ANALYSIS OF THE ISOKINETIC TORQUE CURVES IN SHOULDER MOVEMENTS

LOCOMOTOR APPARATUS IN EXERCISE AND SPORTS

ORIGINAL ARTICLE

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ABSTRACT

The torque curve of an isokinetic evaluation provides indication about muscular performance and possibly deficit in the evaluated subject. However, automatic reports supplied by isokinetic systems may produce equivocated data and interpretations errors. Thus, the purpose of this study was to analyze the isokinetic torque curve, identifying at which point of the curve speed becomes constant according to the performed test. Moreover, it assesses if the maximum peak torque (MPT) is within the protocol stabilization. Swimming athletes (n=10) were evaluated at the isokinetic dynamometer Kin-Com® 125 AP. The athlete was requested to perform the maximum concentric (CC) - eccentric (EE) contraction in the movements of internal (IR) - external rotation (ER), flexion (FL) - extension (EX) and horizontal abduction (AB) - adduction (AD) of shoulder, 120°/sec and supine position. The Matlab 6.0 and Origin 6.0 softwares were used to process the curves. In the IR-ER movements in CC-EE contractions, considered more stable and with a lower lever arm, the speed remained constant in the range of 5 to 98% of the curves; For FL-EX and horizontal AB-AD movements, considered more unstable and with higher lever arms, the constant speed was observed between 10 to 98% of the curves. The movements of concentric IR and EX and concentric-eccentric FL and horizontal AB-AD, the MPT was concentrated in the first third of the isokinetic curve, which requires attention in the processing of the torque values. In the FL-EE, 80% of the MPT values were outside of the pre-set speed, requiring reprocessing, which would not occur in the reports automatically supplied. We suggest the disposal of the 5% initial and final torque curves for shoulder rotation movements and 10% for FL-EX and horizontal AB-AD in order to obtain more reliable interpretations of peak torque and acquisition of the true muscle condition.

Keywords: torque, shoulder joint, data analysis, muscle contraction, biomechanics.

INTRODUCTION

In order to evaluate muscular function it is useful to use an instrument which enables the generation of quantitative, objective, valid and reliable data, such as the isokinetic dynamometer[1-5]. Isokinetic dynamometry provides a fast quantitative analysis of many parameters of the muscular function including the peak torque, torque at specific angle, work, power and endurance indices[5,6]. It quantifies the mentioned variables as well as the functional deficit through a large scale of angle velocities[5-7]. Among all these variables, the peak torque presents the highest representativeness in research and clinics[5], in the evaluation of athletes[12] or different pathological conditions[13-16].

The graphic representation of an isokinetic curve exposes the behavior of the muscle during the articular activity and can be obtained in any movement degree such as torque, peak torque and other important variables, such as work and the antagonist/agonist ratio[1,7,8,17]. The evaluator will be able to structure more coherently the bouts of complementary conditioning for any period of the training or rehabilitation macrocycle[5], based on the deficit information on the specific angle from the results obtained with the isokinetic test.

The isokinetic exercise consists of the forced movement of a limb at constant angle velocity[6]. The equipment used for this aim works on the action and reaction principle and allows the use of the muscular capacity in the entire range of motion[18]. The steady angle velocity is obtained with the use of a digital servo-motor controller[6] and at steady angle velocity. The resistance will accommodate the muscle according to the movement arch[1]. There is a velocity stabilization period which enables the reach of the maximum peak torque (MPT) in the pre-set isokinetic velocity. When the subject tries to move the limb faster than the pre-set velocity, the systems does not allow it. Therefore, the strength applied is returned as accommodative resistance[1]. In that situation, maximum torques may be generated preceding the stabilization period of the velocity and movement, generating misinterpretations on the evaluated subject, especially when the data automatically provided by the isokinetic systems are analyzed, a common practice in the issue of reports. Crucial technical information in the torque curves such as the correct articular alignment, the instrument calibration and factors of gravitational correction limit the number of accurate scientific studies which bring valid normative data[13]. Thus, this study aims to evaluate the isokinetic torque curve of swimming athletes, identifying at which point of the curve the velocity becomes steady according to the parameters of the test. Moreover, to verify if the maximum peak torque is within the stabilization phase of the protocol in movements of the shoulder joint.

MATERIAL AND METHODS

The sample of this study was composed of swimming athletes (n = 10), volunteers, male, mean age of 16.3 ± 1.2 years, and shoulder osteomiarticular integrity of the dominant and non-dominant limbs. The anthropometric data with mean and standard deviation (± SD) values were: mean body mass of 68.1 ± 5.5kg, mean height of 175.5 ± 4.7cm and mean wingspan of 180.4 ± 5.7cm. This research was developed in agreement with the Ethics Committee for Research in Humans of the UDESC under the protocol number 100/2001.

Data collection instrument

The instrument used in the data collection was the isokinetic dynamometer Kin-Com® AP-125 which has three primary sources to collect: A) information which indicate the strength applied by the subject; B) the measure point and reference of the velocity parameter; and C) angle values in relation to the positioning of the lever arm. The load cell of the instrument is responsible for the continuous and immediate monitoring of the strength applied and the corresponding resistance. An electronic integrator placed in series with a recorder or monitor provides the record of the force applied in a given period of time.

Data collection procedure

After the anthropometric measures, the athletes performed stretching and warm-up of upper limbs in cycle ergometer, without load, for five minutes. They were placed in dorsal decubitus for performance of the movements of flexo-extension and horizontal abduction and adduction with extended elbows, and internal and external rotation with elbow flexion at 90º. Familiarization with the equipment and comprehension of the movement anteceded the data collection, as well as the strength direction through submaximal trials. Maximal voluntary contractions were asked in the concentric--eccentric activities, angle velocity of 120°/s. The trials were performed on the dominant limb, with three repetitions being evaluated in the overlay mode for each movement, and all repetitions were analyzed. A laser pointer was used in the alignment of the mechanical and biological axis of the equipment (figure 1). Authors[1,6,19,20] have demonstrated the importance of good articular alignment at the moment of evaluation, and the relative error[20] in the axis by articular disalignment is of 10% and can generate a torque relative error of also 10%.

The 120°/s velocity is considered an intermediate velocity[21] and was selected due to the unstable characteristic of the shoulder joint, facilitating the performance of the chosen movements. Since the subjects were athletes, the fast acceleration and deceleration mode was selected, which reflects the characteristic of the movement control of the evaluated subject.


Figure 1. Laser pointer used in the articular and mechanical axis alignment.

STATISTICS

Descriptive statistics with mean and percentage values was used. The Matlab 6.5 and Origin 7.5 softwares were used for calculation of the torque curve variability.

RESULTS

The internal and external rotation movements (IR and ER) are considered the steadiest movements within the analyzed ones due to the interaction of the rotator cuff[4] and smaller lever arm muscles. Thus, in the concentric and eccentric activities, the velocity was steady according to the parameters of the protocol in the 5 to 98% of the curve interval. Its beginning (0 to 5%) represents the acceleration period until reaching the pre-set velocity, and at the end (98 to 100%), the deceleration of the movement (figure 2).

In 16.7% of the subjects in the IR movement, in the concentric activity, the MPT was found outside the isokinetic curve. Thus, there was the need of a second processing so that it was found in the selected velocity. However, for the same movement, 66.7% of the MPT were found in the initial 5% of the curve. Concerning the ER concentric and eccentric activities, 53.3% of the MPT were concentrated on the mean third of the curve (table 1), which guarantees reliability in the values obtained and only 3.3% of the MPT were outside the isokinetic curve for the two activities.

Generally speaking, in the internal and external rotations, eccentric contraction, the peak torques were within the curve of isokinetic velocity, since rotation is the shoulder movement with smallest range of motion, smallest lever and steadiest positioning in the isokinetic evaluation amongst the selected ones.

Considering the mean and standard deviation (± SD) of the beginning of the stabilization of the isokinetic velocity (on a scale from 0 to 100% of the movement) in the concentric and eccentric activities, it was observed that: during the horizontal AB 6 ± 2.4% and AD 5.7 ± 3.4%, FL 5.5 ± 2.2% and EX 4.6 ± 2.1% in the concentric activity and horizontal AB 3.3 ± 3.6% and EX 3.4 ± 2.5% eccentric, the velocity was steady according to the parameters of the protocol in the mean interval with values between 6 and 98% of the curve. For the movements of horizontal AD 9.6 ± 9.5% and FL 8.7 ± 6.5% eccentric, the mean of the velocities was steady in the interval from 10 to 98% of the isokinetic torque curve, being considered movements of greater instability. In 20% of the repetitions, the velocity stabilization in the FL and eccentric horizontal AD occurred after the 20% initial of the curve (figure 2).

Concerning the MPT location in the torque curves in the shoulder flexion movements during the three repetitions, in 33.3% of the cases the MPT in the concentric activity were found outside the selected velocity (acceleration and deceleration phase of the movement); for the eccentric activity, 80% of the MPT values were outside the isokinetic velocity pre-set of 120°/s.

Concerning the shoulder extension, the MPT values in the concentric activity were very reliable, since in none of the trials the MPT was located outside the pre-set velocity; however, in the eccentric activity, 23.3% of the values should be reprocessed again and agree with the curves whose torque was located in the initial third of the movement (table 1).

As can be seen in table 1, for the FL-EX and horizontal AB-AD movements, the MPT are concentrated on the initial third of the isokinetic curve, which require more care in the processing of the

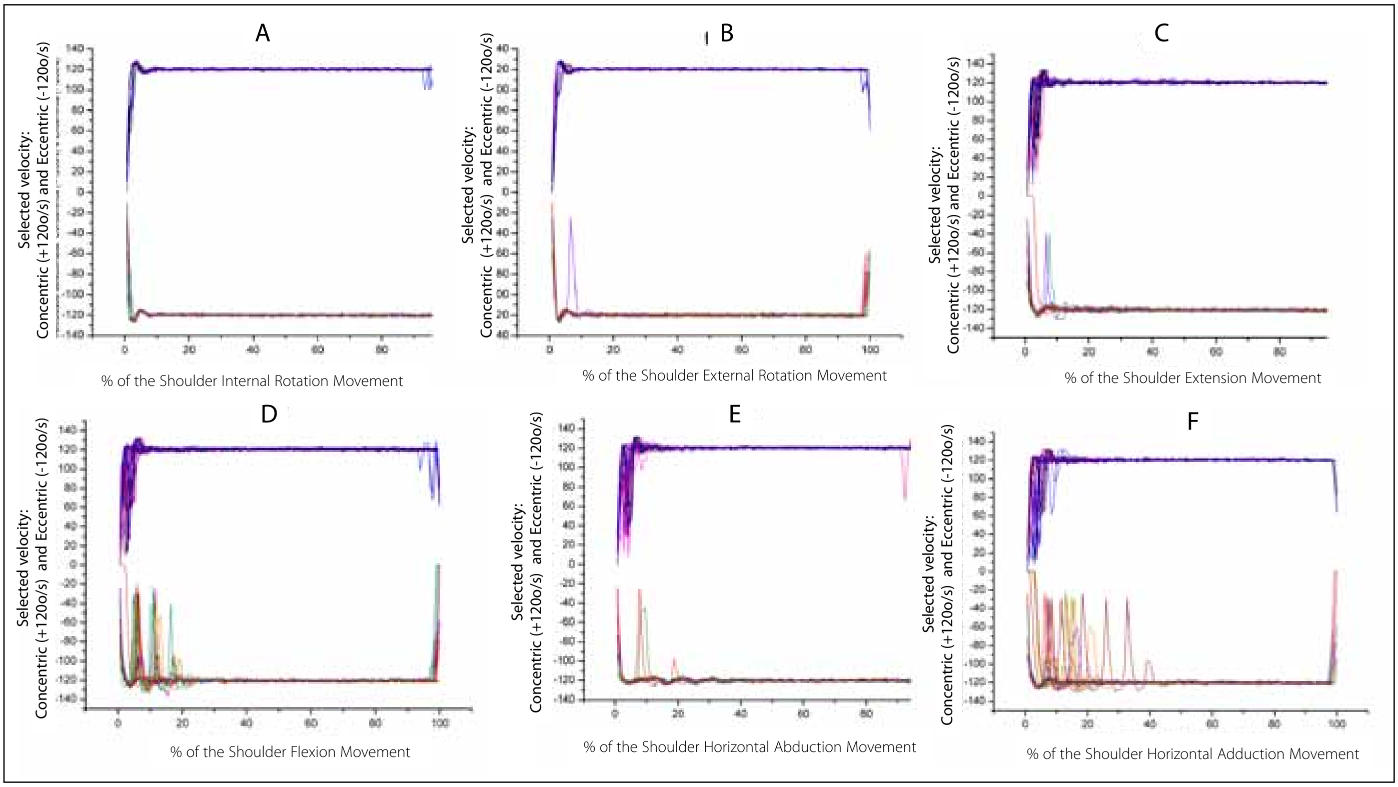

Figure 2. Representative curves of the stabilization of the isokinetic velocity selected in the protocol (120º/s), in the shoulder internal (A) and external rotations (B), extension (C) and flexion (D), horizontal abduction (E) and horizontal adduction (F)movements, 30 repetitions for each activity – concentric (1) and eccentric (2), from 0 to 100% of the performed movement.

Table 1. Location of the MPT in the initial, mean and final thirds of the isokinetic curve*.

	IR		ER		FL		EX		AB		AD	
	Conc	Exc	Conc	Exc	Conc	Exc	Conc	Exc	Conc	Exc	Conc	Exc
Initial MPT	100%	-	33.3%	6.7%	80%	86.7%	66.7%	23.3%	90%	76.7%	90%	70%
Mean MPT	-	36,7%	53.3%	53.3%	10%	3.3%	30%	66.7%	-	-	-	3.3%
Final MPT	-	63,3%	13.3%	40%	10%	10%	3.3%	-	10%	23.3%	10%	26.7%

* IR and ER movements (internal e external rotations), FL and EX (flexoextension) and shoulder AB and AD (horizontal abduction-adduction) in the concentric (Conc) and eccentric (Exc) activities.

torque values. Only in the eccentric extension, the greatest distribution of the maximal torque values was found in the mean third of the curve.

23.3% and 20% of the MPT that were found outside of the isokinetic velocity, respectively, were observed for the concentric activity of the shoulder abductors and adductors. In the eccentric activities for the same movements, three repetitions, 16.7% and 56.7% of the MPT, respectively, are outside of the isokinetic curve.

DISCUSSION

It is possible to detect through the isokinetic evaluation the point of muscular weakness in the range of motion, besides the identification of the structural integrity of the joints and sustaining structures. It is crucial to favor the standardization and coherent processing of data concerning the muscular strength for accuracy in the determination of the torque values[5,6,19,21]. Within this perspective, the study of the graphic tracing of the obtained torque curve becomes essential[1,19].

In an unstable joint, as the shoulder one, especially in movements with the long lever arm (flexo-extension, horizontal abduction and adduction), the lack of reproducibility of functional movements, possible errors generated by the inadequate alignment of the biological axis to the axis of the equipment [6,20] and "gaps" present in the lever arms of the measuring instruments are generators elements of misinterpretations. In the movements with short lever arm, as in the shoulder rotations, the acceleration and deceleration periods of the movement are steadier, generating more reliable data. In spite of that, in 16.7% of the concentric IR movements, the MPT was concentrated outside the isokinetic curve.

A great amount of MPT can be observed outside the pre-set speed with this study, especially for movements with the long lever arm, which would generate misinterpretation errors of the evaluated subjects, in case subsequent processing of the curve was not performed.

Deslandes *et al.*[6] created a virtual model with analytical analysis followed by a numerical simulation capable to preview the measure errors of the joint torques due to the dislocation of the rotation centers between the segment of the ergometer body and arm. Since the dislocation is present, the errors increase due to the influence of the inertia, gravity, limb stiffness caused by the attachment of belts, friction effects and so on. These effects may increase the torque error, especially when dislocation occurs (isokinetic exercise). The model presents a maximal relative error of 11%, for relative dislocation of 10% of the rotational centers. Such aspects corroborate that care should be taken with the patient positioning, the equipment handling and data processing. Horstmann and Kranemberg[17], who studied the reproducibility of the torque peaks in the shoulder joint, found lower reproducibility, and big variability can be reached in the comparison between the shoulder joint and knee joint, depending on the range of motion and exercise mode chosen.

In tests with the LIDO-Active 2.1 controlled servo-motor iso kinetic dynamometer, Handel *et al.*[22] verified continuous torque records during the entire movement, regardless of the differences between real and expected velocity. The user was not informed about which torques had been recorded outside the isokinetic velocity, corroborating the data of this study. Therefore, misinterpretations occur due to the attribution of maximum torques for the velocity measures outside the established protocol due to the accelerations involved. Careful methodology should be used in the interpretation of torques and angle velocities provided by the dynamometer especially in faster velocities and in movements of broader amplitudes[19,23].

The results of this study demonstrated that for all the analyzed movements, despite the fact that the sample has been composed of healthy athletes due to their better coordination and movement control, MPT were found outside the pre-set isokinetic velocity. More evident instability in the torque curves was observed in movements with longer lever arm, as in the flexion and adduction and especially in the eccentric contractions, since during the strength production, the muscle fibers are stretched, which demands greater control of the movement[19]. It means that the use of automatic reports provided by the equipment may lead to the intrinsic risk of misinterpretations of the provided results.

This study has as limitation the analysis of a joint at specific positions, in only one isokinetic equipment despite the similar characteristics. Nevertheless, given suggestions in this study can be applied to any instrument.

When subjects with considerable functional deficits and lower coordination of movement are evaluated, the data should be analyzed in distinct perspectives: comparison of the contralateral side and the affected one, study of the alterations in the curve during the time and individual analysis of the graphic tracing to avoid errors in the identification of abnormal patterns in the curves. Especially in rehabilitation, individuals with lower muscular balance will present more difficulty to move the lever arm of the equipment and in maintenance of the alignment of the biological and mechanical articular centers, requiring careful interpretation of the presented data. It is important to define the parameters for the data processing to reach reliable results in order to avoid difficulties to compare them with the literature.[1,6,19,22]. In evaluations of subjects with high level of compromising and difficulty in movement control, it is interesting to analyze each curve individually.

CONCLUSION

In the evaluation of the isokinetic torque curve of shoulder movements of swimming athletes, the internal and external rotations, within the positions evaluated in this study, are the steadiest, with shortest lever arm, and therefore, the ones which offer the most reliable values with the presence of the MPT within the pre-set velocity. However, the cut of the 5% initial and final of the isokinetic torques curve is suggested since velocity stabilization was found from 5 to 98% of the torque chart, and in 16.7% of the movements in concentric RI the MPT was outside the chosen velocity.

For movements composed of long lever arms and amplitude (flexo-extension and horizontal abduction-adduction) and which demand higher motor control, the cut of the 10% initial and final of the isokinetic curve is suggested, since velocity stabilization was found from 10 to 98% of the torque chart. Despite the fact that athletes had been evaluated due to their better movement coordination and muscular control, in the eccentric flexion movement, 80% of the MPT values were outside the expected angle velocity, which means that this movement requires special attention in the data processing.

All authors have declared there is no potential conflict of interests concerning this article.

REFERENCES

1. Jiménez FH, Díaz JG, Montes JV. Técnicas instrumentales de diagnóstico y evaluación en rehabilitación. Dinamometría isocinética. Rehabilitación 2005;39:288-96
2. Fonseca ST, Ocarino JM, Silva PLP, Bricio RS, Costa CA, Wanner LL. Caracterização da performance muscular em atletas profissionais de futebol. Rev Bras Med Esporte 2007;13:143-7.
3. Vilaseca JC, Figuera RG. Aplicaciones clínicas de las pruebas biomecánicas: mitos y realidades. Rehabilitación 2010;44:195-8.
4. Edouard P, Beguin L, Fayolle-Minon I, Degache F, Farizon F, Calmels P. Relationship between strength and functional indexes (Rowe and Walch-Duplay scores) after shoulder surgical stabilization by the Latarjet technique. Ann Phys Rehabil Med 2010;53:99-105.
5. Kannus P. Isokinetic evaluation of muscular performance: implications for muscle testing and rehabilitation. Int J Sports Med 1994;15:11-8.
6. Deslandes S, Mariot JP, Serveto S. Offset of rotation centers creates a bias in isokinetics: A virtual model including stiffness or friction. J Biomech 2008;41:2112-20.
7. Zakas A, Mandruoukas K, Vamvakoudis E, Christoulas K, Aggelopoulou N. Peak torque of quadriceps and hamstring muscles in basketball and soccer players of different divisions. J Sports Med Phys Fitness 1995;35:199-205.
8. Sonza A, Frassetto D, Andrade MC, Machado DB. Avaliação isocinética do equilíbrio muscular agonista e antagonista do ombro em atletas de natação. Fisioter Bras 2002;3:356-62.
9. McMaster WC, Long SC, Caiozzo VJ. Shoulder torque changes in the swimming athlete. Am J Sport Med 1992;20:323-7.
10. Ellenbecker T, Roetert EP. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. J Sci Med Sport 2003;6:63-70.
11. Hadzic V, Sattler T, Markovic G, Veselko M, Dervisevic E. The isokinetic strength profile of quadríceps and hamstrings in elite volleyball players. Isokinet Exerc Sci 2010;18:31-7.
12. Weber FS, Silva BGC, Radaelli R, Paiva C, Pinto RS. Avaliação isocinética em jogadores de futebol profissional e comparação do desempenho entre as diferentes posições ocupadas no campo. Rev Bras Med Esporte 2010;16:264-8.
13. Middleton P, Trouvé P, Puig P; Savalli L. Intérêt de l'evaluation musculaire isocinétique excentrique dans la pathologie de l'épaiile du sportif. Progr Med Phys Readapt 1997;2:43-7.
14. Aubry JF, Petrel K, Rose E. Évaluation et renforcement musculaire isocinétique en neurologie centrale. Kinesither Rev 2009;(89):45-50.
15. Missaoui B, Rakotovao E, Bendaya S, Mane M, Pichon B, Faucher M, et al. Posture and gait abilities in patients with myotonic dystrophy (Steinert disease). Evaluation on the short-term of a rehabilitation program. Ann Phys Rehabil Med 2010;53:387-98.
16. Nestor BJ, Toulson CE, Backus SI, Lyman SL, Foote KL, Windsor RE. Mini-midvastus vs standard medial parapatellar approach: a prospective, randomized, double-blinded study in patients undergoing bilateral total knee arthroplasty. J Arthroplasty 2010;25:5-11.
17. Horstmann F, Kranemberg K. Reproducibility of isokinetic peak torque and angle at peak in the shoulder joint. Int J Sports Med 1994;15:167-72.
18. Davies GJ. A compendium of isokinetics in clinical and rehabilitation techniques. 3 rd ed. Wisconsin: 5 e 5 Publishers, 1987.
19. Williamson SC, Hartigan C, Morgan RF, Stamp WG, Chung JK, Edlich RF. Computerized analysis of isokinetic torque curves for muscle strengthening. J Burn Care Rehabil 1989;10:160-6.
20. Reimann U, Verdonck AJ, Wiek M. The influence of a joint displacement on torque, angle and angular velocity during isokinetic knee extension/flexion. Theoretical considerations. Isokinet Exerc Sci 1997;6:215-21.
21. Davies GJ, Heiderscheit B, Brinks K. Test interpretation. In: Brown L, editor. Isokinetics in human performance. Champaign: Human Kinetics, 2000.
22. Handel M, Dickhuth HH, Mayer F, Gülch RW. Prerequisites and limitations to isokinetic measurements in humans. Investigations on a servomotor-controlled dynamometer. Eur J Appl Physiol Occup Physiol 1996;73:225-30.
23. Taylor NA, Sanders RH, Howick EI, Stanley SN. Static and dynamic assessment of the Biodex dynamometer. Eur J Appl Physiol Occup Physiol 1991;62:180-8.