HIP JOINT POSITION DURING KNEE EXTENSION AND QUADRICEPS FORCE PRODUCTION AND EMG ACTIVATION

Posición de la articulación de la cadera durante la extensión de la rodilla y la producción de la fuerza del cuadriceps y la activación del EMG

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RESUMEN

The assessment of muscle strength is an important parameter for the performance exam in physiotherapy as it is a mean of diagnosis, prognosis, treatment planning and evaluation of physiotherapeutic interventions. Objective: This study aimed to determine the best hip position to produce the maximum moment of muscle strength and its relationship with the electromyographic (EMG) signal. Participants: The study design included the participation of 30 healthy subjects, corresponding to 60 lower limbs of both sexes, aged between 18 and 22 years without restriction to the practice of physical activity. Methodology: The experimental protocol consisted in gathering surface electromyography information of three portions of the quadriceps muscle and of the peak moment of force during isometric contractions. The task consisted of knee extension in a fixed position of 5° of flexion at three angular positions of the hip, 25°, 55° and 85° against an external resistance offered by isokinetic dynamometer Biodex System 3 Pro. Results / Conclusion: It was found that a greater quadriceps strength is produced at 25° of hip flexion. It was observed that from all portions assessed only the rectus femoris was influenced by the variation of the joint position of the hip, showing a greater EMG signal percentage at 25° of hip flexion. In this position the relationship EMG / force had also higher values.

Key words: Muscle strength, electromyographic activity, position the hip joint; quadriceps

ABSTRACT

The assessment of muscle strength is an important parameter for the performance exam in physiotherapy as it is a mean of diagnosis, prognosis, treatment planning and evaluation of physiotherapeutic interventions. Objective: This study aimed to determine the best hip position to produce the maximum moment of muscle strength and its relationship with the electromyographic (EMG) signal. Participants: The study design included the participation of 30 healthy subjects, corresponding to 60 lower limbs of both sexes, aged between 18 and 22 years without restriction to the practice of physical activity. Methodology: The experimental protocol consisted in gathering surface electromyography information of three portions of the quadriceps muscle and of the peak moment of force during isometric contractions. The task consisted of knee extension in a fixed position of 5° of flexion at three angular positions of the hip, 25°, 55° and 85° against an external resistance offered by isokinetic dynamometer Biodex System 3 Pro. Results / Conclusion: It was found that a greater quadriceps strength is produced at 25° of hip flexion. It was observed that from all portions assessed only the rectus femoris was influenced by the variation of the joint position of the hip, showing a greater EMG signal percentage at 25° of hip flexion. In this position the relationship EMG / force had also higher values.

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INTRODUCTION

The assessment of muscular force assists the clinician to establish a differential diagnosis, determining the muscular disability, so that therapeutic measures are applied to minimize or abolish the decrease of the function [(1)] or even increase it. Physical therapists have been especially involved in the development of accurate methodologies to assess the muscle strength [(1)].

The manual muscular test (MMT) is a simple and routinely used in clinical practice with no need of sophisticated equipment. It´s a subjectively rated from 0 to 5 points based on the ability to move the tested body segment member against gravity and against manual resistance applied by the examiner [(2)]. The quadriceps muscle group is a complex structure, favorable to injury which is often affected in the clinical setting.

Therefore, it is important to define the best hip joint position for the quadriceps muscle group to produce maximum muscle strength so that an accurate assessment

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of this muscle is performed and a rehabilitation program established. The instrumental gold measure for muscle function is the isokinetic dynamometer. The advantage of its use is the ability to evaluate separately the weakened muscle groups throughout the range of motion with controlled speed. It allows to quantify the maximum moment strength (peak torque), power and work [(2, 3, 4)].

Although EMG doesn't measure directly muscle strength it shows the muscle electrical activity [(5)] which is a strong sign of the force developed in the contraction since it depends on neural excitation supplied [(6, 7)].

Several authors, Kendall et al., 1971; Currier, 1977; Bohannon, 1986; Carvalho et al., 2007; Kong et al., 2010 [(8, 9, 10, 11, 12)] had measured the maximum force production and EMG of the quadriceps at different angular positions of hip, but the findings have been contradictory.

The present study aims to clarify the best hip position to develop the highest quadriceps force and its relationship with quadriceps EMG signal on the knee extension.

METHODS

The study carried out, the analysis of force production in knee extension with different hip flexion positions is a cross-sectional study. Sample consisted of 30 healthy subjects of both genders (10 males; 27 females), aged between 18 and 22 years (18.80 ±0.92), height between 1.54 and 1.79m (165 ±0.06), weight between 45.50 and 101.50Kg (64.28 ±13.08) and BMI between 19.20and 31.84 kg.m-2 (22.84 ±5.70); corresponding to 60 lower limbs with no restrictions on physical activity. All subjects with any quadriceps injury, or that had lower limb injury within the six months prior to data collection or any pathology that could compromise the tests, or were under medication with muscle effects were excluded.

The experimental protocol, consisted in collecting the EMG signal of three parts of the quadriceps muscle and the peak moment of force applied during the performance of isometric contractions in knee extension. The task consisted of knee extension in a fixed position of 5° of flexion at three hip angular positions, 25°, 55° and 85°, against an external resistance offered by isokinetic dynamometer Biodex System 3.

A clinical evaluation was performed looking for postural changes and muscle shortening (Psoas iliac, rectus femoris, biceps femoris). A warming up consisting in 20 repetitions of marching parade, 10 lunges, squats 5 reps for 5 seconds and 5 squat jumps was performed in order to prepare them for the effort [(2, 10, 12, 13, 14)]. When in the isokinetic the subject performed three maximal contractions of the quadriceps at each position of the hip joint, for 5 seconds with 10 seconds rest between repetitions and 60 seconds between each hip position. The subjects were verbally and visually encouraged to perform maximum strength [(12 - 14)]. To avoid lack of flexibility to influence on testing all subjects were submitted to iliopsoas and rectus femoris extensibility Thomas test [(15)] and popliteal angle was also measured to check for hamstring flexibility. To assure the maintenance of the hip angular positions during the isokinetic tests a camera (EXLIM Casio EX-FH20), was recording at 210Hz frequency, placed perpendicular to the isokinetic dynamometer.

Surface EMG at sampling frequency of 1000 Hz was collected from Rectus Femoral, Vast External and Vast Internal [(12, 13)] with a BioPluxReasearch unit (PLUX, Lisbon, Portugal). After cleaning the skin to reduce impedance bipolar electrodes were placed with 20 mm center-to-center distance (Al/AgCl, disk shape 10 mm Blue Sensor Ambu ® N -00- S).

On the isokinetic dynamometer Biodex System 3 subjects were stabilized by two straps cross on the trunk, one on the pelvis, one on the distal test thigh and one immediately above the malleolus [2, 10, 12, 13, 14]. The test was performed with the arms crossed over the chest and 5° of knee flexion [12]. The order of hip positions was set randomly to decrease study vies and to avoid fatigue effects.

EMG signals were subjected to a digital filter (10-490 Hz), full wave rectified, smoothed with a low-pass filter (Butterworth, 12 Hz, 4th order) and normalized in amplitude using the reference obtained during maximal voluntary contraction (MVC) of the muscles studied in muscle testing position (around 90° hip flexion and knee extension) which corresponds to the peak EMG signal obtained. A 100ms average window was used around peak EMG signal. EMG data was processed through Matlab® (Mathworks Inc., Natick, Massachusetts, USA) self-developed routines. Kinovea version 0.8.15 was used for kinematic analysis of the hip angle.

The sample characterization was performed using descriptive statistics, using the average and standard deviation. Analysis of variance (ANOVA) was used to evaluate differences between hip positions for the studied variables and the Bonferroni test, after verification of variables normality and homogeneity with the Kolmogorov-Smirnov test with Lilliefors correction and Levene [16], for comparison between groups. The significance level was set at 5% for all tests. Statistical analysis was performed using SPSS Statistics 21.0 software (IBM Corporation, New York, USA).

RESULTS

The data obtained for quadriceps strength produced on isokinetic and maximal EMG signal percentage for Vastus Medial, Vastus Lateral and Rectus Femoris is summarized in Table 2.

Table 1. Quadriceps peak Torque and maximal EMG signal percentage for Vastus Medial, Vastus Lateral and Rectus Femoris.

Hip position /variable		N	Min	Max	Mean	Standard deviation
25º Flexion	Quadriceps force (N)	60	12.75	99.05	42.05	18.81
	maxVM_EMG (%)	57	35.08	183.62	92.87	33.57
	maxVL_EMG (%)	59	33.30	174.05	92.74	26.84
	maxRF_EMG (%)	59	58.68	496.96	123.27	73.86*
55º Flexion	Quadriceps force (N)	60	18.78	88.74	41.25	17.75
	maxVM_EMG (%)	60	46.77	194.07	95.89	32.96
	maxVL_EMG (%)	58	49.37	149.50	93.05	20.17
	maxRF_EMG (%)	60	46.91	345.53	114.50	50.45*
85º Flexion	Quadriceps force (N)	60	17.29	96.38	37.81	18.65
	maxVM_EMG (%)	60	53.35	103.15	93.10	10.93
	maxVL_EMG (%)	60	69.99	105.59	93.79	8.76
	maxRF_EMG (%)	60	59.77	100.12	93.59	9.46*

*statistical differences found on maximal EMG signal % for Retus femoris between 85º and 25º of hip Flexion (p=0.01) and 85º and 55º of hip Flexion (p=0.09)

Hip flexion of 25° is the position where a greater force is produced and the one where the rectus femoris shows a higher maximum EMG percentage. The myoelectric activity mean percentages of vastus medialis and lateralis didn't oscillate significantly in all three positions. Only the rectus femoris is influenced by the variation of the hip joint position and a higher EMG activity is achieved at 25° and 85° of hip flexion. A statistical significant difference for Rectus femoris maximal EMG activity is found between 25° and 85° of hip.

DISCUSSION

This study aimed to find the position where quadriceps produces higher force. 60 lower limbs of healthy subjects were assessed. The results show that it is in the position of greatest lengthening of the biarticular rectus femoris muscle, 25° of hip flexion where a greater EMG activity is found.

This same position is also where highest values for maximum force production of the quadriceps muscle group is achieved. This findings may be related with the fact that in external contraction amplitude muscle actin-myosin fibers are in greater elongation and hence have greater potential for shortening. Another possible reason for this result is the role of Psoas Iliac on hip stabilization. Not to disregard is also the possible involvement of other muscles when extending the knee with 25° of hip flexion.

The magnitude of the force generated by a muscle is related to the length in which the muscle is maintained [5]. The ideal length to generate muscular tension is slightly greater than the length at rest because contractile components are producing tension at an optimal level and passive components are storing elastic energy and increasing total tension in the unit. This relationship favors the idea of placing the muscle in a stretching position before starting the muscle contraction. In isometric muscle is activated but keeps the same length, and the production of muscle strength depends on the number of cross-bridges formed, the greater the number formed, the greater the muscle force produced.

Vastus lateralis and medialis do not show significant differences concerning maximal EMG activation. In the study of Correa [17] that aimed to determine which joint angles it is possible to obtain a greater isometric force production and increased EMG on vastus medialis, rectus femoris and vastus lateralis when contacting with different knee extension positions. The 10 sample subjects were positioned sitting with the hip at 110° and the knee at 0° (full extension), 60° and 90°. Three maximal contractions were performed in each position for a period of five seconds and a five minute break between tests has been given. Authors concluded position didn´t affect significantly vastus lateralis and medialis EMG activation as in the present study.

Newman et al. studied [18] the influence that knee angle position and muscle length had on maximum force production and EMG activation. 8 subjects in an isokinetic dynamometer performed isometric knee extension in 10°, 30°, 50°, 70°, 90°, 110° knee positions with a 90° hip flexion. The EMG signal was collected by an electrode placed immediately above the insertion of the vastus lateralis. They didn't find any significant differences in muscle activation at different muscle lengths. Ottoni et. al. (2004) studied vastus lateralis and medialis EMG behavior in knee extension maximal isometric contraction for knee angular positions 150°, 165° and 180° and they had not found any significant difference between the angles.

The authors Shenoy et. al. obtained the opposite results when assessing the influence of different knee joint angles during a maximal voluntary isometric contraction with EMG activity and peak torque of the vastus medialis [19], vastus lateralis and rectus femoris muscles. In a sample of forty healthy subjects (20 men, 20 women), the peak torque and the EMG signal in the dominant leg were measured at 30°, 60° and 90° knee angular positions with the hip positioned at 110° flexion during a 10 second contraction. They found significant differences in EMG activity for the vastus medialis at all angles, with maximum activity at 60° of knee flexion followed by 90° and 30°.

Their findings also contradict to the author Kong et. al. [12] whose outcomes showed that monoarticular and biarticular portions had higher activation values in a sitting position, followed by inclined and lying. In contrast are the findings of Hasler et. al. [20] that obtained a greater vastus externalis EMG signal in extreme positions 90 ° and 180 ° and vastus medialis in a sitting position. Regarding the rectus femoris, Correa et. al. [17] outcomes show that a 90° knee angle is the most appropriate to assess this muscle maximum activation since it is more elongated, which is accordance with our findingswhere rectus femoris shows a greater EMG signal at 25° of hip flexion where it is has the greatest lengthening.

In contradiction the authors Silva and Chilibeck [21, 22] state that when muscle shortening is increased, greater recruitment of motor units occurs to assist the production of maximum force and the greater EMG signal. Our Findings are also in disagreement with the conclusions reached by Maffiuletti et. al. [23] that found a greater EMG activation in a sitting position (90°) while in our study there is a greater activation in the lying position (25°).

Like in our study Kong et. al. [12] states that hip extension is the position with high EMG values for rectus femoris. However Carvalho et. al. [11] didn't find any influence of the hip angular position on EMG activation.

Concernig the maximal Force production our study findings are in agreement with the conclusions reached by previous studies that the production of maximum force is influenced by the position of the hip joint. These findings are similar to those of Bandy et. al. [24] who applied a program training isometric to the quadriceps with different angles of knee flexion - 30°, 60°, 90° with the hip positioned at 110° of flexion and intended to check their influence on the muscle strength and EMG activity. They concluded that the force production was higher when muscle was in greatest lengthening, stating that an effective method for increasing the strength of isometric knee extension and EMG activity throughout the range of motion involves training the quadriceps in a position of greater elongation.

Correa et. al. [17] reported that with the hip positioned at 110°, muscle strength in knee extension is higher and similar to each other in positions 60° and 90° when compared to 0°, suggesting that in 60° there is great mechanical advantage. The authors Bohannon and Currier et al. [9, 10] also reported a higher force production on a position of maximum hip extension which is in accordance with the findings of our study that reveal greater force production in lying position.

Disagreement of this statements is found by Carvalho et. al. [11] that reported that from five positions studied (180°, 140°, 110°, 100°, 900°) the 110° position, with a slight inclination, was the one that produced greater muscle strength, which is consistent with the conclusions reached by Pavol et. al. [25] when they stated that the averages force moments generated by the knee extension at different starting angles were higher with the hip flexion at 80° than in full extension.

CONCLUSION

The present study investigated quadriceps strength and EMG activity during isometric knee extension in order to determine the best angular position of the hip to obtain a higher force production and consequently a higher EMG signal. Thus, based on the assessment to the extensor muscle group of the knee with the hip positioned at different angles relative flexion - 85 °, 55 ° and 25 ° - and the knee held in a position of 5° of flexion was possible to conclude that the quadriceps had the highest moment of force at the position of 25° of hip flexion; the largest percentage of EMG signal was found in rectus femoris muscle with the hip joint positioned at 25° of flexion; the relationship EMG / force showed higher values in position 25° of hip flexion. From our results in healthy young people it is suggested, therefore this position as the most suitable for evaluating the muscular strength of the quadriceps, as well as showing an increased mechanical advantage for increasing muscular strength in this muscle group in a process of physical recovery, regarding the position of the hip joint.

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