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Background: Current conservative management of subacromial shoulder impingement (SSI) includes generic strengthening exercises, especially for internal (IR) and external (ER) shoulder rotators. However, there is no evidence that the strength or the ratio of strength between these muscle groups is different between those with SSI (cases) and an asymptomatic population (controls).

Objective: To identify if isokinetic rotator cuff strength or the ratio of strength is significantly different between cases and controls.

Study Design: Case Control Study.

Method: Fifty one cases with SSI and 51 asymptomatic controls matched for age, gender, hand dominance and physical activity level completed isokinetic peak torque glenohumeral IR and ER testing. IR and ER were measured separately using continuous reciprocal concentric (con) and eccentric (ecc) contraction cycles at a speed of 60^0 degrees per second and again at 120^0 degrees per second. Values of peak torque (PT), relative peak torque (RPT) and ratios were compared using independent t-tests between the SSI and asymptomatic groups. Within group analysis between dominant and non-dominant limbs was also performed.

Results: Significant strength differences between the two groups was only present when the symptomatic SSI shoulder is dominant (con ER PT at 60^0 /second, ecc ER PT at 120^0 /second, ecc ER RPT at 120^0 /second and ecc IR PT at 60^0 /second and 120^0 /second). The control group showed a significant difference within dominant and non-dominant shoulders but SSI (cases) did not.

Conclusions: Rotator cuff strength in SSI may be related to dominance, which may have implications for strengthening regimes.

Level of Evidence: Level 3a

Key Words: *Isokinetic, Peak Torque, Glenohumeral, Rotation, Impingement*

INTRODUCTION

Subacromial shoulder impingement (SSI) is a common condition characterized by anterolateral catching pain or aching of the shoulder, without a history of trauma. Pain originates from the tissues within the subacromial space including the rotator cuff (N. Hanchard, Cummins, & Jeffries, 2004; J. S. Lewis, Green, & Dekel, 2001). In people with SSI it is proposed rotator cuff muscle weakness develops secondary to inflammation and degeneration that occurs as a result of mechanical compression from a structure external to the tendon, known as extrinsic SSI (Michener, McClure, & Karduna, 2003), or as a result of overuse and tension overload affecting the tendons intrinsically, as in tendinopathy, known as intrinsic SSI (Jeremy S Lewis, 2009).

The rotator cuff musculature stabilise as well as move the glenohumeral joint. Subscapularis acts as an internal rotator and infraspinatus, teres minor and supraspinatus act as external rotators (Dark, Ginn, & Halaki, 2007; M.M. Reinold et al., 2004). The rotator cuff has been shown to produce different activity levels dependent on the direction of movement (J. Lewis & Ginn, 2015) and the rotator cuff and biceps have been identified to pre-set prior to actual movement being performed in asymptomatic young male shoulders (David et al., 2000).

Current conservative management of SSI includes generic resistance band strengthening exercises for the rotator cuff particularly shoulder external rotators (ER) (Holmgren, Bjornsson Hallgren, Oberg, Adolfsson, & Johansson, 2012; Kuhn, 2009). Exercises prescribed for SSI appear to be based on results from EMG studies and the experience and general knowledge of the physiotherapist. (Dark et al., 2007; Holmgren et al., 2012; Michael.M. Reinold et al., 2007; Tate, McClure, Young, Salvatori, & Michener, 2010). Previous isokinetic studies comparing rotator cuff strength in a diagnosed SSI group with an asymptomatic group analysed within group differences of the (1) painful versus non-painful shoulder in those with SSI and (2) dominant versus non-dominant shoulder in an asymptomatic group and then (3) compared the values from these two analyses (Leroux et al., 1994; MacDermid, Ramos, Drosdowech, Faber, & Patterson, 2004; Tyler, Nahow, Nicholas, & McHugh, 2005). Although comparison of dominant and non-dominant limbs have been reported there is no indication that matched dominance was considered in recruitment of symptomatic and asymptomatic group participants in these studies. Greater strength in the dominant upper limb compared to the non-dominant upper limb of the asymptomatic group is expected however this may or may not be the case in a SSI population. Lack of matching for arm dominance limits the opportunity to understand specific variations in strength which may be present due to usual physical activities. Matching of dominance should be an essential component to understand upper limb isokinetic testing results.

Isokinetic testing, performed through an active range at a constant velocity, is a reliable measure of shoulder strength (Land & Gordon, 2011). Internal and external rotation are consistently used to assess the rotator cuff, (Ludewig & Cook, 2000; Reddy, Mohr, Pink, & Jobe, 2000) with bilateral comparison of concentric peak torque shown to be the most appropriate outcome parameter for comparisons between healthy subjects and those with a painful condition (van Meeteren, Roebroeck, Selles, Stijnen, & Stem, 2004). A seated testing position with the shoulder positioned in the scapular plane is reported to optimize the length tension relationship of the rotators, maximizing conformity between the humeral head and glenoid and is the most comfortable testing position (Kuhlman et al., 1992).

Functionally, EMG studies have identified that during internal rotation pectoralis major muscle activity is greater than subscapularis which is greater than latissimus dorsi expressed as a percentage of maximum voluntary isometric contraction (%MVIC) at low, medium and high exercise intensities (Dark et al., 2007). During external rotation infraspinatus, teres minor and supraspinatus muscle activity (%MVIC) is much greater than deltoid muscle activity at all exercise intensities and when the arm is positioned in the scapular plane (Dark et al., 2007; M.M. Reinold et al., 2004).

Strength changes in SSI not only result from decreased use of the shoulder to avoid pain but also due to altered motor strategies (Roy, Moffet, & McFadyen, 2008); decreased central motor corticospinal excitability when symptoms are ≥ 12 months (Ngomo, Mercier, Bouyer, Sacoie, & Roy, 2015); and inhibition when low to moderate pain levels are present (Dube & Mercier, 2011). Understanding possible muscle strength changes will assist treating clinicians to provide targeted exercise programs and enhance recovery.

The purpose of this study was to compare rotator cuff strength and strength ratios in a group diagnosed with SSI (cases) and a control group, matched for age, gender, hand dominance and physical activity level. The hypothesis was that there would be a difference in muscle strength between the painful shoulder in the SSI group and the dominance matched shoulder in the control group. An additional aim was to compare the rotator cuff strength and strength ratios between the symptomatic and asymptomatic limbs (both dominant and non-dominant) within the SSI group (cases), between the dominant and non-dominant limbs within the control group and to determine if there were differences between the groups for this analysis.

METHOD

A case control study, using matched pairs, was conducted to compare rotator cuff muscle strength in those with positive signs of SSI, of gradual onset and without trauma, to an asymptomatic control matched for age, gender, hand dominance and physical activity level.

All testing was performed by an experienced musculoskeletal physiotherapist with over 20 years clinical experience, with both shoulders being measured in all participants.

The recruitment, inclusion and exclusion criteria for this case control study have been previously reported and are provided here for the convenience of the reader.

Participant Information and Consent

Ethical approval for this study was granted by the James Cook University (JCU) Human Ethics Committee (approval: H3945). Written informed consent was obtained from each of the participants.

Participants were recruited from the Townsville community and clients presenting to the JCU Physiotherapy Clinic between June 2011 and July 2013. Recruitment for both groups was via emails and word of mouth throughout the University staff, students and their extended networks. In addition, cases were also recruited using an advertisement in the local Townsville press and in the waiting area of the clinic. Cases identified with the advertisement ‘Do you feel a sharp catch in your shoulder when raising your arm which eases when you lower your arm down? Is this making it difficult for you to wash your hair or reach up into an overhead cupboard or get your shirt on easily? Is it becoming painful to lie directly onto that shoulder at night?’ They then contacted the investigator who arranged an assessment to determine eligibility.

Controls were asked to be between 40 and 60 years of age with no history of shoulder, neck or upper back injuries and no reports of painful symptoms in any of these areas in the previous twelve months. Both groups were required to meet the inclusion criteria.

Power Analysis

This study was part of a larger study in which a pre-study sample size calculation was performed, with alpha = 0.05 and power 0.8,(Altman, 1991) which identified a minimum of 45 cases and 45 controls were needed. This sample size was adequate when compared with a calculation based on an isokinetic study comparing rotator cuff strength in a diagnosed SSI group with an asymptomatic group, peak torque external rotation at 60 degrees per second (mean difference 10Nm, standard deviation 2Nm (Leroux et al., 1994)) .

Inclusion and Exclusion Criteria

Forty to 60 year old participants were recruited to reflect the reported peak age for shoulder impingement (Ostor, Richards, Prevost, Speed, & Hazleman, 2005; van der Windt, Koes, de Jong, & Bouter, 1995). Symptom free volunteers as well as people with unilateral shoulder pain completed a screening questionnaire to determine their eligibility for this study. The questionnaire was used to exclude participants, in both the case and control groups, who had:

- Been participating in intense shoulder strength training during the 6 months prior to entering the study. This was defined as high load upper body weight training two or more times per week.

- Recent (within previous two years) or current pregnancy. This exclusion was necessary due to the effect of ligamentous laxity and postural changes associated with pregnancy.
- Previously undergone shoulder surgery or suffered a fracture of the shoulder girdle
- Glenohumeral instability identified by a grade 2 or 3 anterior, posterior or inferior load and shift test (assessed objectively) or a history of shoulder dislocation
- Scoliosis (also observed visually)
- Been experiencing cervical or thoracic pain currently or in the previous six months
- Diagnosed systemic or neurological disease (Type 2 diabetes was not screened for)
- Shoulder corticosteroid injection at any time in the past

If the questionnaire indicated they were eligible, a physical assessment was conducted of both the case and control volunteers.

In order to rule out other shoulder diagnoses and focus only on SSI, case group participants had:

- a minimum of three positive orthopaedic special tests (Michener, Walsworth, Doukas, & Murphy, 2009; Park, Yokota, Gill, Rassi, & McFarland, 2005). Hawkins-Kennedy (Hawkins & Kennedy, 1980) and/or Neer (Neer, 1983) must be positive along with two of the following: external rotation resistance test (Michener et al., 2009),tendon palpation (N. Hanchard et al., 2004), horizontal (cross-body) adduction (Park et al., 2005), painful arc (Kessel &

Watson, 1977), drop arm test (Park et al., 2005), Yergason test (Dalton, 1989), Speed test (Dalton, 1989; Park et al., 2005)

- ‘catching’ or aching pain without appreciable joint stiffness (N. C. A. Hanchard & Handoll, 2008)
- a painful arc elicited with pain easing on lowering the arm (N. Hanchard et al., 2004)
- pain localized to the anterior or antero-lateral-superior shoulder (J. S. Lewis et al., 2001)
- insidious onset of symptoms with a possible history of gradual progression over time but without history of trauma (Bigliani & Levine, 1997)
- xray or ultrasound scans revealing osteophytes within the subacromial region, calcification of tendons or large rotator cuff tears . Alterations in acromial shape and bursal thickening were noted but did not prevent inclusion

Procedure

The shoulder pain and disability index (SPADI) was completed to further describe the SSI group. This outcome measures pain and disability associated with shoulder impairment (Roach, Budiman-Mak, Songsiridej, & Lertratanakul, 1991) and is frequently used for assessment of SSI syndrome (Dogu, Sahin, Ozmaden, Yilmaz, & Kuran, 2013). The visual analogue scale (VAS) was used to measure pain at rest and during activity (Jensen, Karoly, & Braver, 1986). Physical activity level was established by completing the short form of The International Physical Activity Questionaire (IPAQ) (Craig et al., 2003). The IPAQ assesses three specific types of activity (1) walking (2) moderate-intensity activities such as cycling for transport and yard work (3) vigorous intensity activities such as running and boxing. A rating of low, medium or high physical activity is given for the duration (in minutes) and frequency (days) of activity.

Isokinetic testing was performed using a Humac Norm Computerised Dynamometer ((CSMI), 2006). Isokinetic reliability studies were completed prior to data collection. The testing method has been shown to be reliable when testing a group experiencing SSI and an asymptomatic group (MacDermid et al., 2004) and has been used in similar studies (Dulgeroglu, Kirbiyik, Ersoz, & Ozel, 2013; Erol, Ozcakar, & Celiker, 2008; Leroux et al., 1994; Tyler et al., 2005).

Isokinetic peak torque glenohumeral internal (IR) and external rotation (ER) were measured separately using continuous reciprocal concentric and eccentric contraction cycles at a speed of 60^0 degrees per second and again at 120^0 degrees per second. Testing was performed through a total range of 60 degrees from neutral rotation. Neutral rotation to 30^0 IR and from neutral rotation to 30^0 ER. Gravity correction was not applied as the range of motion tested in the seated position resulted in gravity affecting both IR and ER movements equally. Further, as significant error has been found when applying gravity correction due to the inability of the person to relax it was not considered advantageous (Bygott, McMeeken, Carroll, & Story, 2001). (Full details of method in Appendix A).

Data Analysis

Data were analysed using IBM SPSS Statistics Version 22. Descriptive statistics (mean, standard deviation, range) were calculated for each variable. All data was tested and found to be normally distributed.

A reliability study was analysed using intra-class correlation.

The measurements included in analyses were:

1. Peak torque of isokinetic concentric and eccentric ER and IR measured in Newton Metres
2. Relative peak torque of isokinetic concentric and eccentric ER and IR. This was calculated as peak torque divided by individual's body weight
3. Ratio of eccentric peak torque ER to concentric IR peak torque =

$$\frac{\text{eccentric peak torque ER}}{\text{concentric peak torque IR}}$$

4. Ratio of concentric peak torque ER peak torque to concentric IR peak torque=

$$\frac{\text{concentric peak torque ER}}{\text{concentric peak torque IR}}$$

Comparisons between matched SSI cases and controls were completed using independent samples t-tests, with significance $p \leq 0.05$. When the dominant shoulder was painful in the SSI group it was compared to the dominant shoulder in the control group and when the non-dominant shoulder was painful in the SSI group it was compared to the non-dominant shoulder in the control group.

To investigate the second aim, within group paired t-tests were conducted for comparison of symptomatic and asymptomatic limbs within the SSI group (both dominant and non-dominant), and dominant and non-dominant limbs within the control group.

RESULTS

An isokinetic reliability study completed on an asymptomatic group prior to data collection indicated high intra-rater reliability for all measures (ICC 0.948, CI 0.992 to 0.965) (Table 1).

TABLE 1: OUTCOME OF RELIABILITY STUDY

Intra-rater Reliability Study	Number of Measurements	Intraclass Correlation Coefficient ICC	95% Confidence Interval
Humac Norm Computerised Dynamometer	110 Repeated four days later	0.948	0.992 to 0.965

Recruitment and assessment of SSI cases and controls were conducted at the same time, independently of each other, with matching not performed until data collection was completed. Seventy-three SSI cases and 91 controls were assessed and then matched for gender, hand dominance, physical activity level and age (within a bracket of three years). SSI cases reported symptoms being present between 4 weeks to 12 months. This resulted in 51 complete matches in each group. Within the SSI group, 31 dominant limbs were symptomatic and 20 non-dominant limbs were symptomatic. No significant differences in body mass index or physical activity was identified between the groups, with moderate activity level being the most prevalent in both groups (see Table 2). SPADI and VAS scores were significantly different (Table 2).

TABLE 2: COMPARISON OF SSI (CASES) AND CONTROL PARTICIPANTS

	SSI MEAN ± SD N = 51	**CONTROL MEAN ± SD N =51**	**P VALUE**
Age (years)	51.24 ± 5.71	50.80 ± 4.66	.074
BMI	28.14 ± 5.61	28.17 ± 4.65	.393

Gender			1.0
Male	28	28	
Female	23	23	
Dom			1.0
Right	45	45	
Left	6	6	
IPAQ			.282
Low	27%	30.2%	
Mod	42.9%	38.1%	
High	30.2%	31.7%	
			.
VAS Rest	0.25±0.77	0	.000
VAS Activity	5.82±2.81	0	.000
SPADI	26.21±17.92	0	.000

Abbreviations: BMI, body mass index; Dom, dominance; Asym, Asymptomatic; VAS, Visual Analogue Scale; SPADI, Shoulder Physical Activity Disability Index

SSI (Cases) versus Control Analysis

Dominant Shoulder

Significantly less con ER PT at 60^0 /second (p=0.025), ecc ER PT at 120^0 /second (p=0.015), ecc ER RPT at 120^0 /second (p=0.043) and ecc IR PT at 60^0 /second (p=0.013) and 120^0 /second (p=0.031) was identified in the dominant symptomatic SSI shoulder compared to the dominant control shoulder (table 3). While no other statistical differences were identified it was noted that all measures of the SSI dominant shoulder were lower than the dominant control shoulder.

Non-Dominant Shoulder

No significant difference in isokinetic strength was identified between the non-dominant SSI symptomatic shoulder and the non-dominant control shoulder. It is noted however that measurements for ER (PT and RPT, and both ratios in the SSI (cases) were higher in the control group whereas IR (PT and RPT) were slightly lower (table 3).

TABLE 3: ISOKINETIC TESTING FOR SYMPTOMATIC SHOULDER IN SSI GROUP (CASES) AND THE MATCHED SHOULDER IN CONTROL GROUP

OUTCOME MEASURE D (n=31) ND (n=20)	**SSI Mean ± SD (SEM)**	**CONTROL Mean ± SD (SEM)**	**95%CI**	**p value**
PT ER Con				
60^0 sec D	12.74 ± 6.63 (1.191)	17.16 ± 8.43 (1.513)	-8.272 to -0.567	.025
ND	16.05 ± 6.59 (1.473)	14.65 ± 6.76 (1.512)	-2.874 to 5.674	.511
120^0 sec D	10.68 ± 6.08	13.61 ± 7.77	-6.480 to 0.609	.103

		(0.093)	(1.395)		
	ND	11.70 ± 6.08	11.15 ± 6.03	-3.326 to 4.426	.775
		(1.359)	(1.348)		
PT ER Ecc					
60^0 sec	D	21.65 ± 10.71	26.13 ± 10.97	-9.991 to 1.023	.109
		(1.922)	(1.971)		
	ND	25.50 ± 12.93	23.25 ± 9.12	-4.915 to 9.415	.529
		(2.892)	(2.040)		
120^0 sec	D	21.32 ± 6.99	27.23 ± 11.08	-10.61 to -1.198	.015
		(1.255)	(1.990)		
	ND	29.10 ± 16.96	25.50 ± 9.38	-5.171 to 12.37	.411
		(3.791)	(2.097)		
Rel PT ER Con					
60^0 sec	D	0.164 ± 0.079	0.205 ± 0.088	-0.084 to 0.001	.057
		(0.014)	(0.016)		
	ND	0.185 ± 0.067	0.175 ± 0.067	-0.033 to 0.053	.638
		(0.015)	(0.015)		
120^0 sec	D	0.137 ± 0.072	0.163 ± 0.086	-0.066 to 0.015	.209
		(0.013)	(0.016)		
	ND	0.136 ± 0.066	0.136 ± 0.067	-0.043 to 0.042	.989
		(0.015)	(0.015)		
Rel PT ER Ecc					
60^0 sec	D	0.277 ± 0.121	0.311 ± 0.101	-0.090 to 0.023	.242
		(0.022)	(0.018)		
	ND	0.304 ± 0.183	0.281 ± 0.082	-0.067 to 0.114	.607

		(0.041)	(0.018)		
120^0 sec	D	0.274 ± 0.086	0.325 ± 0.105	-0.099 to -0.002	.043
		(0.016)	(0.019)		
	ND	0.352 ± 0.261	0.307 ± 0.088	-0.080 to 0.169	.477
		(0.058)	(0.020)		
PT IR Con					
60^0 sec	D	31.90 ± 11.95	36.16 ± 13.60	-10.76 to 2.247	.195
		(2.146)	(2.443)		
	ND	33.15 ± 11.82	34.45 ± 14.27	-9.689 to 7.089	.755
		(2.643)	(3.192)		
120^0 sec	D	31.13 ± 11.64	33.61 ± 14.10	-9.051 to 4.084	.452
		(2.090)	(2.532)		
	ND	32.20 ± 11.47	30.95 ± 15.13	-7.344 to 9.844	.770
		(2.566)	(3.382)		
PT IR Ecc					
60^0 sec	D	39.87 ± 13.37	49.35 ± 15.71	-16.895 to -2.07	.013
		(2.402)	(2.821)		
	ND	45.80 ± 15.60	48.65 ± 17.72	-13.539 to 7.84	.593
		(3.489)	(3.963)		
120^0 sec	D	41.81 ± 11.52	49.81 ± 16.58	-15.252 to -0.75	.031
		(2.069)	(2.977)		
	ND	47.25 ± 16.08	49.60 ± 18.31	-13.382 to 8.68	.669
		(3.597)	(4.094)		
Rel PT IR Con					
60^0 sec	D	0.415 ± 0.161	0.436 ± 0.142	-0.098 to 0.056	.591

		(0.029)	(0.025)		
	ND	0.398 ± 0.166	0.426 ± 0.170	-0.135 to 0.080	.606
		(0.037)	(0.038)		
120^0 sec	D	0.402 ± 0.145	0.405 ± 0.148	-0.077 to 0.071	.934
		(0.026)	(0.027)		
	ND	0.386 ± 0.161	0.380 ± 0.178	-0.102 to 0.115	.903
		(0.036)	(0.040)		
Rel PT IR Ecc					
60^0 sec	D	0.516 ± 0.177	0.596 ± 0.148	-0.163 to 0.003	.058
		(0.032)	(0.027)		
	ND	0.545 ± 0.205	0.597 ± 0.192	-0.179 to 0.075	.412
		(0.046)	(0.043)		
120^0 sec	D	0.541 ± 0.151	0.599 ± 0157	-0.137 to 0.019	.137
		(0.027)	(0.028)		
	ND	0.553 ± 0.184	0.606 ± 0.187	-0.172 to 0.066	.374
		(0.041)	(0.042)		
Ratio ER Ecc/IR Con					
60^0 sec	D	0.716 ± 0.319	0.745 ± 0.235	-0.171 to 0.114	.690
		(0.057)	(0.042)		
	ND	0.812 ± 0.439	0.710 ± 0.227	-0.122 to 0.325	.362
		(0.098)	(0.051)		
120^0 sec	D	0.723 ± 0.223	0.913 ± 0.581	-0.414 to 0.033	.094
		(0.040)	(0.104)		
	ND	0.975 ± 0.582	0.936 ± 0.496	-0.307 to 0.385	.822
		(0.130)	(0.111)		

Ratio ER Con/IR Con					
60^0 sec	D	0.414 ± 0.189 (0.034)	0.478 ± 0.167 (0.030)	-0.155 to 0.027	.162
	ND	0.523 ± 0.242 (0.054)	0.434 ± 0.141 (0.032)	-0.038 to 0.216	.163
120^0 sec	D	0.341 ± 0.125 (0.023)	0.409 ± 0.150 (0.027)	-0.138 to 0.002	.058
	ND	0.384 ± 0.195 (0.044)	0.381 ± 0.158 (0.035)	-0.110 to 0.117	.952

Abbreviations: PT, Peak Torque; Rel PT, relative peak torque; ER, External Rotation; IR, Internal Rotation; Con, Concentric; Ecc, Eccentric; D, Dominant; ND, Non-Dominant

No significant differences were identified when the asymptomatic shoulder of the SSI (cases) (dominant = 20, non-dominant =31) was compared with the matched shoulder of the control group (table 4).

TABLE 4: ISOKINETIC TESTING FOR ASYMPTOMATIC SHOULDERS IN SSI (CASES) AND MATCHED SHOULDERS IN THE CONTROL GROUP

OUTCOME MEASURE D (N=20) ND (N=31)		SSI MEAN ± SD (SEM)	CONTROL MEAN ± SD (SEM)	95%CI	P VALUE
PT ER Con					
60^0 sec	D	17.00 ± 7.23 (1.616)	16.50 ± 6.72 (1.502)	-3.966 to 4.966	.822
	ND	12.32 ± 5.64 (1.012)	14.10 ± 6.53 (1.174)	-4.874 to 1.326	.257
120^0 sec	D	13.50 ± 7.31 (1.634)	11.70 ± 6.69 (1.496)	-2.685 to 6.285	.422
	ND	10.94 ± 5.73	10.97 ± 6.16	-3.053 to 2.988	.983

		(1.029)	(1.106)		
PT ER Ecc					
60^0 sec	D	26.85 ± 9.26 (2.070)	24.50 ± 8.97 (2.006)	-3.486 to 8.186	.420
	ND	21.61 ± 8.88 (1.595)	22.77 ± 8.70 (1.563)	-5.628 to 3.305	.605
120^0 sec	D	28.80 ± 9.76 (2.183)	27.30 ± 12.38 (2.769)	-5.639 to 8.639	.673
	ND	22.10 ± 8.19 (1.470)	24.06 ± 9.34 (1.678)	-6.430 to 2.495	.381
Rel PT ER Con					
60^0 sec	D	0.193 ± 0.069 (0.015)	0.202 ± 0.073 (0.016)	-0.055 to 0.036	.687
	ND	0.159 ± 0.071 (0.013)	0.169 ± 0.070 (0.013)	-0.046 to 0.026	.573
120^0 sec	D	0.153 ± 0.074 (0.017)	0.139 ± 0.072 (0.016)	-0.033 to 0.061	.554
	ND	0.139 ± 0.067 (0.012)	0.131 ± 0.063 (0.011)	-0.025 to 0.042	.614
Rel PT ER Ecc					
60^0 sec	D	0.307 ± 0.082 (0.018)	0.297 ± 0.087 (0.019)	-0.044 to 0.064	.709
	ND	0.279 ± 0.119 (0.021)	0.275 ± 0.087 (0.016)	-0.049 to 0.057	.879
120^0 sec	D	0.330 ± 0.090 (0.020)	0.327 ± 0.123 (0.027)	-0.066 to 0.072	.930
	ND	0.283 ± 0.098 (0.018)	0.289 ± 0.089 (0.016)	-0.053 to 0.042	.813
PT IR Con					
60^0 sec	D	34.95 ± 10.30 (2.304)	35.50 ± 18.27 (4.084)	-10.04 to 8.943	.907
	ND	34.32 ± 13.28 (2.385)	34.16 ± 13.18 (2.368)	-6.562 to 6.885	.962
120^0 sec	D	30.95 ± 11.79 (2.636)	32.50 ± 15.78 (3.528)	-10.46 to 7.365	.727

	ND	32.55 ± 12.87 (2.312)	31.97 ± 14.41 (2.590)	-6.364 to 7.525	.452
PT IR Ecc					
60^0 sec	D	49.50 ± 14.39 (3.217)	50.30 ± 21.62 (4.834)	-12.55 to 10.95	.891
	ND	43.35 ± 14.74 (2.648)	44.03 ± 15.00 (2.694)	-8.233 to 6.879	.858
120^0 sec	D	50.60 ± 12.32 (2.755)	52.10 ± 18.31 (4.094)	-11.490 to 8.49	.763
	ND	44.71 ± 14.28 (2.564)	45.90 ± 15.30 (2.748)	-8.712 to 6.324	.752
Rel PT IR Con					
60^0 sec	D	0.409 ± 0.122 (0.027)	0.442 ± 0.214 (0.048)	-0.145 to 0.078	.549
	ND	0.444 ± 0.170 (0.031)	0.410 ± 0.132 (0.024)	-0.044 to 0.111	.393
120^0 sec	D	0.362 ± 0.139 (0.031)	0.399 ± 0.175 (0.039)	-0.138 to 0.065	.471
	ND	0.419 ± 0.160 (0.029)	0.381 ± 0.145 (0.026)	-0.040 to 0.115	.334
Rel PT IR Ecc					
60^0 sec	D	0.570 ± 0.144 (0.032)	0.612 ± 0.225 (0.050)	-0.164 to 0.078	.479
	ND	0.556 ± 0.172 (0.031)	0.530 ± 0.145 (0.026)	-0.055 to 0.107	.517
120^0 sec	D	0.587 ± 0.127 (0.028)	0.639 ± 0.188 (0.042)	-0.156 to 0.050	.306
	ND	0.573 ± 0.168 (0.030)	0.551 ± 0144 (0.026)	-0.058 to 0.101	.586
Ratio ER Ecc/IR Con					
60^0 sec	D	0.779 ± 0.202 (0.045)	0.808 ± 0.504 (0.113)	-0.275 to 0.216	.808
	ND	0.663 ± 0.278 (0.050)	0.689 ± 0.187 (0.034)	-0.146 to 0.095	.674
120^0 sec	D	0.997 ± 0.389 (0.087)	0.918 ± 0.467 (0.104)	-0.196 to 0.354	.565

	ND	0.715 ± 0.250 (0.045)	0.838 ± 0.415 (0.075)	-0.296 to 0.052	.164
Ratio ER Con/IR Con					
60^0 sec	D	0.485 ± 0.140 (0.031)	0.516 ± 0.208 (0.046)	-0.144 to 0.082	.585
	ND	0.359 ± 0.099 (0.018)	0.412 ± 0.138 (0.025)	-0.114 to 0.008	.089
120^0 sec	D	0.423 ± 0.138 (0.031)	0.365 ± 0.168 (0.037)	-0.039 to 0.157	.233
	ND	0.332 ± 0.107 (0.019)	0.351 ± 0.129 (0.023)	-0.079 to 0.041	.532

Abbreviations: PT, Peak Torque; Rel PT, relative peak torque; ER, External Rotation; IR, Internal Rotation; Con, Concentric; Ecc, Eccentric; D, Dominant; ND, Non-Dominant

Within Group Analysis – SSI Group

Analysis was completed within the SSI (cases). The dominant symptomatic shoulder was compared to the non-dominant asymptomatic shoulder (n=31) and the non-dominant symptomatic shoulder was compared to the dominant asymptomatic shoulder (n=20). No significant differences were identified (see table 5). Measurements for the symptomatic shoulder were very similar or lower than the asymptomatic shoulder.

TABLE 5: WITHIN SSI (CASES) COMPARISON OF ISOKINETIC TESTING FOR DOMINANT SYMPTOMATIC LIMB TO NON-DOMINANT ASYMPTOMATIC LIMB (N=31) AND NON-DOMINANT SYMPTOMATIC LIMB TO DOMINANT ASYMPTOMATIC LIMB (N=20)

OUTCOME MEASURE	**D**		**p value**	**ND**		**p value**
	Sym Mean ± SD (SEM) n = 31	**Asym Mean ± SD (SEM) n = 31**		**Sym Mean ± SD (SEM) n = 20**	**Asym Mean ± SD (SEM) n = 20**	

PT ER C 60^0sec	12.74 ± 6.63 (1.191)	12.32 ± 5.64 (1.012)	0.679	16.05 ± 6.59 (1.473)	17.00 ± 7.23 (1.616)	0.462
PT ER C 120^0 sec	10.68 ± 6.09 (1.093)	10.94 ± 5.73 (1.029)	0.778	11.70 ± 6.08 (1.359)	13.50 ± 7.31 (1.634)	0.046
PT ER Ecc 60^0sec	21.65 ± 10.70 (1.922)	21.61 ± 8.88 (1.595)	0.988	25.50 ± 12.94 (2.892)	26.85 ± 9.26 (2.070)	0.629
PT ER Ecc 120^0	21.32 ± 6.99 (1.255)	22.10 ± 8.19 (1.470)	0.525	29.10 ± 16.96 (3.791)	28.80 ± 9.76 (2.183)	0.939
Rel PT ER Con						
60^0 sec	0.164 ± 0.079 (0.014)	0.159 ± 0.071 (0.013)	0.709	0.185 ± 0.067 (0.015)	0.193 ± 0.069 (0.015)	0.578
120^0 sec	0.137 ± 0.072 (0.013)	0.139 ± 0.067 (0.012)	0.851	0.136 ± 0.066 (0.015)	0.153 ± 0.074 (0.017)	0.099
Rel PT ER Ecc						
60^0 sec	0.277 ± 0.121 (0.022)	0.279 ± 0.119 (0.021)	0.952	0.304 ± 0.183 (0.041)	0.307 ± 0.082 (0.018)	0.947
120^0 sec	0.274 ± 0.086 (0.016)	0.284 ± 0.098 (0.017)	0.560	0.352 ± 0.261 (0.058)	0.330 ± 0.090 (0.020)	0.711
PT IR C 60^0sec	31.90 ± 11.95 (2.146)	34.32 ± 13.28 (2.385)	0.135	33.15 ± 11.82 (2.643)	34.95 ± 10.30 (2.304)	0.525
PT IR C 120^0 sec	31.13 ± 11.64 (2.090)	32.55 ± 12.87 (2.312)	0.290	32.20 ± 11.47 (2.566)	30.95 ± 11.79 (2.636)	0.598
PT IR Ecc 60^0sec	39.87 ± 13.37 (2.402)	43.35 ± 14.74 (2.648)	0.067	45.80 ± 15.60 (3.489)	49.50 ± 14.39 (3.217)	0.307

PT IR Ecc 120^{0} sec	41.81 ± 11.52 (2.069)	44.71 ± 14.28 (2.564)	0.138	47.25 ± 16.09 (3.597)	50.60 ± 12.32 (2.755)	0.149
Rel PT IR Con 60^{0} sec	0.415 ± 0.161 (0.029)	0.444 ± 0.170 (0.031)	0.151	0.398 ± 0.166 (0.037)	0.409 ± 0.122 (0.027)	0.728
120^{0} sec	0.402 ± 0.145 (0.026)	0.419 ± 0.160 (0.029)	0.286	0.387 ± 0.161 (0.036)	0.363 ± 0.139 (0.031)	0.388
Rel PT IR Ecc 60^{0} sec	0.516 ± 0.177 (0.032)	0.556 ± 0.172 (0.031)	0.078	0.545 ± 0.205 (0.046)	0.570 ± 0.144 (0.032)	0.553
120^{0} sec	0.541 ± 0.151 (0.027)	0.573 ± 0.168 (0.030)	0.159	0.553 ± 0.184 (0.041)	0.587 ± 0.127 (0.028)	0.184
Ratio ER Ecc/IR Con 60^{0} sec	0.716 ± 0.319 (0.057)	0.664 ± 0.278 (0.050)	0.440	0.812 ± 0.439 (0.098)	0.779 ± 0.202 (0.045)	0.724
120^{0} sec	0.723 ± 0.223 (0.040)	0.715 ± 0.250 (0.045)	0.882	0.975 ± 0.582 (0.130)	0.997 ± 0.389 (0.087)	0.844
Ratio ER Con/IR Con 60^{0} sec	0.414 ± 0.189 (0.034)	0.359 ± 0.099 (0.018)	0.156	0.523 ± 0.242 (0.054)	0.485 ± 0.140 (0.031)	0.457
120^{0} sec	0.341 ± 0.125 (0.022)	0.332 ± 0.107 (0.019)	0.719	0.384 ± 0.195 (0.044)	0.424 ± 0.138 (0.031)	0.216

Abbreviations: PT, peak torque; Rel PT, relative peak torque; ER, external rotation; IR, internal rotation; C, concentric; Ecc, eccentric;D, dominant; ND, non-dominant; Sym, symptomatic; Asym, asymptomatic

Within Group Analysis – Control Group

This analysis provides the expected values in a control group matched to the SSI group. Within the control group, all isokinetic parameters except con IR PT, con IR RPT and ratio ER ecc/IR con at both speeds were significantly higher in the dominant shoulder when compared to the non-dominant shoulder (see table 6).

TABLE 6: WITHIN CONTROL GROUP COMPARISON OF ISOKINETIC TESTING FOR DOMINANT TO NON-DOMINANT LIMB

OUTCOME MEASURE	D Mean ± SD (SEM) n = 51	ND Mean ± SD (SEM) n = 51	p value
PT ER C 60^0sec	16.90 ± 7.74 (1.083)	14.31 ± 6.56 (0.919)	<.001
PT ER C 120^0 sec	12.86 ± 7.35 (1.030)	11.04 ± 6.05 (0.847)	0.003
PT ER Ecc 60^0sec	25.49 ± 10.17 (1.425)	22.96 ± 8.78 (1.230)	0.002
PT ER Ecc 120^0 sec	27.25 ± 11.48 (1.608)	24.63 ± 9.29 (1.301)	0.014
Rel PT ER Con			
60^0 sec	0.204 ± 0.082 (0.011)	0.172 ± 0.068 (0.009)	<.001
120^0 sec	0.154 0.081	0.133 ± 0.064	0.004

	(0.011)	(0.009)	
Rel PT ER Ecc			
60^0 sec	0.305 ± 0.095	0.277 ± 0.084	0.002
	(0.013)	(0.012)	
120^0 sec	0.326 ± 0.111	0.133 ± 0.064	<.001
	(0.016)	(0.009)	
PT IR C 60^0sec	35.90 ± 15.42	34.27 ± 13.48	0.140
	(2.160)	(1.888)	
PT IR C 120^0 sec	33.18 ± 14.63	31.53 ± 14.58	0.163
	(2.049)	(2.042)	
PT IR Ecc 60^0sec	49.73 ± 18.05	45.84 ± 16.11	0.007
	(2.527)	(2.256)	
PT IR Ecc 120^0 sec	51.00 ± 16.86	47.35 ± 16.47	0.003
	(2.361)	(2.306)	
Rel PT IR Con			
60^0 sec	0.439 ± 0.171	0.416 ± 0.146	0.091
	(0.024)	(0.020)	
120^0 sec	0.403 ± 0.158	0.380 ± 0.157	0.094
	(0.022)	(0.022)	
Rel PT IR Ecc			
60^0 sec	0.602 ± 0.180	0.556 ± 0.167	0.009
	(0.025)	(0.023)	
120^0 sec	0.619 ± 0.165	0.573 ± 0.163	0.002
	(0.023)	(0.023)	

Ratio ER Ecc/IR Con			
60^{0} sec	0.770 ± 0.362	0.697 ± 0.202	0.122
	(0.051)	(0.028)	
120^{0} sec	0.915 ± 0.534	0.878 ± 0.446	0.620
	(0.075)	(0.062)	
Ratio ER Con/IR Con			
60^{0} sec			
	0.493 ± 0.183	0.420 ± 0.138	0.015
120^{0} sec	(0.026)	(0.019)	
	0.392 ± 0.157	0.363 ± 0.140	0.289
	(0.022)	(0.020)	

Abbreviations: PT, peak torque; Rel PT, relative peak torque; ER, external rotation; IR, internal rotation; C, concentric; Ecc, eccentric; D, dominant; ND, non-dominant

DISCUSSION

Rotator cuff weakness is reported to be associated with SSI (J.S. Lewis, 2009; Michener et al., 2003) yet very few studies have investigated rotator cuff strength in an SSI group and an asymptomatic group.The hypothesis that a significant difference in muscle strength would be found in the painful shoulder in the SSI group (cases) compared to the dominance matched shoulder in the control group has not been clearly identified in this study. Only one concentric variable (ER PT at 60^0 /second) was significantly different between the two groups. Yet concentric testing has been shown to be more reliable than eccentric testing when comparing an SSI group to an asymptomatic group (MacDermid et al., 2004). A concentric contraction produces less force than an eccentric contraction, thereby reducing the influence of pain on performance (Anderson, Bialocerkowski, & Bennell, 2006).

Only one previous study has compared concentric isokinetic ER and IR PT in an SSI symptomatic shoulder with a control group (Dulgeroglu et al., 2013). All PT values were found to be significantly lower for con IR and con ER, at 90^0 sec and 180^0 sec, in the SSI symptomatic shoulder compared to the dominant shoulder of the control group. However, of the 22 symptomatic shoulders assessed only 14 of these were actually the dominant shoulder (Dulgeroglu et al., 2013). The remaining eight shoulders were non-dominant, however these were compared to the dominant shoulders of the control group. This analytical and methodological anomaly, together with the relatively small sample size of the study, may explain why the findings of the current study differ from the results reported (Dulgeroglu et al., 2013)

Differences in eccentric strength in this study were only present when the dominant shoulder was the effected shoulder in the SSI group. Significantly less ecc ER PT at 120^0 /second, ecc ER RPT at 120^0 /second and ecc IR PT at 60^0 /second and 120^0 /second was found when compared to the matched control shoulder.

When the non-dominant shoulder was the affected shoulder in the SSI (cases) no significant differences were identified compared to the matched non-dominant shoulder in the control group.

No previous studies have been identified which have directly compared these variables in an SSI group and a control group.

Mean values for all measurements of the dominant shoulder in the SSI (cases) were consistently lower compared to the matched dominant shoulder in the control group. However, when the non-dominant shoulder was the affected shoulder in the SSI (cases) the values were very similar or slightly higher compared to the control group. It appears that changes in strength in SSI are related to the dominance of the SSI symptomatic shoulder, which may have implications for strengthening regimes.

Examination of strength in a clinical setting is performed by comparison between limbs of a single individual with clinicians expecting the dominant limb to be stronger in 40 to 60 year olds (Roy et al., 2009). This strength difference was identified between the dominant and non- dominant shoulders in the control group with all dominant measurements recorded being higher than the non-dominant limb except for con IR. This lack of difference between IR measurements may be due to the action of pectoralis major which is not affected by SSI and has been shown to have greater EMG muscle activity during IR (Dark et al., 2007). A significant difference was not identified in the SSI group (cases), however recorded measurements were similar or lower in the dominant limb to the non-dominant limb. This observation may be due to the influence of pain inhibition (Dube & Mercier, 2011), decreased primary motor cortex excitability (Ngomo et al., 2015) or a general decrease in activity due to pain being present. In addition, the symptomatic non-dominant measurements were greater than the symptomatic dominant measurements within the SSI group. This finding may again be due to the increased limitations resulting from the dominant shoulder being affected.

Isokinetic testing in a SSI group and an asymptomatic group using a similar age group, tested in the seated position, with the shoulder positioned in the scapular plane, has been reported in five previous studies (Dulgeroglu et al., 2013; Erol et al., 2008; Leroux et al., 1994; MacDermid et al., 2004; Tyler et al., 2005).

One study reported within group differences of an SSI group compared to within group differences of an asymptomatic group (Erol et al., 2008). Only right hand dominant participants were recruited to both groups and matched for age, sex, height and body weight, with concentric testing performed at 60^0 sec. No within group difference between dominant and non-dominant limbs in the SSI group was identified whereas a significant difference was found in the asymptomatic group. The similarity in findings with this study, albeit a small sample size (13 SSI, 25 control), likely reflects the same methodology of matched limb dominance, age and gender.

Other studies which used the same isokinetic testing position to compare an SSI group with an asymptomatic group did not report dominance of the recruited participants but then analysed within group differences for the (1) painful and non-painful shoulders in those with SSI and (2) dominant versus non-dominant shoulder in an asymptomatic group and then (3) compared the values from these two analyses (Leroux et al., 1994; MacDermid et al., 2004; Tyler et al., 2005). This statistical analysis differs from the analysis in this study. Within group comparison of the involved and uninvolved shoulders in those with SSI and comparison of the dominant and non-dominant shoulders in the control group was included in this study with no difference between groups identified, as per Tyler et al., (2005) (table of results in Appendix B). The findings of these previous studies are difficult to compare to the outcomes of this study as limb dominance and the presence of pain will both have an effect on isokinetic performance.

Limitations of this study include the availability of only one assessor to perform all isokinetic testing, however extraction of computer generated data was checked by an independent assessor. Another limitation was the participants not being familiar with the use of the isokinetic dynamometer which is in common with other isokinetic studies. Although instructions were clear before commencing the trial reminders to apply maximum effort throughout and which direction to apply resistance were sometimes needed for both those in the SSI group and the control group. However, this was true for both cases and controls so the measurement bias is likely to be non-differential. The effect of pain was minimized by the position and range chosen for testing. Selection bias (volunteer bias) may be present due to a snowballing effect recruitment strategy. This study only included participants aged 40 to 60 years. While the primary age of SSI, these findings should only be applied to this age group. A strength of this study is the matching of cases and controls on age, gender, hand dominance and physical activity levels.

CONCLUSION

This study is the first to compare isokinetic rotator cuff testing at 60^0 and 120^0 per second through a total range of 60^0 in 40 to 60 year olds experiencing SSI and a control group matched for age, gender, hand dominance and physical activity levels.

Differences in muscle strength were not clearly identified between the SSI cases and control group with significant strength differences only found when the dominant SSI shoulder was symptomatic (con ER PT at 60^0 /second, ecc ER at 120^0 /second, ecc ER RPT at 120^0 /second and ecc IR PT at 60^0 /second and 120^0 /second). No strength differences were evident when comparing the non-dominant symptomatic SSI shoulder and the non-dominant control shoulder indicating strength in SSI may be related to dominance, which may have implications for strengthening regimes.

Significantly higher measurements were found in the dominant compared to non-dominant shoulders of the control group, with no significance found between the dominant (measurements similar or lower) and non-dominant shoulders of the SSI (cases).

APPENDIX A

Methodological Detail

Isokinetic Assessment

Isokinetic testing was performed using a Humac Norm Computerised Dynamometer ((CSMI), 2006). Calibration was completed prior to testing taking place. The asymptomatic group were randomly allocated by drawing a piece of paper from a box to determine the arm to be tested first. The asymptomatic limb was consistently tested first in the SIS group, with this familiarisation encouraging maximal effort when testing the symptomatic limb.

The participant was seated in the standardised position ensuring the seat position allowed the testing arm to be at 45 degrees abduction in the scapular plane. The set up was consistent with those provided in the Humac Norm System User's Guide,page 5-34 ((CSMI), 2006). The chair was rotated to 35^0, dyna tilt was 45^0 and dyna rotation was 5^0. A heat moulded wrist splint was attached before the arm was positioned and strapped into place. Initial recruits displayed visible flexion and extension occurring at the wrist during testing. A small study was then conducted, using asymptomatic young participants, performing the same protocol with the splint in situ and without and no significant difference in peak torque values was found at either speed. However, it was decided to use the heat moulded splint for all participants to standardise the wrist joint position. The zero rotation position was established using a spirit level resting on the fixed arm attachment of the machine. Standardised instructions were given by the examiner explaining which direction the movement was to occur, to provide maximum effort, and keep the pressure throughout the entire movement. 3 practice reps were allowed before each test. The examiner advised not to provide maximum effort in the practice reps but just get used to the machine. One minute rest was provided between practice and trial. Five trials were done in each direction. These were reciprocal concentric/eccentric external rotation and concentric/eccentric internal rotation at 60 degrees per second. One minute rest was then given followed by reciprocal concentric/eccentric external rotation and concentric/eccentric internal rotation at 120 degrees per second. All tests were completed on one arm before adjusting the seat set –up to allow testing with the other arm. All 5 repetitions at each speed were included in the analysis.

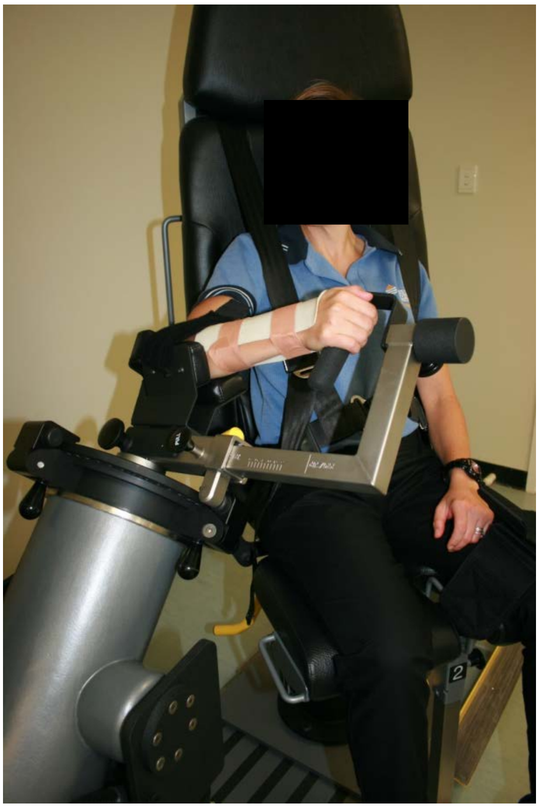

FIGURE 1. Humac Norm Set Up

APPENDIX B: WITHIN GROUP COMPARISON OF ISOKINETIC TESTING FOR SSI GROUP. SYMPTOMATIC LIMB TO ASYMPTOMATIC LIMB

OUTCOME MEASURE	Sym Mean ± SD (SEM) n = 51	Asym Mean ± SD (SEM) n = 51	p value
PT ER C 60^0sec	14.04 ± 6.75 (0.945)	14.16 ± 6.65 (0.931)	0.881
PT ER C 120^0 sec	11.08 ± 6.04 (0.846)	11.94 ± 6.45 (0.903)	0.188
PT ER Ecc 60^0sec	23.16 ± 11.66 (1.632)	23.67 ± 9.30 (1.303)	0.764
PT ER Ecc 120^0 sec	24.37 ± 12.38 (1.733)	24.73 ± 9.35 (1.309)	0.832
Rel PT ER Con			
60^0 sec	0.172 ± 0.075 (0.010)	0.172 ± 0.072 (0.010)	0.969
120^0 sec	0.137 ± 0.069 (0.010)	0.145 ± 0.070 (0.010)	0.307
Rel PT ER Ecc			
60^0 sec	0.288 ± 0.147 (0.021)	0.290 ± 0.106 (0.015)	0.928
120^0 sec	0.305 ± 0.178 (0.025)	0.302 ± 0.097 (0.014)	0.911
PT IR C 60^0sec	32.39 ± 11.79 (1.652)	34.57 ± 12.09 (1.693)	0.135
PT IR C 120^0 sec	31.55 ± 11.47	31.92 ± 12.36	0.761

	(1.606)	(1.731)	
PT IR Ecc 60^0sec	42.20 ± 14.43	45.76 ± 14.77	0.047
	(2.021)	(2.069)	
PT IR Ecc 120^0 sec	43.94 ± 13.61	47.02 ± 13.73	0.037
	(1.905)	(1.922)	
Rel PT IR Con			
60^0 sec	0.408 ± 0.161	0.430 ± 0.153	0.204
	(0.023)	(0.021)	
120^0 sec	0.396 ± 0.150	0.397 ± 0.153	0.945
	(0.021)	(0.021)	
Rel PT IR Ecc			
60^0 sec	0.527 ± 0.187	0.562 ± 0.160	0.105
	(0.026)	(0.022)	
120^0 sec	0.546 ± 0.163	0.578 ± 0.152	0.052
	(0.023)	(0.021)	
Ratio ER Ecc/IR Con			
60^0 sec	0.754 ± 0.369	0.709 ± 0.255	0.410
	(0.052)	(0.036)	
120^0 sec	0.822 ± 0.417	0.826 ± 0.338	0.941
	(0.058)	(0.047)	
Ratio ER Con/IR Con			
60^0 sec	0.457 ± 0.216	0.408 ± 0.131	0.112
	(0.030)	(0.018)	
120^0 sec	0.358 ± 0.156	0.368 ± 0.127	
	(0.022)	(0.018)	0.608

Abbreviations: PT, peak torque; Rel PT, relative peak torque; ER, external rotation; IR, internal rotation; Con, concentric Ecc, eccentric; Sym, symptomatic; Asym, asymptomatic;

Within the SSI group symptomatic and asymptomatic shoulders differed in relation to IR peak torque eccentrically at 60 degrees per second and at 120 degrees per second (Appendix B). No other differences were observed.

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