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## ORIGINAL

### DOES THE "SIT AND REACH" TEST MEASURES FLEXIBILITY? A CASE STUDY

### ¿EL TEST "SIT AND REACH" MIDE LA FLEXIBILIDAD? UN ESTUDIO DE CASOS

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## ABSTRACT

The aim of this study was to determine muscular activity during the Sit and Reach development. Two subjects were selected, one with hamstring shortness (S1) and the other without hamstring shortness (S2). Sit and Reach test was developed and superficial electromyography and hip angle were measured.

Results shows that linear and angular values are higher in S2. In both subjects electromyographic activity got increased in anterior and posterior muscles. Only dorsal lumbar activity decreased in S2.

We can conclude that Sit and Reach test measures agonist muscles strength and antagonist muscles resistance to stretching.

**KEY WORDS:** Electromyography, goniometry, eccentric contraction, extensibility, stretching, resistance to stretching, nervous tension.

## RESUMEN

El objetivo de este estudio es determinar la activación de la musculatura implicada en la ejecución del test sit and reach. Se ha seleccionado un sujeto con cortedad isquiosural (S1) y otro sin ella (S2). Se ha realizado el test sit and reach, electromiograma superficial y medición del ángulo de la cadera.

Los resultados obtenidos son que los valores lineales y angulares son mayores en el sujeto sin cortedad isquiosural (S2), la actividad electromiográfica durante la ejecución del test sit and reach (SR) de la musculatura anterior se incrementa, que únicamente disminuye la actividad electromiográfica de la musculatura sacrolumbar del sujeto S2 y que la actividad electromiográfica del resto de la musculatura posterior se incrementa.

Por lo que el test sit and reach mide linealmente el resultado de la fuerza que genera la musculatura agonista responsable de la ejecución del test y la resistencia al estiramiento que oponen los músculos antagonistas.

**PALABRAS CLAVE:** EMG, goniometría, contracción excéntrica, extensibilidad, elongación, estiramiento, resistencia al estiramiento, tensión del tejido nervioso.

## INTRODUCTION

In the field of physical activity, one of the most employed lineal tests to measure flexibility is the Sit and Reach test (SRT). Despite it has been used during several years, there is still controversy regarding its objective.

Originally, Wells and Dillon designed the test to measure back and lower limb flexibility (Wells & Dillon, 1952). Heyward defined flexibility as the joint ability to move fluently on its range of movement (ROM) (Heyward, 2008).

The Sit and Reach test (SR) one of the most employed lineal test to measure flexibility on the field of Physical Activity. It has been used in several cases to measure the total body flexibility (Koebel, Swank, & Shelburne, 1992). Wells and Dillon (1952) proved that the test is suitable for the back and the lower limbs regions. Jackson and Backer (1986) and Arregui (2008) declared that the test measures mainly hamstring flexibility, and that the lumbar region is secondary. Jackson y Langford (1986) said that the SR test was suitable to measure hamstring flexibility in men and women, and the lumbar region in men. Heyward (2008) pointed that the ACSM and the CSEP recommended this test to measure lumbar and hamstring flexibility.

Laubach y McConville (1966a, 1966b) indicated that the SR test was more reliable than other simple test to measure the trunk flexion flexibility, either in young or in adults.

Liehmonh et al (1994) said that the hamstring elongation was directly related to the signals obtained in the SR test. Magnusson et al. (1997) developed a flexibility program and used the SR test and electromyography (EMG) to determine muscular actions. They concluded that the test measures hamstring flexibility. There were no significant differences between hamstring shortness (n=10) and no hamstring shortness (n=9) subjects. Simoneau (1998) concluded that SR test was a hamstring flexibility test. Hui et al (2000, 1999) indicated that all the SR versions were moderately reliable to measure hamstring flexibility.

George et al (1996) considered that SR test measured lumbar, hip extensors and knee flexors flexibility.

Cornbleet y Woolsey (1996) carried out the SR test and also measured the hip angle in adolescent. They established that girls reached better scores than boys and this difference was significant. Both the SR test and the hip angle measurement correlated ( $R= 0,76$ ;  $p<0,005$ ). Baltaci et al (2003) compared different SR test versions (SR, ChairSTR, BSSR). They measured the hip angle with a goniometer, and developed the passive straight-leg-raise test. Both test correlated in the left ( $r=0,63$   $p<0,01$ ) and the right leg ( $r=0,53$   $p<0,01$ ).

López Miñarro et al (2009) compared traditional SR test and backsaver sit and reach (BSSR) with the passive straight-leg-raise test in men and women. Results showed that SR test had an stronger correlation than BSSR test with

the pelvic angle in the passive straight-leg-raise test ( $r=0,66$  to  $0,76$  in women;  $r=0,51$  to  $0,59$  in men). Mier 2011 said that SR test correlated moderately with the passive straight-leg-raise test in women but not in men. Ayala et al (2011) considered that SR test correlate moderately with the passive straight-leg-raise test in professional indoor soccer women but not in men. López-Miñarro et al (2011) proved that the subjects that obtained the higher scores in the passive straight-leg-raise test (more than  $86^{\circ}$ ) had a better correlation in the lineal test than the lower scores ones (less than  $76^{\circ}$ ). Muyor et al (2012) asserted that the higher scores (more than  $86^{\circ}$ ) obtained by young athletes in the passive straight-leg-raise test are not related with the dosal spine, but the lower values (less than  $76^{\circ}$ ) were related with a higher thoracic kyphosis and the pelvic retroversion.

Marques et al (2009) showed that the increase in the hamstring extensibility could be related with the tolerance for stretching instead of with the flexibility increment. Owing to Halbertsma & Göeken (1994) and Shrier & Gossal (2000), increments in the range of movement after a one week flexibility program are due to the less muscle resistance to the movement. This could explain the reduction in the EMG activity.

Chillon et al (2010) asserted that in the SR test, the hip angle explains the 42% of the final result; the lumbar angle, the 30%; and the dorsal angle, the 4%. And affirmed that either the BSSR or the SR test are valid to measure hip and lumbar flexibility in adolescents.

In this study, the SR test was selected following the EUROFIT protocol. The 0 value is placed at 15 centimeters before the foot buttress (Committee of experts on sports research, 1988).

As it has been showed in the studies, there is a lack of studies comparing SR test and electromyography (EMG) results. There is little information about the real muscle function during this test. The objective of this study is to measure the muscles activity during the SR test performance. EMG scores and hip angle will be registered in the initial and final position of the test.

## METHODS

### Selection and description of participants

A simple case study with two different young subjects was developed. Subject 2 was a 32 year old woman without hamstring shortness. Subject 1 was a 27 year old man with hamstring shortness. Weight, height, arm-span, seated height, and skinfolds were acquired as anthropometric characteristics from each subject. They are shown in table 1. Hamstring shortness was measured using the “straight leg test” (Santonja & Martinez, 1992) (Santonja, Ferrer, & Martínez, 1995). To carry out the test, the subject was located lying supine on a stretcher with a long arm goniometer attached to facilitate the measurement. The hip was in a neutral position and the femur throchanter was aligned with the goniometer. The evaluator raised up one of the subject’s leg until it lost the straight alignment (figure 1). In this position, a hip angulation under 70 degrees from the horizontal plane indicates hamstring shortness (Santonja & Martinez, 1992) (Santonja, et al., 1995).

### Measurement of muscle electromyography

Before starting the electromyography assessment (EMG), a permanent marker was used to determine electrode location point on the skin. The procedure followed was the palpation of each muscle during manually resisted contractions, outlining its length and belly according to information available from anatomical atlas, and signing the middle of the muscle belly, as it has been explained in previous research (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000; Rainoldi, Melchiorri, & Caruso, 2004).

Myoelectric signals were detected from each muscle using the SX230 EMG sensor (Biometrics Ltd.). The portable data logger had dimensions 10x5x2 cm, including a battery and a memory card. It has eight integral electrodes with a fixed electrode distance of 20mm. The amplifier input impedance was of >10.000.000 MOhms, which means in practice that little or no skin preparation and no conducting gels are required because quality of the recorded signal is absolutely high for both static and dynamic applications. The logger can simultaneously record two types of analog inputs (electrical goniometry and EMG). The samples were digitized and stored on a personal computer by Bluetooth.

Electrodes were positioned on the location point previously marked on the skin and oriented parallel to the muscle fibers, following the recommendations of Rainoldi et al (2003). Electromyographic activation measurement was developed in each repetition of the test by pair of muscles (agonist and antagonist) and in the right and left side of the body simultaneously. The electrical goniometer was fixed on the right side of the hip. In figure 2 it is illustrated the goniometer location and the electrodes placement for the tibialis anterior and medialis gastrocnemius.

The following muscles were measured: tibialis anterior, medialis gastrocnemius, rectus femoris, biceps femoris, semitendinosus, gluteus maximus, rectus abdominal, dorsal lumbar, latissimus dorsi, pectoral major, upper trapezius, biceps and triceps longitudinal.

### **Seat and Reach test procedures**

Once all the electrode location point were marked, with the electrodes placed in the first right and left pair of muscles to assess and the goniometer fixed to the hip, the Seat and Reach test was carried out.

Prior to the test, a warm up period was followed. It consisted of three different exercises. In the first one, the subject on a standing position had to bend the waist trying to touch the floor with the hands. The same movement was realized in the second exercise, but crossing one leg in front of the other. The third one consisted of trying the Seat and Reach test in a seated position. Five repetitions of ten seconds were developed for each exercise. This procedure has been established elsewhere (Sanz Arribas, 2002, 2003, 2011).

For the test performance, the subject was placed seated on the floor with the legs stretched, barefooted, and with the soles of the foot attached to the Seat and Reach case. Case dimensions were 35x45x32 centimeters. A slide rule was attached at the top of the case with the 0 at 25 centimeters from it.

In the initial position, S2 had the trunk stretched on the vertical plane with the head aligned, and the arms stretched on the front with one hand over the other (figure 3). It was necessary to modify the initial position in S1, setting the arms behind the back with the hands on the floor (figure 4). From this position, the subject had to lean forward trying to reach the case with the hands. Knee flexion was not allowed during the movement. The final position has to be maintained during 3 seconds. The centimeters reached in the test were also measured. Subjects 1 and 2 final positions are shown in figures 5 and 6. Wells and Dillon (1952) guidelines has been followed to develop the test.

To make data collection easier, and having on account that the execution velocity doesn't modify electromyography results (Cramer, et al., 2002; Jeon, Trimble, Brunt, & Robinson, 2001), the test performance was standardized for both subjects in three phases. Phase 1 was the initial position. Phase 2 corresponded with the lean forward movement. And phase 3, with the final position. Each one was 3 seconds long in order to register the muscles activation during the same time. The phase duration was controlled by the evaluator.



**Table 1.** Anthropometric characteristics of the subjects.

Hamstring shortness	Gender	Age (years)	Height (m)	Weight (kg)	BMI (Kg/m <sup>2</sup> )	Arm-Span (m)	Seated Height (m)	Body fat (%)
S2	No	Woman	32	1,63	54	20,20	1,67	25,85
S1	Yes	Man	26	1,57	56	22,71	1,61	10,57

BMI = body mass index.

Body fat= obtained using biceps, triceps, subscapularis and spraspinal skinfolds.



**Figure 1.** Straight leg test.



**Figure 2.** Goniometer and electrodes location.



**Figure 3.** Seat and Reach. Initial and final position. S2.



**Figure 4.** Seat and Reach. Initial and final position. S1.

## RESULTS AND DISCUSSION

Results and discussion have been unified in this paragraph. In the first part, flexibility results are presented. In the second part, the muscle activation is analyzed.

### Flexibility

The subject with hamstring shortness, S1, arrived at 13,2 cm with a hip flexion of 57,4° in the Sit and Reach test. While S2 reached 25,2 cm with a hip flexion of 74,8° (Table 2). Hip flexion was measured since the middle frontal plane in anatomical position.

Following the AAHPERD the normal measure for the Sit and Reach test is of 25 cm with a hip flexion of 80°, for every age and not having on account anthropometric values (Cornbleet & Woolsey, 1996). Baltaci et al (2003) obtained a mean value of 21,9 cm for young women. Chillon et al (2010) found that hip angle explains the 50% of the score in adolescents. In this way we can assure that S2 had a normal flexibility and S1 had a poor flexibility.

**Table 2.** Centimeters and goniometer results.

	<b>Sit and Reach test</b>	<b>Hip flexion angle</b>
<b>S1</b>	13,2 cm	57,4°
<b>S2</b>	25,2 cm	74,8°

## Muscle activation

To make easier the understanding of the results obtained in our study, these have been grouped according to each subject: S2 and S1, and dividing the anterior and posterior muscles. Only the more relevant muscles are shown.

In S2, posterior muscles were grouped as follows: Group 1: biceps femoris, semitendinosus, gluteus maximus, dorsal lumbar, triceps longitudinal. Group 2: latissimus dorsi. Group 3: upper trapezius. In S1, posterior muscles were divided in: Group 1: biceps femoris, semitendinosus, upper trapezius and triceps longitudinal. Group 2: gluteus maximus and dorsal lumbar. Group 3: latissimus dorsi.

Anterior muscles analysis were grouped as follows in S2: Group 1. Rectus abdominal (upper and lower portions) and rectus femoris, Group 2. Pectoral major, Group 3. biceps longitudinal. And in S1: Group 1. Rectus abdominal (upper and lower portions), Group 2. Pectoral major and rectus femoris.

### **S2 Posterior Muscles:**

*S2, Group 1: biceps femoris, semitendinosus, gluteus maximus, dorsal lumbar, triceps longitudinal.*

Those muscles increased their activity from the start to the end of the movement, decreasing slightly in the last test phase (Figure 5). This behavior means that there is a resistance to be stretched during the movement producing a limitation of it, surely because of the higher stress generated. Probably muscles stretched and activated at the same time will limit the test results.

We consider that the more representative muscle is biceps femoris, which keep the lower activation in the first phase (0,0015 mv) to experiment a sixfold increase during the movement (0,00935 mv), maintaining it at the moment of maximal stretching (0,00895 mv).

On the other hand, dorsal lumbar muscle had the same behaviour than the other muscles, but the activation decrease in the last phase is higher (Phase1: 0,0056mv; Phase2: 0,006mv; Phase 3: 0,00325mv). This may be due to the higher elongation obtained in the last test phase, owing to the higher forward tilt of S2. The trunk weight, arms extended forward and flexed neck cause a torque increase of the lumbar region. Gravity force and the traction of the flexor muscles help this to occur and cause the muscle relaxation preventing injuries.

Biceps femoris and semitendinosus are not as relaxed as the dorsal lumbar muscle in the last test phase. It seems that they are not as affected by the "trunk hiperflexion".

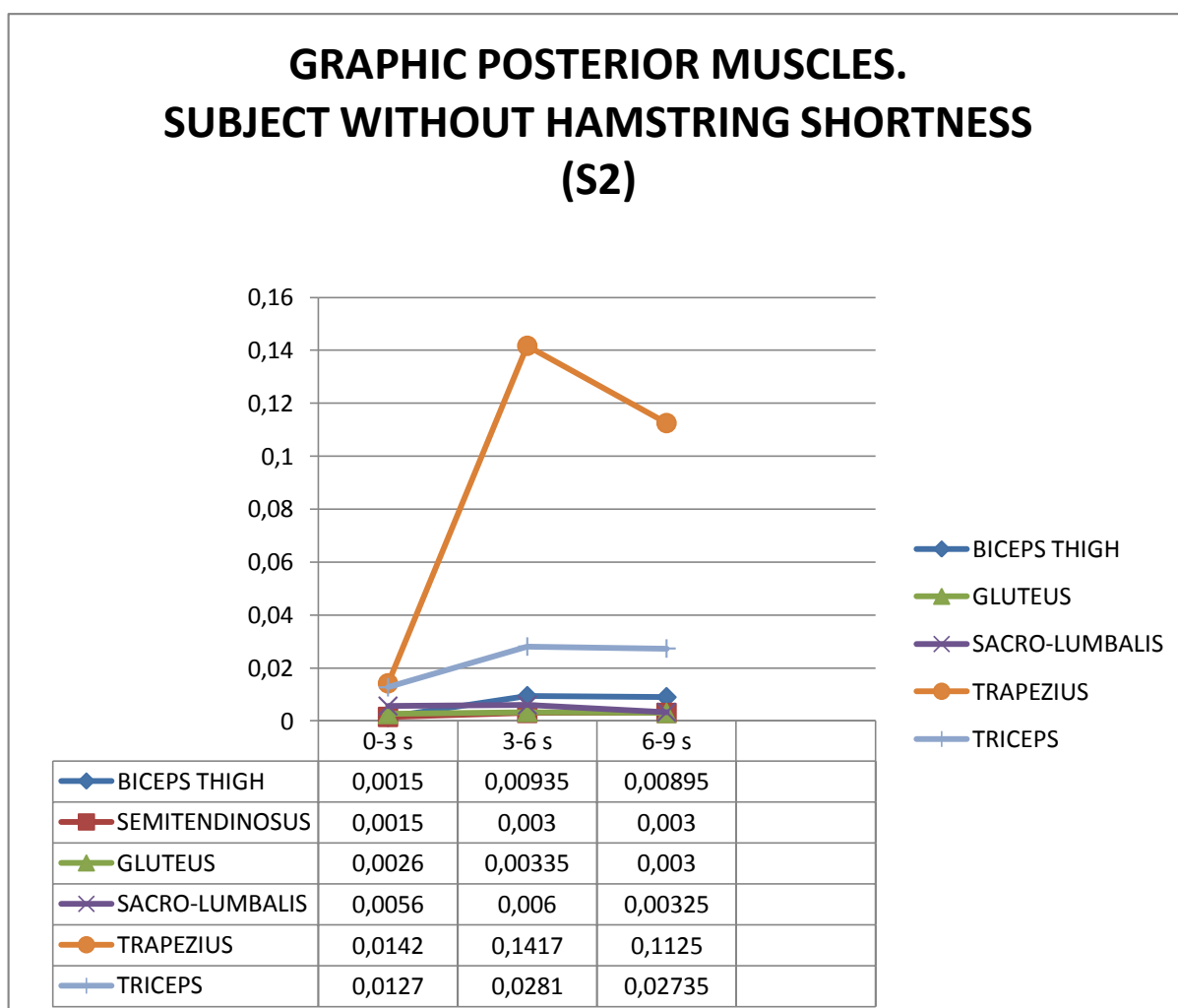
The activation of triceps longitudinal means that it contract to extend the elbow. This activation get lower when hands get to the drawer.

*S2, Group 2: Latissimus dorsi.*

This muscle decreases its activity since the start till the end of the test. So it is stretched during the Sit and Reach test in the subject without hamstring shortness.

*S2, Group 3: upper trapezius.*

Upper trapezius has a different behavior than the other muscles. Despite it is a posterior muscle and it should keep or decrease its activation during the movement, S2 active it while it is elongated to keep arms raised (Figure 5). In this case it is more evident because S2 reaches a greater forward tilt. The decrease in its activation in the last phase could be due to the hands support on the drawer.



**Figure 5.** Posterior muscle activation of S2.

## **S1 Posterior Muscles:**

*Group 1: biceps femoris, semitendinosus, upper trapezius and triceps longitudinal.*

As it happened in S2, all those muscles increased their activity from the start to the end of the test. In the first stage, biceps femoris and semitendinosus were the less activated muscles, so we consider that they were the more elongated as well. During the movement, those muscles kept the elongation to maintain the posture, but their activation got increased, so they made an eccentric contraction (Figure 6).

The fact that upper trapezius and triceps longitudinal increased their activation from the beginning until the end of the test seems to be related with concentric muscular contractions. This action is necessary to keep the humeri high (upper trapezius) and the elbows extended (triceps longitudinal). This muscular behavior is different from the S2. It could be related to the S1 inability for supporting the arms on the drawer.

This test is similar to the *sciatic nerve neurodynamic seated test* or *the rising an straight leg test*, commonly used as the Sit and Reach contrast test. All of them look for the position in which pain is generated for stretching nervous structures. The common muscular reply to prevent this nervous stretching and the pain generated is its contraction, to recover de neutral position (Herrington, Bendix, Cornwell, Fielden, & Hankey, 2008). Following McHugh et al (2012), EMG activation is increased when neural tension is added to a neutral position.

Pincivero et al (2000) confirmed that muscular activation measured with EMG in the forward lunge exercise, was produced simultaneously in vastus lateralis, vastus medialis and biceps femoris to estabilize the neck. Semitendinosus didn't play this role.

There are two ways for increasing stretching and articular range of movement (Shrier & Gossal, 2000). The direct one is the muscle stiffness decrease, and the indirect one is to obtain the central nervous system inhibition by decreasing actin-myosin cross bridges. Those authors assert that the proprioceptive neuromuscular facilitation is the more effective technique for increasing stretching toleration owing to the eccentric contraction experimented by muscles during the stretching.

*Group 2: gluteus maximus and dorsal lumbar.*

The results presented in Figure 6 shows that these muscles get their activation increased from the stage1 to the stage2, decreasing it during stage 3. At the same time the goniometer indicates that these muscles stretches during the movement. It means that gluteus maximus and dorsal lumbar muscles are resisting the stretching, especially in phases 1 and 2. In phase 3 activation get decreased but it is still higher than the one registered at the beginning of the

test. In conclusion, both muscles are developing an eccentric contraction during the Sit and Reach test.

Group 3: *latissimus dorsi*.

It is the exclusive muscle that decreases its activation from the beginning to the end of the test in S1. This results could be affected by the initial position of S1, with hands on the floor supporting the trunk position.

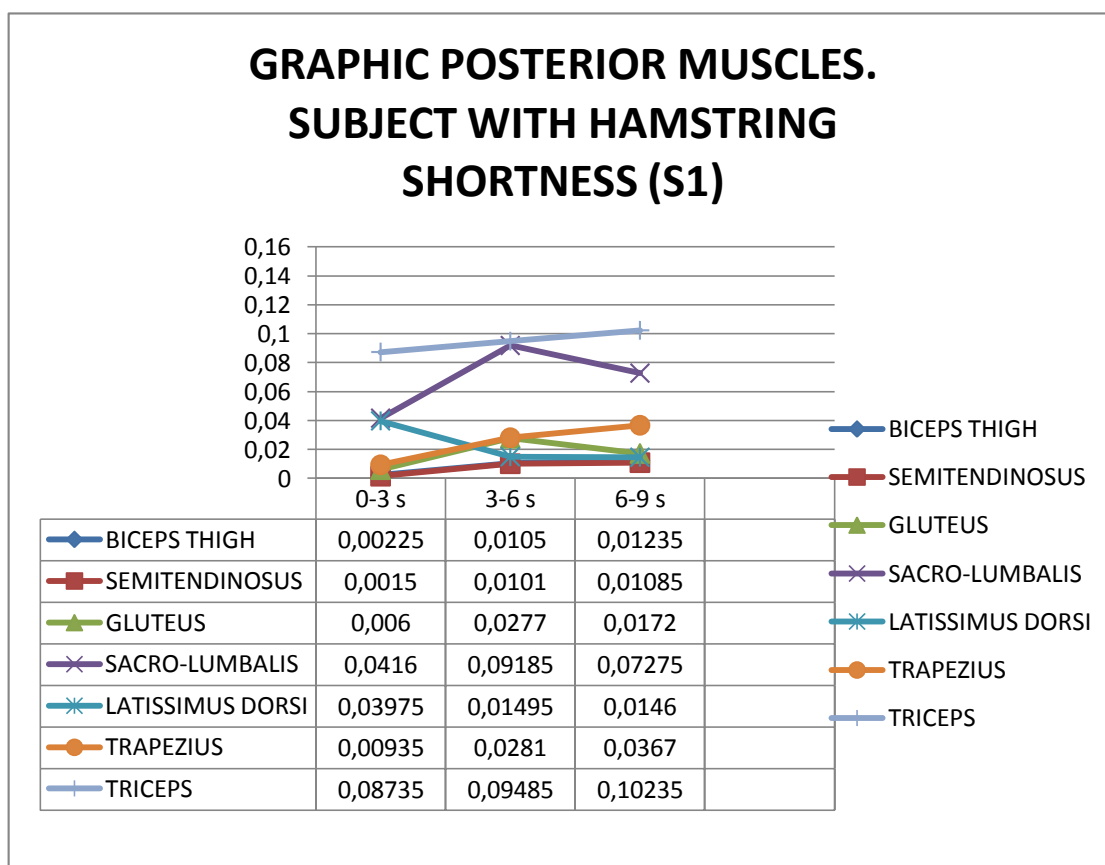


Figure 6. Posterior muscle activation of S1.

## **S2 anterior muscles**

*Group 1. Rectus abdominal (upper and lower portions) and rectus femoris.*

These muscles increased their activity at the beginning of the test and kept it till the end (Figure 7). The reason to explain this behavior could be related with their liability to develop the hip and trunk flexion in the Sit and Reach test. These are our expected results, and are in accordance with Arregui (2008) who proved the relationship between transversal muscle section and the Sit and Reach test.

*Group 2. Pectoral major.*

Pectoral major is a muscle which decreases its activity since the beginning till the end of the test (Figure 7). It seems to be stretched without an eccentric contraction. The fact is that during the test, humerus are moving away from the trunk sides, so pectoral major and latissimus dorsi are agonist muscles.

*Group 3. biceps longitudinal.*

Biceps longitudinal behavior was conditioned by the test development. Firstly, an activation increment could be related to the shoulder flexion. In the final part of the test, its relaxation is due to the position of the arm and the support of the hands on the drawer.



### GRAPHIC ANTERIOR MUSCLES. SUBJECT WITHOUT HAMSTRING SHORTNESS (S2)

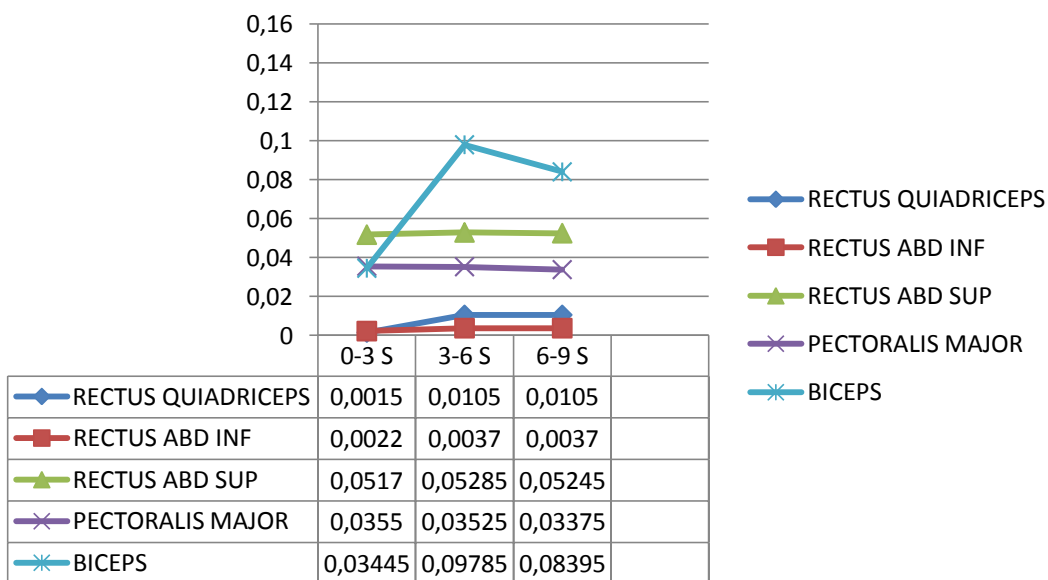


Figure 7. Anterior muscle activation of S2.

## **S1 anterior muscles**

*Group 1. Rectus abdominal (upper and lower portions) and biceps longitudinal.*

Rectus abdominal (upper and lower portions) increased considerably their activity from the beginning to the end of the test (Figure 8). It could be due to the fact that they are the trunk flexion required responsible. So it is logical that these muscles got activated progressively during the test.

With respect to the biceps longitudinal, it increased the activity when the elbow got extended (Figure 8). This fact results paradoxical, but it is necessary to have on account that biceps longitudinal is also a shoulder flexer. It is probably that its shoulder flexion function could be the responsible of this activity increment, because S1 never supported the hands on the drawer. On the contrary, in S2 the biceps longitudinal activity decreased in the final stage of the test, probably because the hands were on the drawer.

*Group 2. Pectoral major and rectus femoris.*

Pectoral major and rectus femoris were activated in the first phase and during the execution of the test, decreasing their activity in the final phase (Figure 8). However, in phase 1 pectoral major were more activated than rectus femoris, and the last one activity increased much more than pectoral major during phase 2.

This result shows a rectus femoris strong activation from phase 1 to phase 2 when the movement is developed slowly and continuously. The activity got decreased during phase 3 possibly because antagonist muscles increased their activity causing the relaxation of rectus femoris.

Pectoral major is not a relevant muscle to develop the Sit and Reach test.

### GRAPHIC ANTERIOR MUSCLES. SUBJECT WITH HAMSTRING SHORTNESS (S1)

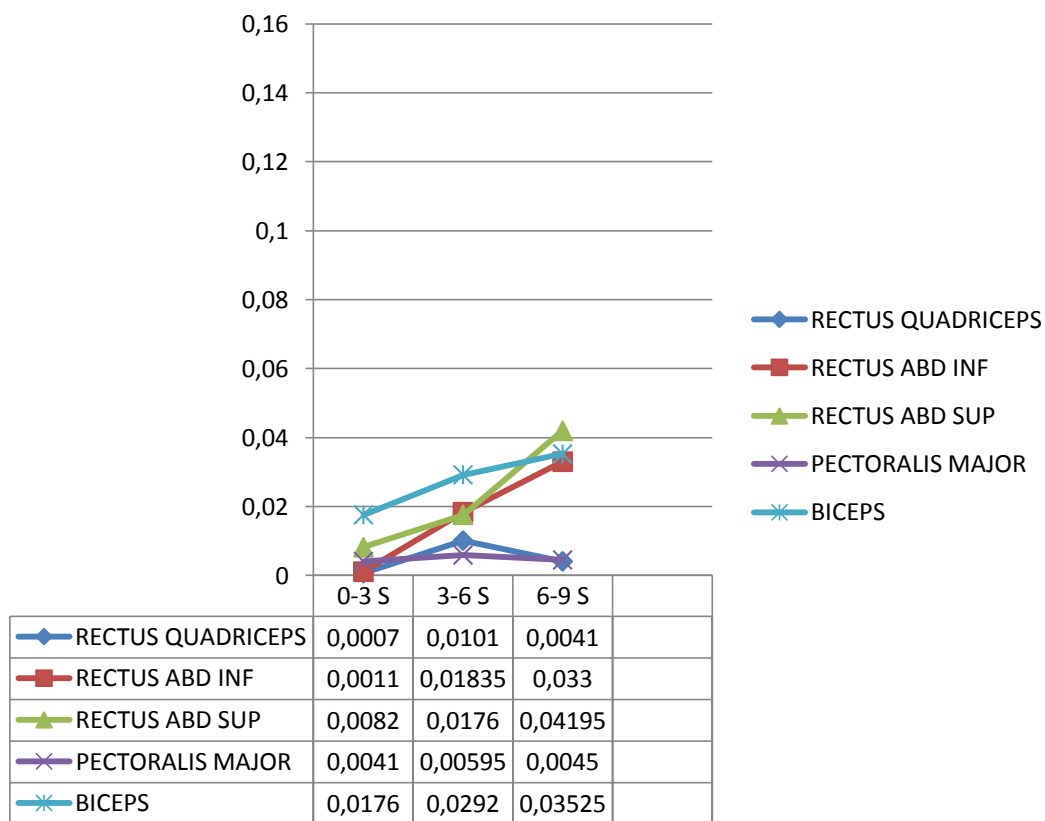


Figure 8. Anterior muscle activation of S1.

## CONCLUSIONS

In the subject without hamstring shortness the Sit and Reach test is conditioned by the elongation ability of dorsal lumbar muscle. And also by the strength generated in the hip and trunk flexion for the rectus femoris and the rectus abdominal. It could be expected that iliopsoas developed the same behavior, but it haven't been valued because it is not a superficial muscle.

In the subject with hamstring shortness, the Sit and Reach test is more a muscular resistance to stretching test than a stretching test. The less lineal score in the test means an eccentric muscular contraction, which difficult muscular stretching.

The hip flexion is a component of the movement in the development of the Sit and Reach test.

The study limitation was the superficial measurement of activity with electromyography.

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