

Coactivation and peak torque of extensors and flexors knee muscle in chronic hemiparetics in sitting and supine positions

Coativação e pico de torque dos músculos extensores e flexores do joelho em indivíduos hemiparéticos crônicos nas posições sentada e supina

Coactivación y pico de torque de los músculos extensores y flexores de rodilla en sujetos hemiparéticos crónicos en las posiciones sentada y supina

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ABSTRACT | Disorders in co-activation and decreased muscle strength are often described in hemiparetic subjects. Changes in muscle length resulting from postural change may result in different responses of co-activation and strength of these individuals. The objective of this study was to evaluate the influence of sitting and supine positions in Co-activation Index (CI) and peak torque (PT) of chronic hemiparetic subjects after stroke. The participants were twenty individuals with mean age of 54±12.14 years; mean body mass index of 26.93±3.34 kg/m²; average stroke time of 55.85±49.4 months; Mini-Mental State Examination score between 27-30; and Fugl-Meyer of lower limb between 15-30. The electromyographic record was obtained while the volunteers performed five isokinetic contractions (60°/s) of knee extension and flexion in the sitting and supine positions. The semitendinosus muscle of paretic limb exhibited lower CI in the supine position compared to sitting: 0.36±0.33; 0.44±0.33 (p=0.048). There was no difference in CI of the rectus femoris between positions: 0.28±0.25 sitting and 0.23±0.21 supine. The PT of extensor and flexor muscles of the paretic limb did not vary between positions (PT extensor: sitting = 56.48±37.62 Nm, supine = 52.29±32.37 Nm; PT flexor: sitting = 12±11.1 Nm, supine = 10.95±6.4 Nm). The supine position showed lower CI in the semitendinosus muscle of paretic limb. The change of position did not influence the CI of rectus femoris muscle neither the PT of both muscle groups of the paretic limb. Thus, the supine position appears to be indicated during movement and

strength training of these muscles in chronic hemiparetic patients after stroke.

Keywords | Stroke; Muscle Strength; Electromyography.

RESUMO | Distúrbios na coativação e diminuição de força muscular são frequentemente descritos em indivíduos hemiparéticos. Alterações do comprimento muscular decorrentes da mudança postural podem resultar em diferentes respostas de coativação e força desses indivíduos. O objetivo deste estudo foi avaliar a influência das posições sentada e supina no Índice de Coativação (ICa) e no pico de torque (PT) de indivíduos hemiparéticos crônicos pós-AVE. Participaram do estudo vinte indivíduos com média de 54±12,14 anos; Índice de Massa Corpórea médio de 26,93±3,34kg/m²; tempo médio de AVE 55,85±49,4 meses; escore do minitaxa do estado mental entre 27-30 e Fugl-Meyer do membro inferior entre 15-30. O registro eletromiográfico foi obtido enquanto os voluntários executavam cinco contrações isocinéticas (60°/s) de extensão e flexão do joelho, nas posições sentada e supina. O músculo semitendíneo do membro parético exibiu ICa menor na posição supina em comparação à sentada: 0,36±0,33; 0,44±0,33 (p=0,048). Não houve diferença no ICa do reto femoral entre as posições sentada (0,28±0,25) e supina (0,23±0,21). O PT dos músculos extensores e flexores do membro parético não variou entre as posições (PT extensor: sentado = 56,48±37,62Nm, supino = 52,29±32,37Nm; PT flexor: sentado = 12±11,1Nm; supino = 10,95±6,4Nm). A posição

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supina mostrou menor ICa no músculo semitendíneo do membro parético. A mudança de posição não influenciou o ICa do músculo reto femoral nem o PT de ambos os grupos musculares do membro parético. Assim, a posição supina parece ser indicada durante mobilizações e treinamento de força desses músculos em pacientes hemiparéticos crônicos pós-AVE.

Descritores | Acidente Vascular Cerebral; Força Muscular; Eletromiografia.

RESUMEN | Los trastornos en la coactivación y disminución de la fuerza muscular están frecuentemente descritos en sujetos hemiparéticos. Las alteraciones del tamaño muscular debido al cambio postural a los sujetos les pueden resultar diferentes respuestas de coactivación y de fuerza. En este estudio se pretende evaluar la influencia de las posiciones sentada y supina en el Índice de Coactivación (ICa) y en el pico de torque (PT) de sujetos hemiparéticos crónicos pos-ACV. Veinte personas han participado del estudio con promedio de 54±12,14 años; Índice de Masa Corporal promedio de 26,93±3,34kg/m²; promedio de tiempo del ACV de 55,85±49,4 meses;

puntuación del Mini-Examen Cognoscitivo entre 27-30 y Fugl-Meyer del miembro inferior entre 15-30. Se obtuvo el registro electromiográfico mientras los participantes ejercían cinco contracciones isocinéticas (60°/s) de extensión y de flexión de la rodilla, en las posiciones sentada y supina. El músculo semitendinoso del miembro parético presentó ICa menor en la posición supina que en la sentada: 0,36±0,33; 0,44±0,33 (p=0,048). No hubo diferencias en el ICa del recto femoral entre las posiciones sentada (0,28±0,25) y supina (0,23±0,21). El PT de los músculos extensores y flexores del miembro parético no presentó variación entre las posiciones (PT extensor: sentada = 56,48±37,62Nm, supina = 52,29±32,37Nm; PT flexor: sentada = 12±11,1Nm; supina = 10,95±6,4Nm). La posición supina mostró menor ICa en el músculo semitendinoso del miembro parético. El cambio de posición no influyó el ICa del músculo recto femoral tampoco el PT de ambos grupos musculares del miembro parético. De esta manera, la posición supina parece ser la indicada durante movilizaciones y entrenamientos de fuerza de dichos músculos de sujetos hemiparéticos crónicos pos-ACV.

Palabras clave | Accidente Cerebrovascular; Fuerza Muscular; Electromiografía.

INTRODUCTION

Hemiparesis is the main sequela from cerebrovascular accidents (CVA), and it is characterized by the presence of spasticity and disorders in the reciprocity and inhibition of antagonist muscles, which generates excess muscle coactivation¹. These disorders lead to muscle weakness and wasting of energy². Changes in muscle coactivation or cocontraction have been the targets of several studies that aim to understand and minimize their effects, such as the positioning a certain individual adopts^{3,4}.

Sitting and supine positions may exert different influences in the motor activity of hemiparetic patients, as they cause the length of rectus femoris and hamstring muscles to be changed, which results in different activation and muscle strength responses^{3,5}. Thus, understanding such influences may help professionals dealing with this population's rehabilitation choosing how to position patients, especially in tasks requiring action from these muscles.

Electromyography is the main technique used to evaluate muscle coactivation, although some studies only use activation intensities of antagonist muscles

to analyze it, which generates controversial results, as seen by Clark et al.⁶, who reported higher antagonist activation in their control group as compared to a group of spastic hemiparetic patients during knee extension; and Fleuren et al.⁷, who showed statistically higher antagonist activation of paretic limbs as compared to non-paretic limbs during the same movement. Thus, the Coactivation Index (CaI) is an option for standardizing the evaluation of muscle cocontraction. This method expresses coactivation by comparing the electromyographic activity of a muscle while it is acting as an antagonist and agonist⁸.

Peak of Torque (PT) is provided by isokinetic dynamometers, and it represents the maximum torque recorded during muscle contractions. This is a variable frequently used to evaluate muscle strength⁹. Healthy individuals have been shown to be capable of producing higher knee extensor and flexor PTs during situations of isometric and isotonic contractions in body positions causing further muscle stretching¹⁰. Michaelsen et al.⁵ and Bohannon¹¹ stated the same thing for knee flexors of post-CVA subjects during isometrics. Despite its being more frequent in daily tasks, no studies were

found to evaluate torque during isotonic contractions or hemiparetic patients in such conditions.

Considering that, this study intended to evaluate the influence from sitting and supine positions in the Coactivation Index (CaI) of rectus femoris and semitendinosus muscles and in the isokinetic concentric Peak of Torque (PT) of knee extensor and flexor muscle groups of post-CVA chronic, spastic hemiparetic subjects.

METHODOLOGY

This is an observational, cross-sectional study involving comparisons between muscle coactivation and peak of torque levels between sitting and supine positions and between paretic and non-paretic hemibodies of subjects with history of CVA. This research was conducted in the Federal University of Pernambuco's Kinesiology and Functional Evaluation Laboratory, according to Resolution 466/2012 of the Brazilian Ministry of Health's National Health Council, and it was approved by the Research Ethics Committee of the Federal University of Pernambuco (CAAE no. 05479912.9.0000.5208).

It included subjects who had suffered ischemic or hemorrhagic CVAs at least six months before, with no relapses of associated pathologies (orthopedic, rheumatic, or metabolic ones), who were capable of executing the proposed experimental protocol, with normal blood pressure levels, who did not make use of medications that could influence motor performance (muscle relaxants or botulinum toxin), and who mostly had arm, thigh, or both sequelae, as long as they had scores between 10 and 30 in the lower extremity domain of the Brazilian version of the Fugl-Meyer Assessment^{12,13}.

The excluded subjects were the ones who had scores lower than 19 (if illiterate) or 25 (if literate) in the Brazilian version of the Mini Mental State Examination (MMSE)^{14,15}; who had hypertensive peak episodes (Systolic pressure greater than 140 mmHg or diastolic pressure greater than 90 mmHg) verified before the evaluation; and those who were not capable of fully extending their knees (0°).

Volunteers were selected by convenience from a file in the laboratory. The ones considered apt signed informed consent forms.

Twenty subjects took part in the study. They were 54±12.14 years old in average; average Body Mass Index: 26.93±3.34 kg/m²; and Average time of CVA of 55.85±49.4 months. Subjects had Mini Mental State Examination scores between 27 and 30, and Fugl-Meyer Assessment of lower limb scores between 15 and 30.

Miotool 400 (Miotec[®]), electromyograph was used to record EMG values. It had four channels, gain of 1000, and common-mode rejection ratio of 110dB to 60Hz. Butterworth analog filters (4th order), high pass at 20Hz, low pass at 500Hz, and a notch filter at 60Hz. 14-bit analog/digital converter, and 2 KHz sampling frequency.

Surface electrodes of 3 cm in diameter (Meditrace[®]) were used to capture electric signals from Rectus Femoris (RF) and Semitendinosus (ST) muscles. Before the electrodes were placed, the patients' skin was sanitized through local trichotomy, cleaning with 70% ethyl alcohol, and abrasion with a rugged sponge. The electrodes were placed pursuant to the recommendations from SENIAM – Surface Electromyography for the Non-Invasive Assessment of Muscle¹⁶. They were 20 mm distant from each other, and the reference electrode was fixed on the head of the fibula in the evaluated limb.

The captured data were exposed in the MiotecSuite[®] software. The electromyographic data were recorded at the same time patients performed an activity in the isokinetic dynamometer.

A Humac2009/Norm dynamometer (CSMi[®]) was used to record muscle strength - subjects were asked to perform ten knee extension and flexion repetitions in the concentric mode, the first five for warm-up purposes and the last five after 30 seconds, for analysis purposes, using a speed of 60°/s. After a three-minute break, the same task was performed in the supine position.

In the sitting evaluation, subjects were stabilized via restraining belts and placed at a 85° angle from the horizontal plane. The rotation axis of the dynamometer was aligned to the lateral epicondyle of the femur and the lever was fixed in the distal third of the evaluated limb. To calibrate range of joint motion (ROM) the active joint mobilization ability of each subject was considered. Following that, the limb was weighed while fully extended, and these values were used to cancel the effects of gravity in torque values. In the assessment at supine position, the protocol followed the same procedure, and the dorsal chair rest was inclined at 10°.

The signals recorded by the dynamometer were provided by the Humac software and displayed at a sampling rate of 100Hz.

To evaluate cocontraction, Coactivation Index (CaI) was used. This index is expressed by dividing the average RMS value of the antagonist muscle and the average RMS value of this same muscle acting as an agonist. To do so, the crude signal was refiltered (pass band of 20-500Hz and notch 60Hz),

rectified, and fit in a moving window at each 50 ms. When the contraction in which subjects performed their highest extensor and flexor peak torques was identified, the average RMS value was calculated in the 500 ms period, 250 ms before and 250 ms after the electromyographic signal peak from the agonist muscle. The average RMS value of the antagonist muscle was calculated within this same interval (Figure 1).

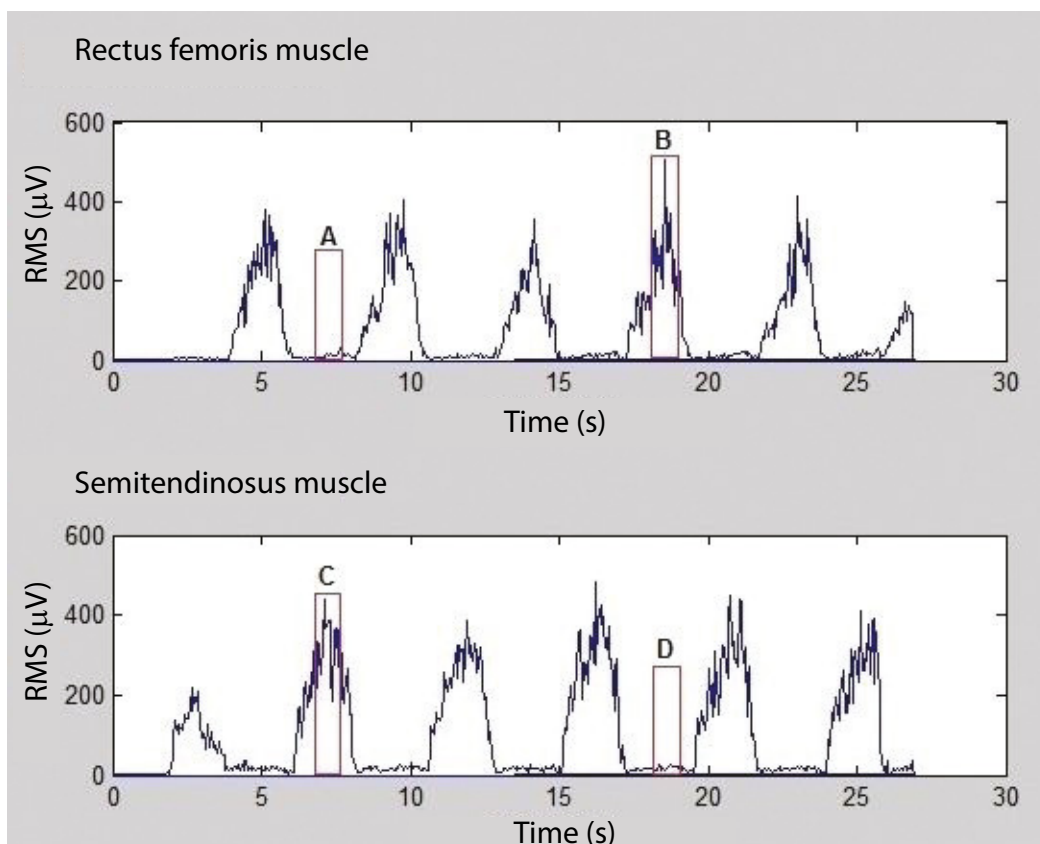


Figure 1. Title: RMS signal of rectus femoris and semitendinosus muscles. Caption: (A) Selection of rectus femoris muscle acting as an antagonist; (B) Selection of rectus femoris muscle acting as an agonist; (C) Selection of semitendinosus muscle acting as an agonist; (D) Selection of semitendinosus muscle acting as an antagonist

The following equations were used:

$$\text{CaI of the rectus femoris muscle: } \frac{\text{RMS AVERAGE ANTAGONIST (A)}}{\text{RMS AVERAGE ANTAGONIST (B)}}$$

$$\text{CaI of the semitendinosus muscle: } \frac{\text{RMS AVERAGE ANTAGONIST (D)}}{\text{RMS AVERAGE ANTAGONIST (C)}}$$

In which A is the time interval the rectus femoris muscle acted as an antagonist during the peak torque of knee flexors; and B is the time interval when this same muscle acted as an agonist during the peak of torque of knee extensors.

In which D is the time interval the semitendinosus muscle acted as an antagonist during the peak torque of knee extensors; and C is the time interval in which this same muscle acted as an agonist during the peak of torque of knee flexors.

Peak of torque (PT) was used to evaluate muscle strength. PT represents the highest torque value recorded within the five extension and flexion contractions performed, and it is expressed in Newton meters (Nm). The Matlab software (Mathworks® 7.6.0) was used to analyze the data.

The variables were compared between sitting and supine positions and between paretic and non-paretic hemibodies. To do so, the data were organized and the Kolmogorov-Smirnov test was performed. Upon verifying sample normality, student's t test for paired samples was applied in the comparisons between positions and between hemibodies. In all cases, a significance level of $p < 0.05$ was adopted. The SPSS statistical software, version 18.0, was used. Results were expressed as average \pm standard deviation.

RESULTS

The CaI of the rectus femoris muscle was not shown to differ between positions for both limbs.

In the comparison between limbs in the sitting position, the paretic one was found to have a higher CaI value: 0.10 ± 0.05 ; 0.28 ± 0.25 ($p = 0.007$), and there was a trend for the same result to be observed in the supine position: 0.11 ± 0.10 ; 0.23 ± 0.21 ($p = 0.05$), (Figure 2).

The semitendinosus muscle in the paretic limb was found to have a lower CaI in the supine position as compared to the sitting one: 0.36 ± 0.33 ; 0.44 ± 0.33 ($p = 0.048$). This muscle was also shown to have a higher CaI in the paretic limb as compared to the non-paretic limb for both positions: sitting 0.12 ± 0.08 ; 0.44 ± 0.33 ($p = 0.001$); supine 0.10 ± 0.09 ; 0.36 ± 0.33 ($p = 0.005$), as shown in Figure 3.

Extensor and flexor PT was shown to be statistically higher in the non-paretic limb as compared to the paretic one for both positions. In the comparison between positions, the only difference was observed in the flexor PT of the non-paretic limb, in which the sitting position was observed to result in a higher PT as compared to the supine position: 29.29 ± 12.9 Nm; 21.38 ± 8.5 Nm ($p = 0.005$), (Figure 4 and 5).

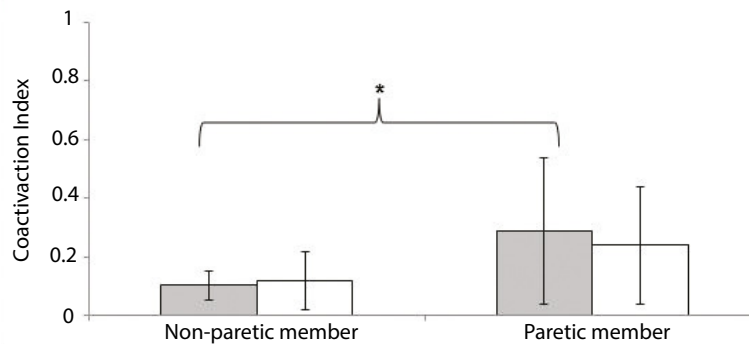


Figure 2. Coactivation Index of rectus femoris muscle. Caption: Grey bar = sitting position; White bar = supine position. *A difference was observed upon comparing paretic and nonparetic limbs in the sitting position ($p < 0.05$)

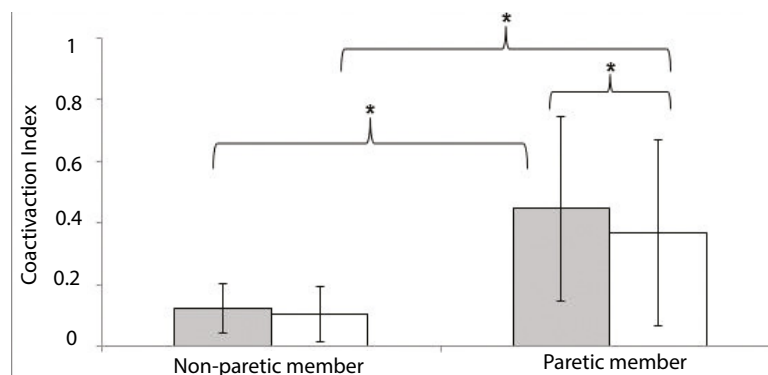


Figure 3. Coactivation Index of semitendinosus muscle. Caption: Grey bar = sitting position; White bar = supine position. *A difference was observed upon comparing paretic and nonparetic limbs in both positions, as well as a difference in the comparison between positions for the paretic limb ($p < 0.05$)

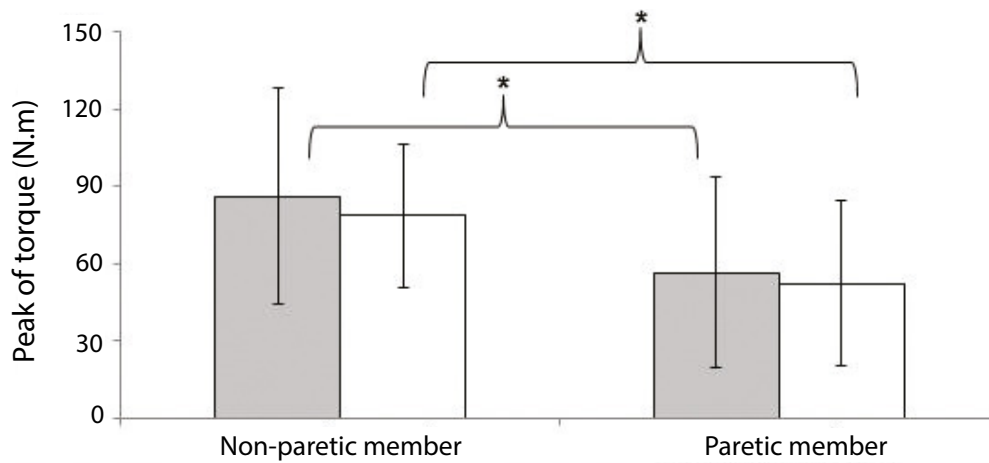


Figure 4. Title: Peak of extensor torque. Caption: Grey bar = sitting position; White bar = supine position. *A difference was observed upon comparing paretic and nonparetic limbs in both positions ($p < 0.05$)

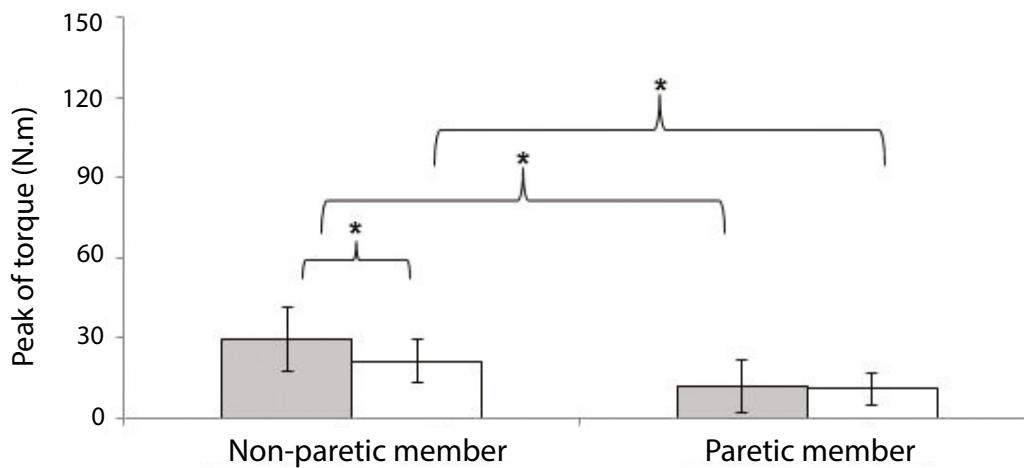


Figure 5. Title: Peak of flexor torque. Caption: Grey bar = sitting position; White bar = supine position. *A difference was observed upon comparing paretic and nonparetic limbs in both positions, as well as a difference in the comparison between positions for the nonparetic limb ($p < 0.05$)

DISCUSSION

According to the results, the shift from a sitting to a supine position was clearly shown to imply reduced CaI of the semitendinosus muscle in the paretic limb and reduced flexor PT in the non-paretic limb. In the comparison between limbs, higher CaI and lower PT values were observed in the affected limb as compared to the opposite one.

The CaI results from the semitendinosus muscle showed that situations with more intense stretching of this muscle, i.e., in the sitting position, result in higher coactivation. The same was observed by Fleuren et al.³,

who evaluated the electromyographic activity of 19 post-CVA hemiparetic subjects in sitting and supine positions. They found a higher level of antagonist activation in semitendinosus and rectus femoris muscles when these were further stretched. That is due to muscle spindles being more sensitive to stretching, because once they are shortened, stretching is faster and more intensely transmitted in spastic muscles⁸.

However, the same result was not observed in this study for the rectus femoris muscle, such as in Horstman et al.¹⁷, who have not reported coactivation differences either for the rectus femoris muscle at different lengths from altered knee angles. He¹⁸ justified that fact by

stating that the increased antagonist activity of the rectus femoris muscle is more frequently seen in severely impaired patients. However, the subjects in this study were observed to have a moderate level of motor activity according to the Fugl-Meyer Assessment, which might have softened the coactivation of this muscle.

Higher CaI values of knee extensor and flexor muscles are commonly seen in spastic individuals as compared to healthy subjects, as seen by Neckel et al.¹⁹ and Hidler et al.²⁰ through EMG and load cell. Regarding the comparison between paretic and non-paretic limbs, Newham and Hsiao²¹ found no significant differences in twelve post-CVA subjects of both genders evaluated through an isokinetic dynamometer, which differs from the result of this study. This disagreement may be justified by the fact that the authors recorded the myoelectric activity during isometric contractions, a mode in which the antagonist coactivation is lower in spastic muscles due to the absence of speed⁶. Another way to justify that is through the fact that the patients studied were in the acute phase (≤ 6 months), a period when CVA sequelae differ from the ones in the chronic phase. In the acute phase there is a predominance of paresis and lack of use of the affected limb, whereas in the chronic period neural adaptations also take place, and these result in muscle hyperactivity and consequent spasticity and cocontraction⁸.

The PT of the paretic limb was lower than the one in the non-paretic limb, and this result corroborates other studies^{11,21,22}. This is justified by alterations that take place in the affected hemibody, such as the diminished efferent commands from the corticospinal pathway, failed reciprocal inhibition that leads to excess coactivation of the antagonist muscle, and secondary muscle alterations, such as reduced cross-sectional area coupled with increased noncontractile tissue^{23,24}.

In the comparison between positions, the sitting position was observed to favor higher PT of knee flexor muscles in the unaffected limb, such as in other studies that evaluated healthy individuals^{10,25-27}. This fact is justified by the stretch-shortening principle, once the sitting position allows insertions to be more distant from each other and hamstring muscles to be consequently stretched. This principle states that a concentric muscle action is intensified when it follows an eccentric action, and that is due to the storage of elastic energy in passive elements, increased cross-bridges, and the muscle spindle strain reflex^{28,29}.

Regarding the paretic limb, no differences were found between positions. Unlike Bohannon¹¹, who

reported higher isometric PT in the sitting position for both hemibodies of twelve acute post-CVA hemiparetic subjects; and Michaelsen et al.⁵, who reported the same thing for ten hemiparetic subjects in the chronic phase. Such disagreement may be justified by the fact that these studies conducted their evaluations during isometrics, in which hemiparetic patients achieve a higher PT as compared to the concentric mode⁶.

In the case of extensor muscles, no PT variations were observed between positions, as there was no influence from the stretch-shortening cycle, once vastus medialis, vastus lateralis, and vastus intermedius muscles³⁰, which account for up to 80% of the knee extensor torque, are monoarticular, and therefore suffer less influence from the hip position^{10,25,26}.

The findings of this study are important, as they provide information to physical therapists and other health care professionals who treat hemiparetic individuals, and also to the very patients with CVA sequelae. As, for example, the semitendinosus muscle in the paretic limb was observed to have reduced coactivation in the supine position and similar peaks of torque among positions, the supine position becomes the most indicated one during strength and motion training of hamstring muscles in this limb. And regarding the extensor muscles, as not differences were observed in the coactivation intensity or either in the peak of torque among evaluated positions, the adoption of the supine position is also recommended when one performs mobilizations or strength training for this muscle group in hemiparetic patients who have respiratory comorbidities, due to the smaller effort this posture requires.

It is important to point out that these interpretations serve for tasks that specifically involve the discussed muscles, such as passive, assisted, active, or resisted mobilizations of knee flexion and extension. Other rehabilitation techniques are required to treat these patients. The adopted positions during the intervention should consequently vary. Besides that, all the interpretations in this study were obtained through evaluation in isokinetic mode, and that is why caution must be observed when these are used in activities involving isotonic or isometric contractions.

This study has as a limitation the sample recruitment, which was conducted by convenience through a database in the laboratory; besides that, the level of physical activity and the fact that patients might have been undergoing physiotherapy treatment were

not controlled during the recruitment of the sample. However, the authors established as an inclusion criterion a predetermined range of scores in the bottom extremity domain of Fugl-Meyer Assessment, which represents a function level that is similar among subjects, regardless of physical activity levels or whether subjects were undergoing physiotherapy treatment.

CONCLUSION

The supine position was found to result in reduced Coactivation Index of the semitendinosus muscle in the paretic limb. In turn, the sitting position favored a higher flexor Peak of Torque in the non-paretic limb. Shifting positions has not influenced the Coactivation Index of rectus femoris or the Peak of Torque of extensor muscles in both limbs. Considering that, it is clear that the supine position seems to be recommended when moving and training the strength of knee extensor and flexor muscles in chronic hemiparetic patients after cerebrovascular accidents.

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