Isokinetic relations at the shoulder joint

J. Carrascosa-Sánchez, A. Slocker, R. Rodríguez, C. Clemente, J. García, J. Fernández and L. Gómez-Pellico

Department of Morphological Sciences and Surgery, School of Medicine, Alcala University. Alcalá de Henares, 28805-Madrid, Spain

Summary

Our aim with the present study was to determine relationships between the isokinetic variables, force and work, during the abduction-adduction movement of the shoulder articular complex. A further goal was to relate these variables between both limbs and to speeds and movements.

With this in mind, and using a sample of 40 healthy young people (20 men and 20 women), all of them right-handed, a muscular evaluation was carried out by means of an electromagnetic dynamometer (Biodex), following a strict protocol for test performance. Peak torque and the total work of each limb were quantified during the abduction-adduction movement on the frontal plane.

Statistical correlations were analysed and each corresponding correlation coefficient calculated. Our results reflect evident statistical correlations between isokinetic peak torque and total work. Likewise, a constant interrelationship of such variables between both limbs appeared, along with interdependence in their abductor-adductor behaviour and between speeds of 60°/s and 120°/s. Since there was a statistically significant linear relationship, the statistic r^2 (determination coefficient) was also high and, as a consequence, a large percentage of the isokinetic behaviour of one variable could be explained with respect to the other.

Key Words: Isokinetics – Shoulder joint – Correlations – Abduction-adduction

Introduction

Many anatomical structures affect the stability of the shoulder articular complex. Among them, the role of muscles is crucial for maintainnig dynamic stability at the shoulder joint.

For this reason, our initial basic purpose was to establish behaviours of movements of the muscular groups at the shoulder on the frontal plane by means of their isokinetic analysis, defining the most significant isokinetic features: peak torque and total work, for both sexes (Carrascosa et al., 1999) (Table 1).

With isokinetic analysis, the dynamic capacity of human muscles to produce force is quantified exactly and accurately, keeping a constant speed throughout the articular stroke (Hislop et al., 1967).

The advantage of such a type of exercise with respect to isotonic exercise is that the contracted muscle is made to reach its maximum capacity at each point of the articular movement arch, keeping a constant speed. It permits the reproduction of muscular behaviour tests under the same conditions in order to evaluate and compare its function.

In the present paper, the relational characteristics between force and work variables are defined for the abductor and adductor muscular groups of the shoulder.

Our specific aim was to define mathematically the interdependence between peak torque and work performed at the articular complex of the shoulder. A further goal was to confirm the relationship existing for the muscular function studied between both upper

Submitted: July 16, 2000
Accepted: September 13, 2000

Correspondence to:
Josefa Carrascosa Sánchez, M.D. Ph.D. Departamento de Ciencias Morfológicas y Cirugía, Facultad de Medicina. Universidad de Alcalá. Carretera Madrid-Barcelona Km. 33,600. Alcalá de Henares, E-28871 Madrid, Spain.
Phone: 91-8854877; Fax: 91-8854593. E-Mail: josefa.carrascosa@uah.es

limbs, and discover possible differences related to sex in this behaviour.

Such findings would be very useful, not only as regards the understanding of the functional anatomy and biomechanics of the human shoulder, but also regarding its extrapolation and clinical application as a diagnostic, therapeutic rehabilitating, post-traumatism or post-surgery complement (Timm, 1997; Mayer et al., 2000; Vanvelcenaher, 2000). Interesting applications might also spill into the field of sports: muscular assessment, training, sports medicine, etc.

Materials and Methods

Isokinetic analyses were performed on a sample of 40 volunteer young subjects (20 male and 20 female), without no apparent pathology affecting the locomotor apparatus and the right extremity as the dominant limb. The anthropometric variables of both groups are defined in table 2.

The study was carried out in the laboratory for kinetic analysis, at the Department of Morphological Sciences and Surgery of the University of Alcalá.

An electromagnetic dynamometer, Biodex 2000 (v.3.0A), connected to a computer for processing isokinetic variables, was used in the investigation.

The results were analysed by means of the Statgraphics plus 3.1 software.

Given the considerable variability of the subjects, shown by the high standard deviation of our study variables, a strictly systematic data collection was required in order to compare our results with those reported in the literature (Connelly-Maddux et al., 1989; Reid et al., 1989; Cahalan et al., 1991; Shklar and Dvir, 1995). As a consequence, our protocol was rigorous for each subject: warming-up, position, axis alignment, plane of movement performance, gravity correction, number of repetitions and angular speed (Wilk et al., 1991; Carrascosa et al., 1999).

A test of concentric modality, always beginning with the right side, was applied for all subjects.

The warming-up exercises were previously performed with the Biodex system, also useful for familiarizing subjects to this type of muscular work. The first test was performed by each subject at a low speed of 60°/s, repeating the abduction-adduction movement 5 times on the frontal plane and covering an arch of 140°-150°.

After a rest, a speed of 120°/s was selected and the movement was repeated 15 times. Following this, the left limb was evaluated.

A series of isokinetic variables was quantified, from which peak torque and total work were selected (Kannus, 1994; Davies, 1992).

Peak torque represents the highest force produced during the repetitions of each movement tested (N.m). Its result along the angular journey defines work, and total work corresponds to the addition of all works performed for each test repetition (J).

Statistical correlations for the isokinetic variables were calculated, after checking the sample for normal distribution with the Kolmogorov-Smirnov test, showing the correlation coefficient and corresponding regression line equation. Correlations between the isokinetic variables with one another were obtained and likewise correlations of these variables between both upper limbs and the relationships between both speeds (60°/s y 120°/s) and between the abduction and adduction movements were obtained.

Results and Discussion

For either the male or female group, the correlation coefficients (r) between the variables studied —peak torque and total work— were statistically significant, as expected, due to the physical and mechanical nature of both variables (Table 3). However, it is not so common that such correlation coefficients were slightly higher for the female group, pointing to a trend of greater interdependency between the previously variables described.

In fact, on analysing the coefficient of determination (r^2), which represents the % of influence of work upon peak torque or vice versa, it may be seen that in the case of the females, both variables proved to be justified by each other by more than 60%. However, for male abduction at a speed of 60°/s for either the right or left side, it cannot be affirmed that one variable influenced the other by more than 25%, in spite of the statistically significant correlation. The same circunstance was seen in the case of adduction at 120°/s, for the male group on the left side.

For the knee, other authors (Kannus, 1992; Slocker and Gómez-Pellico, 1997) found correlations between these two variables over of more than 0.8, pointing to a strong interrelationship. In our study, a similar behaviour was found for the female group, while for the males there were differences. One interpretation of such differences could be that male peak torque was so high throughout the isokinetic test, that total work (the consequence of all torques along the exercise) proved to be less influenced by it.

Table 1.- Mean values and standard deviation for peak torque and total work.

	MEN		WOMEN	
	Abduction	**Adduction**	**Abduction**	**Adduction**
Speed 60°/s				
Peak Torque				
Right side	56.35 (9.6)	77.63 (12.5)	25.01 (4.2)	34.52 (8.3)
Left side	52.28 (10.7)	64.29 (9.6)	24.02 (5.7)	31.26 (6.0)
Total Work				
Right side	400.59 (85.0)	664.69 (118.1)	197.39 (34.5)	280.19 (67.1)
Left side	337.41 (81.4)	511.57 (93.7)	158.48 (45.2)	255.45 (49.5)
Speed 120°/s				
Peak Torque				
Right side	50.54 (9.4)	75.43 (9.2)	23.98 (3.8)	33.91 (7.9)
Left side	47.75 (10.5)	65.65 (8.4)	21.58 (5.4)	30.45 (6.9)
Total Work				
Right side	851.02 (187.2)	1550.84 (294.7)	385.33 (81.3)	613.43 (172.3)
Left side	747.51 (194.9)	1239.00 (227.5)	294.15 (110.7)	535.08 (151.5)

Table 2.- Mean, standard deviation, maximum and minimum for the anthropometric variables, age, weight and height.

		Age (years)	**Weight** (Kg)	**Height** (cm)
MEN (20)	Mean	19.40	75.43	176.06
	SD	1.7	10.9	6.1
	Max.	25	103	185.0
	Min	18	57	167.0
WOMEN (20)	Mean	19.45	57.48	162.46
	SD	1.1	7.1	6.6
	Max.	23	71.6	173.6
	Min	18	45.6	148.9

Table 3.- Isokinetic correlation coefficients (r) between peak torque and total work.

	MEN				WOMEN			
Peak Torque								
Abduction 60°/s								
Right side	.496 *				.782 ***			
Left side	.563 **				.809 ***			
Abduction 120°/s								
Right side		.776 ***				.865 ***		
Left side		.893 ***				.905 ***		
Adduction 60°/s								
Right side			.824 ***				.862 ***	
Left side			.843 ***				.886 ***	
Adduction 120°/s								
Right side				.726 ***				.834 ***
Left side				.580 **				.873 ***
	T. W. abd.60°/s	**T. W.** abd. 120°/s	**T. W.** add. 60°/s	**T. W.** add.120°/s	**T. W.** abd. 60°/s	**T. W.** abd. 120°/s	**T. W.** add. 60°/s	**T. W.** add. 120°/s

T.W: Total Work. Abd: Abduction. Add: Adduction. * P≤ .050 ** P≤ .010 *** P≤ .001

Table 4.- Correlation coefficients (r) between right and left extremities for each one of the variables (peak torque and total work).

	MEN				WOMEN			
Abduction								
Peak Torque								
60°/s	.792 ***				.862 ***			
120°/s		.827 ***				.863 ***		
Total Work								
60°/s			.882 ***				.869 ***	
120°/s				.909 ***				.879 ***
Adduction								
Peak Torque								
60°/s	.782 ***				.777 ***			
120°/s		.652 **				.820 ***		
Total Work								
60°/s			.792 ***				.783 ***	
120°/s				.794***				.850 ***
	P. T. 60°/s	P.T. 120°/s	T.W. 60°/s	T. W. 120°/s	P.T. 60°/s	P.T. 120°/s	T. W. 60°/s	T.W. 120°/s

P.T: Peak Torque. T.W: Total Work. * P≤ .050 ** P≤ .010 *** P≤ .001

Table 5.- Correlation coefficients (r) between speeds, 60°/s y 120°/s, for peak torque and total work.

	MEN				WOMEN			
Abduction								
Peak Torque								
Right side	.801 ***				.756 ***			
Left side		.643 **				.840***		
Total Work								
Right side			.945 ***				.885 ***	
Left side				.950***				.969 ***
Adduction								
Peak Torque								
Right side	.825 ***				.880 ***			
Left side		.683 ***				.806 ***		
Total Work								
Right side			.882 ***				.908 ***	
Left side				.886***				.879 ***
	P. T. right	P.T. left	T. W. right	T. W. left	P.T. right	P.T. left	T. W. right	T. W. left

P.T: Peak Torque. T.W: Total Work. * P≤ .050 ** P≤ .010 *** P≤ .001

Table 6.- Correlation coefficients (r) for each variable, peak torque and total work, between the abduction and adduction movements.

	MEN				WOMEN			
Right side								
Peak Torque								
60°/s.	.599 **				.690 ***			
120°/s.		.760 ***				.597 **		
Total Work								
60°/s			.681 ***				.789***	
120°/s				.745 ***				.865***
Left side								
Peak Torque								
60°/s.	.585 **				.678 ***			
120°/s.		.537 *				.935 ***		
Total Work								
60°/s			.759 ***				.837 ***	
120°/s				.667***				.872 ***
	P.T. 60°/s	P.T. 120°/s	T.W. 60°/s	T.W. 120°/s	P.T. 60°/s	P.T. 120°/s	T.W. 60°/s	T.W. 120°/s

P.T: Peak Torque. T.W: Total Work. * P≤ .050 ** P≤ .010 *** P≤ .001

On analysing muscular mechanical behaviour during the abduction-adduction movements of the shoulder on the frontal plane, relating right peak torque to the left one, and applying the same procedure to total work, we also found statistically significant correlations between the variables of both sides. This points to a measured muscular increase, balanced between both limbs (Table 4).

In a study on the abduction movement, although with a different methodology, Otis (1992) found interdependences between both extremities for peak torque, which permits one to predict peak torque for one side knowing the other one. Some authors calculate force recovery after shoulder surgery through the percentage of the variables of the uninjured shoulder and, with this as a reference, were able to evaluate improvement (Rokito et al., 1996).

Analysing peak torque angle, some authors found no statistically significant correlations between right and left (Connelly-Maddux et al., 1989).

The correlations of our variables between the speed of 60°/s and 120°/s, also reached high significant and constant dependences at each movement and for each limb (Table 5).

Likewise, high interdependencies of each variable could be observed between the abduction and adduction movements, which appeared constantly and with a high level of statistical significance and high correlation coefficients for peak torque and for total work, at each extremity and each speed (Table 6).

Some studies have analysed correlations between anthropometric variables (weight, height) and isokinetic variables (peak torque), and they have not found constant linear dependencies between them, only isolated ones for one limb or movement (Alderink and Kuck, 1986; Mayer et al., 1994; Carrascosa, 1997).

In sum, our study shows that muscular behaviour in the shoulder joint (for a normal population) has a statistically demonstrable relationship between both sides for adduction-abduction movements. It suggest that when such an interrelationship is altered, due to either traumatic or degenerative reasons, or by muscular hypertrophy (repetition of sport gestures), the functional balance of the scapular girdle will be affected. Such an imbalance could be corrected by functional improvement of the muscular groups, with control and follow-up of the muscular response, relating its adequacy to normal values defined by means of isokinetic tests.

References

Alderink GJ and Kuck DJ (1986). Isokinetic shoulder strength of high school and college-aged pitchers. *J Orthop Phys Ther,* 7: 163-172.

Cahalan TD, Johnson ME and Chao EY (1991). Shoulder strength analysis using the Cybex II isokinetic dynamometer. *Clin Orthop Relat Res,* 271: 249-257.

Carrascosa J (1997). Comportamiento isocinético de los movimientos en el plano frontal del complejo articular del hombro. Tesis doctoral. Universidad de Alcalá de Henares. Madrid.

Carrascosa J, Gomez-Pellico L, Slocker A, Clemente C and Fernandez-Camacho J (1999). Isokinetic handedness in the abduction-adduction movement of shoulder. *Eur J Anat,* 3: 41-49.

Connelly-Maddux RE, Kibler WB and Uhl T (1989). Isokinetic peak torque and work values for the shoulder. *J Orthop Sports Phys Ther,* 11: 264-269.

Davies GJ (1992). Interpretation of isokinetic data as the basis for evaluation, treatment, and discharge. In: *A compendium of isokinetics in clinical usage and rehabilitation techniques.* 4th ed. S&S Publishers, Wisconsin (USA).

Hislop HJ and Perrine JJ (1967). The isokinetic concept of exercise. *Phys Ther,* 47: 114-117.

Kannus P (1992). Normality, variability and predictability of work, power and torque acceleration energy with respect to peak torque in isokinetic muscle testing. *J Sports Med,* 13: 249-256.

Kannus P (1994). Isokinetic evaluation of muscular performance: implications for muscle testing and rehabilitation. *J Sports Med,* 15: 11-18.

Mayer F, Horstmann T, Rocker H, Heitkamp HC and Dickhuth HH (1994). Normal values of isokinetic maximum strength, the strength/velocity curve, and the angle at peak torque of all degrees of freedom in the shoulder. *J Sports Med,* 15: S19-S25.

Mayer F and Dickhuth HH (2000). Diagnostics with isokinetic devices in shoulder measurements: potencials and limits. *Isokin and Exer Sci,* 8: 24.

Otis JC, Warren RF, Backus SI, Santner TJ and Mabrey JD (1990). Torque production in the shoulder of the normal young adult male. The interaction of function, dominance, joint angle, and angular velocity. *Am J Sports Med,* 18: 119-123.

Reid DC, Oedekoven G, Kramer JF and Saboe La (1989). Isokinetic muscle strength parameters for shoulder movements. *Clin Biomech,* 4: 97-104.

Rokito AS, Zuckerman JD, Gallagher MA and Cuomo F (1996). Strength after surgical repair of the rotator cuff. *J Shoulder-Elbow Surgery,* 5: 12-17.

Shklar A and Dvir Z (1995). Isokinetic strength relationships in shoulder muscles. *Clin Biomech,* 10: 369-373.

Slocker A and Gomez-Pellico L (1997). Prediction of work and power from the peak torque in an isokinetic study of flexo-extension of the knee. *Eur J Anat,* 1 (Suppl. 1): 30.

Timm KE (1997). The isokinetic torque curve of shoulder instability in high school baseball pitchers. *J Orthop Sports Phys Ther,* 26: 150-154.

Vanvelcenaher J (2000). Isokinetics and chronicle low back pain: Principles of an objective evaluation and of the rehabilitation program. *Isokin Exer Sci,* 8: 25-26.

Wilk KE, Arrigo CA and Andrews JR (1991). Standardized isokinetic testing protocol for the throwing shoulder. The throwers' series. *Isokin Exer Sci,* 1: 63-71.