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STRETCH-SHORTENING CYCLE OF SHOULDER INTERNAL ROTATORS AS MEASURED BY ISOKINETIC DYNAMOMETRY

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SUMMARY

The ability to measure the stretch-shortening cycle of isolated muscle groups is limited. The purpose of this study was to measure the stretch-shortening cycle of shoulder internal rotators. Sixty-eight volunteers, 35 men and 33 women, participated in the test session. A concentric contraction of the dominant internal rotator was measured for peak torque, power and acceleration time on a Cybex NORM isokinetic dynamometer under three conditions: 1) Concentric contraction only, 2) Isometric preload before a concentric contraction, and 3) Eccentric preload before a concentric contraction. Condition 3 displayed significant increase in peak torque production compared to condition 1 ($p<0.001$). Conditions 2 and 3 revealed significant increase in power production compared with condition 1 ($p<0.0001$ and $p<0.003$ respectively). A significant difference was found in all three conditions between genders, with the men producing higher peak torque and power scores.

Keywords: Stretch-shortening cycle, isokinetic dynamometry, shoulder, internal rotators.

ÖZET

OMUZ İNTERNAL ROTATORLARI GERİLME-KISALMA SİKLÜSÜNÜN İZOKİNETİK DİNAMOMETRİ İLE ÖLÇÜMÜ

İzole kas gruplarının gerilme-kısalma siklüsünün ölçüm imkanı sınırlıdır. Bu çalışmanın amacı omuz internal rotatorlarının gerilme-kısalma

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siklüsünü izokinetik dinamometri ile ölçmekti. Otuzbeş erkek ve 33 bayandan oluşan toplam 68 gönüllü denek bir defalık teste tabi tutuldular. Dominant internal rotatorun konsantrik kasılması zirve tork, güç ve ivmelenme süresi parametreleri açısından bir Cybex NORM izokinetik dinamometresinde üç değişik kasılma protokolü ile ölçüldü: 1) Sadece konsantrik kasılma, 2) Konsantrik kasılmadan önce izometrik ön yükleme, ve 3) Konsantrik kasılmadan önce eksantrik ön yükleme. Üçüncü durum birinci duruma oranla zirve tork değeri açısından anlamlı artış gösterdi ($p<0.001$). İkinci ve üçüncü durumlar birinci duruma göre güç çıktısı açısından anlamlı ölçüde yüksek değerler sağladılar (sırasıyla $p<0.0001$ ve $p<0.003$). İki cins arasında her üç durumda da anlamlı fark gözlenirken, erkekler daha yüksek zirve tork ve ve güç değerlerine ulaştılar.

Anahtar sözcükler: *Gerilme-kısalma siklüsü, izokinetik dinamometri, omuz, internal rotatorlar.*

INTRODUCTION

Exercise to train or rehabilitate a muscle group should be designed to reproduce the type of contraction that the muscle group undertakes in a functional activity. The stretch-shortening cycle (SSC) is a natural component of muscle function in many daily activities. The cycle involves an initial lengthening of the muscle through an eccentric contraction (stretch), followed by a shortening of the muscle through a concentric contraction (shorten). Higher torque values are achieved in the latter phase than compared to pure concentric muscle action. Examples of SSC within daily activities abound for every joint of the body, and the most obvious one is probably muscle function around the knee and ankle during gait (14).

The ability to measure this type of muscle contraction in a clinical setting is limited. Many sport and work activities require powerful movements of the upper body. Although explosive power has been extensively studied in lower body activities such as vertical jumping (3,5,8,11), scarce research examined such movements occurring in the upper body. No studies, however, have reportedly used an isokinetic dynamometer to measure the SSC of the internal rotators.

The purpose of this study was to use the Cybex NORM isokinetic dynamometer to measure the SSC of the internal rotators. This was accomplished by comparing the peak torque and power of a concentric

contraction of the shoulder internal rotators of men and women under three conditions: 1) a concentric contraction with no preload, 2) a concentric contraction preceded by an isometric preload, and 3) a concentric contraction preceded by an eccentric preload. The concentric contraction preceded by an eccentric preload was expected to produce the greatest peak torque and power.

MATERIAL and METHODS

Subjects: Sixty eight healthy and sedantery volunteers, 33 women and 35 men, were recruited. Subjects were 19-35 years of age with no current dominant upper extremity pathologies, neurological problems, or other conditions that could be aggravated by the testing protocol or confound the test results. Descriptive statistics of the subjects are reported in Table 1. The subjects signed an informed consent form approved by the Institutional Review Board of the Use of Human Subjects in Research of the Gülhane Military Medicine Faculty. They were requested to refrain from unusual activities or vigorous exercise 24 hours before their testing session.

Instrumentation: The reliability and validity of Cybex NORM has been favorably demonstrated in several studies (7,9). The Cybex NORM was arranged according to the guidelines in the user's manual for measurement of shoulder internal/external rotation in a position of 45°of abduction (6). The dynamometer was calibrated at the start of each session. Each subject was placed supine with the dominant arm abducted to 45°, with 90° of elbow flexion, and standard stabilization strapping was placed across the distal thigh, waist, and chest. Hand placements were limited to grasping the waist stabilization strap.

Table 1. Descriptive statistics for the subjects.

	Age, yrs	Body weight, kg	Height, cm
• All subjects (n=68)			
Mean ± SD	22.2 ± 4.0	66.9 ± 11.6	172.8 ± 9.0
Range	17-37	47-96	158-191
• Men (n=35)			
Mean ± SD	23.5 ± 3.4	75.4 ± 8.8	179.6 ± 6.5
Range	18-35	60-96	167-191
• Women (n=33)			
Mean ± SD	20.7 ± 4.2	57.9 ± 6.0	165.5 ± 4.6
Range	17-37	47-78	158-178

Procedure: A practice session was performed for all subjects before the testing session to familiarize them with the Cybex NORM and the test conditions. The testing session consisted of dominant shoulder internal rotation contractions with the Cybex NORM. The dominant arm was defined as the arm the subject used for hand-writing or soft-ball throw. The shoulder was passively external rotated from 50° of internal rotation to 80° external rotation with the lever arm at a speed of 90°/s. The subject was instructed about three conditions: 1) concentric contraction of the internal rotator muscle group from 80° of external rotation to 50° of internal rotation, 2) the lever arm paused for 1 second at 80° of external rotation, while the subject started an isometric contraction and continued that contraction concentrically as the lever arm moved into 50° of internal rotation, and 3) as the lever arm moved from 50° of internal rotation to 80° external rotation, the subject initiated an eccentric contraction between approximately neutral position (0°) to 80° external rotation and then continued with a maximal concentric contraction as the lever arm moved back into 50° of internal rotation.

Before the testing session started, the subject was allowed a 5 minute warm-up at a light intensity (less than 600 kpm) on a Cybex UBE (Lumex Inc, Ronkonkoma, NY) adapted for upper body exercise, followed by a 30-second stretch of the internal and external rotators. The internal rotators were selected as the muscle group to be tested because of the relationship between their power and an individual's throwing speed (2). All of the tests were performed by the same investigator. Subjects were instructed to give 100% effort and received positive feedback during testing. Subjects were allowed three submaximal contractions of the internal rotators at the beginning of the test condition to familiarize with the test conditions. Each subject performed five maximal contractions in each test condition. Between each condition, a one minute rest was given. The best peak torque and power output of the five test contractions in each test condition were considered for data analysis.

Acceleration time: On a Cybex NORM dynamometer, it is possible to control the rate at which the action arm accelerates from the starting angle up to the preset velocity during any activity. The acceleration time of the concentric phase is defined as the time interval between the beginning of the concentric phase and the point of the concentric phase where the preset velocity is reached.

Data analysis: The Cybex NORM software program provided the measures of peak torque, power and acceleration time. Descriptive

statistics of the means, standard deviations, and ranges were determined for each of the three measures in the three conditions. One-way analysis of variance for repeated measures was used to assess differences among the three conditions for each measure. Tukey's test for post hoc analysis was then used on each significant one-way ANOVA. The Kruskal-Wallis test was used to determine differences between genders for the three measures and the three test conditions, when data were nonhomogenous. The Mann-Whitney U-test was then used on each significant Kruskal-Wallis test to examine the differences among the conditions for each measure for men alone and then for women alone. The level of significance for all statistical analysis was set at $p<0.05$. Then, Bonferroni correction for multiple testing yields a critical value of $p=0.05/3$ ($p<0.0167$).

RESULTS

Descriptive statistics of each measure for all subjects, for men alone and for women alone, for the three conditions: 1) concentric alone, 2) with isometric preload and 3) with eccentric preload are reported in Table 2.

Table 2. Peak torque (Nm) and power (W) scores in three conditions: 1) concentric alone, 2) with isometric preload, and 3) with eccentric preload.

	Concentric alone		Isometric preload		Eccentric preload	
	PT	Power	PT	Power	PT	Power
• All subjects (n=68)						
Mean ± SD	36.3 ± 16.8	33.4 ± 16.9	41.0 ± 18.4	34.7 ± 15.9	44.7 ± 18.3	45.6 ± 22.0
Range	16.0-83.0	5.8-72.9	17.0-86.0	13.5-72.9	24.0-88.0	17.6-93.1
• Men (n=35)						
Mean ± SD	49.3 ± 12.3	46.8 ± 12.0	56.0 ± 12.2	46.8 ± 12.1	59.5 ± 12.5	63.9 ± 14.2
Range	31.0-83.0	28.1-72.9	37.0-86.0	28.1-72.9	39.0-88.0	42.1-93.1
• Women (n=33)						
Mean ± SD	21.7 ± 3.5	19.0 ± 4.4	24.6 ± 3.0	21.4 ± 4.6	28.5 ± 3.1	25.7 ± 4.8
Range	16.0-31.0	5.8-29.2	17.0-32.0	13.5-32.9	24.0-35.0	17.6-41.6

ANOVA for peak torque for the men alone displayed significant differences among the three conditions ($p=0.004$). Post hoc analysis revealed a significant difference between condition 1 and condition 3 only ($p=0.003$). ANOVA for peak torque values for women alone showed significant differences among the three conditions ($p=0.0001$). Post hoc analysis revealed significant differences between conditions 1 and 3 ($p=0.0001$), 1 and 2 ($p=0.002$), and 2 and 3 ($p=0.0001$). ANOVA for power output for

men alone displayed significant differences among the three conditions (p=0.0001). Post hoc analysis revealed significant differences between conditions 1 and 3 (p=0.0001), and 2 and 3 (p=0.0001) only. ANOVA for power output for women alone showed significant differences among the three conditions (p=0.0001). Post hoc analysis revealed significant differences between conditions 1 and 3 (p=0.0001), and 2 and 3 (p=0.001).

The Kruskal-Wallis test (N=68) displayed significant difference between the men and women for peak torque (p=0.002). Post hoc analysis revealed a significant difference between conditions 1 and 3 only (p=0.001).

For the acceleration time, at 90°/s there was no significant difference between the angles of the shoulder at which the set speed was reached when comparing pure concentric action with concentric action after eccentric or isometric action.

The ANOVA test (N= 68) showed no significant difference between the men and women for the acceleration time among the three conditions. Acceleration times for 90°/s for men were as follows: 73.4 ms for pure concentric action; 65.7 ms for concentric action preceded by isometric action; and 43.0 ms for concentric action preceded by eccentric action. Acceleration times for women were as follows: 140 ms for pure concentric action; 123 ms for concentric action preceded by isometric action; and 110 ms for concentric action preceded by eccentric action (Figure 1).

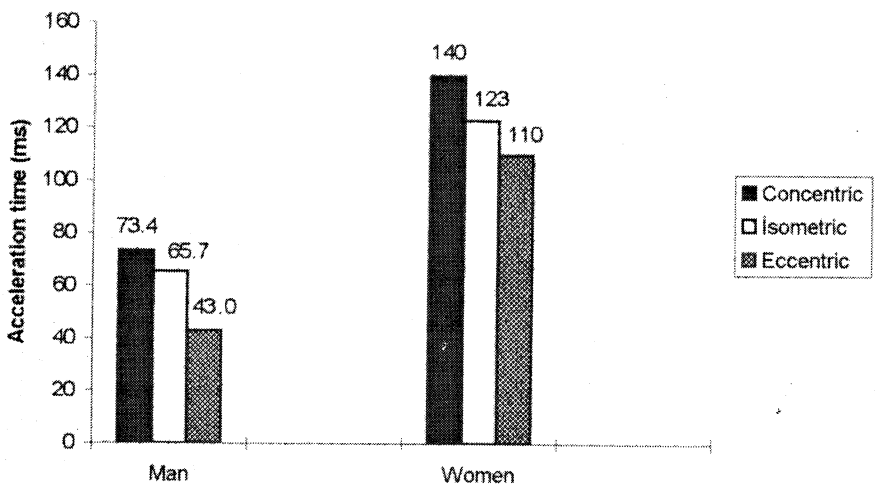

Figure 1. Acceleration times for internal rotator muscles group during pure concentric action (■), concentric action after isometrik action (□) and concentric action after eccentric action (▨). Mean values are given.

For all subjects, the increase in torque between a pure concentric action and a concentric action preceded by an eccentric muscle action was, on the average 23.1 %, and when preceded by an isometric muscle action, 13.0 %. These figures were 20.0 % and 13.6 % for men only, and 31.3 % and 13.4 % for women only, respectively. For all subjects, the increase in power between a pure concentric action and a concentric action was 36.5 % on the average when preceded by an eccentric muscle action, and 3.9 % when preceded by an isometric muscle action. These respective figures were 36.5 % and 0 % for men, and 35.3 % and 12.6 % for women.

DISCUSSION

Results obtained in this study revealed a significant increase in concentric peak torque during the eccentric preload condition compared with the concentric contraction with no preload for the shoulder internal rotators. The isometric preload condition resulted also in greater concentric peak torque than the concentric contraction alone. This concurs with studies of Svantesson et al. (15) who also found an increase in concentric force production after an eccentric preload of the ankle plantar-flexors. A study by Helgeson et al. (8) has shown higher concentric torque values after preceding eccentric and isometric muscle actions.

In contrast to studies where only peak torque was analyzed using dynamometer (8,9,15,16), both peak torque and power were analyzed in this study. Several studies have demonstrated a high correlation (r=0.75-0.99) between peak torque and power (1,10). These findings suggest that peak torque is representative of power. No studies, however, have analyzed power using an isokinetic dynamometer to measure the SSC of the internal rotators. In our study, together with the finding that eccentric preload of the internal rotators increased the power production of the concentric contraction of the muscle group; the isometric preload condition also resulted in greater concentric power than the concentric contraction alone.

Investigation (4,8,12,15) has supported the theory that the stretch phase of the cycle augments the force output during the shortening phase. The results obtained in this study also supported the theory.

Svantesson et al. (16) found in the ankle plantar flexor muscle group that acceleration times for 120°/s were 240 ms for pure concentric action, and 110 ms for concentric action preceded by isometric and

eccentric actions. Acceleration times for 90°/s in this study for men were 73.4 ms for pure concentric action, 65.7 ms for concentric action preceded by isometric action, and 43.0 ms for concentric action preceded by eccentric action. Acceleration times for women were 140 ms, 123 ms, and 110 ms, respectively. The results suggested that acceleration time was faster with the isometric and eccentric preload conditions both for men and women, with women having longer times than men. Time to peak torque and acceleration time is an important consideration in activities requiring speed and power. So, time to peak torque and acceleration time may be considered an artificial measure of isokinetic dynamometry and lead to important data to researchers to evaluate postoperation rehabilitation processes.

Significant differences were found between the men and women for peak torque and power. This is expected because of the larger body sizes of the men. The current study revealed that women had a 31.3 % increase in peak torque for the eccentric preload condition and 13.4 % increase for the isometric preload condition compared with the concentric contraction alone. The men had 20.0 % and 13.6 % increases in peak torque, respectively. This finding provides an indication to the fact that women may utilize stored elastic energy more efficiently than men during the eccentric preload condition. When we analyzed power output for the three conditions, we found that men had a 36.5 % increase in power for the eccentric preload condition and 0 % for the isometric preload condition compared with the concentric contraction alone. Women had 35.3 % and 12.6 % increases in power, respectively. This indicates that women may utilize stored elastic energy more efficiently than men during isometric preload conditions, in terms of power.

Men had significant differences between peak torque and power for the concentric contraction alone and for the isometric or eccentric preload conditions. The eccentric preload condition yielded the greatest mean peak torque and power. This concurs with the higher fast twitch muscle composition in the internal rotator muscle group in men (13), permitting them to generate greater torque more quickly than women. Women displayed a significant difference between the concentric contraction alone and eccentric preload conditions for peak torque and power. As with the men, the acceleration time was also significantly faster in the preload conditions for the women subjects.

There were no significant differences in peak torque and power between concentric action alone and concentric action preceded by

isometric action for men and women. Most likely, the storage of elastic energy will take place to a greater extent in the situation with the muscle stretching (eccentric action) than in the situation with shortening of the sarcomere length (isometric action). In addition, parallel elastic components (PEC) are stretched in the eccentric but not the isometric action. The time for the preceding muscle action may also have an effect on the capacity to utilize stored elastic energy, as slow-twitch and fast-twitch muscle fibres differ in their capacity to store elastic energy.

A limb velocity of 90°/s was used in the current study, and this was fast enough to produce the SSC, but probably too slow to be considered a functional speed, displayed in activities such as throwing. The given velocity of the lever arm was selected for subject safety concerns and to enhance the ability to reproduce the testing protocol. Faster velocities of eccentric preloading may be needed in order to compared with functional activities.

To conclude, the current study indicated that the SSC of the internal rotators can be measured by isokinetic dynamometry, and it revealed significant increases in the peak torque and power of a concentric contraction for the internal rotator muscle group of the shoulder, when followed by eccentric or isometric preloads. As a result, this testing protocol could be used to compare internal rotator muscle performance on an isokinetic dynamometer with functional activities such as throwing. It may also be useful for measuring changes in isolated muscle groups following a plyometric training program. This testing method may give further insight into the mechanisms of stretch-shortening cycles.

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