ELECTROMYOGRAPHIC STUDY OF THE GLUTEOS MAXIMUS MUSCLE BY USING AN ERGOMETRIC TREADMIL BASED ON BRUCE AND NAUGHTON PROTOCOLS: A COMPARATIVE STUDY AMONG THE PROTOCOLS STAGES.

ESTUDO ELETROMIOGRÁFICO DO MÚSCULO GLÚTEO MAXIMO NA ESTEIRA ERGOMÉTRICA UTILIZANDO OS PROTOCOLOS DE BRUCE E DE NAUGHTON: UM ESTUDO COMPARETIVO ENTRE OS ESTÁGIOS DOS PROTOCOLOS.

Antonia Dalla Pria Bankoff, ¹
Antonio Carlos De Moraes²

Resumo: A eletromiografia é uma técnica para monitorar a atividade elétrica de membranas excitáveis, e ela é aplicada em músculos estriados esqueléticos. O glúteo máximo, foi estudado através da eletromiografia em 15 sujeitos do sexo masculino, idade entre 19 a 25 anos, considerados saudáveis sem problemas de locomoção e praticantes de atividades físicas, com o objetivo de estudar os potenciais de ação na esteira ergométrica (Protocolo de Bruce e de Naughton). O trabalho foi realizado no Laboratório de Eletromiografia e Biomecânica de Postura da Faculdade de Educação Física - Unicamp. Foi utilizado para este estudo um eletromiógrafo de marca Lynix - PS6040, contendo 06 canais, adquirido através do processo Fapesp 1996/5708-4. Foi estabelecida a frequência de 1199, 760HZ para a aquisição dos registros eletromiográficos. O aparelho foi calibrado com ganho de 2000HZ, filtro passa baixa de 600HZ e filtro passa alta em 10HZ. A configuração dos limites de entrada dos sinais foi estabelecida em 3000uV (limite superior) e -3000 uV (limite superior) e a faixa de entrada -5V a +5V. O parâmetro de ensaio foi do tipo simples e o modo gráfico foi calibrado em x+y+z+w.t, possibilitando a demonstração dos registros simultaneamente para cada experimento. Os eletrodos foram colocado a 10 cm acima do ponto de inserção (tuberosidade glútea do fêmur). Na esteira ergométrica utilizou-se o protocolo de Bruce e de Naught. Os registros foram realizados nos últimos 10 segundos de cada estágio dos protocolos, lembrando que o protocolo de Naughton modelo II possui oito estágios. Eletrodos de superfície tipo adesivos da marca Bio-logic foram utilizados para captar os sinais eletromiográficos. Os resultados mostraram que o músculo glúteo máximo mostrou ser muito requisitado através dos resultados coletados provenientes dos sinais eletromiográficos e transformados em RMS nas atividades de locomoção na esteira ergométrica, especificamente na utilização do protocolo de Bruce, seguido do protocolo de Naughton.

PALAVRAS CHAVES: Eletromiografia. Músculo Glúteo máximo. Esteira ergométrica.

ELECTROMYOGRAPHIC STUDY OF THE GLUTEOS MAXIMUS MUSCLE BY USING AN ERGOMETRIC TREADMIL BASED ON BRUCE AND NAUGHTON PROTOCOLS: A COMPARATIVE STUDY AMONG THE PROTOCOLS STAGES.

ABSTRACT: Electromyography (EMG) is a technique to monitor the electrical activity of excitable membranes, and they are applied in striated skeletal muscles. We studied the gluteus maximus muscle (GMM) by EMG in 15 male subjects, aged 19~25. They were considered healthy, without problems in walking and performing physical activities. Considering this, we aimed at studying the action potentials on the ergometric treadmill (Bruce and Naughton Protocol). The work was conducted at the Laboratory of Electromyography and Biomechanics of Posture, School of Physical Education, University of Campinas

^{1,2} Faculdade de Educação Física da Universidade Estadual de Campinas

(Unicamp). For this study, we used a Lynix® electromyograph (PS6040), containing six channels, acquired from the FAPESP support 1996/5708-4. To acquire the EMG recordings, we established the frequency of 1199.760 Hz. The instrument was calibrated with 2000 HZ gain, low-pass filter of 600 Hz and high-pass filter of 10Hz. Setting input signal limits was established in 3000 uV (upper limit), -3000 uV (upper limit), and input range from -5 V to +5 V. The test parameter was simple type, and the graphics mode was calibrated in x+y+z+w.t, allowing to demonstrate records simultaneously for each experiment. The electrodes were placed at 10 cm above the insertion point (gluteal femur tuberosity). Considering the ergometric treadmill, we used the Bruce and Naughton protocol. The recordings were made in the last 10 seconds for each protocol stage, noting that the Naughton protocol model II has eight stages. We used adhesive-type surface electrodes (Bio-logic®) to capture the EMG signals. By the results collected from the EMG signals, GMM was quite required. Further, such results were transformed in RMS for the walking activity by using an ergometric treadmill, specifically based on the Bruce protocol, followed by the Naughton protocol.

Keywords: Electromyography; Gluteus maximus muscle; Ergometric treadmill

ESTUDIO ELETROMIOGRÁFICO DEL MÚSCULO GLÚTEO MAXIMO EN LA ESTEIRA ERGOMETRICA UTILIZANDO LOS PROTOCOLOS DE BRUCE Y DE NAUGHTON: UN ESTUDIO COMPARATIVO ENTRE LAS ETAPAS DE LOS PROTOCOLOS.

Resumen: La electromiografía es una técnica para monitorear la actividad eléctrica de las membranas excitables, y se aplica en los músculos estriados esqueléticos. El músculo glúteo máximo, fue estudiado a través de la electromiografía en 15 sujetos del sexo masculino, edad entre 19 a 25 años, considerados sanos sin problemas de locomoción y practicantes de actividades físicas, con el objetivo de estudiar los potenciales de acción en la estera ergométrica (Protocolo De Bruce y de Naughton). El trabajo fue realizado en el Laboratorio de Electromiografía y Biomecánica de Postura de la Facultad de Educación Física - Unicamp. Se utilizó para este estudio un electromiografo de marca Lynix - PS6040, conteniendo 06 canales, adquirido a través del proceso Fapesp 1996 / 5708-4. Se estableció la frecuencia de 1199,760HZ para la adquisición de los registros electromiográficos. El aparato fue calibrado con una ganancia de 2000HZ, filtro paso bajo de 600HZ y filtro pasa alta en 10HZ. La configuración de los límites de entrada de las señales se estableció en 3000uV (límite superior) y -3000 uV (límite superior) y el rango de entrada -5V a + 5V. El parámetro de ensayo fue del tipo simple y el modo gráfico fue calibrado en x + y + z + w.t, posibilitando la demostración de los registros simultáneamente para cada experimento. Los electrodos se colocaron a 10 cm por encima del punto de inserción (tuberosidad glútea del fémur). En la estera ergométrica se utilizó el protocolo de Bruce y de Naughton. Los registros se realizaron en los últimos 10 segundos de cada etapa de los protocolos, recordando que el protocolo de Naughton modelo II posee ocho etapas. Los electrodos de superficie tipo adhesivos de la marca Bio-logic se utilizaron para captar las señales electromiográficas. Los resultados mostraron que el músculo glúteo máximo mostró ser muy solicitado a través de los resultados recogidos provenientes de las señales electromiográficas y transformados en RMS en las actividades de locomoción en la estera ergométrica, específicamente en la utilización del protocolo de Bruce, seguido del protocolo de Naughton.

PALABRAS CLAVES: Electromiografía. Músculo Glúteo máximo. Estera ergometrica.

^{1,2} Faculdade de Educação Física da Universidade Estadual de Campinas

INTRODUCTION

Electromyography (EMG) is a technique to monitor the electrical activity of excitable membranes, and they are applied in striated skeletal muscles. It represents the extent of action potentials for sarcolemma membrane of striated skeletal muscle cell. By using such technique, one can record an action potential, e.g. voltage event in the time. The basis of knowledge and of understanding for EMG is the drive motor¹. Recalling that a motor unit is defined as a cell body and as motoneuron dendrites, with multiple axon branches, which innervate muscle fibres. Anatomical, physiological motor unit factors can vary. Such variations, depending on the muscle, allow a muscle to have nearly from 100 to 1,000 motor units¹.

An action potential is an electrical control, e.g. *everything or nothing*, produced by the cell in response to the impulse received. Both neurons and muscle fibres can generate action potentials. Impulses received by the neuron, which are the basis for the generation of action potentials, occur in the form of synaptic potentials².

In the last decades, the EMG has highly contributed to knowledge in the field of physical education, physiotherapy, and also in the morphofunctional research. Such fact uncovered the functions of skeletal muscles while in movement, in addition to those described in anatomy and kinesiology³.

In our EMG study during this time, we could investigate sundry muscles of the human body, and at such moment came up our GMM interest. It is the most superficial muscle in the gluteal region, and it is a large, thick fleshy mass; thus, in a quadrilateral way, the prominence of the buttocks is formed. Its volume is one of the most characteristic features of the human being muscular system, as it is related with the strength that keeps the trunk in upright posture¹.

Also reports that the GMM acts on the external rotation, extension and abduction of the thigh at the hip joint. The upper fibres contribute to the abduction, especially when the body weight falls only on one member, as in walking or in running. In normal gait, the member remains relaxed for most people, except when used to stop the momentum of the member to complete the forward swing. Primarily, the GMM is not involved in hip extension, if it is not bent in more than 45 degrees, unless there is a strong resistance. In this case, the limitation angle is shorter. People who have lost the

GMM function walk almost normally, but cannot go up stairs, or an incline, without much fatigue; running, jumping, and dancing cause they get tired quickly.

⁴Reports that the GMM seems to dominate the pelvis during walking rather than contribute significantly to the force generation. As thigh is nearly extended during the walking cycle, the GMM function is more related to further extension of the trunk and posterior pelvic tilt. In the contact phase when the foot flexes the trunk, the GMM prevents the trunk from falling forward. As the GMM also externally rotates the thigh, a position of internal rotation puts the muscle on stretch. The GMM function loss does not result in significant impairment in the thigh extension strength, as the hamstring muscles dominate the yield extension.

⁵Assessed 16 muscles related human locomotion at different speeds. He performed the EMG analyses of 1, 2, 3, and 5 Km/h of the same subject. He also reports that among the subjects, there is a difference in the EMG pattern, and that for the same subject there is difference in the EMG pattern for the different speeds.

By contrast, ⁶performs an EMG gait analysis with 30 active and healthy children. The author indicates that in children there is an increased activation of antagonistic muscles during gait; thus, a higher metabolic demand. However, notes that with increasing age this activation of agonist muscles decreases, defining the adult subjects' gait as primarily activation of agonist muscles.

There are also concise reports in the literature, and to people considered to older adults, there is a (a) tendency to deficiency in the locomotion process, considering how quickly are the responses to stimuli and (b) reduction of muscle activation patterns^{7,8}.

⁹Studied the GMM and lumbar iliocostalis by using EMG for ergometric treadmill and for ground. From the results, they demonstrated that the muscles studied were slightly involved by the generation of action potentials during locomotion (running) at 6.5 mph on the ground. However, the ergometric treadmill was at 6 mph, i.e. higher action potentials. Considering the results obtained, the GMM action potentials and lumbar iliocostalis were higher for the ergometric treadmill, when compared with potential action on the ground. Perhaps two factors have caused this difference: (a) ergometric treadmill tilted at 22% in the stage 7 of the Bruce protocol; (b) greater impact on the ergometric treadmill.

^{10,11}Described that the GMM seems to dominate the pelvis during walking rather than contribute significantly to the force generation. As thigh is nearly extended during the walking cycle, the GMM function is more related to further extension of the trunk and posterior pelvic tilt. In the contact phase when the foot flexes the trunk, the GMM prevents the trunk from falling forward. As the GMM also externally rotates the thigh, a position of internal rotation puts the muscle on stretch. The authors also show that GMM function loss does not result in significant impairment in the thigh extension strength, as the hamstring muscles dominate the extension strength yield.

Concerning locomotion, ¹² assessed the gait focused on the position and displacement of centre of gravity of the body. The author also found that the movement occurs during a loss and a balance recovery, sequentially. Gait is a passive activity, the author also concluded; depending on the transfer of body weight above the support. By researching,

¹³Found that the walking cycle consists of phases. Therefore, the author proposed that the components of the walking cycle are five; they are: (1) walking from the first support in contact with the ground; (2) full contact between ground and support; (3) first support off the ground, (4) oscillation phase; and (5) heel of the second support in contact with the ground. The components described as being isolated phases is an important fact, and it occurs orderly and simultaneously. Considering the sequences involved, there will always be a support in contact with the ground, and for a short time in each cycle the two supports will be in contact with the ground.

The gluteus maximus also has great functional importance in the Support. ^{14,15}Demonstrated that maximal gluteus, along with other muscles generated most of the support of body weight at the beginning of the supporting phase. A drop in the center of gravity of the subject characterizes the onset of the support phase during load response. Sixty percent of the weight is transferred in 0.02 seconds resulting in an abrupt load on the support member. It is at this time that the gluteus maximus compresses the sacral iliac joint to provide stability. For the gluteus maximus to be active, the biceps should relax at this stage. The inappropriate activation of the gluteus maximus in gait is suggested as a cause of back pain, resulting in a deficiency in the mechanism of shock absorption in the sacroiliac joint. The biceps femoris muscle is

activated early in patients with sacroiliac dysfunction, which may be considered a compensation for gluteus maximus weakness.

¹⁶Electromyography studies showed a lower electrical activity of the gluteus maximus in patients with chronic low back pain during the anterior flexion movements of the trunk and during the return to the orthostatic position. Patients with low back pain often avoid spinal movements in activities of daily living due to fear of pain and its consequences. This would lead to atrophy of the spinal muscles, especially the multifidus which possibly leads to increased pain and fear of movement.

^{16,17}Electromyographic studies for evaluation of the recruitment pattern Muscle in individuals with low back pain, during some exercises or functional activities have shown that in some situations, the gluteus maximus muscle is inhibited and in others hyperactive. Hyperactivity of the gluteus maximus may be a consequence of an attempt to stabilize the sacroiliac joint in symptomatic individuals or an attempt to compensate for the fatigue of the lumbar extensors during repetitive exercises. Muscle activity may show-semi-blocked to prevent unwanted movement or a painful posture and avoid stressful bent segment.

¹⁸The gluteus maximus is considered a phasic muscle and, in the presence of a muscle imbalance, it may become weak and elongated, as observed in the crossed pelvis syndrome.

In a study conducted by researchers at the University of Belmont, it aimed to evaluate the electromyography activity of the gluteus maximus. This study was performed with 24 people during different exercises such as leg squatting, leg press, hip extension and others. The results showed that, among all the dynamic exercises performed, the one that promoted a greater recruitment of the gluteus maximus was the squatting performed with only one leg. The results of this exercise showed an activation of more than 33% on average. The hip extension made in four supports, which is still very used by people and is very inefficient, was the one that had the lowest activation of the gluteus maximus, with an average of 12% of activation. The stiff had an activation of about 28%, while the leg press had an activation of about 19%. To the surprise of many, unilateral advancement or squatting, which is much like advancing exercise, has promoted large recruitment of both the gluteus maximus and medium ¹⁹.

7

Concerning the ergometric test methodology, it developed more in the early

1950s, especially with the introduction of new and modern ergometers, e.g. rolling

treadmill and exercise bicycle. Until then prevailed the tests in benches with small steps,

with great emphasis on the Master method. Sundry protocols have emerged, e.g. the

rolling treadmill, called so until the 1990s, and from then on ergometric treadmill.

Bruce's model is the most known and currently has the highest acceptance of the

authors. We can quote the protocols of greater acceptance and use for ergometric

treadmill: Bruce, Ellestad, Balke (models: I, II, III), Naughton (models: I, II), and

Kattus. They have many similarities between the main characteristics (number of stages,

mph, inclination %, VO2max, METs, and minutes). Although the protocols present

some similarity, the most widely used are Bruce's and Naugthon's protocol²⁰.

GENERAL OBJECTIVE

Study by electromyography the action potentials generated by the GMM on the

ergometric treadmill, by using Bruce protocol and Naughton protocol and compare the

results of action potentials in the form of RMS, for each stage of the protocols.

MATERIAL AND METHOD

Subjects and location of work

We studied the gluteus maximus muscle (GMM) by EMG in 15 male subjects,

aged 19~25. They were considered healthy, without problems in walking and

performing physical activities. Considering this, we aimed at studying the action

potentials on the ergometric treadmill (Bruce and Naughton Protocol). The work was

conducted at the Laboratory of Electromyography and Biomechanics of Posture, School

of Physical Education, University of Campinas (Unicamp).

^{1,2} Faculdade de Educação Física da Universidade Estadual de Campinas

Revista Saúde e Meio Ambiente - RESMA, Três Lagoas, v. 5, n.3, pp. 1-14, agosto /dezembro. Edição especial

2017. ISSN: 2447-8822

Procedure and data acquisition

For this study, we used a Lynix® electromyograph (PS6040), containing six channels, acquired from the FAPESP support 1996/5708-4. To acquire the EMG recordings, we established the frequency of 1199.760 Hz. The instrument was calibrated with 2000 HZ gain, low-pass filter of 600 Hz and high-pass filter of 10Hz. Setting input signal limits was established in 3000 uV (upper limit), -3000 uV (upper limit), and input range from -5 V to +5 V. The test parameter was simple type, and the graphics mode was calibrated in x+y+z+w.t, allowing to demonstrate records simultaneously for each experiment. The electrodes were placed at 10 cm above the insertion point (gluteal femur tuberosity). Considering the ergometric treadmill, we used the Bruce and Naughton protocol. The recordings were made in the last 10 seconds for each protocol stage, noting that the Naughton protocol model II has eight stages.

All subjects wore only underpants, focused on leaving the GMM as free as possible, so we had no problems when placing the electrodes. Before placing the electrodes on the skin, we performed trichotomy by using a Gillette® shaving razor, thus preventing hair interfering in electromyographic signals. All subjects performed the task on the same day. Initially, subjects performed the Naughton protocol and after ten minutes of rest they performed the Bruce protocol. We used an adhesive-type surface electrode (Bio-logic®) to capture the EMG signals.

RESULTS AND DISCUSSIONS

Before we begin presenting the results collected by using GMM-EMG, we present the protocols by tables of Bruce and Naughton.

Table 1. Bruce protocol²⁰.

Stage	Mph	Inclination %	VO2max	METs	min
1	1.7	10	15	4	3
2	2.5	12	25	7	3
3	3.4	14	35	10	3
4	4.2	16	45	13	3
5	5.0	18	55	16	3
6	5.5	20	65	19	3
7	6.0	22	75	22	3

Table 2 – Naughton protocol. (Model II)²⁰.

Stage	mph	inclination %	VO2max	METs	min
1	2.0	7	14.0	4.0	3
2	2.0	10.5	17.5	5.0	3
3	2.0	14.0	21.0	6.0	3
4	3.0	10.0	24.5	7.0	3
5	3.0	12.5	28.0	8.0	3
6	3.4	12.0	31.5	9.0	3
7	3.4	14.0	35.0	10.0	3
8	3.4	16.0	38.5	11.0	3

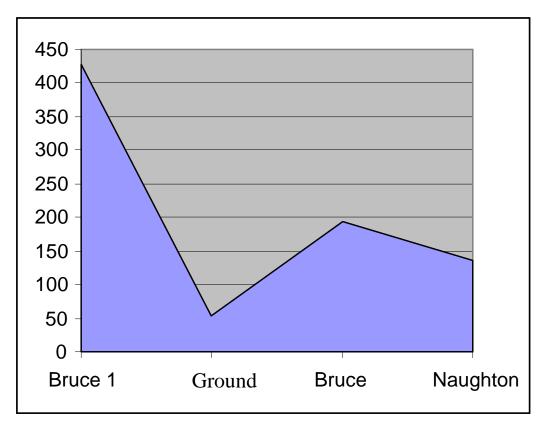
Table 3 – Distribution of overall means in Rout Means Square (RMS) and Standard Deviation (SD) for the GMM of 15 male subjects on an ergometric treadmill by using the Bruce's and Naughton's protocol.

	BRUCE PROTOCOL		NAUGHTON PROTOCOL	
STAGES	RMS	SD	RMS	SD
1	72.95	62.24	58.32	47.96
2	102.35	75.77	62.51	47.71
3	135.68	121.92	109.47	81.12
4	203.86	189.47	124.0	100.0
5	240.20	226.06	135.74	115.06
6	272.0	261.0	169.46	165.75
7	335.0	332.0	195.02	185.61
8	-	_	232.24	201.25

^{*} Naughton protocol model II has eight stages

Graphic 1 – Distribution of overall means for action potentials in the form of GMM and RMS: Bruce 1 – data collected only in the stage 7; ground run; Bruce and Naughton overall mean for sum of all stages of the protocols performed.

^{1,2} Faculdade de Educação Física da Universidade Estadual de Campinas



* Bruce 1 and Ground refer to³

From the data in table 3, was evident that the action potentials were higher for the ergometric treadmill by using the Bruce protocol. We found that action potentials have already started when they were higher, from the first stage, when compared with the Naughton protocol. It is interesting to observe that the action potentials organised in ascending way, according to the stages. The biggest growing difference, however, is between stage 6 and stage 7, i.e. when the speed is roughly from 5.5 mph to 6.0 mph and the inclination from 20 % to 22 %. Although the Bruce test is most known and most acceptable by assessments regarding the stress test, one can realise that the component distribution of biomechanical loads requires more from subjects who are running on the ergometric treadmill. It occurs due to the initial speed and to the inclination percentage. Thus, it requires sundry passes early in the beginning of the test, also including length of the passes, pass impact; i.e. a bolder and more-prescribed-for-athlete stress test. In our view, is hugely important to be careful when entering this test for people, especially the sedentary people and those with heart disease. Data presented in graphic number 1 corroborate these statements and findings when they point out the overall means of

2017. ISSN: 2447-8822

^{1,2} Faculdade de Educação Física da Universidade Estadual de Campinas
Revista Saúde e Meio Ambiente – RESMA, Três Lagoas, v. 5, n.3, pp. 1-14, agosto /dezembro. Edição especial

EMG data extracted from the studies of³, performed by using ergometric treadmill pointing RMS higher than the findings in this study (427,46). Still here, Bankoff has expressed concern over the values of action potentials found when compared with the ground. The author was worry about how to (a) perform and apply the Bruce test and (b) indicate the Bruce ergometric treadmill for cardiac rehabilitation. The author also belied that rehabilitation is more appropriate to walk on the ground.

According to ^{10,11}, GMM seems to dominate the pelvis during walking rather than to contribute significantly to the force generation. As thigh is nearly extended during the walking cycle, the GMM function is more related to further extension of the trunk and posterior pelvic tilt. In the contact phase when the foot flexes the trunk, the GMM prevents the trunk from falling forward. As the GMM also externally rotates the thigh, a position of internal rotation puts the muscle on stretch. In our study, the GMM by using an ergometric treadmill, specifically in Bruce protocol, presented more frequently and thus more action potential. Hence, such activity performed by using ergometric treadmill with Bruce protocol requires a lot from GMM.

The results presented by the Naughton protocol, in overall means of the subjects in the form of RMS, were also organised in ascending order for each stage; however, without many significant differences between stages when compared with the Bruce protocol. It gives the impression to be a more relaxed protocol to perform by using an ergometric treadmill, i.e. such protocol seems to present biomechanical loads regarding inclination percentage, as well as an Mph better when compared to that of Bruce.

Considering the neuromecanics of neurones and of muscle cells concerning ratio to innerve, organise, and recruit cells by motor units, it seems that Bruce test requires much more from the motor units to feed the muscle fibre recruitment to the work. It is also relevant that to understand the motor unit function, we need to combine information on motoneuron excitability with the details of the impulses they receive².

We worry about this knowledge when involved with cardiac assessment, considering the speed and impact generated during the Bruce protocol performance. However, if we expect to strengthen the GMM within less time, it is advisable to exercise by using ergometric treadmill locomotion. Nevertheless, beware of the impact, if instead we suggest walking on the ground where we believe the impact is minor.

^{1,2} Faculdade de Educação Física da Universidade Estadual de Campinas

CONCLUSION

By the results collected from the EMG signals, GMM was quite required. Further, such results were transformed in RMS for the walking activity by using an ergometric treadmill, specifically based on the Bruce protocol, followed by the Naughton protocol. Considering the results shown in graphic 1, the action potentials were smaller for ground locomotion.

BIBLIOGRAPHIC REFERENCES

- 1- Bankoff. ADP. Morfologia e Cinesiologia Aplicada ao Movimento Humano.1ª ed., Editora Guanabara Koogan, RJ,2007, pg 178.
- 2- ENOKA, RM. Bases Neuromecânicas da Cinesiologia. 1ª ed., Ed.Manole, São Paulo, 2000, pg 237.
- 3- Bertazzoli, BF, Bankoff, ADP. Electromyography study of skeletal muscle during locomotion in a treadmil test: a case study. Electromyogr.clin. Neurophysiol.2009, v.49, pg.125-128.
- 4- Lander, JE. Effects of center of mass manipulation on the performance of the squat exercise. Unpublished Doctoral dissertation, University of Oregon, 1984.
- 5- Ivanenko, Y, Poppele, L, Mecellari, V, Lacquanti, F, Five basic muscles activation patterns account for muscles activity durin human locomotion. Journal of physiology, 2004,556(1): 267-82.
- 6- Frost, G, Dowling, J, Dyson, K, Bar-or, O. Cocontraction in three ages groups of children during treadmill locomotion. J Electromyogr. Kinesiol, 1997, 7, 179-86.
- 7- Henriksson, M, Hirschfeld, H. Physically active older adults display alterations in gait initiation. Gait and Posture, 2005, 21, 289-96.
- 8- Tirosh, O, Sparrowb, WA. Age and walking speed effects on muscle recruitment in gait termination. Gait and Posture, 2005, 21, 279–88.

- 9- Bankoff, ADP, Boer, NP. Electromyographical study of the ilicostalis lumborum and gluteus maximus muscles during locomotion on a treadmill and in a ground. Electromyogr.clin. Neurophysiol., 2007, 47, 285-91.
- 10- Hamil,J.; Knutzen, M. K. Bases Biomecânicas do Movimento Humano.1ª ed., Editora Manole Ltda, São Paulo, 1999.
- 11- Hamil,J.; Knutzen, M. K. Bases Biomecânicas do Movimento Humano.2ª ed., Editora Manole Ltda, São Paulo, 2008.
- 12- Inman, V.T. Human walking. 1^a ed., Baltimore, Williams & Wilkins, 1981.
- 13- Adelaar, RS. The practical biomechanics of running. Am J Sports Med. 1986,14, 497–15.
- 14-Anderson, FC, Pandy, M G. Individual muscle contributions to support in normal walking. Gait Posture, 2003, 17 (2): 159-69.
- 15- Hossain, M, Nokes, LD. A model of dynamic sacro-iliac joint instability frommalrecruitment of gluteus maximus and biceps femoris muscles resulting in lowback pain. *Med. Hypotheses*, 2005, 65(2):278-85.
- 16-Clark, BC. *et al.* Electromyographic activity of the lumbar and hip extensorsduring dynamic trunk extension exercise. *Arch. Phys. Med. Rehabil*,2002,83(11):1547-52.
- 17- Jonkers, I, Stewart, C, Spaepen, A. The complementary role of theplantarflexors, hamstrings and gluteus maximus in the control of stance limb stability during gait. *Gait Posture*, 2003,17(3): 264-72.
- 18- Jull, GA, Janda, V. Muscle and motor control in low back pain: Assessment and management. In: Twomey, L. T. & Taylor, J. L. (eds.) *Physical therapy of the low back.*, New York: Churchill Livingstone, 1987, 253-78.

19-Boren, K, Conrey,C, Le Coguic, J, Padrocki, L, Voight, M, Robinson, TK. Electromyographic analysis of gluteus medius and gluteus maximus during rehabilitation exercises. Int J Sports Phys Ther, 2011, 6, 206-23.

20-Araujo, WB. Ergometria e Cardiologia Esportiva, 1ªed. Editora Medsi, Rio de Janeiro, 1986.

^{1,2} Faculdade de Educação Física da Universidade Estadual de Campinas