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ORIGINAL ARTICLE

Influences of the extensor portion of the gluteus maximus muscle on pelvic tilt before and after the performance of a fatigue protocol

Influência da porção extensora do músculo glúteo máximo sobre a inclinação da pelve antes e depois da realização de um protocolo de fadiga

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Abstract

Introduction: There is a lack of data in the literature for determining the influences of the extensor portion of the gluteus maximus muscle on pelvic tilting and, thus, on lumbar stability. **Objectives:** To assess the influences of the extensor portion of the gluteus maximus muscle on pelvic tilt. **Methods:** Ten healthy young subjects were recruited, with a body mass index (BMI) below 24.9 kg/m^2 and leg length discrepancy below 1 cm. The BMI, pelvic perimeter and lower-limb lengths were assessed and, subsequently, the degrees of hemi-pelvic tilt and asymmetry between them were analyzed using lateral view photographs of the subjects in a standing position, using SAPO (Software for Postural Assessment). Next, fatigue was induced in the extensor portion of the gluteus maximus muscle on the dominant side, and after that the hemi-pelvic tilt and the asymmetry between the hemi-pelvises were reassessed. The Pearson *r* and Student *t* tests were conducted at the significance level of α=0.05. **Results:** There were no significant correlations between the confounding variables and asymmetry of the hemi-pelvic angles. There were significant changes in the hemi-pelvic angle of the dominant side (t=3.760; p=0.004). **Conclusions:** Fatigue in the extensor portion of the gluteus maximus muscle can generate increases in the tilt angle of the ipsilateral pelvis.

Key words: gluteus maximus; fatigue; pelvic tilt.

Resumo

Introdução: Há carência na literatura de dados que determinem qual a influência da porção extensora do músculo glúteo máximo na inclinação da pelve no plano sagital e, portanto, na estabilidade lombar. **Objetivos:** Verificar a influência da porção extensora do músculo glúteo máximo sobre a inclinação da pelve. **Métodos:** Foram recrutadas 10 voluntárias jovens, saudáveis, com índices de massa corpórea (IMC's) menores que 24,9 kg/m^2 e com dismetria real de membros inferiores (MMII) inferior a 1 cm. Foram avaliados o IMC, o perímetro pélvico e o comprimento dos MMII e, posteriormente, os graus de inclinação das hemipelves e a assimetria entre elas pela análise de uma fotografia em perfil ortostático usando o SAPO (*Software* para Avaliação Postural). Em seguida, a porção extensora do músculo glúteo máximo do lado dominante foi induzido à fadiga, após a qual foram determinadas novamente a inclinação das hemipelves e a assimetria entre elas. Testes de *Pearson r* e teste *t* de *student* foram realizados no nível de significância α=0,05. **Resultados:** Não houve correlação entre as variáveis de confusão e a assimetria dos ângulos das hemipelves. O ângulo da hemipelve apresentou modificação significativa do lado dominante (t=3,760; p=0,004). **Conclusões:** A fadiga da porção extensora do músculo glúteo máximo pode gerar um aumento do ângulo de inclinação da pelve homolateral.

Palavras-chave: glúteo máximo; fadiga; inclinação pélvica.

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Introduction

Lumbar spine movements involve a complex phenomenom which, in addition to knowing its stabilization mechanisms, is also the understanding of its intrinsic movements and those set so that it is coordinated with the pelvis. The lumbar spine demonstrates several factors which contribute to its stabilization, such as the passive elastic forces of the soft tissues that cross the intervertebral joints and the muscles which are adjacent to these forces, and the ones which are responsible for the stabilization of proximal bone segments[1]. Thus, some observational studies have been performed in relation to lumbar spine movement and the consequent pelvic movement[2-4]. These studies associated the anterior and posterior pelvic tilt, respectively, to proportional increases or reductions on the lumbar curvature. Moreover, Neumann[4] reported that greater lordosis increased compressive forces over the articular processes of the lumbar vertebrae.

Walker et al.[5] associated the pelvic tilt angle and the degree of the lumbar curvature to abdominal muscles performance data. Even though they did not find any significant correlations between these variables, their findings were justified by the median intra-examiner reliability found during the muscle performance tests. On the other hand, Simm[6] related lumbar lordosis to both the abdominal and gluteal muscular conditions, and the results pointed to the direction in which the weaknesses of these muscles, plus the dorso-lumbar muscles tended to increase lumbar lordosis. According to the above, there were a lack of conclusions in the literature in relation to the existence, or not, of significant influences of the extensor portion of the gluteus maximus on maintaining pelvic tilt.

In some of the mentioned studies[3,7,8], the methods for evaluating the pelvic tilt angle was indirect, and recent studies[9-11], even though they did not show any specific data on pelvic positioning, have demonstrated that the determination of the balanced position of some body segments, indirectly measured through observations, had acceptable correlations with radiographic imaging. In these studies[9-11], individuals were observed using photographs taken at several moments with skin markers positioned over certain bone prominences. Sacco et al.[12] used software for posture assessment called *Software para Avaliação Postural* (SAPO), that is distributed for free and was designed by Brazilian researchers aiming to assist health care professionals in evaluating posture.

Musculoskeletal pain is the major cause of seeking medical attention and is the most important cause of disability in the world[13]. The prevalence of a significant low back pain episode ranges from 60% to 90%[14], being classified as specific, when its cause is known, and non-specific when its cause is unknown, and this latter group composes 90% of the cases. The incidence of occurrence is 28 for each 1000 people per year, with episodes associated to referral of symptoms to the lower limbs (LL) occurring at a ratio of 11.6 to 1000[15].

Lumbar segment instability can be an important factor for the etiology of low back pain. According to An[16], Comeford and Mottran[17] and Nicholls[18], changes in muscle activity would affect joint stability by means of decreasing the contact between articular surfaces crossed by these muscles, allowing excessive translational moments.

Muscular inability to generate force was already defined as fatigue[19]. Thus, a fatigued muscle could not develop sufficient strength to stabilize in a proper manner, a specific body segment. Leinonen[20] proved this theory by showing that patients with chronic low back pain demonstrated reduced myoelectric gluteus activity during trunk extension and flexion. According to Vollestad[19], this reduced activity could be an indicator of muscle fatigue and the consequent failure to generate force.

Neither the study of the gluteus muscle decreases in its ability to generate force in healthy individuals nor the observation and determination of a balanced position of the pelvis were the object of research. Therefore, this study aimed to assess the influences of the extensor portion of the gluteus maximus muscle on pelvic tilt in the saggital plane after inducing a decrease in the ability of this muscle to generate force.

Methods

Sample

A convenience sample was used for this study. Ten female subjects with ages varying from 20 to 25 yrs old were assessed. Subjects included in this study did not have a history of low back pain, with no reports of osseous or joint injuries in the lower limbs (LL) in the six months that preceded the evaluation. Moreover, the subjects were excluded from this study when they had a real leg length discrepancy, as clinically measured[21], and greater than one cm; had any inflammatory or chronic degenerative diseases, or demonstrated a body mass index (BMI) greater than 24.9 kg/m^2 on the day of the assessment. Finally, all subjects signed a formal consent form that was approved by the Ethics Committee on Research of the Universidade Federal de Juiz de Fora (nº: 321/2007), Juiz de Fora (MG), Brazil, and, when applicable, the consent form to the use of images.

Initially, a clinical assessment was performed to collect the following data: body weight, age, pelvic perimeter, and also,

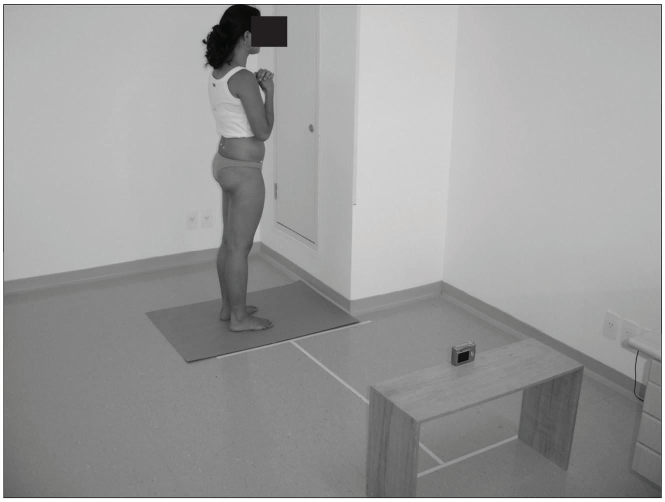

Figure 1. Demonstration of the bench with height of 60 cm, the camera positioned at its midpoint, placed 1.5 m from the edge of the paper. The figure also shows the mark in the form of an "H" on the floor that was used as a reference.

subjects were asked to inform about their lower limb (LL) dominance. Thus, the LL considered to be dominant was the one referred by the subject as the one which was preferably used first when they had to climb a step. The pelvic perimeter measurement was obtained by using a tape measure which was placed over the subjects' anterior superior iliac spines (ASIS). The arithmetic mean values of two consecutive measurements was used for analyses. Later, the remaining evaluations described below were performed, were completed in a single day with each subject at the physical analysis lab facility of the university hospital.

Instruments and procedures

Lower Limbs (LL) length measurements[21]

With the subject positioned in supine position lying on a table, the examiner positioned himself besides the limb to be measured holding a 1.5 m tape measure with its extremity that initiated the marking between left hand's first and second fingers, addressed cranially in relation to the subject. By palpation, the examiner ran his fingers anteriorly along the iliac crest to the ASIS and positioned the portion of the tape that initiated the marking over it. He then slid the tape with his other hand to the medial and inferior termination of the medial malleolus of the subject. These measures were noted, collected and followed by the repetition of the entire procedure. The arithmetic mean values of the two consecutive measurements were used for data analyses. Then, the same procedure was applied to the contra-lateral limb.

Pelvic position measurements

An "H" shape mark was applied with adhesive tape on the floor, and one of the borders of a brown paper sheet, measuring 50 cm x 80 cm, was placed with adhesive tape in parallel to the first vertical line that determined the "H" (Figure 1), on which the subject would stand during the photo shoot. A bench was placed in parallel to the other vertical line, with a 5.1 megapixels resolution Sony® digital camera placed over its midpoint. In that way, the distance between the digital camera and the paper on which the subject was positioned for the photo remained the same. The wooden bench was 60 cm in height and was positioned at a distance of 1.5 m from the border of the paper sheet. Initially, the ASIS and the posterior superior iliac spine (PSIS) were found by palpation of the iliac crest inferiorly for the first mark and posteriorly for the second one, according to the skinfold that was frequently over the last one[22]. Position of these osseous prominences from both sides were marked with a spherical (3 mm radius) Styrofoam patch attached with a piece of double-sided tape that measured 0.5 x 0.5 cm. The subject was then requested to remain in a relaxed standing position over the brown paper sheet in a way that she would start the measurement facing the wall. Then, the contour of the feet of the subject was marked on the paper sheet with a magic marker to allow that the same initial position would be reproduced during the repetition of the measurement. Prior to the image capture, the examiner confirmed that all skin marks previously placed were appearing in the camera display image. When a mark was not apparent, the bench was moved parallel to the second vertical line of the "H" that was marked on the floor until all ASIS and PSIS markers were evident on the image to be captured.

Hence, every time it was necessary to laterally move the bench, a mark was made on the floor to ensure that the camera would be in the same position in the following photograph to be taken on that same side of the subject. To prevent any movements produced by the assessor at the time of the image capture that could negatively interfere with it, a time sensor was used to perform the capture 10 secs after the camera button was pressed. To guarantee a similar subject position for the contra-lateral side, positioning was done after the marked brown paper sheet was rotated 180°. Only one photographic record was performed for each side of the subjects in the above positions.

Both photographs were transferred to a microcomputer in which the SAPO software was already installed. Because this program allows that angles between two points to be calculated, provided that some reference from the vertical position was allowed, the brown paper sheet on which the subject was positioned was placed on the floor at a distance of 5 cm from the edge of the wall. Once the camera was opened, the calibration of the rotation of the image was performed. In this calibration, a grid over the edge of the wall was made with a computer mouse to be used as a reference.

The angle of inclination of the pelvis on each side was calculated using the option "measurement of free angles" existing

Figure 2. Position for the performance of the fatigue protocol.

on the software. ASIS and PSIS skin markers were then identified for software recognition and the asymmetries between hemi-pelvic angles were also calculated by subtracting the angle found on the right pelvis from the one found on the left pelvis. Thereby, positive values meant that the anterior tilt was greater on the right side, and negative values meant that the anterior tilt was greater on the left side.

Fatigue protocol for the extensor portion of the gluteus maximus muscles[23]

The subject was placed in a standing position beside the headboard of a metal bed that already had an adapted EMG *System* do Brasil® traction dynamometer (Figure 2). A strap adjusted to a steel cable connected to the dynamometer was placed on the distal portion of the subjects' thigh of the side that was to be submitted to the fatigue protocol for the gluteus maximus. Instructions were given to the subject on how the fatigue protocol was going to be performed, followed by a three minute rest period in the test position for adaptation. Later, a test was done so the maximum isometric load was determined. Subjects were guided to extend their thigh until it was held in a 180º angle in relation to their trunk, while keeping their knees flexed at 90º. Then, the steel cable was adjusted so that there was no slack between the adaptation of subjects' thigh and the traction dynamometer existed. After that, the test, consisted of three maximum volunteer isometric contractions (MVIC) held for five seconds, were taken. Between each contraction, a three min rest was given, and verbal feedback was provided throughout the contraction period, so that the subjects would perform the test at the best level of their strength abilities. Maximum loads were then defined by the greatest values for all three contractions. A standard MVIC percentage to perform the fatigue protocol for the gluteus maximus was not found in the literature, so a 50% percentage of the maximum force generated for each subject was used based upon the results obtained in the pilot study. After a five min rest period, the subjects was then requested to make an isometric effort in the same position where they had previously made the effort to determine maximum load that was corresponded to 50% of the calculated maximum force values. These values should be held until referred exhaustion and/or the verification of the subjects' inability to sustain the selected load within a variation of ±10% from its value for at least five seconds. To stimulate the subjects to remain to hold for as long as they could the sub maximal contraction, verbal feedback was given during the entire procedure. Upon completion of this protocol, the measures of the position of the pelvis were repeated. To assure acceptable reproducibility, skin markers placed in the pre–fatigue assessments were kept during the fatigue protocol procedure.

Assessor

All performed measures and the fatigue protocol were performed by one trained assessor who was submitted to intra-examiner reliability tests, which revealed intra-class correlation coefficients (ICC) that were considered to be excellent[24]. The pilot study for the reliability tests were performed with 10 women with ages varying from 20 to 25 yrs old and BMIs varying from 19.62 and 23.50, which were assessed within a one week interval between measures, with the following test-retest reliability values being found (mean±standard error of measurement, respectively):

a) measurement of pelvic position (16.4±0.40 e 16.24±0.42): CCI=0.99;
b) measurement of pelvic perimeter (85.56±0.65 e 85.48±0.64): CCI=0.99;
c) measurement of LL length (91.11±0.64 e 90.97±0.65): CCI=0.99.

Statistical analysis

Descriptive statistics were used initially for all analyzed variables. Besides, the Pearson's r correlation parametric test was performed in order to verify the existence of a relation between possible confounding variables (BMI, pelvic perimeter, real LL asymmetry) and the asymmetry of the angle of the hemi-pelvises. This analysis aimed to ensure that no covariate had an influence over the determination of the pelvis position angle. Then, the Shapiro-Wilk test was performed in order to identify if the variables pelvis inclination angle of the dominant side, pelvis inclination angle of the non-dominant side and hemi-pelvises angles asymmetry before the fatigue protocol demonstrated normal distribution. Because these variables demonstrated a normal distribution ($p \geq 0.208$), the paired Student-t test was performed to verify the variation of hemi-pelvis inclination angles and also of the asymmetry between them. All statistical procedures were performed using the Statistical Package for Social Sciences (SPSS®) software, version 15.0 at a significance level of $\alpha=0.05$.

Results

Description of the sample

All subjects reported that their right lower limb was their dominant limb. Descriptive data on age, height, body weight, BMI, pelvic perimeter, lower limbs length discrepancy, right and left hemi-pelvises angles asymmetry and maximum force of subjects who completed the assessments are displayed in Table 1.

Table 1. Demographic and clinical characteristics of participants (n=10): age, height, weight, body mass index (BMI), leg length discrepancy (LLD), maximum force (Fmax) and pelvic perimeter of the subjects.

Descriptive characteristics				
Variable	Minimum	Maximum	Means	Standard deviations
Age (yrs)	22	25	23.5	±1.08
Height (m)	1.53	1.71	1.62	±0.057
Weight (kg)	46	62.7	55.85	±5.61
BMI (kg/m²)	19.62	23.5	21.13	±1.46
LLD (m)	0	0.007	0.002	±0.003
Fmax. (kgf)	34.42	47.44	41.09	±4.62
Pelvic perimeter (m)	0.68	0.92	0.84	±0.077

Inferential results

Pearson's *r* test revealed that no significant correlations were found between the possible confounding variables (BMI, pelvic perimeter and real LL discrepancy) and the asymmetry of the hemi-pelvises angles. Right and left hemi-pelvis angle values, revealed that the asymmetry values found between these angles prior and after the fatigue protocol for the extensor portion of the gluteus maximus of the dominant side and their level of significance are displayed in Table 2.

Discussion

The presence of a homogeneous sample characterized by female subjects in this study diminished the influences of non-controlled variables which could have occurred on the force of the extensor portion of the gluteus maximus and its influence on the pelvic position. The absence of correlations between possible confounding variables and the asymmetry of the angles of the hemi-pelvis guaranteed that no other variable influenced the determination of the angle of the pelvic position in the evaluated sample.

According to Faria, Lima and Teixeira-Salmela[25], no studies were found in the literature, which demonstrated normative data related to the asymmetries between hemi-pelvic angles, which would determine the presence, or not of pelvic torsion. Thus, it was not possible to predict if the degree of asymmetry found between hemi-pelvises in this study was a value considered below or above the one that was considered the standard pattern.

Looking at the results obtained at the variation of the angles of pelvic inclinations, it could be inferred that there was a real change in all inclination measures assessed. In that way, there were a significant and positive changes in the hemi-pelvis angles and also changes in the asymmetries between right and left hemi-pelvis of subjects. Moreover, these asymmetries suffered statistically significant changes of values prior and after the fatigue protocol. These findings indicated that once a situation of insufficiency of the extensor portion

Table 2. Mean values of the angles of the right pelvis (RPA), left pelvis (LPA) and asymmetry between the angles of inclination of the hemi-pelvis (Ass.HP) before and after the performance of the protocol and their statistically significance levels.

Angles of the pelvis before and after the fatigue protocol						
Variable	Before		After		t	p-values
	Means	Standard Deviations	Means	Standard Deviations		
RPA (degs)	17.58°	±3.60	19.93°	±4.20	-3.760	0.004*
LPA (degs)	16.61°	±5.66	17.39°	±5.74	-2.162	0.059*
Ass.HP (degs)	0.97°	±2.89	2.54°	±3.15	-2.599	0.029*

*significance levels p<0.05.

of the gluteus maximus was generated in one limb, there will be an increase in the ipsilateral inclination that could also occur contra-laterally, what could in turn, aggravate the asymmetries between the hemi-pelvic positioning angles. The possibility of the occurrence of some degree of fatigue of the gluteus maximus on the non-dominant side could be considered because of the assumed position during the fatigue protocol, which could have contributed to the present findings.

There is still the need to consider the great variations found by looking at the standard-deviation values for the asymmetries between the pelvic inclination angles in the saggital plane prior and after the fatigue protocol. These results demonstrated large variations before the protocol and an even a greater one after it, indicating that, even though all subjects demonstrated a similar musculoskeletal apparatus, its use was unequal between each one of them. Thus, it is possible that different motor control strategies for the maintenance of pelvic stability in the saggital plane were being used, and asymmetries might have suffered greater increases in those subjects who used more of the extensor portion of the gluteus maximus and less in those who used other strategies that were not the aim of this study. However, these differences might have been accentuated due to the unilateral induction of muscle fatigue; nevertheless, pelvic positions suffered changes and tended to increase its anterior inclination, that is, the pelvis assumed an anterior tilt position greater than the pre-existing one.

The findings of Walker et al.[5], who investigated the relationships between pelvic angles and abdominal muscular performance data and did not find any associations between them, could be explained, not only due to the moderate intra-examiner reliability indicated by them, but also because the influences of the abdominal muscles in maintaining the pelvic tilt in the saggital plane may be less relevant than what is expected in literature. According to Huijing[26], there are mechanisms of force transmission between synergist muscles which rely on the relative passive stiffness demonstrated by each one of these muscles. Thus, it is possible that the present results may have occurred not only because of the fatigue in the extensor portion of the gluteus maximus, which was also a consequence of the inefficiency of force transmission from the hamstrings to maintain the pelvic position. Involuntarily, the ability to generate forces in two muscles and not only one, would have been adversely affected. However, the development of future studies that could assess the main stabilizing muscles of the pelvis are necessary so that those muscles indeed provide the greatest contributions to the pelvic positioning.

It is important to mention that during the fatigue protocol for the extensor portion of the gluteus maximus, the subjects remained for a significant amount of time in a one-legged position with many of them indicated fatigue and/or pain of the supporting lower limb that was, in this case, the non-dominant limb. This may have caused the interruption of the protocol, in some cases, earlier than the necessary time to actually induce fatigue in the studied muscle. Therefore, a limitation of this study was that the MVIC was not performed after the fatigue protocol, what could have confirmed the inability of the gluteus muscle to generate force. As the findings of present study were statistically significant, this bias could be minimized by the percentage of chance in the pelvic position found after the fatigue protocol.

According to Fonseca, Ocarino and Silva[27], mechanical properties of muscles allow these structures the ability to resist deformation, and their stiffness is dynamically modifiable by the level of muscle activation. These changes in muscle stiffness can be considered as stabilization mechanisms applied during functional activity performance[28]. These findings suggested that physical therapists, during their clinical practice, could generate changes in the pelvic tilt in the saggital plane when changing the levels of the extensor portion of the gluteus maximus muscle activity[28]. Mahieu et al.[29] reports that muscle stiffness can be increased by implementing a strengthening training. For example, if the goal was to reduce the anterior pelvic tilt and consequently reduce the lumbar curvature of the patient, a strength and hypertrophy training protocol would be required. On the other hand, the implementation of a stretching protocol for this muscle would increase the anterior pelvic tilt and, consequently, the lumbar curvature, as the stretching would tend to reduce muscle stiffness, as demonstrated by Mahieu et al.[29].

In addition to this, because of the influence of fatigue of the extensor portion of the gluteus maximus in the pelvic position in the saggital plane, as observed in the present study, it is important that the physical therapist is aware of this fact, in case of attempting to execute strengthening protocols for this muscle, so no undesired threshold of fatigue is reached, which could cause consequences in the segment stability.

Ragonese[30] stated that the duration, the overload and the repetition of some activities with positions and regular movements promote an adaptation process causing deleterious effects on posture. Hence, the present findings suggested that physical therapists, during the assessment of the patient in which they intend to promote changes in the degree of the pelvic tilt, should investigate both strength and resistance to fatigue of the muscles involved in the stabilization of the pelvic tilt in the saggital plane, for these variables could affect the maintenance in the short- and/or long-term of the pelvic positions.

Conclusions

According to the findings of this study, the extensor portion of the gluteus maximus muscle of the dominant side of young healthy women that did not have considerable overweight or significant LL length discrepancy influences on the maintenance of the pelvic tilt in the saggital plane. Thereby, this muscle insufficiency can generate positive changes, that is, an increase in the tilt angle of the ipsilateral pelvis. Thus, there was a contribution of a fatigued muscle in one antimere for the increase on asymmetries between the hemi-pelvis. Therefore, if physical therapists aim to affect the equilibrium position of the pelvis and, consequently, one of the stabilization mechanisms of the lumbar spine, they should consider a program of exercises which includes strengthening and/or stretching of the extensor portion of the gluteus maximus, knowing the changes in its stiffness will change the influence that this muscle exerts on the pelvis in the saggital plane.

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