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original article

# Effects of a subsequent task after sit-to-stand movement on muscle activation and initiation of movement

## *Efeitos da tarefa subsequente ao sentar e levantar sobre a ativação muscular e início do movimento*

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**Abstract** – Muscle activation (activation time) and the beginning of movement (motor reaction time) can be changed depending on the complexity of the task. The objectives of this study were to compare the time for activation of the paraspinal and the vastus lateralis muscles, and the motor reaction time during the execution of the tasks sit-to-stand (STS) and sit-to-walk (STW), which includes the execution of the subsequent task of gait initiation. Twelve healthy young subjects participated in the study. They performed two tasks (STS and STW), five times each, randomly, separated by two minutes of rest. The kinematics of the movement were recorded using a digital electrogoniometer attached to the hip joint and muscle activation using surface electromyography in both muscles. The average of the five repetitions was calculated for each task. The beginning of the task was signaled by a luminous device, which was also used to identify the initial point for calculating the activation time and motor reaction time. Both muscles showed a longer latency for the activation time and motor reaction time during the STW task when compared with STS. Based on these results, it can be concluded that both the postural (paraspinal) and prime mover muscles (vastus lateralis) undergo change in the motor programming during the execution of the STS task when a subsequent task (gait initiation) is included. Motor programming is dependent on task complexity, where a more complex task (STW) will result in delays of movement programming and execution.

**Key words**: Dual-task; Electromyography; Movement initiation.

**Resumo** – *A ativação muscular (tempo para ativação) e o início do movimento (tempo de reação motor) podem ser alterados em consequência da complexidade da tarefa. Os objetivos do estudo foram comparar o tempo para ativação dos músculos paravertebral e vasto lateral e o tempo reação motor durante a execução das tarefas de sentar e levantar (SPV) e sentar e levantar com a execução da tarefa subsequente de deambular (SPVE). Doze sujeitos jovens sadios participaram do estudo. Cada sujeito executou as duas tarefas (SPV e SPVE), realizando-as em cinco repetições, com intervalo de dois minutos, sendo estas escolhidas de forma aleatória. Foram analisadas a cinemática do movimento, utilizando um eletrogoniômetro digital acoplado a articulação do quadril e a ativação muscular, utilizando eletromiografia de superfície. Posteriormente, a média das cinco repetições foi calculada. O início da tarefa foi identificado por um sinal luminoso, sendo este também utilizado na identificação do ponto inicial para o cálculo do tempo para ativação e motor. Tanto o músculo paravertebral quanto o vasto lateral, apresentaram maior latência para o tempo para ativação e motor na tarefa SPVE quando comparada a SPV. Conclui-se que tanto músculos posturais (paravertebrais) quanto os motores primários (vasto lateral) para a execução da tarefa SPV sofrem alteração na programação motora, quando uma tarefa subsequente (deambulação) é incluída. A programação motora é dependente da complexidade da tarefa a ser executada, sendo que uma tarefa mais complexa implica maiores latências para a programação e execução do movimento.*

**Palavras-chave**: *Eletromiografia; Início do movimento; Tarefa subsequente.*

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# INTRODUCTION

The physiological and biomechanical mechanisms that allow humans to maintain a bipedal posture, generally called postural control, are frequent topics in the area of biomechanics and motor control[1-4]. Therefore, an efficient control of the muscles by the central nervous system (CNS) is required in order to maintain the position and body orientation in space[3]. Thus, it is vital that sensory and motor information are precisely coordinated so that the desired task is performed successfully[1,5].

The sit-to-stand (STS) movement is common in our everyday lives and is essential in maintaining an individual's independence. This movement requires synergistic actions among the extensor and flexor muscles of the trunk and knees. Studies[1,6,7] that analyzed electromyographic patterns during the STS task in healthy young adults have assigned the role of prime movers to the quadriceps and hamstring muscles, while the paraspinal, tibialis anterior, soleus, abdominal, sternocleidomastoid, and trapezius muscles were considered responsible for fine postural adjustments during the action of the prime movers.

Disturbances caused by a subsequent task have been explored during dual tasks (where the posture and the subsequent task are independently controlled) or in tasks that recognize posture as being dependent on the goals of the next task with integrated control between both[8]. Within the context of analyzing the response of the subsequent task, it is important to emphasize that the anticipation is primarily a perceptual function that is associated with the term "what is to come." However, anticipation only occurs when existence of the perturbation is known[4]. The efficiency of anticipatory movements depends on 1) the perception of the initial position of the limbs and body in space, 2) the evaluation of the distance between a body segment and the desired position and finally, 3) programming of the timed commands for muscle activation[9,10]. Studies that have sought to understand sequential tasks addressed basically postural tasks associated with subsequent manual tasks[11,12], unlike in the present study. Thus, to our knowledge, there is a gap in the literature on studies that address the relationship of the STS task with the subsequent task of gait initiation.

Therefore, we aimed to compare the anticipatory activation of the paraspinal and vastus lateralis muscles during the STS and STS with the execution of the subsequent task of gait initiation, or sit-to-walk (STW). Furthermore, we checked whether anticipatory activation changes the beginning of the movement itself. In this article we will use the terms "*activation time*" (AT) as being the time interval between the visual stimulus and the beginning of muscle activation, and "*motor reaction time*" (MRT) as being the time interval between the visual stimulus and the beginning of the movement itself. We hypothesized that the inclusion of the subsequent task of gait initiation would result in longer latency for AT and MRT[13] due to the inclusion of a new task resulting in a longer time to process the information in the central nervous system.

# METHODS

The participants in this study were chosen unintentionally. The exclusion criteria were any history of pain or dysfunction in the spine and/or any condition that might interfere with static and dynamic postural control. All subjects signed a term of informed consent approved by the local Ethics Committee and in accordance with the Declaration of Helsinki. Twelve male subjects with average ± standard deviation of 24.5±3.7 years old, body mass of 70.92±3.85kg, and a height of 172±0.04cm participated in the study.

## Instrumentation

Muscle activity was recorded using electromyography (*Miotool 400, Miotec, Brazil*) and surface electrodes (*Kendal Meditrace, Ag/AgCl,* 2.2cm in diameter) in bipolar configuration. The preparation and fixation techniques used were those recommended in SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles)[14], aiming to ensure the best positioning of the surface recording electrodes. After the preparation of the skin, the electrodes were placed parallel with the approximate direction of the muscle fibers of the paraspinal and vastus lateralis muscles on the subject's preferred lower limb (dominant) between the motor point and the muscle's insertion tendon. These muscles are strongly active during the STS task[1,6]. The ground electrode was positioned on the bone protuberance of the lateral malleolus on the subject's preferred lower limb. The kinematic analysis of the movement was measured using a digital electrogoniometer (*Miotool 400, Miotec, Brazil*) attached to the hip joint in order to identify the beginning and end of the movement (MRT). All data was acquired at a sampling frequency of 1000Hz.

## Experimental procedures

Subjects were seated on a chair without armrest, but with a height-adjustable seat, remaining with both feet on the ground and with the knee and hip joints at a 90-degree angle.

To carry out each task, subjects were instructed as to the existence of luminous device responsible for informing the beginning of the task execution, determined by the researcher. In addition to triggering the start of the task, the device also generated an electrical impulse used to synchronize the signals from the electromyograph and electrogoniometer.

The identification of the MRT was performed using an electrogoniometer attached to the hip joint of the subject's preferred limb, with one of the rods connected to the lateral region of the thigh and the other connected to the side of the trunk with the axis of movement on the greater trochanter of the femur. Previous studies have shown that the first movement to perform the STS task occurs at the hip level[15].

After proper positioning and familiarization, each subject performed two tasks: (1) execution of the task sit-to-stand (STS) and (2) execution of the sit-to-stand task with the addition of a subsequent walking task (STW), consisting of three steps. Each task was repeated five times with two-minute intervals in order to minimize possible effects of fatigue. The tasks were performed randomly, where the first task was defined by drawing and subsequently repeated five times, followed by five repetitions of the second task. The subject was instructed to always perform the task as soon as the luminous devices was turned on and to perform the task as naturally as possible.

## Data analysis

Data of muscle activation (AT) and angular movement (MRT) were stored in Microsoft Excel 2007 spreadsheets (Microsoft Corp., USA) and analyzed using scripts developed in the software Matlab 7.3 (MATLAB 7.3, Mathworks Inc., Novi, MI, USA). The EMG data was filtered using a bandpass filter of 10-1000Hz and amplified 500 times. No filter was used for angular movement data.

The EMG data of each trial was analyzed as follows: after the electromyographic signal was rectified, the instant that the light signal went on was identified (the moment when the subject was instructed to begin the task), which was called $T_0$. Starting from $T_0$, a baseline epoch was created starting at 50ms after $T_0$ and ending 100ms after $T_0$ while the subject was still at rest. From there the average and a value greater than two times the standard deviation of the electromyographic signal was calculated. Values greater than twice the standard deviation of the average electromyographic signal at rest (baseline epoch) and lasting longer than 5ms were used to identify the point in time when muscle activation (AT) took place[4]. The same procedures used in the analysis of the electromyographic signal were performed for the electrogoniometer's data (MRT). A baseline epoch was created and the beginning of movement was defined by a value greater than twice the standard deviation of the rest angle (Figure 1).

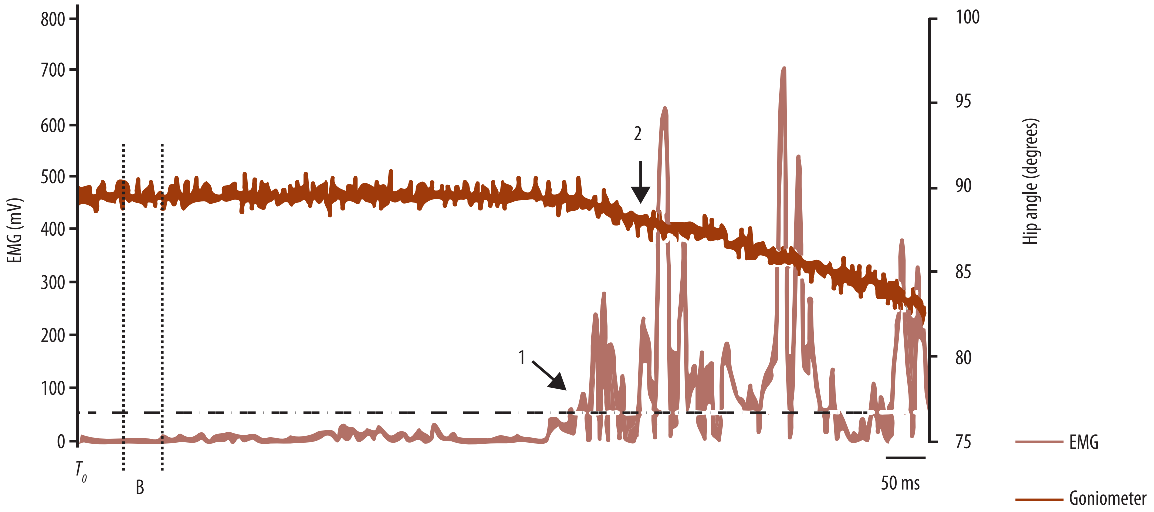

**Figure 1.** Muscle activation (grey line) and kinematic (black line) pattern of a single subject. T0 = Time at which instruction was given to begin the task (light signal), B = baseline epoch for calculating the average of the EMG (AT) and angular (MRT) signal starting 50ms and finishing 100ms after T0. The activation time is represented by the arrow 1 (value two times greater than the standard deviation; horizontal dotted line) while the movement start time is represented by arrow 2. Both are calculated from values greater than two standard deviations from the average calculated in the baseline epoch.

## Statistical analysis

Standard descriptive statistics was performed and the data is reported as mean ± standard deviation. The normality of the data was verified using the Shapiro-Wilk test. Dependent Student's *t* test was used to compare the AT and MRT (dependent variables) between the muscles analyzed and between the STS and STW tasks. Statistical analysis was performed using SPSS for Windows version 13.0 (*Statistical Package for Social Sciences Inc., Chicago IL, USA)* with $\alpha=0.05$.

# RESULTS

The data was verified as having normal distribution. The speed of movement between the two tasks was not significant ($p=0.06$).

The paraspinal muscle showed lower values of AT for the STS task compared with the STW task [$t_{(11)} = -3.132$; $p=0.010$] (Figure 2A). The vastus lateralis muscle also showed significantly lower values of AT for the STS task compared with the STW task [$t_{(11)} = -4.776$; $p=0.001$] (Figure 2B).

Similarly, MRT had significantly lower values on the STS task when compared to the STW task [$t_{(11)} = -3.902$; $p=0.002$] (Figure 3).

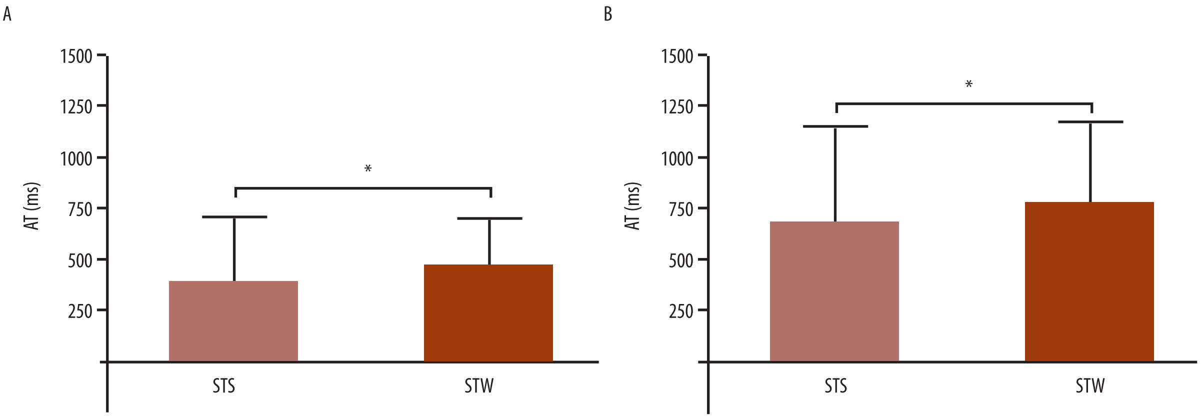

**Figure 2.** Activation time (AT) of the paraspinal (2A) and the vastus lateralis (2B) muscles for the STS and STW tasks (*p<0.05)

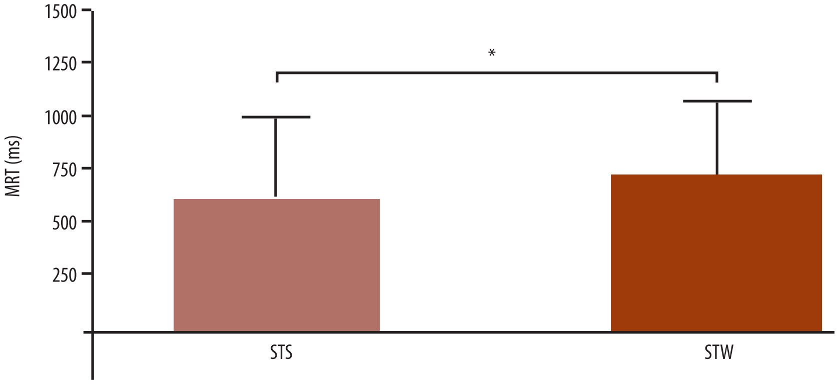

**Figure 3.** Motor reaction time (MRT) of the hip joint in relation to the STS and STW tasks (*p<0.05)

## DISCUSSION

This study aimed to compare muscle activation time (AT) and motor reaction time (MRT) between the STS and STW tasks. Our main results show that both the paraspinal muscle as well as the vastus lateralis muscle had a longer latency for starting muscle activation for the STW task when compared with STS task. Furthermore, the MRT was shorter when only one task was assigned (STS). Thus, our results indicate that the introduction of a new task implies in a new motor planning illustrated by the longer latency in muscle activation and longer MRT when executing the subsequent task (STW), which confirms our initial hypothesis.

The activation of the muscles involved in postural control occurs prior to the main movement aiming to avoid excessive or unnecessary movements that could result in loss of body stability[16]. Some studies[1,6,7] observed the patterns of muscle activation during the STS task. Goulart[6] analyzed muscle activation during the sit-to-stand task in healthy young adults. These authors attributed the role of prime movers of the STS task to the quadriceps and hamstring muscles while the paraspinal muscle was considered responsible for fine postural adjustments, stabilizing the body during the action of the prime movers. Our results are consistent with this theory as we found greater anticipation for the paraspinal muscle when compared to the vastus lateralis muscle. Therefore, we believe that anticipatory muscle activation is a representation of the subject's postural stability protection, especially in relation to the spine.

The electrical activity of the trunk's stabilizing muscles, in this case the paraspinal muscle, has been reported as anticipatory and related not only with arm movements, but also with lower limbs[16]. Moreover, we found a significant difference in the AT of the paraspinal and vastus lateralis muscles when comparing the STS and STW tasks. Therefore we can infer that motor programming is dependent on the complexity of the task, so when a second task is established, the CNS needs to process a larger amount of information, slowing down the anticipatory activation. Furthermore, these effects extend not only to the prime movers (knee extensors), but also to secondary movers (spine extensors) which are responsible for controlling the inclination of the trunk forward in the beginning of the STS movement and extend the spine after the subject loses contact with the chair.

As already cited in another study[17], anticipatory activity can improve the efficiency of the movement and move the body segments to a more suitable position for performing the activity without excessive expenditure of energy and loss of postural stability. Anticipatory postural adjustments are important since they stabilize the body against perturbations[2].

Despite the pattern of muscle activation of the task STS is well described in the literature, studies on the influence of the subsequent task are still inconclusive. It's known that the disturbances caused by realizing a subsequent task have been explored during dual tasks (posture and task are controlled independently) and tasks where posture is understood to be dependent on the objectives of the subsequent task with an integrated control between the two[18]. Some studies[11,12,19] observed that when the subject aims a target with a pointer at different speeds and distances, the center of mass always moves toward the target, while the upper limbs have different behaviors depending on the distance and the speed at which the pointer reaches the target. These results demonstrate that during a subsequent hand task, posture was not significantly affected by the perturbation, perhaps due to the coordinated movements of the entire body in order to keep the hand function. Another study[20], however, states that integration occurs between tasks and suggests that posture adjusts itself depending on the task in order to optimize its execution, considering that the subsequent task imposes restrictions on postural control so that it adjusts according to the demand from the first task. Taking into consideration our results, we can suggest that the amount of time to plan the movement is influenced by multiple tasks. The results showed that more time was needed to plan and execute the STW task when compared with the STS task. This idea is supported by the results of Eversheim and Block[21], which suggest that in all taken actions, there is an interval of time between the intention to act and the beginning of the movement, and this time period is occupied by the decision-making process and is called reaction time.

Thus, we suggest that the individual plans in advance what is to come, in this case the task of walking, even before performing the sit-to-stand task. The primary motor cortex in the CNS, known to be active during the execution and preparation of movements, increases its activity when individuals perform sequential movements. The cerebellum is essential for motor coordination, adaptation, and predictive control, and is therefore inevitably involved in the programming and execution of sequential movements[22]. Thus, the agreement of the results of AT and MRT strengthens the idea that there is a longer latency in processing information during dual tasks. Thus, based on the idea that the decision and planning processes affects the reaction time, the result of this study acknowledges that the subsequent task of walking initiation is dependent on the sit-to-stand task with integrated control between the two.

A limitation of the study was not using other kinematic equipment to analyze the movement of the body as a whole. These results would contribute to analyze the movement and motor programming more precisely. Moreover, a greater number of electromyography channels could help to understand which other muscles are active during specific periods of the movement.

## CONCLUSION

Our results showed that the more complex the task (such as in the case of the task STW), longer the latency for AT both for the paraspinal and the vastus lateralis muscles. Consequently, the MRT (start of the movement) is also affected by the complexity of the task. Therefore, it can be concluded that motor programming is dependent on the complexity of the task to be performed and a more complex task implies in longer latencies for programming and executing the movement. The results indicate that the initial motor programming of the paraspinal muscle is generated before the movement starts and any change that this motor program has to undergo needs enough time to generate the postural corrections necessary to maintain postural stability. Our results can contribute to the development of postural rehabilitation protocols and guide treatment strategies involving sequential tasks.

## REFERENCES

1. Millington PJ, Myklebust BM, Shambes GM. Biomechanical analysis of the sit-to-stand motion in elderly persons. Arch Phys Med Rehabil 1992;73(7):609-17.
2. Mochizuki L, Amadio AC. Sensory information for posture. Fisioter Mov 2006;19(2):11-8.
3. Pavol MJ, Pai YC. Feedforward adaptations are used to compensate for a potential loss of balance. Exp Brain Res 2002;145(4):528-38.
4. Santos MJ, Kanekar N, Aruin AS. The role of anticipatory postural adjustments in compensatory control of posture: 1. Electromyographic analysis. J Electromyogr Kinesiol 2010;20(3):388-97.
5. Schenkman M, Berger RA, Riley PO, Mann RW, Hodge WA. Whole-body movements during rising to standing from sitting. Phys Ther 1990;70(10):648-51.
6. Goulart FR, Valls-Sole J. Patterned electromyographic activity in the sit-to-stand movement. Clin Neurophysiol 1999;110(9):1634-40.
7. Hodges PW, Cresswell AG, Thorstensson A. Perturbed upper limb movements cause short-latency postural responses in trunk muscles. Exp Brain Res 2001;138(2):243-50.
8. Berrigan F, Simoneau M, Martin O, Teasdale N. Coordination between posture and movement: interaction between postural and accuracy constraints. Exp Brain Res 2006;170(2):255-64.
9. Goodman SR, Latash ML. Feed-forward control of a redundant motor system. Biol Cybern 2006;95(3):271-80.
10. Strother L, Obhi SS. The conscious experience of action and intention. Exp Brain Res 2009;198(4):535-9.
11. Norrie RG, Maki BE, Staines WR, McIlroy WE. The time course of attention shifts following perturbation of upright stance. Exp Brain Res 2002;146(3):315-21.
12. Pozzo T, Stapley PJ, Papaxanthis C. Coordination between equilibrium and hand trajectories during whole body pointing movements. Exp Brain Res 2002;144(3):343-50.
13. Tombu M, Jolicoeur P. A central capacity sharing model of dual-task performance. J Exp Psychol Hum Percept Perform 2003;29(1):3-18.
14. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesol 2000;10(5):361-74.
15. Lomaglio MJ, Eng JJ. Muscle strength and weight-bearing symmetry relate to sit-to-stand performance in individuals with stroke. Gait Posture 2005;22(2):126-31.
16. Paula FVR, Faria CDC, Vieira DSR. Teoria de programação motora: uma perspectiva da sua evolução teórica. Fisioter Mov 2007;20(2):63-71.
17. Goulart F, Chaves CM, Vallone MLDC, Carvalho JA, Saiki KR. O movimento de passar de sentado para de pé em idosos: implicações para o treinamento funcional. Acta Fisiatr 2003;10(3):138-43.
18. Bloem BR, Valkenburg VV, Slabbekoorn M, van Dijk JG. The multiple tasks test. Strategies in Parkinson's disease. Exp Brain Res 2001;137(3-4):478-86.
19. Rankin JK, Woollacott MH, Shumway-Cook A, Brown LA. Cognitive influence on postural stability: a neuromuscular analysis in young and older adults. J Gerontol A Biol Sci Med Sci 2000;55(3):M112-9.

20. Stoffregen TA, Hettinger LJ, Haas MW, Roe MM, Smart LJ. Postural instability and motion sickness in a fixed-based flight simulator. Hum Factors 2000;42(3):458-69.
21. Eversheim U, Bock O. The role of precues in the preparation of motor responses in humans. J Mot Behav 2002;34(3):271-6.
22. Middleton FA, Strick PL. Basal ganglia and cerebellar loops: motor and cognitive circuits. Brain Res Rev 2000;31(2-3):236-50.

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