

Abstract

Shoulder isokinetic assessment: A critical analysis

B. Forthomme, D. Maquet, J.M. Crielaard and J.L. Croisier

Department of Physical Medicine and Rehabilitation, CHU Sart Tilman, Liège, Belgium

Objectives: The literature dealing with shoulder isokinetic assessment presents some contradictions in methodological aspects, protocol design and even muscles targeted [1]. Nevertheless, quantitative and objective measurement of strength is of paramount importance in the evaluation of shoulder function, particularly in some pathological contexts and in training management [2]. The aims of this study were to perform a comparative study between different installations and to assess the influence of age and position on internal (IR) and external (ER) rotator isokinetic results.

Table 1

CV (%) calculated from a test-retest procedure for the shoulder ER – IR peak torques and ratios (ER/IR) in the concentric mode in three testing positions

	ER			IR			ER/IR		
	I	II	III	I	II	III	I	II	III
Conc 60	8.9	7.1	19.1	11.8	7.9	9.8	7.5	11.5	12.2
Conc 240	7.5	7.9	16.6	10.5	8.2	9.5	7.8	12.1	12.9

I = supine position with the arm at 90° of abduction.

II = supine position with the arm at 45° of abduction.

III = seated position with the arm in the scapula plane.

Methods: A group of 12 healthy male (mean age of 24.4 ± 1.7 years) was assessed on a Cybex Norm dynamometer throughout a concentric protocol (60°/s and 240°/s) in three different positions: two lying supine with the arm 90° or 45° abducted in the frontal plane and the third in a seating installation with the arm 45° abducted in the scapula plane. The assessment of a second group, constituting of 10 middle aged male subjects (average age 42.2 ± 5.3 years), allowed us to establish the influence of age. A third group of 10 male

volunteers (mean age 24.2 ± 2.9 years) sustained an adapted protocol including a fast velocity (400°/s) in the concentric mode as well as eccentric contraction at 60°/s on the rotator muscles.

Results and Discussion: Based on the reproducibility data, the seating installation provided unacceptable coefficients of variation (CV) on the ER peak torque (reaching 19.1 %) and the weakest reproducibility for the ratios ER/IR (Table 1). Consequently, we recommend the use of both lying positions for the shoulder rotator assessment: either 90° of abduction or 45° if some pain arises (CV did not exceed 12%). Regarding the influence of position on strength performance measurement, the IR improved in the seated position and the ER were stronger in a supine position with 90° of abducted arm. The ER/IR ratio reached 0.68 to 0.79 depending on the testing conditions with highest values in lying supine, arm 90° abducted. The bilateral asymmetries reached 11% on average for all rotator groups and a dominance effect only appeared on the IR at high speed. On the basis of statistical cutoffs, we proposed 15% of bilateral difference as the upper limit corresponding to a normal shoulder status. In the comparison between young and older male subjects, the strength developed by the rotators showed highly significant differences ($p < 0.001$) whatever the speed: the youngest were on average 40% stronger than the oldest. In the frame of sportive population assessment, we proposed to include a 60°/s eccentric contraction (with CV reaching 8.4% and 12% respectively for the IR and ER) and the fast speed of 400°/s in the concentric mode (with CV reaching 10.7% and 15.3% re-

spectively for the IR and ER). A mixed ratio (ER in the eccentric mode at 60°/s/IR in the concentric mode at 240°/s) characterized by good reproducibility (CV = 10.5%) was built with the aim of being more functional.

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Abstract

Reproducibility of isokinetic shoulder testing

P. Codine^{a,b}, P.L. Bernard^c, P. Sabayrolles^b and C. Herrison^b

^a*Clinique La Pinède, Route de Peyrestortes, 66240 Saint Estève, France*

^b*Service Central de Rééducation, Hôpital Lapeyronie, 34295 Montpellier cedex 5, France*

^c*Laboratoire "Sport - Performance - Santé", UFR STAPS, 700 av Pic Saint Loup, 34090 Montpellier, France*

Introduction: Few studies have evaluated the reproducibility of isokinetic shoulder tests, in contrast to the many studies on knee evaluation. Moreover, the results of these shoulder studies indicate that reproducibility depends on the choice of statistical test and the population size and characteristics. Yet to assess changes over the course of a specific strength-building program, or to compare the results on one side with the other, both the precise degree of reproducibility and the variation should be known.

Objective: To evaluate the reproducibility of isokinetic shoulder measurements in a population of healthy voluntary subjects. Two tests were performed at a 1-week interval, and a simple correlation test was used. This preliminary study will provide the basis for a future study on a much bigger population of subjects using several methods to calculate the reproducibility of the measures.

Population: Twenty-two healthy adults, 10 women and 12 men, volunteered to participate. The mean age was 31.64 years (± 12.84) and none had shoulder pathology or pain.

Method: After a warm-up of 2 series of 15 squats with 2 min of rest between them, the subjects were familiarized with the dynamometer, with 3 movements in each contraction mode and angular velocity.

The isokinetic test was performed on a Biodex[®] in the seated position with a 90° angle between the trunk and thighs and the arms in 45° abduction in the scapular plane (30° in the frontal plane). Range of motion was 70°, 30° in internal rotation (IR) and 40° in external rotation (ER).

Both sides were evaluated. For the first test, the first side tested was randomly chosen, and that same side was then again tested first for the second test.

Five movements at 2 angular velocities (60°/s and 120°/s) were performed in concentric contraction with 2 min of rest between the series. Five movements at an angular velocity of 30°/s were performed in eccentric contraction. The resistance was set at 60 Nm for the men and 40 Nm for the women.

The following were measured: peak torque, mean power, and the IR/ER ratios for peak torque and mean power.

Statistical tests: The non-parametric Pearson correlation coefficient was calculated for the values of T1 and T2 (Statistica 6.0). Significance was set at $p < 0.05$.

Results: The values and significance are shown in Tables 1, 2, and 3.

Discussion and conclusion: The reproducibility for the values of peak torque and maximal power of the internal and external rotators was systematically high ($p < 0.0001$) at all velocities and modes of contraction. This was shown by Forthomme et al. [1], who found a test-retest coefficient of variation of 11% for the IR and 15% for the ER, but Mayer et al. [3] found variations from 15 to 20% in concentric contraction and much higher variations (about 30%) in isometric and eccentric contraction.

In contrast, the reproducibility for the IR/ER ratio was less constant. It was satisfactory ($p < 0.01$) only on the right side for peak torque. This lower reproducibility for the agonist/antagonist ratio than for the peak torque values and maximal power was also described

Table 1

Mean values in Nm and standard deviations (+/-SD) of peak torque (PT) of the internal rotators (IR) and external rotators (ER) on the right (R) and left (L) sides in concentric contraction at 60 and 120°/s and in eccentric contraction at 60°/s. The correlation coefficient calculated for the values at T1 and T2 was significant, $p < 0.05$

PT		C 60 R	C 60 L	C 120 R	C 120 L	E 30 R	E 30 L
IR	T1	41.45 (17.13)	39.22 (13.80)	39.77 (17.44)	36.80 (14.65)	50.34 (22.60)	46.94 (17.90)
	T2	39.43 (15.01)	36.76 (13.04)	38.57 (15.82)	35.35 (13.28)	48.82 (20.78)	43.40 (15.46)
r		0.98	0.95	0.97	0.95	0.96	0.94
$p <$		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
ER	T1	29.01 (12.46)	27.18 (9.2)	26.34 (11.06)	25.17 (9.69)	41.18 (20.01)	40.70 (18.05)
	T2	29.88 (12.30)	27.85 (9.12)	26.05 (11.16)	25.05 (8.32)	43.52 (21.36)	40.76 (19.26)
r		0.83	0.88	0.95	0.92	0.91	0.92
$p <$	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	

Table 2

Values in Nm and standard deviations (+/-SD) of the mean power (MP) of the internal rotators (IR) and external rotators (ER) on the right (R) and left (L) sides in concentric contraction at 60 and 120°/s and in eccentric contraction at 60°/s. The measures at T1 and T2 were correlated according to the r coefficient, $p < 0.05$

MP		C 60 R	C 60 L	C 120 R	C 120 L	E 30 R	E 30 L
IR	T1	30.47 (15.20)	27.59 (12.25)	50.97 (29.42)	46.22 (25.42)	15 (10.09)	13.44 (7.18)
	T2	29.20 (12.79)	26.97 (10.96)	48.03 (24.79)	43.02 (20.08)	14.26 (8.51)	12.54 (6.32)
r		0.98	0.92	0.98	0.94	0.97	0.67
$p <$		0.0001	0.0001	0.0001	0.0001	0.0001	0.001
ER	T1	21.80 (11.37)	19.88 (8.33)	33.21 (19.97)	30.77 (16.63)	11.94 (7.31)	10.73 (5.37)
	T2	21.18 (10.05)	19.84 (7.28)	31.65 (17.88)	30.08 (13.56)	12.52 (7.41)	11.41 (6.68)
r		0.95	0.89	0.95	0.94	0.88	0.83
$p <$		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Table 3

Mean values in Nm and standard deviations (+/-SD) of the IR/ER ratio calculated from the peak torque and mean power values on the right (R) and left (L) sides in concentric contraction at 60 and 120°/s and in eccentric contraction at 60°/s. The correlation coefficient calculated for the values at T1 and T2 was significant, $p < 0.05$

IR/ER		C 60 R	C 60 L	C 120 R	C 120 L	E 30 R	E 30 L
PT	T1	1.45 (0.32)	1.47 (0.28)	1.52 (0.34)	1.49 (0.33)	1.27 (0.26)	1.20 (0.24)
	T2	1.36 (0.32)	1.32 (0.21)	1.51 (0.35)	1.40 (0.23)	1.17 (0.26)	1.12 (0.19)
r		0.76	0.24	0.84	0.35	0.43	0.39
$p <$		0.0001	NS	0.0001	NS	0.04	NS
MP	T1	1.73 (0.81)	1.41 (0.32)	1.66 (0.74)	1.62 (0.63)	1.24 (0.37)	1.29 (0.36)
	T2	1.42 (0.32)	1.36 (0.26)	1.62 (0.55)	1.44 (0.31)	1.13 (0.24)	1.17 (0.30)
r		0.09	0.28	0.81	0.26	0.68	0.32
$p <$		NS	NS	0.0001	NS	0.001	NS

by Hutchinson et al. [2], but they offered no explanation for their findings. The IR/ER ratio is considered to be a constant by some, but in fact is less reliable and reproducible than the absolute values of maximal peak torque and mean power. The great variability in this ratio needs to be taken into account in longitudinal studies of patients or when one shoulder is compared with the other. However, this work was preliminary, with a small number of subjects and no homogeneity in age or physical activity level. This study will be expanded to include a much greater number of subjects assigned to homogenous groups so that we can confirm or invalidate these initial data.

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Influence of the position of the scapula in isokinetic assessment: An example with high level athletes

Cédric Dupuis^{a,b}, Claire Tourny Chollet^{a,b}, David Leroy^{a,b} and Françoise Beuret Blanquart^b

^a*CETAPS, EA 3832, Faculté des Sciences du Sport et de l'Éducation Physique, Université de Rouen, Rouen, France*

^b*GRHAL, Faculté de Médecine, CHU Charles Nicolle, Université de Rouen, Rouen, France*

1. Introduction

In isokinetic assessments of the shoulder joint, the influence of the modalities in muscular exploration is fundamental for the obtained strengths (Forthomme et al. [3]). The most investigated movement is without doubt the internal and external rotation of the joint. Rotator muscles of the shoulder are responsible of the joint stability and mobility. For the athletes, the roles of stability and mobility of these muscles are more important because the velocity of execution is considerable. In fact, angular velocity of rotation of the arm can reach values superior to $6000^{\circ} \cdot s^{-1}$ (Dillman and al. [2]). Then, this muscular group determines the performance. During a throw in baseball, a smash in volleyball or a tennis serve, internal rotators (IR) are contracted in concentric mode to execute the technique while external rotators (ER) are contracted in eccentric mode to maintain stability of the joint and to protect the joint from any pathology. These technical movements in sport are composed of phases. The hit in volleyball and tennis or the throw in baseball result of the contraction of rotators muscles during the cocking phase and the acceleration phase. To understand movements in sport, considering a consequent range of motion, it is interesting to analyze the peak and the average torque of isokinetic tests.

The review of literature points out various positions of reference and their influences or not on the muscular relaxation of the analyzed muscles (Saha et al. [7], Soderberg et al. [8]). Two positions of assessment are

more frequently used in the literature but are subject to controversy : the frontal plane and the plane of the scapula. The choice of the frontal plane comes from the isokinetic devices (the seat is perpendicular to the lever arm). Furthermore, this plane presents the advantage that obtained strengths are reproducible (Hellwig et al. [5]). The plane of the scapula, 30° of anterior flexion to the frontal plane, is justified by the relations of optimal "length-tension". The maximum tension is reached when the length of the muscles indicate the best stretch of the individuals sarcomeres. A muscle develops maximal strength when it measures 90% of its maximum length. On the other hand, minimal strength is obtained when the muscle is totally contracted [9]. The capsule of the glenohumeral joint is more relaxed in this plane than in the frontal plane. The center of the humeral head and the labrum are in the same alignment [6]. This relaxed position of the joint can be considered as a comfort position.

The aim of this study is to compare the strengths of high level athletes in a position of assessment in the scapular plane and in the frontal plane, with the shoulder at 90° of abduction.

2. Material and methods

Eight healthy teenage males without history of shoulder pathology participate in this study. The majority of the participants are high level sportsmen (swimmers

Table 1
Anthropometric characteristics of the experimental population

Sportsmen ($n = 8$)	
Mean age in years (SD)	(19.63 \pm 1.51)
Mean height in cm (SD)	(177.75 \pm 3.96)

and volleyball players). The anthropometric characteristics are described in Table 1.

The strength of the shoulder rotator muscles is assessed using an isokinetic dynamometer (Kin Com[®] 500 H, Chattecx Corp., Chattanooga, TN, USA). Each volunteer is seated and then stabilized in the chair with two crossed belts, placed at 0° of flexion from the lever arm for assessment in the frontal plane and at 30° from the lever arm for assessment in the scapular plane [1]. Each subject is fixed across the chest with belts, from the axilla and over the shoulder. To minimize trunk movements, the subject's back remains in contact with the chair throughout the test. The subjects are assessed with the arm in 90° abduction. The subject's elbow is placed in a V-shaped elbow support and the resistance pad is adjusted just above the wrist. The hand is in pronation on the pad. The zero position of the lever arm always corresponds to the horizontal line. The entire range of motion is 110°, from the vertical line to 20° under the horizontal line. With the Kin Com[®] dynamometer, the range of motion (ROM) does not change during the test. A value is not accepted if the subject does not apply force throughout the entire assessment test ROM.

The procedure considers two dates of assessment. Two groups are composed: a group with assessment in the frontal plane at the first date and a second group which is assessed in the scapular plane at first. Subjects are randomly attributed to each group. Assessment in scapular plane and assessment in frontal plane are identical. The procedure of these two planes of assessment includes three tests for each side. The first side assessed is randomly determined. Test 1 evaluates the maximal strength of IR and ER in concentric mode at 90°.s⁻¹. Test 2 evaluates the maximal strength of IR and ER in eccentric mode at 90°.s⁻¹. Test 3 evaluates the maximal strength of IR and ER in concentric mode at 180°.s⁻¹. Prior to isokinetic testing, each volunteer performs a 10 minutes warm-up of the shoulders consisting of internal and external rotations of both shoulders with a rubber band. Then, ten submaximal repetitions at 120°.s⁻¹ of angular speed repetitions are done on the Kin Com[®] in internal and external rotation. The testing order is always respected: test 1, 2 and 3. The subjects have 1 minute and 30 seconds of rest between tests and sides. The second assessment is done one

week after the first one. Each group changes of plane at the second assessment.

For the data analysis, statistical tests are done on peaks torque and averages torque. The number of experimental subjects required a non-parametric test, and the Wilcoxon signed rank test was chosen. One significant threshold was fixed at $p < 0.05$.

3. Results

No statistical difference is found between averages and peaks torque. To compare with the literature, peaks torque are presented in these results. The peaks torque of IR and ER in concentric and eccentric modes at 90°.s⁻¹ and 180°.s⁻¹ are presented in Newton-meters (Nm) in Table 2. The values represent the average of the peaks torque of the whole experimental population. The assessment in these two different planes has no significant effect on the results of IR and ER strengths of the athletes. There is no significant difference between the average of the peaks torque between dominant and non dominant arm for any speed and any modes.

Conventional ratio (IR conc/ER conc) and dynamic ratio (IR conc/ER ecc) are determined with peaks torque of IR and ER in the two planes (Fig. 1). Values of ratios of athletes at 90°.s⁻¹ and 180°.s⁻¹ did not show significant difference between the two planes of assessment. There is no significant difference between ratios of the dominant and the non dominant arm.

4. Discussion

The results of the present study do not indicate significant difference between both planes: the frontal plane and the scapular plane. This is in agreement with the study of Hellwig et al. [5] on sedentary subjects. The same trademark of dynamometer (Kin Com[®]) used in Hellwig study [5] can explain this resemblance. However, the protocol differs from this of the present study (40° of flexion for the plane of the scapula, 60.s⁻¹ of angular speed and 85° of ROM). The peaks torque of Tis et al. [10] indicate differences between both planes contrary to the peaks torque of the present study. The evaluations of female subjects in Tis study [10] were recorded on a Cybex 6000[®] dynamometer, in a supine position. The authors justify the differences of their results with those of Hellwig et al. [5] by the position of testing. The peaks torque to body weight in the study of Greenfield et al. [4] also significantly increase in the

Table 2
Average of peaks torque of concentric and eccentric strength of internal and external rotators of the dominant and the non dominant arm at $90^{\circ} \cdot s^{-1}$ and $180^{\circ} \cdot s^{-1}$ in the two planes

Peak torque	Plane	ER Dom. Arm	IR Dom. Arm	ER Non Dom. Arm	IR Non Dom. Arm
Concentric $90^{\circ} \cdot s^{-1}$	Frontal	47.38 (\pm 12.67)	52.75 (\pm 14.79)	56.38 (\pm 16.94)	58.50 (\pm 19.03)
	Scapula	46.50 (\pm 12.06)	52.34 (\pm 16.24)	51.38 (\pm 13.53)	52.75 (\pm 17.30)
Eccentric $90^{\circ} \cdot s^{-1}$	Frontal	54.00 (\pm 15.78)	70.38 (\pm 23.71)	57.75 (\pm 21.78)	74.38 (\pm 23.40)
	Scapula	57.00 (\pm 21.28)	72.75 (\pm 19.93)	55.88 (\pm 15.03)	70.88 (\pm 25.28)
Concentric $180^{\circ} \cdot s^{-1}$	Frontal	45.25 (\pm 16.06)	46.75 (\pm 11.82)	51.63 (\pm 15.36)	49.63 (\pm 16.60)
	Scapula	47.88 (\pm 13.63)	48.50 (\pm 15.22)	50.50 (\pm 9.43)	46.50 (\pm 14.48)

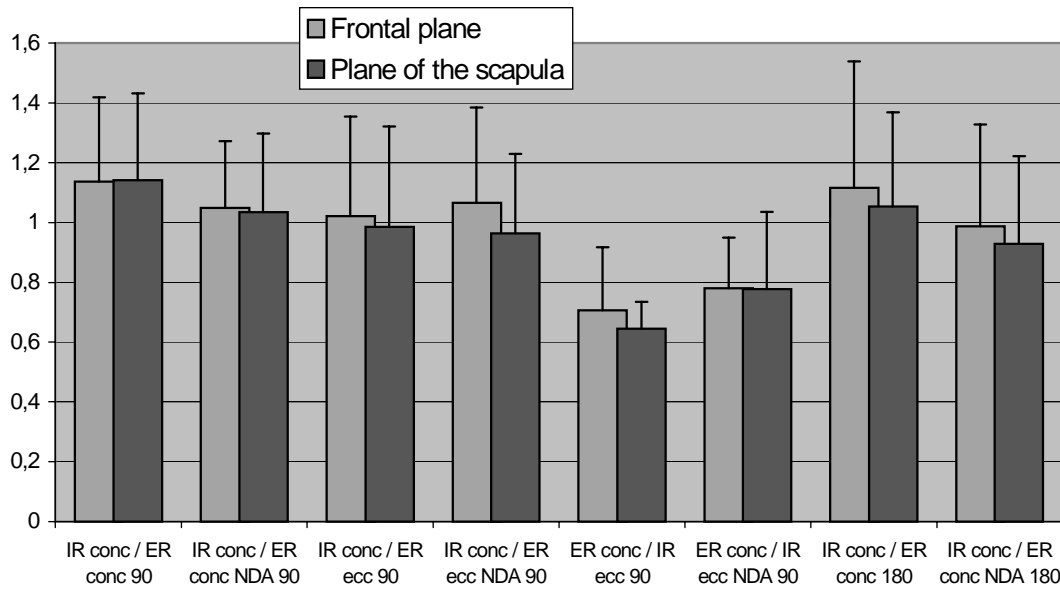


Fig. 1. Ratios of peaks torque of internal and external rotators at $90^{\circ} \cdot s^{-1}$ and $180^{\circ} \cdot s^{-1}$ of the dominant arm and the non dominant arm in the plane of the scapula and in the frontal plane.

plane of the scapula comparing to those in the frontal plane. In this study, the strengths of rotator muscles of female subjects were assessed in a supine position with a Merac[®] isokinetic dynamometer. This position is very debatable because of the numerous possible compensations. These differences of results between the studies come from differences of protocol and confirm the argument supported by Forthomme et al. [3]: differences in the protocol (position of the body, angular velocity, range of motion, degree of flexion and abduction) and especially the trademark of dynamometer can end in very different conclusions. Therefore, it is not possible to compare the peaks of moments of force, the averages of moments of force, the ratios (conventional or functional) and the evolution of the strength according to the velocity. These differences of results between the trademarks of dynamometer and protocol do not question the reliability and the reproducibility of every dynamometer.

Some sportsmen in the present study indicated during the test an uncomfortable position in the frontal plane and particularly in external rotation. This comment also appears in the discussion of Hellwig study [5]. Even if the results of their study do not indicate statistical difference between both planes, the authors advise an evaluation in the plane of the scapula to avoid one “closed packed position” (engendering a stress of soft tissues in a pathological case or an embarrassment in a evaluation of non pathological subjects). Effectively, in the frontal plane, the muscles rotators are not in the best relation of tension-length probably due to anatomical factors. Naturally, this position of comfort results from the study of sports subjects but this position is also advised for isokinetic evaluation of pathological subjects.

For other dynamometers than Kin Com[®], the investigations in the plane of the scapula confirm better results compared with the results obtained in the frontal

plane, inviting the future investigations of isokinetic evaluations of the rotator muscles of the shoulder to be realized in the scapular plane.

Thus, it seems thus preferable to estimate rotator muscles of the shoulder in the plane of the scapula, whether evaluations are recorded on a Kin Com[®] dynamometer or with an other isokinetic dynamometer trademark.

5. Conclusion

High level athletes are assessed with an isokinetic Kin Com[®] dynamometer in the frontal plane and in the plane of the scapula. This evaluation is realized at $90^{\circ} \cdot s^{-1}$ and $180^{\circ} \cdot s^{-1}$ in concentric and eccentric mode. The results do not indicate significant difference between both planes. The differences of results concerning the distinction between these two planes according to the studies can be explained by the differences in the protocol and especially the dynamometer trademark. However, beyond the isokinetic results, the biomechanical constraints in the frontal plane consolidate the idea that estimating in the plane of the scapula is better.

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Abstract

Assessment of isokinetic shoulder rotational strength in dominant and non dominant side in three high level athlete populations (tennis, swimming, volley-ball)

V. Gremeaux^{a,b}, G. Gozlan^c, L. Bensoussan^d, J.M. Coudreuse^c, J.M. Viton^d and A. Delarque^d

^aService central de Rééducation Fonctionnelle, CHU Lapeyronie, 34295 Montpellier cedex 5, France

^bEA 2991 Efficience et Déficience Motrices, UFR STAPS, Montpellier, France

^cService de Médecine du Sport, CHU Salvator, Marseille, France

^dFédération de Médecine Physique et de Réadaptation, CHU Timone, Marseille, France

Objective: to compare external and internal rotator (ER and IR) muscle strength of both shoulders in a sport with asymmetrical movements (tennis), one with symmetrical movements (swimming), and one with both movement types (volley-ball).

Material and Methods: retrospective study on 42 high level athletes, free from any muscular problems. We evaluated the strength of ER and IR of both shoulders on a CYBEX NORM[®] isokinetic dynamometer, in the concentric mode, in the Davies modified position [1], at 2 different speeds (60° and 180°s⁻¹). Peak Torque (PT) of ER and IR and ER/IR ratios have been analysed. Statistical analysis has been performed with a Student t-test on mean difference in PT of ER and IR and on mean difference in ratios ER/IR between dominant and non dominant shoulder.

Results: *Tennis:* IR Peak Torque of the dominant shoulder was significantly higher compared to the non dominant shoulder. ER/IR ratio of dominant shoulder was significantly lower in women. *Swimming:* ER strength and ER/IR ratio of the dominant shoulder were higher on the dominant side in men at 60°s⁻¹. Both shoulders presented comparable strength in women. *Volley-ball:* shoulder muscular strength was symmetrical.

Table 1

Mean difference in Peak Torque of External Rotator muscles (ER) and Internal Rotator muscles (IR) between Dominant (D) and Non Dominant (ND) shoulder (expressed in percentage ± standard deviation)

	ER D Vs ND		IR D Vs ND	
	180°/s	60°/s	180°/s	60°/s
Tennis-women	-3.5 (± 20) NS	-7.6 (± 26) NS	23.9 (± 9) D > ND (p < 0.01)	24.1 (± 6.2) D > ND (p < 0.0001)
Tennis men	-5.6 (± 40) NS	-13.6 (± 47) NS	16.6 (± 10) D > ND (p < 0.05)	16.2 (± 3.35) D > ND (p < 0.0001)
Female swimmers	-1.8 (± 20.1) NS	7.3 (± 27.3) NS	8.6 (± 13.69) NS	0.1 (± 8) NS
Male swimmers	7.9 (± 14.9) NS	18.5 (± 18) D > ND (p < 0.01)	4.5 (± 11.3) NS	5.7 (± 18.9) NS
Volley-ball players	-14.3 (± 31.5) NS	-8.3 (± 18.2) NS	-5 (± 10.5) NS	-6.4 (± 14.5) NS

NS = Non significant difference.

Discussion: Internal rotator muscles higher strength of the dominant shoulder in tennis players (performing asymmetrical movements) had already been reported in the literature [2,3]. Male volley-ball players (practicing both types of movements in serving, reception, smashing and counter-attack) had similar ER and IR strength in both shoulders. Different results

Table 2

RATIOS External Rotator muscles Peak torque (PT)/Internal Rotator muscles PT: Mean difference (expressed in percentage \pm standard deviation) between ratios ER/IR of Dominant shoulder (D) and Non Dominant shoulder (ND)

	TEST SPEED	
	180°/s	60°/s
Tennis-Women	-12.1 (\pm 3.9) D < ND (p < 0.05)	-13.2 (\pm 3.8) D < ND (p < 0.05)
Tennis men	-5.3 (\pm 0.9) NS	-8.1 (\pm 1.1) NS
Female swimmers	-5.1 (\pm 1.2) NS	3.1 (\pm 0.9) NS
Male swimmers	1.1 (\pm 0.5) NS	5.6 (\pm 2.8) D > ND (p < 0.05)
Volley-ball players	-3.5 (\pm 0.7) NS	-1.7 (\pm 0.3) NS

NS = Non significant difference.

had previously been found among female volley-ball players [4], but test position was different. Swimmers (supposed to practice a “symmetrical” sport) showed significant higher strength of ER and lower ER/IR ratio in dominant shoulder. To our knowledge, these results had never been reported before. Rupp et al. found a lower ER/IR ratio on both sides in swimmers suffering from shoulder pain, compared to non-swimmers con-

trol, with a ratio independent of sex, dominant side, history of pain and pain at examination [5]. Our results in athletes free from shoulder problems could question the “symmetrical” notion of the 3 sports examined in this study.

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Abstract

Consequences of latissimus dorsi transfer on shoulder function

B. Forthomme^a, O. Heymans^b, F.X. Granjean^b, S. Klinkenberg^a, S. Hoffmann^a and J.L. Croisier^a

^aDepartment of Physical Medicine and Rehabilitation, CHU Sart Tilman, Liège, Belgium

^bDepartment of Plastic, Esthetic and Reconstructive Surgery, CHU Sart Tilman, Liège, Belgium

Objectives: The latissimus dorsi is one of the largest muscles in the body. This muscle recognizes many applications in reconstructive surgery [1]. Since its introduction, the technique of latissimus dorsi myocutaneous flap breast reconstruction has yielded results characterized by excellent tissue vascularity and low donor site morbidity [2]. This study was undertaken to determine the functional consequences associated with the latissimus dorsi muscle donor site.

Methods: Twelve women (mean age of 50.1 ± 7.5 years) were studied before and up to 3 months after a latissimus dorsi transfer following mastectomy (one woman sustained a bilateral musculo-tendinous transfer), six of the thirteen shoulders sustained a 6 month follow-up. They sustained a bilateral isokinetic shoulder assessment involving the internal (IR) and external (ER) rotators and the abductor (ABD) and adductor (ADD) muscles. The ER-IR were tested in a lying supine position (45° of abduction in the frontal plane) at $60^\circ/s$ and $240^\circ/s$ in the concentric mode. The ABD-ADD were assessed in a newly designed lying lateral position between 0° and 90° of abduction in the frontal plane at $60^\circ/s$ and $180^\circ/s$ in the concentric mode [3]. The passive goniometric range of motion was measured in flexion, extension, internal and external rotation with shoulder placed either at 0° or at 90° of abduction. The subjective pain was evaluated by means of a visual analogic scale (VAS) before and after isokinetic assessments. The subjects also benefited from specific clinical testing of conflict (Hawkins, Yocum and Neer test) on both shoulders.

Results and Discussion: Six months post-surgery, patients recovered a subnormal passive mobility, with only the external rotation at 0° of abduction standing significantly inferior ($p < 0.05$; 7%) in comparison with the contralateral healthy shoulder. They did not describe any complaints through the VAS either before or after the isokinetic measurement except for one woman who presented a slight pain before and after the strength assessment (2.2. and 3.7 respectively on the VAS). Four out of thirteen operated shoulders (three months follow-up) and three out of six (six months follow-up) showed a Hawkins and/or Yocum positive testing.

Three months after the latissimus dorsi transfer, the affected shoulder developed a significant ($p < 0.05$) weakness on the IR ($16.8 \pm 10.6\%$ at $60^\circ/s$), the ADD ($38.6 \pm 12.5\%$ at $60^\circ/s$) and the ABD ($9.3 \pm 12.4\%$ at $60^\circ/s$) in comparison with the pre-surgery strength profile. Hence, compared to the healthy side, the operated shoulder showed a significant ($p < 0.05$) decrease of strength on the IR ($14.8 \pm 21.4\%$ at $60^\circ/s$) and ADD ($37.3 \pm 9.4\%$ at $60^\circ/s$). No improvement occurred within the 6 months follow-up group and they still presented a significant ($p < 0.05$) deficit six months after surgery ($20.9 \pm 12.9\%$ on the IR; $37.1 \pm 7.9\%$ on the ADD; $17.9 \pm 10.9\%$ on the ABD at $60^\circ/s$) in comparison with the non-operated shoulder.

The ER/IR and ABD/ADD concentric ratios were increased on the operated shoulder comparatively to the healthy side after surgery. For instance, at 3 months post-surgery, we obtained 0.96 ± 0.17 versus $0.68 \pm$

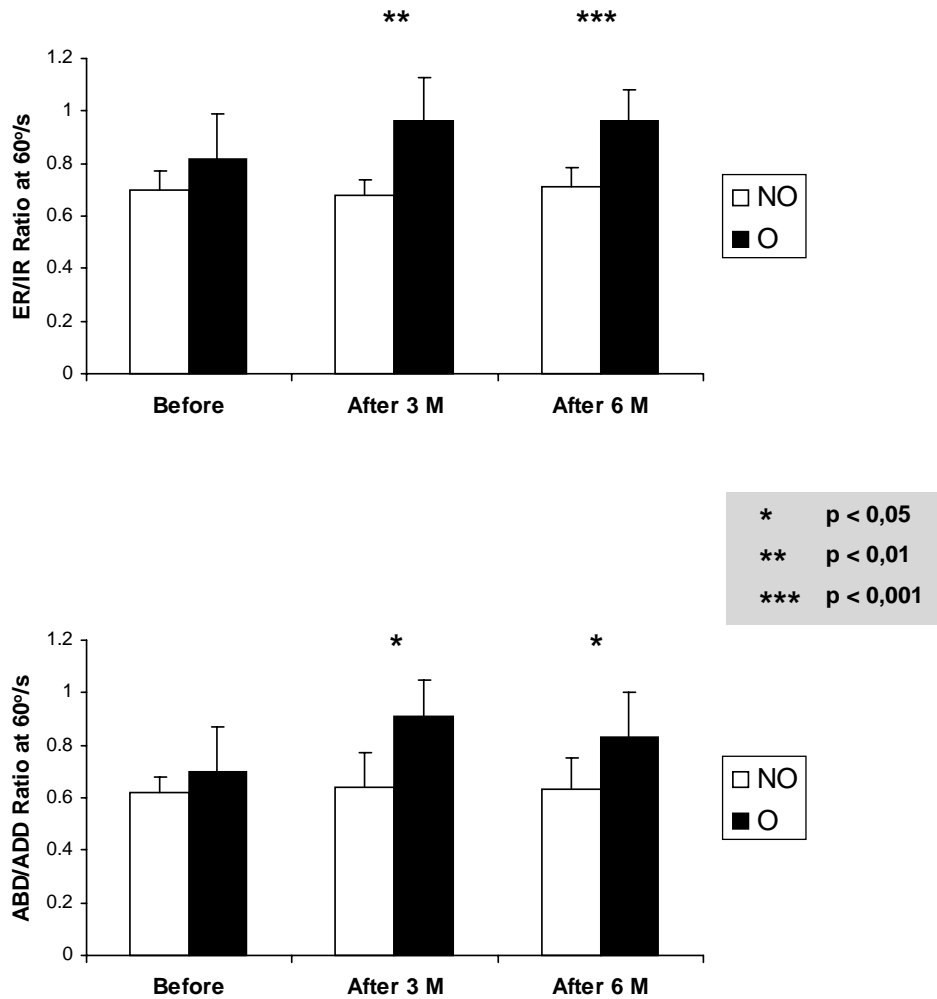


Fig. 1. ER/IR and ABD/ADD ratios at 60°/s in the concentric mode before, three (3 M) and six (6 M) months after latissimus dorsi transfer.

0.06 for the ER/IR ratio at 60°/s and 0.91 ± 0.13 versus 0.64 ± 0.13 for the ABD/ADD ratio at 60°/s (Fig. 1).

Conclusion: Three and 6 months after a latissimus dorsi transfer following mastectomy, the operated shoulder showed a significant weakness mainly in the IR and ADD muscles, entailing to higher ER/IR and ABD/ADD ratios in comparison with the contralateral side. In spite of a satisfactory passive motion pattern, some of these shoulders developed positive conflict signs.

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Shoulder isokinetic profile after Latarjet's technique

B. Forthomme^a, S. Willems^b, S. Hurllet^b, J.P. Berger^b, G. Houben^c and J.L. Croisier^a

^a*Department of Physical Medicine and Rehabilitation, CHU Sart Tilman, Liege, Belgium*

^b*Department of Orthopedic Surgery, Saint Joseph Hospital, Liege, Belgium*

^c*Department of Radiology, Saint Joseph Hospital, Liege, Belgium*

Abstract. The following procedures were performed on 23 patients (15 of them males): a shoulder strength isokinetic evaluation of the internal (IR) and external (ER) rotators (with the shoulder 45° and 90° abducted in the frontal plane), a passive range of motion measurement, a Rowe score and a scanner exam. These patients had previously undergone open coracoid transposition using Latarjet's technique according to two different surgical procedures: a tenotomy ($n = 6$) or a splitting ($n = 17$) of the subscapularis muscle approach. In our retrospective study, the period of time between surgery and assessment was an average of 30 months.

The average Rowe score was 89 on a scale of 100, with a good pattern of passive mobility. The isokinetic data showed an external rotator weakness (in all testing conditions), most notably at 60°/s in 45° of abduction position ($p < 0.001 - 12.2%$). By contrast, the internal rotators were only significantly ($p < 0.05$) impaired (8.2%) at 60°/s in the 90° of abduction position. Consequently, the external/internal rotator ratio (ER/IR) was reduced in the 45° of abduction installation only, highlighting the influence of testing position on the isokinetic results and therefore on the shoulder muscle profile.

Surgical technique comparison revealed that only the tenotomy procedure entailed an IR deficit (17%) measured at 45° of abduction installation. Shoulders ($n = 5$) presenting a fatty degeneration of the subscapularis muscle \geq stage II (corresponding exclusively to the tenotomy surgical approach) showed an internal rotator weakness (19%) measured in 45° of abduction. Patients ($n = 13$) without subscapularis fatty degradation (corresponding solely to the horizontal splitting approach) did not develop any impairment of strength in internal rotators. Furthermore, no correlation between mobility pattern and strength impairment was observed in the study.

1. Introduction

An intricate balance between the static and dynamic stabilizers confers stability of the shoulder joint [1,8, 12,19,20]. Static stabilizers include bony structures, glenoid labrum, glenohumeral ligaments, capsule, and rotator interval [12,14]. Dynamic constraints correspond to the rotator cuff and the scapular muscles [12]. Any imbalance in this relationship can lead to shoulder instability [12]. Furthermore, good coordination of rotator cuff contraction plays a significant role in the maintenance of stability of the glenohumeral joint [12]. In the case of recurrent dislocations, successful surgical treatment for anterior instability can be performed using either open or arthroscopic approaches [8,15]. Forms of open repair surgery have ranged from soft

tissue procedures (e.g. Putti Platt) to those involving transfer of a bony block (e.g. Latarjet) or reattaching the detached labrum and associated glenohumeral ligaments (e.g. Bankart) [15]. Choice of technical procedure and surgical approach certainly affects functional results in the shoulder [16,17].

The aim of this study was to provide a functional analysis of the operated shoulder, including internal (IR) and external (ER) rotator isokinetic profile, passive range of motion measurement, Rowe score and a scanner exam in patients who had previously undergone an open coracoid transposition using Latarjet's technique. We also compared two surgical procedures: vertical trans-subscapularis section and muscle splitting approach.

2. Material and methods

A retrospective study was performed on 23 patients (35.2 ± 15 years), including 15 men, who had undergone a coracoïd transposition using Latarjet's technique (by the same surgeon) 30 months ago. Focusing on the surgical approach, either an L-shaped incision of the subscapularis tendon 1 cm medial to the lesser tuberosity ($n = 6$) or a subscapularis muscle-splitting approach ($n = 17$) had been performed to gain access to the underlying capsule. Patients included in the study presented a healthy contralateral shoulder and no postoperative dislocation. They were all clinically reviewed and completed a questionnaire concerning post-surgical rehabilitation. A functional score according to Rowe [18] was carried out. Goniometric passive range of motion in external rotation at 0° and 90° of abduction was registered bilaterally. The interview, clinical examination and range of motion measurement were carried out by the same experimenter. The fatty degeneration status of the operated shoulder was evaluated by means of a scanner exam in accordance with the Goutallier et al. [9] classification.

All patients underwent an isokinetic assessment of both shoulders using a Cybex Norm dynamometer (Henley Healthcare, Sugar Land, TX, USA). The internal (IR) and external (ER) rotators were tested throughout two different supine positions: in 45° or 90° of abduction in the frontal plane. The side and testing position order were randomly assigned. The concentric speeds of $60^\circ/s$ (3 repetitions) and $240^\circ/s$ (5 repetitions) were assessed after an adequate warm-up and familiarization with the isokinetic exercise. The range of motion was constantly fixed at 115° covering 60° in internal rotation and 55° in external rotation. Absolute peak-torques (PT in N.m), bilateral differences (%) between the operated and non-operated shoulder and ER/IR ratios were considered.

3. Statistical analysis

Results were expressed as means \pm standard deviations. Mean independent or dependent values were compared by an unpaired or paired Student t-test. The association between two variables was measured by the Pearson product moment correlation coefficient. Results were considered to be significant at the 5% critical level ($p < 0.05$).

4. Results

4.1. Rowe score, range of motion and scanner exam

According to the rating system proposed by Rowe [19], the total score was 89. The operated shoulder averaged a decrease in external rotation of $7^\circ \pm 10^\circ$ in the 0° abducted position and $3^\circ \pm 5^\circ$ in the 90° abducted installation in comparison with the contralateral healthy side (no statistical difference).

Of the 17 patients who had sustained a horizontal muscle splitting approach, only 4 (23.5%) presented stage I of subscapularis fatty degeneration as revealed by the CT scan. By contrast, 5 of the 6 (83%) shoulders with a vertical tendon incision developed fatty degeneration of the subscapularis muscle superior or equal to stage II.

4.2. Isokinetic results

Figure 1 shows the ER and IR absolute PT at $60^\circ/s$ and $240^\circ/s$ for the operated and unoperated shoulders throughout the 45° and 90° of abduction position.

The ER of the affected shoulder were impaired in all isokinetic conditions and the highest deficit corresponded to the 45° of abduction position at $60^\circ/s$ ($12.2 \pm 14\%$, $p < 0.001$). A significant ($p < 0.05$) IR weakness was only observed at $60^\circ/s$ in the 90° of abduction position ($8.2 \pm 18.3\%$).

Figure 2 illustrates the ER/IR ratios at $60^\circ/s$ and $240^\circ/s$ for both assessment positions. The ER/IR ratios were only significantly ($p < 0.05$) reduced at 45° of abduction. This was due to the ER weakness measured in that assessment position which was not combined with any IR strength alteration. In the 45° of abduction installation, we observed a significant ($p = 0.013$) difference between shoulders operated on by the splitting technique (no IR weakness) and those that had received a tenotomy of the subscapularis tendon (17% of IR deficit at $60^\circ/s$). In the 90° of abduction installation, the greatest IR deficit was again observed in shoulders with the tenotomy surgical approach (18% as against 5% for the splitting approach), but with no significant difference.

In the same way, the shoulders ($n = 5$) showing a fatty degeneration greater than or equal to stage II (tenotomy surgical approach) presented an IR impairment at $60^\circ/s$ in the 45° of abduction position ($19 \pm 10\%$). By contrast, those with no fatty degeneration ($n = 13$) did not develop any IR weakness and corresponded to the splitting subscapularis surgery.

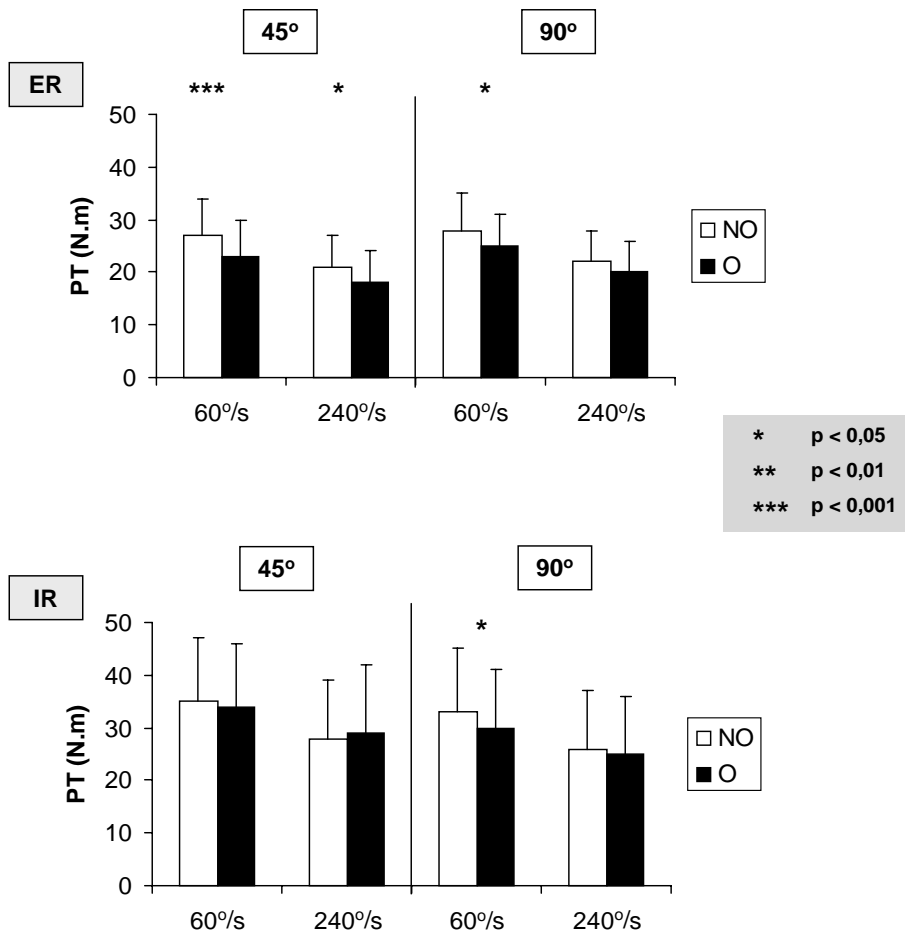


Fig. 1. External (ER) and internal (IR) rotators concentric peak torques (PT) in N.m at 60°/s and 240°/s for the operated (O) and the non operated (NO) shoulder in 45° or 90° of abduction installation.

There was no correlation between IR and ER muscle weakness. IR strength recovery was correlated with both positions at 45° and 90° of abduction ($r = 0.48$), but such a relationship was not found for ER. There was no relationship between mobility pattern and strength impairment.

5. Discussion

One of the ways to manage shoulder instability is to transfer the coracoïd process with its attached tendons to the antero-inferior glenoid rim [8]. The coracoïd process is secured to the glenoid rim with a screw, creating a sling effect, or by making a bone block [8]. Several surgical approaches through the subscapularis muscle have been described. In this study, the surgeon had used two different subscapularis incisions: either an L-shaped incision of the subscapularis tendon (tenotomy)

($n = 6$) or horizontal subscapularis muscle splitting ($n = 17$). We focused retrospectively on the functional results 30 months after Latarjet's technique by considering the results of the following: an isokinetic assessment, a Rowe score, a range of motion measurement and a scanner analysis. Furthermore, the influence of the surgery approach on the data was also gauged.

We demonstrated a Rowe score of 89 on a scale of 100 units and a passive external rotation impairment mainly at 0° of abduction ($7° \pm 10°$). Such a profile should be considered as a good result in a 30-month follow-up to a Latarjet stabilization procedure. Even though current studies are most commonly devoted to the arthroscopic Bankart repair, only few articles [2,3, 6,10,16,17,21] have described similar functional scores and passive mobility results following coracoid transfer surgery.

For Gill and Zarins [8] and MacCarty et al. [13], the ideal criteria for return to play following surgery are:

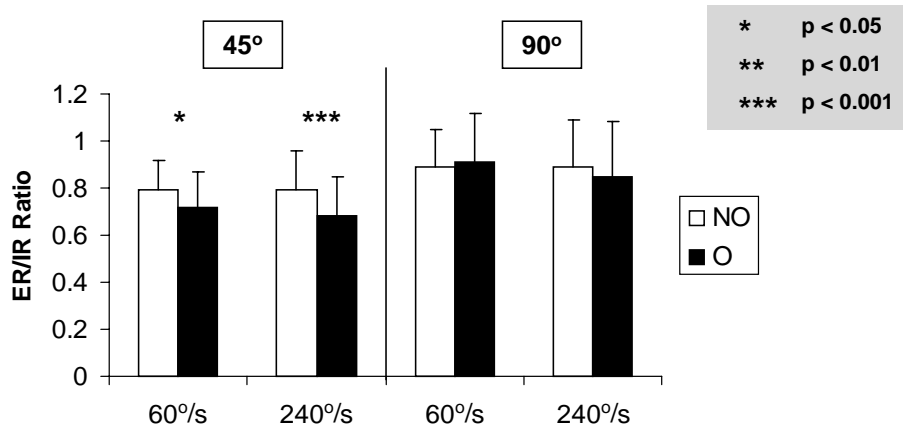


Fig. 2. ER/IR concentric ratios at 60°/s and 240°/s for the operated (O) and the non operated (NO) shoulder in 45° or 90° of abduction installation.

pain free functional range of motion, no apprehension and normal shoulder strength status. After surgical management, the rotators strength recovery represents a target goal [5], given their paramount dynamic implication in the glenoid concavity compression in addition to their mechanical role.

In the isokinetic designing protocol, the IR and ER muscle groups were chosen due to their major involvement in dynamic shoulder stability [5,12,15,17]. Levine et al. [12] highlighted the significant role of coordinated rotator cuff contraction in the maintenance of stability. Warner et al. [22] further demonstrated altered rotator cuff strength in patients with symptomatic shoulder instability with an IR deficit in comparison with the asymptomatic shoulder. Equally, Tsai et al. [20] found a significantly lowered isokinetic IR peak torque in the context of non-operated shoulder instability. Gill and Zarins [8] also emphasized the role of rotational muscle strengthening exercises in the success of non-operative management.

Based on the influence of shoulder installation on isokinetic data [7], our patients sustained two different supine position assessments, at 45° and 90° of abduction in the frontal plane. Due to the pathological context, the rotators were only tested in the concentric mode, throughout a slow (60°/s) and a high (240°/s) velocity.

Surprisingly, the highest deficit measured on the affected shoulder concerned the ER (12.2%) when assessed at 45° of abduction. The existence of a relationship between ER weakness and passive mobility impairment in external rotation at 0° of abduction could be suspected. However, we did not observe such a correlation. Besides, the ER showed a muscle weakness

in comparison with the healthy side in all testing conditions. The IR affected by the subscapularis muscle surgical approach seemed to be significantly impaired ($p < 0.05$; 8.2%) uniquely at 60°/s in the 90° abducted position, showing great individual variation.

To date, only sparse literature has been devoted to isokinetic assessment after Latarjet's technique. Regan et al. [17] reported a significant ($p < 0.05$) ER weakness assessed in both neutral and 90° of abduction position, without bilateral difference on the IR, flexor and the extensor muscle groups. The average time of the follow up among these overhand athletes was 6.75 years after the coracoid process transfer. The author's assumption was that the imbalance might be inherent to a previous throwing practice, entailing a pre-surgery ER weakness, as frequently described in overhand athletes [17]. Felicetti et al. [6] showed, 18 months after Latarjet's technique surgery, a slight rotator weakness tested at 60°/s on the operated shoulder without statistically significant difference. Picard et al. [16] found a significant decrease in IR strength measured in the Lift off test position with a handy dynamometer, they did not assess the ER strength development.

The patients followed in our study had benefited from non-standardized rehabilitation (as regards length and techniques) after surgery. None of them had sustained any isokinetic training program. Based on classical concepts and underestimated participation in shoulder instability, rehabilitation rarely promotes the ER strengthening. Even so, Cain et al. [4] insisted on the role of the posterior rotator cuff in reducing strain on the glenohumeral anterior structures due to its capacity to pull the humeral head posteriorly during the cooking phase of the throwing motion.

Surprisingly, the IR strength developed by the operated shoulder tended to be normalized. The only significant ($p < 0.05$) IR bilateral deficit measured in the 90° of abduction shoulder installation might be due to a lengthening of the subscapularis musculo-tendinous unit. That could inhibit strength development, even if the patients did not report any discomfort.

A more marked fatty degeneration (\geq stage II) of the subscapularis muscle, revealed by the CT scan exam, was accompanied by a pronounced IR weakness reaching 19% on average. By contrast, the subjects with a normal muscular image in the CT scan exam did not show any IR deficit on average. Interestingly, five of the six patients sustaining a tenotomy approach showed fatty degeneration, the splitting approach surgery mainly corresponding to normal muscular strength status. Similarly, only the tenotomy group presented an IR deficit (17%) at 45° of abduction installation. Picard et al. [16] observed that the vertical section of the subscapularis muscle in Latarjet's technique frequently entailed muscle degeneration, but the authors did not report a correlation between muscle degeneration and IR strength developed in a Lift off test position. They suspected a post-surgery total or partial tear of the subscapularis tendon. In that study, a significant correlation was observed between the fatty degeneration level and passive mobilization in external rotation measured at 0° of abduction [16]. MacCarty et al. [13] advised against open procedures involving a takedown of the subscapularis tendon, which requires a longer period of avoidance in external rotation mobilization and in IR strengthening. The open subscapularis splitting approach allows earlier mobilization and rapid rehabilitation [13]. Regan et al. [17] observed that early rehabilitation is important in managing the resultant functional deficit.

For the ER/IR ratio results, we also highlighted the influence of shoulder installation. The ER/IR ratio was only significantly lower at 45° of abduction with no bilateral difference at 90°. Obviously, at 90° of abduction, both agonist and antagonist muscles were impaired. This was contrary to 45° of abduction where the installation corresponding to ER strength decreased without reduction of the IR peak torque.

6. Conclusion

- This long-term follow-up study showed good results for both the Rowe score and passive mobilization 30 months after Latarjet's technique.

- The isokinetic shoulder assessment demonstrated an ER weakness in all isokinetic conditions, mainly (12.2%, $p < 0.001$) at 60°/s in 45° of abduction in the frontal plane.
- Surprisingly, IR were only significantly impaired ($p < 0.05$; 8.2%) at 60°/s in 90° of abduction in the frontal plane.
- Consequently, the ER/IR concentric ratio was reduced in the 45° of abduction position at both isokinetic speeds due to ER weakness with no IR variation, highlighting the influence of position on the isokinetic data.
- In the 45° of abduction installation, there was a significant ($p = 0.013$) difference between the splitting of the subscapularis muscle surgical approach (no IR weakness) and tenotomy of the subscapularis tendon (17% of IR deficit at 60°/s).
- Shoulders with a fatty degeneration greater than or equal to stage II showed an IR weakness (19%) measured in 45° of abduction. These all corresponded to a tenotomy surgical approach. Shoulders with a normal muscular status in the CT scan exam did not show any IR impairment. All these had undergone splitting approach surgery.
- There was no correlation between mobility pattern and strength impairment.

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Abstract

Isokinetic performance of upper limb muscle groups in high-level tennis players

E. Brassinne, S. Dumas, P.-M. Dugailly and D. Mouraux

Department of Physical Therapy and Rehabilitation, Erasmus Hospital, ULB, Brussels, Belgium

E-mail: Eric.Brassinne@ulb.ac.be

Introduction: Repetitive loading during high-level tennis practice submits the forearm muscles and rotator cuff of the dominant arm under maximum stress [1].

Epidemiological data indicates that epicondylitis and overload injuries of the shoulder commonly occur in tennis players.

Different authors [2] have suggested that “strength imbalance” may increase the risk of injury for athletes.

The aim of this study was to evaluate the isokinetic flexor and extensor strength of the wrist, and the rotational strength of the shoulder, in concentric and eccentric modes in a group of high-level tennis players compared to a control group.

Materials and methods: Two groups of 15 subjects (without history of upper extremity injuries within the past 4 years) were evaluated: a control group of non-competitive males and a group of high-level tennis players.

Each subject was tested on an isokinetic dynamometer (Cybex Norm). The tests were performed on both right and left sides.

Wrist flexor (Fl) and extensor (Ext) were assessed in seated position, the forearm in supination, the elbow flexed at 90°. Subjects performed movement at 60°/sec in concentric and eccentric mode (total range of motion: 120°).

Shoulder internal (IR) and external rotators (ER) were assessed in supine position with the arm abducted (90°). The test was performed at two angular velocities in the concentric mode (60°/sec and 180°/sec) and at 60°/sec in the eccentric mode. The total range of motion was 140°.

Table 1

Peak Torque (Nm) of wrist extensors and flexors of the dominant (D) and non-dominant (ND) arms

	Extensor Con60°/s		Flexor Con60°/s	
	D	ND	D	ND
Tennis players	16 ± 4*	12 ± 4	20 ± 5	18 ± 4
Control	13 ± 3	11 ± 2	20 ± 4	18 ± 3
Tennis players	22 ± 6	17 ± 4	27 ± 5	25 ± 5
Control	18 ± 3	16 ± 3	26 ± 2	24 ± 4

*: significant difference between D/ND ($P < 0.004$).

The testing procedures used were those recommended by the manufacturer’s guidelines.

Statistical analysis: Data obtained for both sides or in both groups were compared using Student’s t-test for dependent or independent samples. Level of statistical significance was adjusted by means of the Bonferroni correction for multiple comparisons ($p = 0.004$).

Results: For the wrist (Table 1), the tennis group displayed a significantly higher (25%) extensor peak torque of the dominant arm (D) than that of the non dominant arm (ND). In contrast, no statistical difference was found for the flexor muscles.

In the control group, no difference was observed between the D and ND arms.

For the eccentric evaluation no differences were found for both groups.

Regarding rotator cuff muscle strength (Table 2), no statistical difference was demonstrated for external rotators between D and ND arm in either groups.

In the tennis player group, a statistical difference was observed for the D arm internal rotators in the

Table 2
Peak Torque (Nm) of the external and internal rotator of the shoulder on dominant (D) and non-dominant (ND) arms

	Con60°/s		Con 180°/s		Ecc 60°/s	
	D	ND	D	ND	D	ND
External rotator						
Tennis players	32 ± 4	32 ± 4	27 ± 6	27 ± 3	45 ± 6	43 ± 6
Control	33 ± 5	32 ± 4	27 ± 5	28 ± 6	41 ± 5	40 ± 5
Internal rotator						
Tennis players	47 ± 9*	39 ± 6	41 ± 7*	33 ± 7	59 ± 8*	49 ± 9
Control	41 ± 6	38 ± 6	37 ± 5	32 ± 4	48 ± 9	49 ± 11

*: significant difference between D/ND ($P < 0.004$).

concentric mode at 60°/sec and 180°/sec. The same result was found in the eccentric mode.

Discussion and conclusion: In our study, it appears that intensive practice of tennis increases strength of wrist extensor muscles of the dominant arm. Regarding the fact that our subjects were free of pathology in the past years, we can hypothesise as Strizak [3] that high-level tennis players may protect their lateral epicondyle muscles insertion by increasing their strength.

Further studies are needed to promote strengthening of wrist extensor as a reasonable prevention against “tennis elbow”.

As several authors, we have observed a better performance for shoulder internal rotator muscles of the dominant arm in the tennis player group.

An increase of internal rotator strength could be expected to be accompanied by an increase of external rotator strength, especially in the eccentric mode. It is well known that external rotators play an important role

in the deceleration of the arm in eccentric contraction mode.

However, no evidence of such eccentric adaptations of dominant arm external rotators was provided by this study.

Considering the parallel evolution of concentric and eccentric parameters in healthy tennis players we suggest to evaluate the contribution of eccentric assessment in clinical contexts.

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Abstract

Isokinetic assessment of shoulder rotator cuff sutures 36 months after surgery

J. Binet^a, B. Forthomme^b and J.L. Croisier^b

^a*Department of Physical Medicine and Rehabilitation, CHR, Tournai, Belgium*

^b*Department of Physical Medicine and Rehabilitation, CHU Sart Tilman, Liège, Belgium*

The rotator cuff lesion is one of the most common shoulder pathology. A well-achieved rehabilitation usually guarantees a successful recovery. Our preliminary study [1] showed that, our patients suffered from significant strength and mobility deficiency 6 months after surgery. The goal of this second study is objectifying in the long term the patient profile after rotator cuff surgery.

Our first study dealt with 42 rotator cuff suture performed by 2 surgeons. The second study reexamined 34 of them 3 years later. The isokinetic evaluation of the rotator's strength was made in concentric mode at 60, 120 and 240 degrees per second and at 60 and 180 degrees per second for the abductors-adductors. The evaluation modalities "for the rotators" were: patient lying supine, arm abducted to 90 degrees in the frontal plane (the engine rotating axis matches with the glenohumeral joint centre). The testing position "for the abductors-adductors" was the following: lateral lying supine, dynamometer behind the patient, against rest put on the distal part of the arm, amplitude purposely ranging from 0 to 90 degrees of abduction. Range of motion, peak torques (absolute and body-weight normalized values) and the ratios were taken into account.

When comparing to the unaffected arm at low speed 3 years after surgery, male patients gained 1% for the external rotators (–16% after 6 months), 10% for the internal rotators (–6%), 3% for the abductors (–21%) and for the adductors (–7%). Females showed the same gain for the external rotators (–21% at 6 months), 9% for the internal rotators (–5%), 7% of gain to the

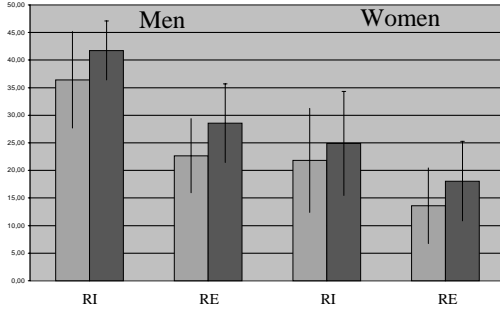
adductors (–10%) and 1% of deficiency for the abductors (–23%).

At 6 months, the dominant factor was crucial in the strength recovery process. The biggest difference (especially at low speed) as compared to the unharmed arm was noticed on the internal rotators: 2% of deficiency among the dominant-side operated shoulder and 18% among the non-dominant side. This effect is gradually weakening after 3 years and the internal rotators regain 12% among the dominant-side and 2% (non significant) among the non-dominant side. Surprisingly enough, the external rotators of non-dominant shoulders regain strength (26% at low speed; –13% at 6 months) whereas there still is a 6% deficiency (–20% at 6 months) for the dominant-side patients.

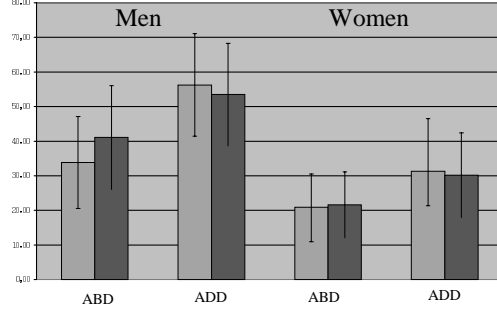
Normalization is obtained when comparing the results between dominant-side operated men and referential sedentary men. The same comparison at low speed among female patients gives us normalized rotators, a 23% deficiency for the abductors (–28% at 6 months) and 28% for the adductors (–36% at 6 months). The external rotators recovery is better among patients operated after a traumatism than among degenerating shoulders ($p < 0.05$) and those who underwent surgery on only one tendon recovered their abductors-adductors better than those operate of more than one tendon.

The amplitude for men shows a 1% deficiency on internal and external rotation whereas women's deficiency is 2% on external rotation and 5% (non-relevant) on internal rotation.

Shoulder Internal and External rotator peak torques (in N.m) comparison at 60°/sec between men and women operated arms



Shoulder abductor and adductor peak torques (in N.m) comparison at 60°/sec between men and women operated arms



We can conclude that a 3-year strength recovery is similar for male and female patients. Mobility does not cause any problems on men whereas women do keep a non-relevant deficiency on internal rotation. The patient's age (thus the trophic tissue quality) modified the results: harmed patients (50, 7 years old on average, $n = 18$) recovered better than degenerating ones (58, 7 years old on average, $n = 16$). The heaviness of surgery also influences the recovery. Our patients showed a nearly normal mobility and a "stronger" shoulder than the healthy one. However the findings have to be taken cautiously because of no pre-surgery

tests. Our patients still showed weakness six months after surgery, which let us wonder whether the rehabilitation was not stopped too prematurely. 3 years after the operation, we can conclude that this kind of surgery fully restores all functional features and a well-achieved 6-month rehabilitation seems to be enough.

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The shoulder of the archer: Clinical, video and isokinetic evaluation

H. Delahaye^a, A. Tomaszewski^a, J.B. Diard^a, V. Olivier^b, J. Vanvelcenaher^a and L. Dupont^a

^a*Department of Evaluation-Prevention in Sport & Health, Rehabilitation Center L'Espoir, Lille Hellemmes, France*

^b*League of Flandres of Archery, Lille, France*

Abstract. *Purpose:* Painful pathology of shoulder is frequent in archery. The aim of this study is to search for predisposing factors and to provide guides for physical training in order to prevent this pathology.

Method: Video analysis of a training session, isokinetic assessment of extensors, flexors and rotators muscles of both the shoulder and the trunk.

Population: 13 competitive archers including 7 injured athletes.

Results: A muscular chain links trunk, scapula and arm. There is a great implication of the scapulo-thoracic musculature. The muscular demands are different for the two shoulders. Impingement syndromes are frequent. We observe a tendency to stiffness of the shoulder of the injured athletes. Isokinetic tests show low values of shoulder ratios (External Rotation/Internal Rotation, ER/IR, Flexion/Extension), weakness and lack of endurance of the trunk muscles, high values of the F/E trunk ratios and imbalance of trunk rotators ratios.

Conclusion: Physical training of archer should include limbering up exercises, muscular reinforcement of the trunk and the scapulo-thoracic joint, readjustement of the muscular balance between great and little muscles, agonists and antagonists of the trunk and of the shoulders so as to prevent painful conflicts and overloads.

1. Introduction

This study was carried out within the Department of Evaluation-Prevention in Sport & Health of the Rehabilitation Center L'Espoir, on request of the French Federation of Archery, of the League of Flandres of Archery and of the Regional and Departmental Service of Youth and Sports.

Within the context of a preventive action, the purpose was to understand the factors predisposing to injury of the shoulder of the archers in order to correct these factors with adequate physical training. Out of 2100 questionnaires sent to permit-holders of the region Nord-Pas-de-Calais practising exclusively archery, 328 were filled out (15%): 110 athletes declared an injury and 71 a shoulder pathology. All the women of the French Team underwent an injury during the two years preceding the survey [7]. Injuries concern mainly the shoulder of string.

Training is often restricted to the practising of archery. There is neither systematic warm-up or re-

cuperation after training, nor codified period of rest between the flights of arrows.

The load of training during a session adds up to 80 to 120 arrows or even more. The power of arc permit a shoot at 70 meters; it must be sufficient to limit the effect of the wind on the precision of the shooting. The tensile strength for the male seniors reaches 18 to 22 kg and for the female seniors 14 to 16 kg. Most of the injuries occur following an increase of the power of arc together with an increase of the number of arrows shot; they appear after repeated efforts and do not occur at a particular point of the gesture.

2. Methods

2.1. Subjects

The study was carried out in November-December 2003 on 13 archers: 7 have a national level, 3 an international level and 3 a regional level; 11 practise classi-

Table 1
Isokinetic assessment protocol

	Mode	Position	ROM	Speeds	Number of repetitions	Gravity correction
Flexion-extension of arms	Conc.	Supine	100°	60°/s et 120°/s	5	Yes
Rotations of arms	Conc.	Sitting; Davies position	90°	60°/s 120°/S	5	No
Flexion-extension of the trunk	Conc.	Standing	75°	30°/s	5	No
	Exc.			120°/s	20	
				30°/s	5	
Rotation of the trunk	Conc.	Sitting	45°	60°/s	5	No
				150°/s	20	

cal arc, 2 pulley-arc, 7 are or were injured, 2 are left-handed, 11 right-handed. Mean age is 27.5 years (14–37). Mean number of years of practise is 15 (2–29). For the trunk only, we compared isokinetic values of the trunk with values of 30 healthy athletic subjects. No normative data were available for the athletic shoulder in the position tested in this study.

2.2. Protocol

The study includes video recording during a training session, clinical examination and isokinetic assessment of the trunk and the shoulders on isokinetic devices, Cybex™ – Norm® and Cybex™ – Torso® after warm-up on bicycle or rower.

For statistical analysis, non parametric tests (Mann-Whitney) were used (5% significance level).

3. Results

3.1. Video recording

Archery is an assymetric sport; the shoulder of string seems the most sollicited.

On the side of the string shoulder, we distinguish two phases:

- The tension setting of the string is slow; then the archer maintains the tension in an apparently static position, during ten seconds or more before releasing the string. The shape and the duration of this action are precise because they are coordinated with the taking aim of the archer (visual and motor coordination). The movement combines an horizontal extension of the arm, an important retropulsion of the scapula with an extension of the elbow. It demands an excellent strength of the scapulo-thoracic muscles.

- At the time of string releasing, one can see a shake of the shoulder with a very fast backward movement of the arm. This phase requires a powerful muscular contraction to prevent glenohumeral subluxation; it probably necessitates the eccentric contraction of the anterior musculature of the shoulder added to the action of the rotator cuff.

On the side of the shoulder of arc, the limb has to resist to the counterpush of the arc by a static antepulsion, arm horizontally flexed and elbow extended; then at the time of the release of the string, this limb has to make a brutal braking of the antepulsion by an eccentric contraction of the posterior musculature of the shoulder.

3.2. Clinical examination

- *Mobility*: the two shoulders are more stiff in the injured athletes; mobility is inferior to the values of the 30 healthy athletes (NS, non significant difference). There is no assymetry between the two shoulders. The extensibility of the posterior chain of the trunk and of the lower limbs is only slightly lower than the norm of healthy athletes (NS).

	Injured archers (n = 7)	Non injured archers (n = 6)
Gleno-huméral abduction	95 (5.4)	102 (11.5)
External rotation, arm in abduction	85 (28.8)	108 (10.8)

Passive mobility of the shoulder of string (°): mean values (sd).

- Score of Constant:
- VAS permits the assessment of pain during the practise of archery: values are between 2 and 6/10 among the injured athletes (0 for the non injured athletes).

	Injured archers	Non injured archers
Pain (0: constant pain – 15: no)	9 (4.3)	15 (0)
Discomfort in daily activities (0: very severe; 20: no)	18 (2.7)	20 (0)

Scores of Constant of the shoulder of string: mean values (sd).

- Type of pathology:
Half of the competitors has or had a painful episode which leads to a decrease of the training and of the results. It is often an impingement syndrome.

Impingement syndrome	6
Tendinitis of biceps brachialis	2
Cervical pain	2
Gleno-humeral laxity	2

Pathology of the injured archers.

3.3. Isokinetic assessment

- Flexion-extension of the shoulders: flexors and extensors of the arm of string are stronger. At slow speed, we note an asymmetry of the ratios F/E.

	Shoulder of string	Shoulder of arc
Flexors	52 (25.7)	45 (18.0)
Extensors	75 (28.2)	72 (21.0)
Flexors/Extensors	56 (12.4)	68 (20.9)

Isokinetic values of flexors and extensors of the arm at 60°/S (Nm): mean values (sd).

- External and internal rotations of the shoulders: there is no asymmetry of strength and ratios. ER/IR ratio is low.

	Shoulder of string	Shoulder of arc
External rotation	20 (9.4)	20 (8.1)
Internal rotation	41 (12.8)	39 (12.1)
ER/IR ratio (%)	46 (11.4)	51 (8.7)

Isokinetic values of rotators of the arm at 60°/S (Nm): mean values (sd).

- Trunk flexion and extension:

	Archers	Norm (n =30)
Flexors	249 (46)	328 (45)
Extensors	278 (76)	424 (62)
Flexors/Extensors	95 (21)	78 (12)

Isokinetic concentric strength values of flexors and extensors of the trunk at 30°/S (in percent of Body Weight, %BW): mean values (sd).

The concentric and excentric values are very low in comparison with our normative data. The ratio

	Archers	Norm (n = 30)
Flexors	–321 (45)	–466 (52)
Extensors	–361 (84)	–605 (82)
Flexors/Extensors	93 (24)	77 (6)

Isokinetic excentric strength values of flexors and extensors of the trunk at 30°/S (%BW): mean values (sd).

F/E is high: there is a relative weakness of the extensors. The shape of the graphs of extensors does not show the classical plateau: there is often a S shape, the torque being not maintained from beginning to end of the motion: it suggests the weakness of the paravertebral muscles in the whole chain of extension.

The slopes of fatigue at high speed are less marked than in our norm (5 subjects have no slope); this result underlines the deficit of endurance of the trunk musculature.

	Archers	Norm (n =30)
Flexors	11 (10)	15 (8)
Extensors	17 (12)	26 (18)

Slopes of fatigue of the trunk musculature (%) in concentric at 120°/s.

- Trunk rotation: The values are very low in comparison with our normative data. The ratio shows an imbalance, left rotators being often stronger. The shape of the graphs is often asymmetric: the torque cannot be maintained to the end of motion for one of the rotators group (right or left).

	Archers	Norm
Right rotators	230 (59.4)	344 (59)
Left rotators	245 (53.1)	341 (70)
Ratio G/D%	108 (8.4)	98% (8)

Isokinetic concentric values of trunk rotators muscles at 150°/s (%BW): mean values (sd).

There is no significant difference of isokinetic values between the injured and the non injured archers.

4. Discussion

4.1. Video analysis

Muscular functioning of the two arms differs. At the release of the string, the excentric muscular contraction, which stabilizes the shoulders, apparently concerns the retropulsors for the arm of arc and the an-

tepushers for the arm of string. During the tension setting of the string, muscular contraction is apparently static: it concerns the antepushers for the arm of arc and the retropushers for the arm of string. Therefore reinforcement of the upper limbs should be differentiated, specific for each arm.

Endurance of trunk musculature is particularly solicited.

This observation has to be completed by a more accurate analysis of movement.

4.2. *Isokinetic assessment of the shoulders*

In spite of differences in testing protocol, we find a hierarchy of strength similar to that of other studies, with decreasing values for extensors, flexors, internal rotators then external rotators [3,11,17].

The ER/IR ratios are low (1/2) in comparison with the usual 2/3 but we cannot conclude that there is an imbalance because we did not take account of the gravity phenomenon: gravity increases values of IR and reduces values of ER. Our values are close to those of Hartsell [8], who tested healthy and non athletic subjects without gravity correction; nevertheless we must remark that our ratios are particularly low for the arm of string (46%).

Regarding rotations, studies usually show that sedentary or occasionally athletic subjects do not exhibit difference of strengths or ratios between the two shoulders [10]; a difference is noted (although inconstantly) among competitors practising asymmetric sports [1–4, 7,9,10,14,18,19]. Archery is asymmetric but we do not detect difference between the two shoulders among the 13 competitors.

Extensors and flexors of the shoulder of string are stronger; they actively participate to the motion while the rotators have not a direct action on the movement but are mainly stabilizers. The ratio F/E is low in comparison to the classical 4/5 [10], emphasizing the relative weakness of the flexors; this weakness is more pronounced for the shoulder of string.

It has been noticed that in case of impingement syndrome, pain has little impact on isokinetic values [6]. In the pathology of impingement, some studies pointed out modifications of rotator strength or ratios ER/IR but all the studies do not agree [6,12,20]. In our study, strengths and ratios do not differ between painful and non painful archers.

The type of sport have an impact on isokinetic values [7]. In archery, there is neither (or little) rotation of the arms, neither raising of the arms nor wide and fast

movements, as in tennis, volley-ball, base-ball; therefore we cannot compare our results with such series.

Several factors can lead to microtraumatic painful pathology of shoulders:

- Stiffness, even moderate, as the one we notice in the injured archers, may disrupt the harmony of the scapulo-humeral motion and lead to conflicts or mechanical overloads [15].
- Weakness or imbalance between agonists and antagonists may lead to subtle repeated micro-movements of the gleno-humeral joint (especially if laxity preexists) [13,18].
- Interaction between scapulo-thoracic and gleno-humeral joints is important to maintain the harmony of the movement, especially in sports [16]. Insufficiency of scapulo-humeral muscles perturbs the alignment of the articular components and the strengths involved around the gleno-humeral joint. Regarding the loads supported by the shoulder in archery, it seems important to develop a balanced and sufficient musculature not only for the arm rotators, flexors and extensors but also for the scapulo-thoracic muscles.

4.3. *Isokinetic trunk assessment*

Is the trunk rotators asymmetry due to the asymmetry of gesture of archery which includes a rotation of the trunk?

Muscular sheathing of the trunk is important to stabilize the arc and to permit a precise archery. Muscular weakness of the pelvis and lower limbs can lead to chronic low back pain, the insufficiency of these links painfully overloading the other links of the whole corporal chain.

In archery, a functional chain of extension and rotation of the trunk, horizontal extension and retropulsion of the arm is solicited; this chain includes trunk, scapulas and arms muscles (especially long muscles as latissimus dorsi). Insufficiency of the trunk musculature can lead to painful overload of a component of this chain as the shoulder joint. It underlines the necessity to correct the muscular weakness of the trunk and particularly the lack of endurance, a muscular quality especially required in archery.

The occurrence of cervical pain and the proprioceptive function of the cervical muscles (especially trapezius) incites to include their reinforcement in the physical training.

4.4. Criticism of our protocol and perspectives

Our test of flexors and extensors muscles of the arm does not account of the scapulo-thoracic muscles because it is made supine, immobilizing this joint.

In order to reflect more precisely the demands and the specificity of the gesture of archery, it would be interesting to make the following tests:

- concentric and excentric horizontal rétroimpulsion and antéimpulsion of the arm,
- flexors and extensors of the elbow,
- shoulder girdle protraction and retraction. Cools [5] showed the good reproducibility of this test in standing position.

The painful symptoms appear with repeated efforts and when the number of volleys of arrows increases: assessment of shoulder muscles fatigability would allow to detect a deficit of endurance.

5. Conclusion

This study of a sport at high risk for the shoulder underscores some factors which may increase the vulnerability of this joint and that athletic training must fight: tendency of stiffness, shoulder extensors and flexors asymmetry, low values of shoulder agonists-antagonists ratios, imbalanced ratios, weakness and lack of endurance of the trunk. The observation of the movement suggests an important contribution of the scapulo-thoracic muscles. There is a specific demand on the musculature of each upper limb which calls for differentiated reinforcement. Strength and endurance of the trunk must be developed in order to provide a stable socle so as to ensure the precision of the archery. We must see to maintain a good balance between agonists/antagonists in order to improve the shoulder stability. A balanced strength between large muscles (of the trunk and of the shoulder) and the little muscles of the gleno-humeral joint guarantees a harmonious gesture and prevents excessive loads, sources of tendinitis and conflicts. The delicate adjustment of the muscular actions requires isokinetic assessment to guide physical training.

This study must be completed by isokinetic assessment that even more closely reflects the reality of the archery.

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