Doi: 10.11606/issn.2317-0190.v14i3a102817

ARTIGO ORIGINAL

Efeito do movimento passivo contínuo isocinético na hemiplegia espástica

Effect of isokinetic continuous passive mobilization in spastic hemiplegia

Vanessa Pelegrino Minutoli[1], Marta Delfino[1], Sérgio Takeshi Tatsukawa de Freitas[2], Mário Oliveira Lima[2], Charli Tortoza[3], Carlos Alberto dos Santos[4]

RESUMO

O Acidente Vascular Encefálico (AVE), afeta freqüentemente a função do Sistema Nervoso Central (SNC). O objetivo principal da reabilitação física é a restauração da função motora para executar as atividades de vida diária tais como, agarrar, alcançar e realizar movimentos complexos. As funções motoras são dependentes do controle da força muscular que se torna comprometida com os danos do Sistema Nervoso Central e se manifesta com incoordenação, hiperreflexia, espasticidade e fraqueza muscular unilateral. Existem vários métodos para quantificar a espasticidade. Atualmente o dinamômetro isocinético demonstra ser um equipamento mais eficaz, pois favorece a padronização da angulação, velocidade de estiramento e posicionamento, podendo minimizar a subjetividade da avaliação. Desde modo, o objetivo desse trabalho foi analisar o efeito da mobilização passiva continua em duas velocidades (120º/s e 180º/s) em pacientes hemiplégicos com hipertonia espástica. Cinco pacientes entre 40 – 55 anos de ambos os sexos com história de AVE apresentando espasticidade, foram submetidos a mobilização passiva contínua por um dinamômetro isocinético por 30 repetições, em velocidades de 120º/s e 180º/s. Todos apresentaram grau 2 de espasticidade dos músculos extensores do joelho e graus 0, 1 e 1+ dos músculos flexores pela escala modificada de Ashworth. Os resultados mostraram uma redução significativa da resistência passiva a partir da 6ª repetição em ambas as velocidades angulares. Concluiu-se que o movimento passivo continuo realizado no dinamômetro isocinético é uma maneira eficaz para medir e reduzir a espasticidade.

PALAVRAS-CHAVE

acidente cerebrovascular, hemiplegia, espasticidade muscular, reabilitação, dinamômetro de força muscular, atividade motora

ABSTRACT

Cerebrovascular Accidents (CVA) often affect the central nervous system (CNS) function. The primary concern addressed in physical rehabilitation is the restoration of the motor function required to perform activities of daily living (ADL), such as grasping, reaching and performing complex movements. Motor tasks depend on the control of muscular strength, which is compromised by damage to the CNS and manifests as impaired coordination, hyperreflexia or spasticity and unilateral muscular weakness. Several methods are used to quantify spasticity. The isokinetic dynamometer seems to be a more effective device, as it allows for the standardization of joint angles, speed of stretching and positioning, in addition to minimizing the subjectivity of the evaluation. Therefore, our objective was to analyze the effect of the continuous passive mobilization at two speeds (120º/s and 180º/s) in hemiplegic patients with spasticity. Five patients of both sexes between 40 - 55 years old with a history of CVA and accompanying spasticity were enrolled in the study. All patients presented degree 2 spastic extensor muscles of the knee joint at the Modified Scale of Ashworth and degrees 0, 1 and 1+ flexor muscles at the same scale. All the individuals were submitted to continuous passive mobilization by an isokinetic dynamometer at speeds of 120º/second and 180º/second with 30 repetitions of each. The results showed a significant reduction of passive resistance

1 Fisioterapeuta – Universidade do vale do Paraíba - Faculdade de Ciências da Saúde
2 Coordenador do Curso de Pós-Graduação Lato-Sensu da UNIVAP; Mestre em Ciências Biológicas pela Universidade do Vale Paraíba
3 Mestre em Ciências da Motricidade - UNESP; Educador Físico
4 Mestre em Ciências da Saúde - UNIFESP; Fisioterapeuta do Hospital Auxiliar de Suzano do Hospital das Clínicas da FMUSP

ADDRESS FOR CORRESPONDENCE
Hospital Auxiliar de Suzano do Hospital das Clínicas da Faculdade de Medicina USP / Carlos Alberto dos Santos
Av. Dr. Prudente de Moraes, 2200 - Suzano - SP - Cep 08675-970
E-mail: cafishas@hcnet.usp.br

Recebido em 02 de Agosto de 2006, aceito em 04 de Julho de 2007.

after the 6th repetition, regardless of the angular velocities. We concluded that continuous passive mobilization by an isokinetic dynamometer is an effective way to quickly measure and reduce spasticity.

KEYWORDS
cerebrovascular accident, hemiplegia, muscle spasticity, rehabilitation, muscle strength dynamometer, motor activity

INTRODUCTION

The cerebrovascular accident (CVA) is an affection of the blood vessels in the central nervous system (CNS) that causes focal alterations of the encephalic functions. Most patients with CVA present some kind of impairment in the superior motor neuron that leads to spastic hypertonia, which many times significantly interfere in the rehabilitation program of these patients, preventing the necessary functional gains and requiring a specific assessment.[1,2,3,4]

One of the main characteristics of the CVA is the presence of spasticity in the upper limbs where the flexor muscles predominate, adduction posture and internal rotation of the shoulder, elbow flexion, forearm pronation and finger flexion. In the lower limbs, the predominance is in the extensor muscles, with extension and internal rotation of the hip, knee extension, plantar flexion and foot inversion.[3,4]

Spasticity is common to the injuries of the superior motor neuron of the spinal cortical-reticular-bulb pathway and results in a neuronal hyperexcitability (alpha and gamma), causing an increase in the resistance to muscular stretching, hyperactivity and hyperreflexia[4,5,6,7,8] and also due to alterations in the viscoelastic properties of the muscle.[9,10] The mechanism of the physiopathology of spasticity is controversial, due to the complexity the neuronal system presents in its spinal and supra-spinal pathways.[5]

Among the several physiopathological mechanisms originated in several points of the stretching reflex pathway involving the alpha, gamma, medullary interneurons and afferent and efferent pathways, the tonus theory is stressed, secondary to the loss of the descending inhibitory influences (reticular-spinal pathway), as a result of injuries that compromise the cortical-spinal tract. The loss of the descending inhibitory influences will result in an increased excitability of the gamma fusimotor neurons and alpha motor-neurons. The main neurotransmitters involved in the mechanism of muscular tonus are: gamma-aminobutyric acid (GABA) and glycine (inhibitory) and glutamate (excitatory), in addition to noradrenaline, serotonin and neuromodulators such as adenosine and several neuropeptides.[4,11]

The assessment of spasticity is very important for the therapeutic procedure. When assessing spastic hypertonia, the modified Ashworth scale (Table 1) is the most often used tool in semiologic clinic by the Physical therapist, despite its known subjectivity.[12]

Bohannon & Smith,[13] observed advantages in the use of the modified Ashworth scale, as it is not necessary to use tools and it a simple, fast as well as affordable technique.

However, the limitations of this type of scale are the lack of standardization of the measurement procedures and the dependence of the examiner's interpretation in the definition of the obtained score, thus being subjective and little reliable.[1,5,14,15,16] According to Akman,[17] the quantification of spasticity is a complex problem for clinicians and researchers and, although the modified Ashworth Scale is the most commonly employed and broadly accepted technique, its use is surely questionable.

Considering the examiners' difficulties regarding the interpretation of the scale, several researchers investigated different methods and tools to evaluate spasticity.[6,17,18,19,20] Currently, the Isokinetic Dynamometer a frequently used tool, as this equipment allows the investigator to standardize the velocity and range of movement (ROM) and objectively register the amount of torque generated by the muscular apparatus. The method, therefore, starts to present simplified and reproducible process and interpretation, which can be applied to a variety of joints and muscles.[17,20]

Perell et al[21] and Thilmann et al[6] suggested that some factors can directly interfere in the results obtained in tests performed with the isokinetic dynamometer. The first important observation is that the velocity used in the test must be higher than 100º/s, necessary to excite the stretching reflex; however, the study by Franzoi et al,[22] shows that, for elevated grades of the scale, the velocity of 60º/s was sufficient, demonstrating that the chosen velocity can produce significant differences in the obtained results.

Another important factor that tends to interfere in the results is the number of performed movements. Franzoi et al,[22] assessed their subjects based on the mean obtained from 5 repetitions performed in the passive mode of the dynamometer, whereas Perell et al,[21]

Table 1
Modified Ashworth Scale

Grade	Clinical observations
0	Normal muscular tonus.
1	Slight increase in muscular tonus, manifested by transient tension or by minimal resistance at the end of the range of movement (ROM) when the affected region is moved in flexion or extension.
1+	Slight increase in muscular tonus, manifested by abrupt tension, followed by minimal resistance in less than half of the remaining ROM.
2	More accentuated increase in muscular tonus during most of the ROM, but the affected parts are easily moved.
3	Considerable increase in muscular tonus, difficult passive movement.
4	Rigid affected parts, in flexion or extension.

analyzed the data of 12 repetitions. According to Vodovnik et al,[18] a test of passive movement with more than 7 repetitions in subjects with medullary lesions that present spastic hypertonia can induce the onset of a hypotonic condition (called accommodation), which suggests that the less severe spastic individuals present differences in the spasticity behavior.

Franzoi et al,[22] reported that the stretching reflex is affected in the passive movement and at the repetition. For these authors, the reduction in the stretching reflex is due to fatigue caused by several repetitions.

These factors (repetitions and velocities) cause an accommodation in the spastic muscles, i.e., they result in the alteration of the resistance to stretching and an expected lower capacity to produce muscular tension with repeated stimulation, also characterized as fatigue.

The fatigue phenomenon has a multifactorial characteristic, thus not being easily identifiable and its interpretation often generates several doubts as well as conceptual contradictions. Classically, the phenomenon is subdivided in peripheral fatigue and central fatigue, with the first being attributed to metabolic causes and the second being correlated essentially with supraneural aspects.

Due to the lack of standardization in the assessment of spasticity, the aim of the present study is to analyze the effect of continuous passive mobilization at two velocities (120º/s and 180º/s) in hemiplegic individuals with spastic hypertonia by Isokinetic Dynamometry and verify at what number of repetitions (0 to 30) the accommodation of spasticity occurred, represented by the significant decrease in resistance torque.

MATERIAL AND METHODS

Subjects

Five individuals of both sexes aged 40 to 55 years, with a diagnosis of Encephalic Vascular Accident (EVA), who presented spastic hemiplegia, were assessed. Inclusion criteria: all the hemiplegic individuals presented grade 2 spasticity at the modified Ashworth Scale in the extensor muscles of the knee joint and grade 0, 1 and 1+ in the flexor muscles, with free range of movement (ROM), i.e., they did not present muscle rigidity or shortening

The individuals were informed about the procedure and singed the free and informed consent form to participate in the study, which was approved by the Ethics Committee of this University.

Procedures

Semiologic Evaluation: before the assessment with the isokinetic dynamometer, all the individuals were submitted to a semiologic evaluation by 2 physical therapists, based on the modified Ashworth Scale, of the extensor and flexor muscles of the knee joint in the hemiplegic limb. With the patient on dorsal decubitus on the stretcher and the distal extremity of the lower limb outside the stretcher, the therapist performed an abrupt and fast passive movement of extension and flexion of the knee joint. This assessment was performed to confirm the necessary scale grades to include the patient in the study.

Isokinetic Dynamometer: All patients were submitted to the resistance to stretching test by the Computerized Isokinetic Dynamometer (Biodex System 3). For the test, the individuals were sitting and stabilized on the chair of the equipment, with the hip and the knee flexed at 90º. The lever arm support was positioned 2 cm above the malleoli (medial and lateral) and the dynamometer axis coincided with the axis of the movements of flexion and extension of the knee joint (Fig. 1). When the patient was positioned, the dynamometer was engaged to perform a continuous passive mobilization, with a series of 30 repetitions of flexion (stretching extensors) and extension movements (stretching flexors) of the knee joint with ranges of 90º, at a velocity of 120 º/s and, later, at the velocity of 180 º/s. The individuals were instructed not to perform any type of contraction or voluntary movement during the test. The resistance torque values were registered by the isokinetic dynamometer device at a frequency of 100 Hz, i.e., at every second of collection the device registered 100 torque values and thus, the variations in resistance to stretching have a precision of 10 ms.

Data Analysis

After the isokinetic dynamometer data collection, the data were exported to an electronic spreadsheet, where the mean torque was quantified (summing up the torque values divided by the time of movement) for each repetition and 30 values were obtained for each velocity, at each direction of movement (flexion and extension). As the weight of the leg and foot segments were not disregarded in the assessments, the mean torque values represent the weight of the leg and the foot and that of the lever arm fixed to the limb, multiplied by the horizontal distance of their mass centers in relation to the movement axis (support point) added to the resistance that the limb offers to stretching. As the effects of the weight produced by the mass of the segment cannot be avoided in therapeutic mobilizations, it was chosen not to disregard it during this experiment.

Figure 1
Isokinetic dynamometric assessment of the spastic muscles (extensors) of the knee joint in hemiplegic individuals.

To analyze the effect of the repetitions on the mean torque (accommodation), the mean torque values in each repetition were grouped in groups of 5 (1-5, 6-10, 11-15, 16-20, 21-25 and 26-30); later they were compared among them by analysis of variance (1-way ANOVA) at each velocity and for each one of the movement directions (flexion or extension) , in order to observe whether there were significant variations between the sets of repetitions and *post hoc* by Tukey's test to confirm where the differences occurred. This analysis was performed separately for each subject.

RESULTS

The analysis of the results showed that there was a significant variation in the resistance to stretching ($p< 0.01$) in 18 of the 20 experimental conditions analyzed (5 subjects X 2 velocities (120 °/s and 180 °/s) X 2 directions (flexion and extension).

As expected, the tests performed at the velocity of 180 °/s produced a higher resistance torque variation ($p<0.002$); however, these variations are not always translated as decreased resistance, but refer to the increased resistance, indicating that there is no sign of accommodation (Figures 2, 4 and 8). Figure 6 shows that, for subject 3, there was some grade of accommodation from the 16th repetition on ($p<0.0001$) in the extension movement. In the flexion movement, subject 3, after a slight increase in resistance from the 2nd repetition on, presented a significant decrease after the 16th repetition ($p< 0.008$).

For subject 5 (Figure 10), the results indicate a significant decrease ($p<0.0006$) in extension after the first repetitions and that resistance was maintained relatively constant until the end. In the movement of flexion, this subject presents accommodation at the 20th, but only in comparison with the initial values ($p<0.0436$), with the remaining variations being non-significant.

The results observed at 120º/s show that, similarly to 180º/s, there were variations of torque resistance as the limb was passively manipulated. At this velocity, however, only subject 1 presented increased torque in flexion ($p<0.0002$) and extension ($p<0.0029$), as shown in Figure 3. For the remaining subjects (Figures 5, 7, 9 and 11) the manipulation at 120º/s produced accommodation (decreased torque), except for the subjects 2 ($p=0.3180$) and 4 ($p=0.9245$) in the extension movements, where the variations were not significant (Figures 5 and 9).

The results of the *post hoc* tests at the velocity of 120º/s indicate that, for subjects 2 and 4, the variations confirmed by the statistical test in extension refer to the small, but significant variations observed at the end and at the intermediary repetitions, respectively (Figures 5 and). For subject 3 (Figure 7), the accommodation inflexion was observed after the 15th repetition ($p<0.0001$) and in extension, after 10 repetitions ($p<0.001$). For subject 5 (Figure 11) the accommodation was observed after 5 repetitions in extension ($p< 0.0002$) and in flexion ($p<0.004$).

DISCUSSION

Recently, the isokinetic dynamometers have been used to evaluate spasticity. This equipment allows the investigator to standardize the velocity, ROM and the positioning of the patient's limbs and trunk, objectively recording the amount of force generated by the patient's muscles.[16] However, there are several ways to interpret the results obtained from the force record (torque), which is attained

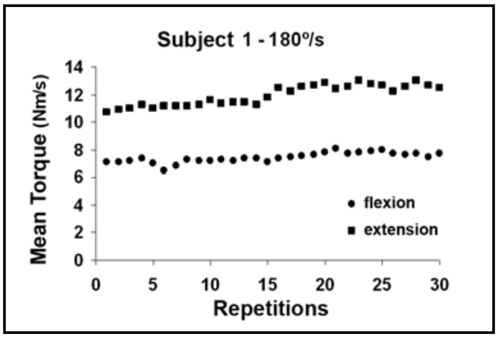

Figure 2
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 180º/s.

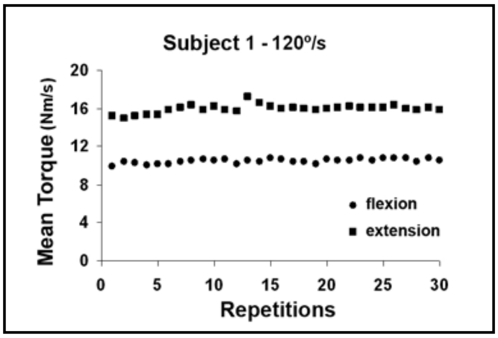

Figure 3
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 120º/s.

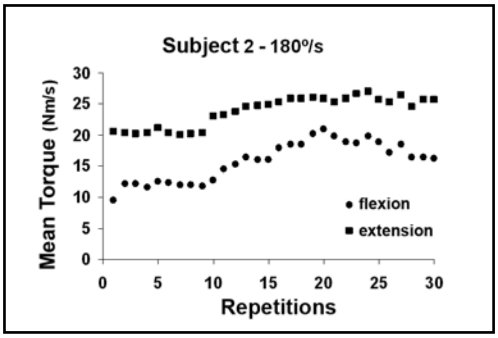

Figure 4
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 180º/s .

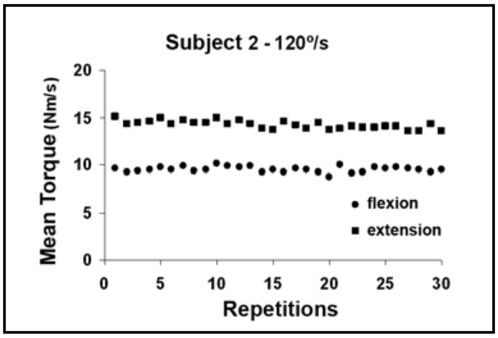

Figure 5
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 120º/s.

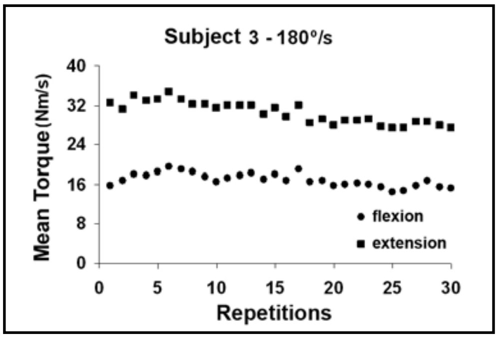

Figure 6
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 180°/s.

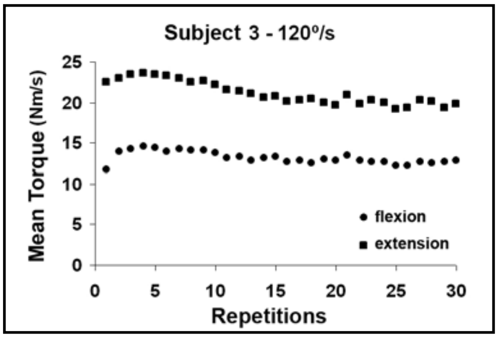

Figure 7
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 120°/s.

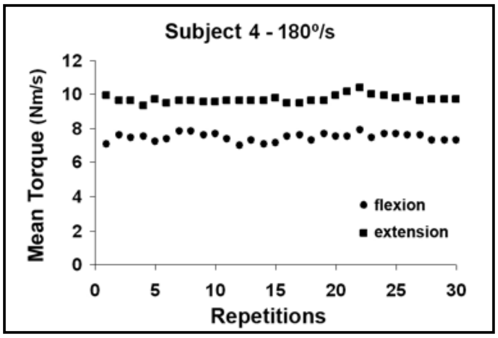

Figure 8
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 180°/s.

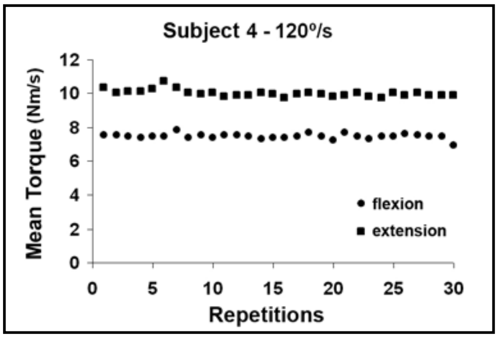

Figure 9
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 120°/s.

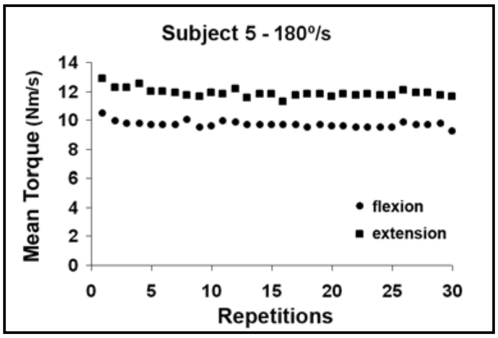

Figure 10
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 180°/s.

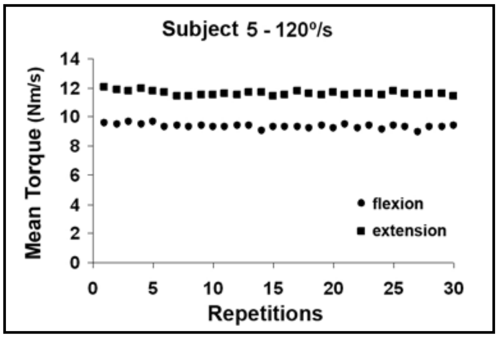

Figure 11
Evaluation of the spastic hemiplegic individual at the isokinetic dynamometer at the velocity of 120°/s.

by the variation in the resistance to the rotational manipulation of the limb.

Franzoi et al[22] used peak torque values as those related to spasticity, as they represent the maximum torque obtained at any phase of the movement. However, as the spasticity can affect not only a fraction of, but the movement as a whole, the mean torque value was chosen as variable, which considers the variations of resistance during the entire range of movement. According to our results, the mean torque seems to represent the expected behavior in terms of resistance to manipulation of the spastic limb.

The number of movements performed is a factor that tends to interfere with the results. Franzoi et al[22] evaluated their subjects based on the mean obtained from 5 repetitions performed in the passive mode of the dynamometer, whereas Perell et al,[21] analyzed the data of 12 repetitions. According to Vodovnik et al,[18] a test of passive movement with more than 7 repetitions in individuals with spinal cord injuries who present spastic hypertonia can induce the onset of a hypotonic condition (called accommodation), which suggests that the less severe spastic individuals present differences in spasticity behavior. Franzoi et al,[22] reported that the stretching reflex is affected in the passive movement and at the repetition. For these authors, the probable reduction in the stretching reflex is due to fatigue caused by numerous repetitions.

In the present study, 30 repetitions were performed in the passive mode of the isokinetic dynamometer and a wide-ranging effect was observed on the resistance torque caused by the spastic hypertonia as the limb of the subjects with spastic hemiplegia was manipulated. For the accommodation to take place, it was considered that there must be a relative and significant variation of the mean torque as the repetitions are performed.

As observed, there were differences regarding the number of repetitions necessary to elicit accommodation of the spastic hypertonia. Although we did not analyze the several factors that can produce these differences, these are probably due to the varied grades (0, 1 and 1+) of the Modified Ashworth Scale presented by each subject, at the movement of extension of the knee joint. As the fatigue phenomenon has a multifactorial characteristic, not being easily identifiable in addition to the fact that its interpretation generating several doubts, as well as presenting conceptual contradictions,[23,24] the different accommodations were produced by individual adaptive factors produced in the presence of the spastic picture. When there is a voluntary contraction, the phenomenon is classically subdivided as peripheral and central fatigue, with the first being attributed to metabolic causes and the second being essentially correlated with neural aspects. There are some hypotheses for the occurrence of peripheral fatigue; one of them is that the blocking of the calcium and sodium-potassium pumps causes a decrease in the muscular contraction capacity. In the case of prolonged exercises, especially with at certain intensity, an important loss of potassium is observed; this reduction could be enough to modify the functionality of the transversal tubules and prevent the release of Ca++ from the sarcoplasmatic reticulum, a situation that could lead to the decreased capacity of muscular strength production.[23]

The term central fatigue is understood as the a complex set of factors that determine the decrease in muscular contractility regardless of the intramuscular and/or metabolic factors.[23,24] Central fatigue occurs when the central nervous system (CNS) becomes incapable of generating an adequate stimulus, allowing a hypothesis to be formulated, demonstrated by the decrease in the nervous command proposed to a muscular contraction and also whether the role of the peripheral metabolic factors has a predominance in the decreased contractile capacity of the muscle.[23]

The mechanism of fatigue control works essentially as a safety device that is triggered by a subconscious mechanism at the encephalic level. The regulatory mechanism of the brain is modulated by the CNS or the peripheral nervous system, of which objective is to preserve the structural integrity of the muscular fiber, preventing possible irreversible damage to the fiber through the reduction or complete discontinuation of the activity[23,24] and in the case of the present study, related to a lower muscular response in the presence of passive mobilization.

Another very likely effect and little discussed in the literature concerns the decreased resistance to stretching as a result of the thyxotropic.[25] This effect is produced as the limb is mobilized and the stable connections between the myofilaments decrease, as a consequence of the muscular inactivity state.

As also observed in our results, some spastic individuals presented increase in the mean torque when submitted to passive mobilization. As the stretching resistance present in spasticity is strongly associated to the induced state of reflex hyperactivity, this muscular response is probably associated to the decrease in the inhibition of the motorneurons associated to the reflex mechanism, confirming the idea that the reflex is a state-dependent response,[25] and therefore tends to produce different results.

Another factor that can interfere with the results of the assessment carried out by the isokinetic dynamometer is the velocity. Perell et al[21] and Thilmann et al[6] in studies of individuals with spinal cord injuries, reported that the isokinetic dynamometer is a quite useful tool to quantify spasticity; however, their results suggested that the velocity directly interfered n the results obtained at their assessments. The first important observation is that the velocity used in the test must be >100º/s, necessary to elicit the stretching reflex. Nonetheless, the study by Franzoi et al[22] in individuals with spinal cord injuries, that at the higher grades of the Ashworth scale, the velocity of 60º/s was enough to elicit the stretching reflex, showing that the selected velocity can produce significant differences in the obtained results.

Regarding the results presented by the isokinetic dynamometer, the spastic hemiplegic individuals demonstrated some differences between the velocities of 120º/s and 180º/s. It is noteworthy the fact that we observed increased mean torque responses for subject 1 and decreased ones for subjects 3 and 5, regardless of the selected velocity. On the other hand, subjects 2 and 4 presented decreased mean torque at 120º/s and increased mean torque at 180º/s.

Although we assessed individuals with similar symptomatology, our results are in accordance with those by Perell et al,[21] who compared 3 different groups of subjects with spinal cord injuries at the isokinetic dynamometer (subjects with spinal cord injury and spasticity, with flaccidity, and normal subjects) at the velocities of 30º/s, 60º/s and 120º/s, demonstrating that there was a significant difference only at the velocity of 120º/s.

As the weight of the limbs were not disregarded at the moment of data collection and analysis, the torque variations are relative to each subject assessed at each one of the tested situations and thus, there are no mean and absolute values of decrease in resistance to stretching that can be characterized as accommodation. Therefore, it was understood that the accommodation must be considered based on the individual conditions of reference. This characteristic restricts the range of these results to the other populations that do not present such specific characteristics related to spastic hypertonia.

As it can be observed, many questions have not been answered by our study. The phenomenon of spasticity seems to be very complex and determines significant variations and differences in the results. To minimize these differences, a larger sample size must be assessed and other variables, such as muscular activity, must be investigated. However, we observed the important influence of the factors passive movement velocity and number of repetitions on the accommodation (or increase) of spasticity in hemiplegic individuals and the direct influence on the results obtained through the Isokinetic Dynamometer. Thus, these factors must be considered at the clinical assessments and throughout the rehabilitation process.

CONCLUSION

The present study demonstrated that the Isokinetic Dynamometer is an effective tool to measure the resistance to muscular stretching (spasticity) at high velocities (120º/s and 180º/s), but that the muscular responses can vary among them. It also showed that the accommodation can occur after the 6th repetition in some individuals, after the 11th in others and only at the 20th for one of the assessed individuals. These variations can be related to the variability of spastic hypertonia that oscillated from grade 0, 1, 1+ to 2 of the Ashworth scale, in the knee flexor muscular group.

REFERENCES

1. Greve JMD. Fisiopatologia e avaliação clínica da espasticidade. Rev Hosp Clin Facul Méd São Paulo. 1994:49(3):141-4.
2. Lianza S. Medicina de reabilitação. 3 ed. Rio de Janeiro: Guanabara Koogan; 2001.
3. Sullivan SBO, Thomas J, Nascimento FG. Fisioterapia: avaliação e tratamento. 2 ed. São Paulo: Manole; 1993.
4. Teive HAG, Zonta M, Kumagai Y. Tratamento da espasticidade. Arq Neuropsiquiatr. 1998;56(4):852-8.
5. Greve JMD. Fisiopatologia da espasticidade. Med Reabil. 1997; 46:17-20.
6. Thilmann AF, Fellows SJ, Garms E. The mechanism of spastic muscle hypertonus. Variation in reflex gain over the time course of spasticity. Brain. 1991;114 (Pt 1A):233-44.
7. Machado ABM. Neuroanatomia funcional. 2 ed. São Paulo: Atheneu; 2000.
8. Doretto D. Fisiopatologia clínica do sistema nervoso: fundamentos da semiologia. 2 ed. São Paulo: Atheneu; 2001.
9. Rothwell J. Control of human voluntary movement. 2 ed. New York: Chapman e Hall; 1994.
10. Kandel ER, James HS, Thomas MJ. Fundamentos da neurociência e do comportamento. Rio de Janeiro: Guanabara Koogan; 2000.
11. Teixeira SLF. Atualização da abordagem fisioterápica na espasticidade de pacientes hemiplégicos crônicos. Rev Fisioter Univ São Paulo. 1999;6(20):25-30.
12. Pereira AC, Araújo RC. Estudo sobre a eletromiografia de superfície em pacientes portadores de espasticidade. Rev Bras Fisioter. 2002;3(6):127-34.
13. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther. 1987;67(2):206-7.
14. Teixeira LF, Olney SJ, Brouwer B. Mecanismos e medidas de espasticidade. Rev Fisioter Univ São Paulo. 1998;5(1):4-19.
15. Johnson GR. Outcome measures of spasticity. Eur J Neurol. 2002; 9(Suppl 1):10-6.
16. HINTON RC. Acidentes vasculares encefálicos. In: Samuels MA. Manual de Neurologia: diagnóstico e tratamento. 4 ed. Rio de Janeiro: Medsi; 1992.
17. Akman MN, Bengi R, Karatas M, Kilinç S, Sözay S, Ozker R. Assessment of spasticity using isokinetic dynamometry in patients with spinal cord injury. Spinal Cord. 1999;37(9):638-43.
18. Vodovnik L, Bowman BR, Bajd T. Dynamics of spastic knee joint. Med Biol Eng Comput. 1984;22(1):63-9.
19. Noreau L, Vachon J. Comparison of three methods to assess muscular strength in individuals with spinal cord injury. Spinal Cord. 1998;36(10):716-23.
20. Firoozbakhsh KK, Kunkel CF, Scremin AM, Moneim MS. Isokinetic dynamometric technique for spasticity assessment. Am J Phys Med Rehabil. 1993;72(6):379-85.
21. Perell K, Scremin A, Scremin O, Kunkel C. Quantifying muscle tone in spinal cord injury patients using isokinetic dynamometric techniques. Paraplegia. 1996;34(1):46-53.
22. Franzoi AC, Castro C, Cardone C. Isokinetic assessment of spasticity in subjects with traumatic spinal cord injury (ASIA A). Spinal Cord. 1999;37(6):416-20.
23. Bisciotti GN, Vilardi NP, Manfio EF. A fadiga: aspectos centrais e periféricos. Fisioter Bras. 2001;2(6):15-20.
24. Mcardle WD, Katch FI, Katch VL. Fisiologia do exercício: energia, nutrição e desempenho humano. 4 ed. Rio de Janeiro: Guanabara Koogan; 1998.
25. Enoka RM. Bases neuromecânicas da cinesiologia. São Paulo: Manole; 2000.