjects were not included in the chart review if concomitant procedures were performed including rotator cuff repair, thermal capsulorraphy, or capsular plication. To be included in the study, subjects had to free from injury or surgery in the contralateral extremity as that extremity served as the baseline for bilateral testing in this investigation. To be included in this study, subjects had to have a type II labral tear which required arthroscopic surgical repair using direct suture technique and suture anchors. Patients with labral debridement were not included in this investigation. The research procedure was reviewed and approved by the Institutional Review Board of Physiotherapy Associates (Memphis, TN).

Rehabilitation Program

Additional information regarding the post-operative rehabilitation protocol is described to provide insight into the specific treatment each patient received following the arthroscopic SLAP repair. Sling use was directed by the physician with the recommendation for use in precarious situations (such as when outside the home or work environment) and to provide comfort. No specific objective criterion were used to monitor and direct sling use. Due to the possible attenuation of the superior labral repair during forceful muscular contraction of the biceps brachii, patients were instructed to avoid lifting objects and to wear the sling to prevent and minimize biceps muscle contraction in the immediate post-operative period. The time interval between surgery and the initial visit of physical therapy post surgery was 2.6 ± 1.93 weeks for the 39 patients in this study. Patients were given instructions for gentle active assistive ROM including Codman's pendulum exercises by the referring physician to perform until reporting for their initial post surgical rehabilitation visit.



Early passive, active assistive, and active ROM and glenohumeral joint mobilization was initiated in all planes of motion. Basic science research has provided guidance to the provision of early range of motion for patients following superior labral repair. Morgan and Burkhart[14] have identified the concept of the "peel back" mechanism. *(Figure 1)* The peel back mechanism occurs with the glenohumeral joint in 90 degrees of abduction and external rotation; in a position simulating the throwing motion. In this position, the biceps tendon force vector has been found to assume a more vertical and posterior direction creating the peel back of the superior labrum.

In the first 6 weeks following surgery, all patients were not placed in the abduction - external rotation position with any external load applied to minimize the effects of the peel back mechanism. Kuhn et al[15] tested cadaveric specimens in the abduction-external rotation "peel back position" as well as simulating the "follow-through phase" of the throwing motion (60 degrees abduction and 15 degrees horizontal adduction). They found significantly less load to failure of the biceps labral complex in the peelback position as compared to the follow-through position, thereby, supporting the vulnerability of the shoulder and, specifically, the biceps labral complex in the abducted externally rotated position. Glenohumeral external rotation range of motion and stretching was performed in 0-45 degrees of abduction during this time period. Terminal ranges of motion were targeted in all other planes of motion using primarily physiologic mobilization and end range stretching techniques. The use of accessory mobilization during this time period was limited to minimize glenoid shear over the repaired labral structure.

Patients also performed active assistive range of motion on a multiple daily basis (2-3 times a day) at home using an overhead pulley to address elevation range of motion in the scapular plane, In addition, a stick or cane was used in the supine position.

In the early post-surgical phase (weeks 1-3) submaximal resistive exercise was initiated for the rotator cuff. The primary movements initiated were internal and external rotation, and prone shoulder extension and horizontal abduction. These movements were targeted due to activation of the infraspinatus, teres minor, and subscapularis muscles and use of protective positions below 90 degrees of elevation, short lever arms, and positioning of the glenohumeral joint in or anterior to the scapular plane.[16,17,18,19] Use of tan level Thera-band tubing (Hygenic Corp, Akron, OH) and little or no added weight to the extremity was recommended initially to minimize substitution. Moncrief et al[20] have shown how the use of these resistive exercise patterns can lead to increases in rotator cuff strength using a low resistance high repetition format utilized in this study.

In the early post-operative rehabilitation phase, patients performed isolated manual resistance of the scapula in the motions of protraction and retraction. Exercises emphasizing scapular retraction and depression were given to recruit the serratus anterior and lower trapezius force couple without the use of rowing and other traditional scapular exercises that utilize substantial elbow flexion muscle activity. Use of early active shoulder flexion in the balance point position refers to the use of a supine patient position with the extremity in 90 degrees of flexion. In this position the patient is able to balance their extremity with minimal muscular activation and perform short active motions of flexion and extension and horizontal abduction/adduction with the therapist guiding the patient's ROM. At 6 weeks post surgery, progression of the balance point work to the integration of rhythmic stabilization to this balance point position is also followed using the command "hold, don't let me move you" while the patient holds the 90 degree flexed extremity stabilizing against external challenges in multiple directions of movement by the therapist.[21] A position of scapular protraction or "plus" position is employed with this exercise, as well, based on the concepts of Mosley et al[22] and Decker et al[23] to increase activation of the serratus anterior.

The use of shoulder flexion initially in an active assistive role and then active and eventually resisted role is warranted based on the work of Yamaguchi et al[24] and Levy et al.[25] These studies have shown minimal levels (1.7-3.6% of maximal voluntary contraction) of muscle activation of the biceps long head during multiple directions of shoulder movement such as scapular plane elevation and glenohumeral rotational movements. This basic science research helps to differentiate early exercise and active range of motion patterns for clinicians to utilize while protecting the repaired superior labrum and biceps long head anchor. Resistive exercise for the elbow flexors is delayed until between 6-8 weeks post-surgery and is applied in the form of rowing variations, upper body ergometry, and isolated elastic and isotonic resistance exercise.

At 10-12 weeks post-surgery, patients were introduced to the isokinetic dynamometer at submaximal intensities. The accommodative resistance, ability to exercise via a sequence of progressively increasing contractile velocities, and objective feedback all provide the rationale for inclusion of this type of resistive exercise.[26] Additionally, previous studies have reported significant increases in glenohumeral joint internal and external rotation following isokinetic training.[27,28] Upper extremity plyometrics were also introduced during this time interval to provide both concentric and eccentric muscle activation.

Outcome Measures

Variables included in the retrospective review were, subject age, dominant arm, estimated time from injury to surgery, time from surgery to initiation of physical therapy, as well as objective measures of ROM and strength. Range of motion was measured passively in the supine position at 6 weeks post-surgery for forward flexion and abduction with a universal goniometer and standardized measurement techniques.[29] Internal and external rotation was measured actively with 90 degrees of glenohumeral joint abduction and scapular stabilization.[30,31] At 12 weeks post-surgery, active ROM measurements were taken with the subject in a seated position such that antigravity forward elevation and abduction were measured, in addition to supine active internal and external rotation with 90 degrees of abduction with scapular stabilization.[30] The identical active ROM procedure was used to document the ROM of the uninjured extremity during the initial post-operative evaluation. Measurements were recorded to the nearest degree. All measures were taken by the senior author as part of the rehabilitation process with prior test-retest reliability of the glenohumeral joint rotational measures published previously.[30]

Isokinetic strength testing was performed on all 39 patients 12 weeks post-surgery using a Cybex 6000 Isokinetic dynamometer (Stoughton, MA). Testing was performed with the patient in a standing position with the dynamometer placed in 30 degrees of tilt from the horizontal base position and placed the patient's shoulder in 30 degrees of elevation in the scapular plane.[26] A ROM of 70 degrees of internal rotation and 30 degrees of external rotation was set using ROM stops. Four gradient (ie 50, 75, 90 and 100% of maximal effort) submaximal warm-up repetitions were used followed by five maximal effort repetitions for data collection at the testing speeds of 90, 210 and 300 degrees per second with 30 seconds rest between testing speeds followed. Testing was performed at three test speeds to provide information from the patient's ability to generate resistance at slow, intermediate, and a fast testing speed. Testing was performed on the uninjured extremity first without randomization of testing speed sequence to enhance reliability.[32]

Following testing on the uninjured extremity, identical set-up and testing procedures were used on the post-operative extremity. Isokinetic parameters chosen to represent muscular strength in this sample were the single repetition work value calculated by the Cybex 6000 software as the area under the torque curve versus joint angle curve for the best repetition of the five performed by the subject. Additionally, the external/internal rotation unilateral strength ratio was recorded as calculated by the Cybex 6000 software by dividing the external rotation work value obtained at each speed by the corresponding internal rotation value. The reliability of the Cybex 6000 concentric isokinetic dynamometer has been previously published,[33] as has the reliability specific to the application of isokinetic testing to the glenohumeral joint.[34]

The self report section of the modified American Shoulder Elbow Surgeons (ASES) rating scale was administered at 12 weeks post-surgery.[35,36] Patients answered the series of 15 questions following standardized instructions estimating their ability to perform the activities with their injured extremity at time the instrument was completed. Each patient's responses were tallied to form a composite score against 45 possible points. The modified ASES rating scale has been studied and found to have excellent test-retest reliability and responsiveness in patients with shoulder pain.[35,36] The modified ASES rating scale compared favorably to other shoulder rating scales and was found to be more sensitive to change than a generic questionnaire and was chosen for use in this investigation.[35]

RESULTS

The mean $\pm$ standard deviation (SD) age of the 39 patients (6 females and 41 males) studied was 43 $\pm$ 14.9 years. The mean time from initial injury to surgical repair of the superior labrum was 23 $\pm$ 26.83 weeks with a range of 4 weeks to 92 weeks. Patients were seen for their first visit of physical therapy and evaluated 2.6 $\pm$ 1.93 weeks post-surgery. Surgery was performed on the dominant arm in 27 of 39 cases.

Passive ROM measures for forward flexion and abduction taken in the supine position and active internal and external rotation measures also taken in the supine position 6 weeks following arthroscopic rotator cuff repair are presented in Table 1. In addition the active ROM values of the contralateral limb taken during the initial evaluation are listed for reference. Passive ROM values measured in the supine position at 6 weeks post surgery showed greater forward flexion than active anti-gravity measures from the uninjured extremity and less than 10 degree differences in movement for abduction and external rotation. The largest difference in ROM at 6 weeks post surgery was in the motion of internal rotation measured with 90 degrees of glenohumeral joint abduction.

Table 2 contains the active ROM measures taken at 12 weeks following superior labral repair as well as the number of degrees of difference relative to the uninjured extremity. Values obtained for forward flexion, abduction, and external rotation actually exceeded those measured on the uninjured extremity by 2-6 degrees at the 12 week post surgery. Mean deficits of 12 degrees in internal rotation were measured at 90 degrees abduction and compared to the uninjured extremity.

Table 3 contains the isokinetic single-repetition work values. In addition, Table 3 presents isokinetic bilateral strength comparisons, expressed as the percent deficit of the injured extremity relative to the uninjured extremity for shoulder internal and external rotation at the three testing speeds. Results show deficits of 7-11 % for external rotation compared to the uninvolved extremity. Internal rotation strength deficits of 8-9 % were measured at 90 and 210 degrees per second, with 4 % greater strength identified on the injured extremity at 300 degrees per second.

Table 4 contains the external/internal rotation work ratios for the injured and uninjured extremity. Mean external/internal rotation ratios ranged between 48 and 61% similar to that measured on the contralateral extremity. The self report section of the modified ASES rating scale administered 12 weeks post surgery produced mean values of 37 out of 45 possible points.

Table 1. Passive Range of Motion (PROM) of the Involved Extremity 6 Weeks following Arthroscopic Superior Labral Repair and Active Range of Motion (AROM) of the Uninvolved Extremity taken at Initial Examination (n = 39 patients).

	PROM Injured Extremity			AROM Uninjured Extremity		
Movement	Mean	SD	Range	Mean	SD	Range
Forward Flexion	164.54	7.9	(140-175)	157.81	9.2	(135-175)
Abduction	158.67	17.9	(115-180)	163.91	14.4	(110-180)
External Rotation @ 90 Abduction	84.83	16.4	(50-105)	92.83	11.0	(65-115)
Internal Rotation @ 90 Abduction	41.37	11.0	(10-62)	55.63	11.5	(30-70)

Note: All measures expressed in degrees

Table 2. Active Range of Motion of the Involved Extremity 12 Weeks following Arthroscopic Superior Labral Repair (n = 39 patients).

	Injured Extremity			Degrees Different from Uninjured Extremity	
Movement	Mean	SD	Range	Mean	SD
Forward Flexion	161.21	8.7	(130-175)	-3.40*	12.1
Abduction	169.62	9.7	(150-180)	-5.71*	15.4
External Rotation @ 90 Abduction	94.51	9.21	(75-115)	-1.68*	31.0
Internal Rotation @ 90 Abduction	45.41	9.43	(25-65)	10.22	23.6

Note: All measures in degrees.

(*) measures expressed as negative values indicate injured extremity exceeds value measured on uninjured extremity.

DISCUSSION

This study provides descriptive information on the short-term outcome following a common surgical procedure seen in orthopaedic and sports physical therapy clinics. The ROM findings reported in this patient series suggest the value of limited immobilization post-surgery and early physical therapy and ROM exercise. The use of this rehabilitation protocol produced ROM values in nearly all planes of motion within 5-10 degrees of the contralateral uninjured extremity as early as 6 weeks post-surgery. By 12 weeks post-surgery, the ROM values actually exceeded baseline contralateral ROM values in all planes except for internal rotation. One possible explanation for the decrease in internal rotation ROM measured at 90 degrees of glenohumeral joint abduction with scapular stabilization was the demographic that 19 of the 39 patients in this series were former or current competitive baseball, tennis, or softball players (athletes performing overhead activities). Since pre-operative measures were not performed on this series of patients, the assumtion for the purpose of this study was that subjects had bilaterally symmetric glenohumeral joint ROM values. However, research has consistently shown in athletes performing overhead activites, reductions in dominant arm internal rotation ROM from osseous adaptations such as humeral retroversion[37] and musculotendinous and capsular tightness[38,39,40] which may explain the larger internal rotation ROM mean difference in this series of patients following superior labral repair.

Comparison of this series to others with respect to specific objective measurement of glenohumeral joint ROM is limited. Most studies following arthroscopic superior labral repair use composite functional outcome ratings and return to specific activity statistics with limited objective data on range of motion or muscular strength.[10,11,12] Kim et al[12] evaluated 34 patients at a mean 33 months following superior labral repair using a UCLA rating score. Repair of the superior labrum resulted in satisfactory UCLA scores in 94% of the patients with 91% reporting a full return to pre-injury shoulder function. Despite the long-term follow-up, no objective data on ROM or strength was reported. Ide et al[11] reported on 40 patients 41 months following superior labral repair using suture anchors. A modified Rowe score was used showing improvement from 27.5/100 preoperatively to 92.1 points. Seventy five percent of the patients were rated as excellent on the modified Rowe score with 75% reporting a return to pre-injury level athletic activity. While long-term outcomes research such as these studies do provide valuable information that can be disseminated to patients regarding their overall recovery following surgery, little can be gained regarding the objective parameters directly affected during post-operative rehabilitation while the physical therapist has direct contact with the patient.

Table 3. Isokinetic Internal (IR) and External Rotation (ER) Strength Single Repetition Work Values and Injured/Uninjured Comparisons Measured at 12 Weeks Status Post Arthroscopic Superior Labral Repair (n = 39 subjects).

Motion / Speed	Injured		Uninjured		% Deficit *		
	Mean	SD	Mean	SD	Mean	SD	Range
ER 90°/s	23.44	8.6	26.47	8.7	11.18	15	(-36-40)
ER 210°/s	16.28	7.5	18.18	7.1	10.34	20	(-33-45)
ER 300°/s	11.60	6.6	12.60	6.3	7.71	29	(-55-67)
IR 90°/s	38.44	13.0	43.15	14.1	9.60	18	(-44-42)
IR 210°/s	29.68	12.0	32.94	12.4	8.50	23	(-82-40)
IR 300°/s	23.97	12.0	24.55	12.5	-4.15	48	(-237-48)

Note: All measures expressed in foot pounds (1 foot pound = 2.98 newton meters)
* negative value indicates involved extremity is stronger than uninvolved
°/s = degree per second

Table 4. External/Internal Rotation Ratios Measured at 12 Weeks following Arthroscopic Superior Labral Repair (n = 39 subjects)

Speed	Injured			Uninjured		
	Mean	SD	Range	Mean	SD	Range
90°/s	61.92%	15.3	(36-105)	62.28%	13.6	(42-100)
210°/s	55.63%	15.1	(31-100)	55.76%	13.2	(32-83)
300°/s	48.15%	15.9	(22-93)	54.36%	22.0	(21-125)

°/s- degree per second

Cadaveric research[13] has highlighted the importance of dynamic musculotendonous stabilization in the glenohumeral joint following simulated SLAP lesion and subsequent repair. A complete restoration of glenohumeral joint stability requires the addition of muscular stabilization, which is a key component of shoulder rehabilitation programs in physical therapy.[41,42,43,44] Long term outcome studies have shown a high rate of return to overhead sports[11,12] following SLAP repair which indirectly infer the return of dynamic stabilization to the shoulder. However, studies using objective documentation of muscular strength during long-term follow-up are lacking.

The present study shows a return of internal and external rotation strength documented isokinetically within 10% of the contralateral extremity during dynamic testing. External/internal rotation ratios which are used to quantify muscle balance between opposing muscle groups, were also calculated and measured in this study. Normal values for the external/internal rotation ratio in healthy uninjured shoulders have been reported to be 66% in descriptive studies.[26,45,46] Ratios measured in the patients 12 weeks following superior labral repair ranged between 48 to 61%, well below the normal range targeted in post-operative rehabilitation. Continued emphasis on posterior rotator cuff strengthening to improve external/internal rotation muscular balance is recommended for these patients both during continued rehabilitation and in home programming following discharge. Further research, including long term follow-up, with documentation of specific muscular strength relationships beyond the 12 week post-operative time interval is presently needed.

Another important component measured in this study was the patient's perception of their function captured using the modified ASES rating scale. The self-report section totaled 37/45 possible points 12 weeks following surgery. The compares closely to patients following mini-open rotator cuff repair 12 weeks post-surgery who measured 38.7/45 points.

A limitation of this study is that the study was performed retrospectively, and followed patients for a limited time interval post-operatively while they were undergoing outpatient physical therapy. An additional limitation is that the study design included only a single surgeon and physical therapist. Therefore, the ability to generalize this information beyond this surgical technique and rehabilitation protocol used in this study is cautioned. One strength of the use of a single physical therapist in this study was that this therapist performed all goniometric measures increasing reliability of recording over other studies using multiple examiners. An additional strength was the use of an objective reliable measurement instrument for internal and external rotation strength.

CONCLUSION

The data collected 12 weeks following superior labral repair show deficits of 10 degrees in internal rotation Active ROM and a full return of flexion, abduction, and external rotation relative to the contralateral extremity. Deficits in muscular strength of 7-11 % were found in the internal and external rotators 12 weeks following surgery. Self reported data from the modified ASES Rating Scale showed patients to score 37/45 points. These results show a nearly complete return on active ROM and strength following repair of the superior labrum and post-operative rehabilitation.

REFERENCES

1. Matsen FA, Harryman DT, Sidles JA. Mechanics of glenohumeral instability. *Clin Sports Med.* 1991;10:783-788.
2. Kvitne KS. Shoulder instability in the overhead or throwing athlete. *Clin Sports Med.* 14:921, 1995
3. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med.* 1995;23:233-239.
4. Perthes G. Ueber operationen der habituellen schulterluxation. *Deutsche Ztschr Chir.* 1906;85:199.
5. Bankart ASB. Recurrent or habitual dislocation of the shoulder joint. *BMJ*. 1923;2:1132-1133.
6. Bankart ASB. The pathology and treatment of recurrent dislocation of the shoulder joint. *BMJ*. 1938;26:23-29.
7. Snyder SJ, Karzel RP, Del Pizzo W, et al. SLAP lesions of the shoulder. *Arthroscopy.* 1990;6:274-279.
8. Morgan CD, Burkhart SS, Palmeri M, et al. Type II SLAP lesions: Three subtypes and their relationships to superior instability and rotator cuff tears. *Arthroscopy*. 1998; 14:553-565.
9. Cheng JC, & Karzel RP, Superior labrum anterior posterior lesions of the shoulder: Operative techniques of management. *Oper Tech Sports Med*. 1997;5:249-256.
10. Segmuller HE, Hayes MG, Saies AD. Arthroscopic repair of glenolabral injuries with an absorbable fixation device. *J Shoulder Elbow Surgery*. 1997;6:383-392.
11. Ide J, Maeda S, Katsumasa T. Sports activity after arthroscopic superior labral repair using suture anchors in overhead-throwing athletes. *Am J Sports Med.* 2005; 33:507-514.
12. Kim SH, Ha KI, Kim SH, Choi HJ. Results of arthroscopic treatment of superior labral lesions. *J Bone Joint Surgery.* 2002;84A:981-5.
13. Burkart A, Debski RE, Musahl V, McMahon PJ. Glenohumeral translations are only partially restored after repair of a simulated type II superior labral lesion. *Am J Sports Med.* 2003;31:56-63.
14. Morgan CD, Burkhart SS. The peel-back mechanism: Its role in producing and extending posterior type II SLAP lesions and its effect on SLAP repair rehabilitation. Technical Note. *Arthroscopy*. 1998:14:637-640.
15. Kuhn JE, Lindholm SR, Huston LJ, et al. Failure of biceps superior labral complex in the throwing athlete: A biomechanical model comparing maximal cocking to early deceleration. Presented at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Anaheim CA February, 1999.

16. Ballantyne BT, O'Hare SJ, Paschall JL, et al. Electromyographic activity of selected shoulder muscles in commonly used therapeutic exercises. *Phys Ther*. 1993; 73:668-677.

17. Blackburn TA, McLeod WD, White B, Wofford L. EMG analysis of posterior rotator cuff exercises. *Athletic Training*. 1990;25:40.

18. Reinhold MM, Wilk KE, Fleisig GS, et al. Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *J Orthop Sports Phys Ther*. 2004;34:385-394.

19. Townsend H, Jobe FW, Pink M, et al. Electromyographic analysis of the glenohumeral muscles during a baseball rehabilitation program. *Am J Sports Med*. 1991;19:264.

20. Moncrief SA, Lau JD, Gale JR, Scott SA. Effect of rotator cuff exercise on humeral rotation torque in healthy individuals. *J Strength Cond Res*. 2002;16:262-270.

21. Sullivan PE, Markos PD, Minor MD. *An Integrated Approach to Therapeutic Exercise: Theory and Clinical Application*. Reston Publishing Co, Reston, VA, 1982.

22. Mosely JB, Jobe FW, Pink M. EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med*. 1992;20:128-134.

23. Decker MJ, Hintermeister RA, Faber KJ, Hawkins RJ. Serratus anterior muscle activity during selected rehabilitation exercises. *Am J Sports Med*. 1999;27:784-791

24. Yamaguchi K, Riew DK, Galatz LM, et al. Biceps activity during shoulder motion: An electromyographic analysis. *Clin Orthop*. 1997;336:122-129.

25. Levy AS, Kelly BT, Lintner SA, et al. Function of the long head of the biceps at the shoulder: Electromyographic analysis. *J Shoulder Elbow Surg*. 2001;10:250-255.

26. Davies GJ. *A Compendium of Isokinetics in Clinical Usage*. S & S Publishers, LaCrosse, WI, 1992.

27. Ellenbecker TS, Davies GJ, Rowinski MJ. Concentric versus eccentric isokinetic strengthening of the rotator cuff. Objective data versus functional test. *Am J Sports Med*. 1988;16:64-69.

28. Mont MA, Cohen DB, Campbell KR, et al. Isokinetic concentric versus eccentric training of shoulder rotators with functional evaluation of performance enhancement in elite tennis players. *Am J Sports Med*. 1994;22:513-7.

29. Norkin CC, White DJ: *Measurement of Joint Motion: A Guide to Goniometry*, 2nd Edition, Philadelphia, F A Davis Company, 1995.

30. Ellenbecker TS, Roetert EP, Piorkowski PA, Schulz DA. Glenohumeral joint internal and external rotation range of motion in elite junior tennis players. *J Orthop Sports Phys Ther*. 1996;24:336-341.

31. Ellenbecker TS, Roetert EP, Bailie DS, et al. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Med Sci Sports Exercise*. 2002; 34:2052-2056.

32. Wilhite MR, Cohen ER, Wilhite SC. Reliability of concentric and eccentric measurements of quadriceps performance using the Kin-Com dynamometer. The effects of testing order for three different speeds. *J Orthop Sports Phys Ther.* 1992;15:175-182.

33. Timm KE, Genrich P, Bruns R, Fyke D. The mechanical and physiological performance reliability of selected isokinetic dynamometers. *Isokinetics and Exercise Science.* 1992;2:182-190.

34. Malerba JL, Adam ML, Harris BA, Krebs DE. Reliability of dynamic and isometric testing of shoulder external and internal rotators. *J Orthop Sports Phys Ther.* 1993;18:543-52.

35. Beaton D, Richards RR. Measuring function of the shoulder: A cross-sectional comparison of five questionnaires. *J Bone Joint Surgery*. 1996;78A:882-890.

36. Beaton D, Richards RR. Assessing the reliability and responsiveness of five shoulder questionnaires. *J Shoulder Elbow Surgery.* 1998;7:565-572.

37. Crockett HC, Gross LB, Wilk KE, et al. Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *Am J Sports Med.* 2002; 30:20-26.

38. Borsa PA, Dover GC, Wilk KE, Reinold MM. Glenohumeral range of motion and stiffness in professional baseball pitchers. *Med Sci Sports and Exercise.* 2006;38:21-26.

39. Grossman MG, Tibone JE, McGarry MH, et al. A cadaveric model of the throwing shoulder: A possible etiology of superior labrum anterior to posterior lesions. *J Bone Joint Surgery.* 2005;87A:824-831.

40. Koffler KM Bader D, Eager M, et al. The effect of posterior capsular tightness on glenohumeral translation in the late-cocking phase of pitching: A cadaveric study. Presented at Arthroscopy Association of North America Annual Meeting, Washington, DC, 2001.

41. Andrews JA, Wilk KE. *The Athletes Shoulder.* Churchill Livingstone, New York, NY, 1994.

42. Ellenbecker TS. *Clinical Examination of the Shoulder*. Elsevier Science, Philadelphia, PA, 2004.

43. Wilk KE, Arrigo CA. Current concepts in the rehabilitation of the athletic shoulder. *J Orthop Sports Phys Ther.* 1993; 18:365-378.

44. Wilk KE, Reinold MM, Dugas JR, et al. Current concepts in the recognition and treatment of superior labral (slap) lesions. *J Orthop Sports Phys Ther.* 2005;35:273-291.

45. Ellenbecker TS, Davies GJ. The application of isokinetics in testing and rehabilitation of the shoulder complex. *J Athletic Training*. 2000;35:338-350.

46. Ivey FM, Calhoun JH, Rusche K, Bierschenk J. Isokinetic testing of shoulder strength: Normal Values. *Arch Phys Med Rehabil.* 1985;66:384-386.

Appendix

ARTHROSCOPIC SUPERIOR LABRAL (SLAP) REPAIR POST-OPERATIVE PROTOCOL

- Note: Specific alterations in post-operative protocol if SLAP repair is combined with thermal capsulorrhaphy, capsular plication, rotator interval closure or repair of full thickness rotator cuff repair.

- Sling use as needed for precarious activities and to minimize bicep muscle activation during initial post-operative phase. Duration and degree of sling use determined by physician at post-op recheck.

- Early use of stomach rubs, sawing, and wax-on/wax-off exercise to stimulate home based motion between therapy visits recommended.

<u>PHASE I - EARLY MOTION (Weeks 1 - 3):</u>

1. Passive range of motion of the glenohumeral joint in movements of flexion, scapular and coronal plane abduction, cross arm adduction, internal rotation in multiple positions of elevation. External rotation performed primarily in the lower ranges of abduction (<60 degrees) to decrease the stress on the repair from peel-back mechanism. Cautious use of glenohumeral joint accessory mobilization unless specific joint hypomobility identified on initial post-operative examination. Use of pulleys and supine active assistive elevation using a cane applied based on patient tolerance to initial passive range of motion post-op.

2. Patient to wear sling for comfort as needed.

3. Range of motion of elbow, forearm, and wrist.

4. Manual resistive exercise for scapular protraction and retraction minimizing stress to glenohumeral joint.

5. Initiation of submaximal internal and external rotation resistive exercise progressing from manual resistance to very light isotonic and elastic resistance based on patient tolerance using a position with 10-20 degrees of abduction in the scapular plane.

6. Manual resistance for elbow extension, forearm pronation/supination, and wrist flexion/extension as well as the use of theraputty or ball squeezes for grip strengthening. ** NOTE: No elbow flexion resistance or bicep activity for the first 6 weeks post-op to protect the superior labral repair.

7. Modalities to control pain in shoulder as indicated.

PHASE II – PROGRESSION OF STRENGTH AND ROM (Weeks 4-6):

1. Continue with previous exercise guidelines.

2. Begin to progress gentle passive range of motion of the glenohumeral joint with 90 degrees of abduction to terminal ranges with full external rotation with 90 degrees of abduction expected between 6 and 8 weeks post-op. All other motions continue from in Phase I, with continued use of both physiological and accessory mobilization as indicated by the patient's underlying mobility status.

3. Advance rotator cuff progression using movement patterns of sidelying external rotation, prone extension, prone horizontal abduction using a light weight or elastic resistance.

4. Initiate upper body ergometer for scapular and general upper body strengthening

5. Rhythmic stabilization performed in 90 degrees of shoulder elevation with limited flexion pressure application to protect SLAP repair.

PHASE III TOTAL ARM STRENGTH: (Weeks 6 - Week 10):

1. Initiation of elbow flexion (biceps) resistive exercise.

2. Initiate seated rowing variations for scapular strengthening.

3. Advance rotator cuff and scapular progressive resistive exercise using oscillation based exercise to increase local muscular endurance. Initiation of 90 degree abducted exercise in scapular plane for internal and external rotation if patient requires extensive overhead function at work or in sport.

4. Progression to closed chain exercises by week 8 including step-ups, quadruped rhythmic stabilization, and progressive weightbearing on unstable surface.
5.
6. Initiate upper extremity (two arms) plyometric program progressing from Swiss ball to weighted medicine balls as tolerated.

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PHASE IV: ADVANCED STRENGTHENING (Weeks 10 – 12/16):

1. Begin isokinetic exercise in the modified neutral position at intermediate and fast contractile velocities.
   Criterion for progression to isokinetics:
   a. completion of isotonic exercise with a minimum of a 3# weight or medium resistance with elastic tubing.
   b. pain-free range of motion in the isokinetic training movement pattern

2. Isokinetic test performed after 2-3 successful sessions of isokinetic exercise. Modified neutral test position.

3. Progression to 90 degree abducted isokinetic and functional plyometric strengthening exercises for the rotator cuff (shoulder internal and external rotation) based on patient tolerance.

4. Continue with scapular strengthening and range of motion exercises listed in earlier stages.

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PHASE V - RETURN TO FULL ACTIVITY:

1. Return to full activity is predicated on physician's evaluation, isokinetic strength parameters, functional range of motion, and tolerance to interval sport return programs.

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CLINICAL TESTING FOR EXTRA-ARTICULAR LATERAL KNEE PAIN. A MODIFICATION AND COMBINATION OF TRADITIONAL TESTS

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ABSTRACT

Knee pain is one of the most common problems encountered by recreational and competitive athletes. Pain over the lateral aspect of the knee can be the result of intra or extra articular conditions. The purpose of this clinical suggestion is to present the modification of a traditional clinical test to aide in the differential diagnosis of lateral knee pain. This method has not been described elsewhere and anecdotally has been helpful in the evaluation of patients with lateral knee pain.

Key Words: differential diagnosis, iliotibial band, Noble compression test, Ober test

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PROBLEM

Functional limitations due to knee pain are among the most common problems encountered by physically active individuals. For healthcare professionals, a thorough history and physical exam will often enable accurate medical diagnosis. In some cases, however, differentiation among multiple pathologies is difficult.

One area in which differential diagnosis can be difficult is in determining the source of lateral knee pain in the active individual. For individuals experiencing lateral knee pain as a result of high volume training (e.g., running, biking), patellofemoral syndrome (PFS) and iliotibial band syndrome (ITBS) are common. In addition to these common overuse conditions, a myriad of other possibilities should be considered *(Table 1)*.

To narrow down the list of possibilities, special tests are commonly utilized. For the diagnoses listed in Table 1, numerous special tests exist to confirm these conditions. Many of these tests, although stated for a specific pathology, have not been proven to yield satisfactory sensitivity and

Table 1. *Potential causes of lateral knee pain*

- Patellofemoral syndrome
- Iliotibial band syndrome
- Popliteus syndrome
- Lateral meniscus tear
- Discoid lateral meniscus
- Lateral collateral ligament sprain
- Lateral compartment osteochondral injury/arthritis
- Proximal tibio-fibular joint sprain or instability
- Patellar instability
- Hamstring strain
- Common fibular (peroneal) nerve injury
- Popliteal artery entrapment
- Lumbar radiculopathy
- Distal femur bone stress injury

specificity.[1,2] Apley's compression and McMurray tests, advocated in the evaluation for a meniscus injury,[3,4] will often yield a pain response in individuals with PFS or ITBS. To evaluate extra-articular lateral knee pain the Noble compression test[3] and Ober test[3,5] are commonly recommended for the differential diagnosis of ITBS. The Noble compression test is begun with the patient supine and the knee flexed to 90 degrees. The clinician applies and maintains pressure to the lateral femoral epicondyle while extending the knee. A positive test is indicated if the patient complains of pain over the lateral femoral epicondyle at approximately 30 degrees of flexion, the approximate point at which the iliotibial band moves over the lateral femoral epicondyle.

The Ober test is performed by positioning the patient on their side with the extremity being tested facing upward. The clinician flexes the knee to 90 degrees and abducts and extends the hip to place the thigh in line with the trunk. From this starting position the clinician allows the thigh to adduct as far as possible. The "modified Ober test" is performed in the same manner as the original Ober test but the knee is fully extended at the start of the test and knee extension is maintained as the lower extremity is allowed to drop into adduction. The Ober test, while assessing for flexibility, does not frequently reproduce the patient's symptoms.

While the iliotibial tract (ITT) insertion is often listed as localized to the lateral tubercle of the tibia (Gerdy's tubercle),[4,6] a recent anatomical study of the anatomy of the ITT has demonstrated a complex network of distal insertions to various structures about the knee joint.[7] In addition to the insertion at Gerdy's tubercle, the ITT also has insertions at the linea aspera, lateral epicondyle, lateral patella, as well as a broad capsular-osseous insertion.[7]

In many patients with subacute or infrequent symptoms, these two tests may be of marginal benefit in reproducing patient symptoms. Since the onset of symptoms experienced during running may not present within the early stages of lower-level activity, a movement placing more stress on the implicated tissue has proven helpful.

SOLUTION

In order to better localize iliotibial band related pain from other conditions about the lateral knee, is suggested combining the Ober's and Noble compression test into a singular special test. Begin by taking the patient into the Ober's position with the knee flexed to 90 degrees. With the knee flexed to 90 the clinician should passively extend and flex the knee, while applying direct pressure over the lateral femoral epicondyle, monitoring the patient for a pain response.*(Figure 1)*

Figure 1. *Combined Noble compression and Ober's test with passive knee extension and flexion.*

If this combination does not reproduce the patient's symptoms some modifications can be added to further strain the iliotibial band while moving the knee. Testing is progressed from passive extension and flexion of the knee to active flexion and extension of the knee. Evaluation through an arc of motion is supported by Orchard et al[8] who reported that iliotibial band impingement, at the lateral femoral epicondyle, occurred at different angles of knee flexion. Furthermore, the addition of a medially or laterally directed patellar glide during passive or active flexion and extension of the knee may further impact symptom reproduction and localization.*(Figure 2)* Medial patellar glide commonly results in an increase of symptoms while application of lateral patellar glide more commonly reduces the patients symptoms. Application of internal rotation of the tibia while moving from flexion to extension may also aide in symptom reproduction.*(Figure 3)* When the side-lying technique does not adequately reproduce the patient's

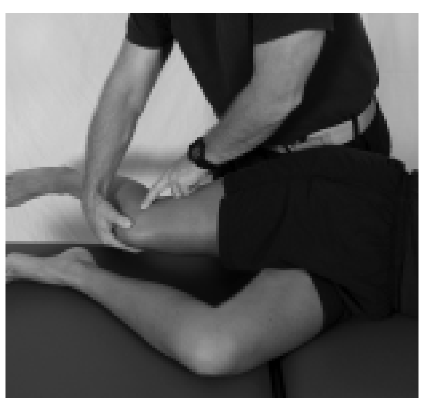

Figure 2. *Combined Noble compression and Ober's test with application of medial patellar glide.*

symptoms the same test movement can be performed in weight bearing, either partially unloaded *(Figure 4)* or with full weight acceptance. The movement pattern in standing is similar to a drop-step or "corkscrew" lunge with the uninvolved leg passing behind the involved leg. Caution is recommended if performing this movement in full weight bearing due to the increased load placed on the lateral compartment of the knee and the potential for adversely impacting intra-articular pathology.

Figure 3. *Combined Noble compression and Ober's test with tibial internal rotation.*

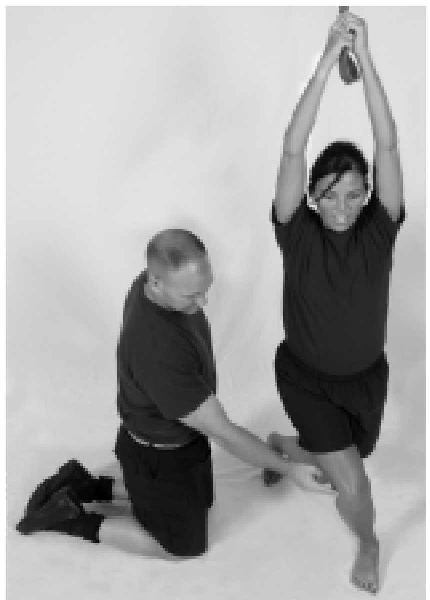

Figure 4. *Combined Noble compression and Ober's test in a partially unloaded weight bearing position.*

DISCUSSION

As with many special tests, a key component is accurate reproduction of the patient's symptoms. Not only has this testing sequence been helpful for differentiating iliotibial band pain but also for reproduction and localization of lateral patellofemoral joint pain.

Critical review of clinical tests combined with advancing knowledge of anatomy and orthopedic pathology may lend itself to further modifications of currently accepted physical examination techniques. Clinical research would be helpful to further substantiate the aforementioned techniques along with other orthopedic special tests and their modifications.

REFERENCES

1. Cleland J. *Orthopaedic Clinical Examination: An Evidence-Based Approach for Physical Therapists.* Carlstadt, NJ: Icon Learning Systems; 2005.
2. Hegedus EJ, Cook C, Hasselblad V, et al. Physical examination tests for assessing a torn meniscus in the knee: A systematic review with meta-analysis. *J Orthop Sports Phys Ther.* 2007;37:541-550.
3. Magee DJ. *Orthopedic Physical Assessment.* Philadelphia, PA: W.B. Saunders; 1992.
4. Richardson MK, Iglarsh ZA. *Clinical Orthopaedic Physical Therapy.* 2nd ed. Philadelphia, PA: W.B. Saunders; 1994.
5. Donatelli R, Wooden MJ. *Orthopaedic Physical Therapy.* New York, NY: Churchill Livingstone; 1989.
6. Oatis CA. *Kinesiology: The Mechanics and Pathomechanics of Human Movement.* Philadelphia, PA: Lippincott Williams and Wilkins; 2004.
7. Vieira ELC, Vieira EA, da Silva RT, et al. An anatomic study of the iliotibial tract. *Arthroscopy.* 2007;23:269-274.
8. Orchard JW, Fricker PA, Abud AT, Mason BR. Biomechanics of iliotibial band friction syndrome in runners. *Am J Sports Med.* 1996;24:375-379.

EDITORIAL

HIGH PERFORMANCE PREPARATION FOR ATHLETES OF DIVERSE ABILITIES

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This summer brings great anticipation as the world's best athletes prepare to compete in Beijing, China for the Olympic and Paralympic Summer Games. Athletes, coaches, technical staff, and sport medicine specialists are all hard at work, carefully planning the final phases of training and competition strategy.

Canada is paying special attention to these Games, as we eagerly await our turn in hosting the world! The 2010 Winter Olympic/Paralympic Games will take place in beautiful Vancouver, BC. Although the Winter Games are still in the future, we can definitely feel the spirit and momentum building!

Canada and the United States have shared a proud sport medicine history of supporting our national athletes during international competition. Each country provides an accomplished Integrated Support Team (IST) to manage the health and wellness needs of its athletes. Sport Physiotherapy Canada (SPC) is one of the Expert Provider Groups through which sport physiotherapists are selected to the Canadian Olympic and Paralympic Games' medical teams. We know that our athletes will be in very competent hands! However, we also recognize the need for on-going professional development of our members and are committed to leaving a strong sport medicine legacy for the future.

One upcoming educational initiative will demonstrate the evidence-based approach to elite level physiotherapy for Paralympic Athletes. SPC and the Vancouver Olympic/Paralympic Organizing Committee (VANOC) are pleased to present *High Performance Preparation for Athletes of Diverse Abilities*. This course will be offered as a post-congress course to the Canadian Physiotherapy Association's (CPA's) Annual Congress (May 29-June 1, 2008) in Ottawa, Ontario on June 2, 2008.

Course Objectives

This course will introduce physiotherapists to the unique area of Paralympic and Olympic winter sport. The classification system used in para-sport will be outlined and the role of physiotherapists working with athletes with a physical difference will be identified. Physiotherapists will be provided with resources to use in their communities to promote sport participation for individuals of all abilities. The epidemiology of injury in Paralympics and Olympics past will be examined. Physiotherapists will also be updated on the sport medicine team preparations for the winter 2010 Paralympic and Olympic Games. An evidence-based review of high performance preparation and recovery techniques for these athletes will also be featured. Our keynote presenters are Nancy Quinn, Chief Canadian Therapist for the Beijing Paralympic Games and Rick Celebrini, Chief Therapist for the 2010 Olympic Winter Games.

Learning Outcomes

Upon completion of this workshop participants will

1. Increase awareness and expertise specific to the unique physiotherapy management of Paralympic and Olympic athletes.
2. Maximize knowledge and expertise in preparation for the unique role as a Paralympic and Olympic team therapist.
3. Increase knowledge related to an evidence-based approach to high performance sport preparation and recovery techniques for athletes of diverse abilities.
4. Have resources to take back to their communities to promote sport participation for individuals of all abilities.

We warmly welcome our American Sports Physical Therapy Section (SPTS) colleagues and students to participate! Learn more about the program and register for the course at the CPA website www.physiotherapy.ca, or contact information@physiotherapy.ca for assistance.