Spasticity Assessment through Pendulum Testing in Individuals with Tetraplegia Undergoing Rehabilitation with Neuromuscular Electrical Stimulation

Eliza Regina Ferreira Braga Machado de Azevedo[1], Renata Manzano Maria[1], Renato Varoto[2], Karina Cristina Alonso[1] and Alberto Cliquet Junior [1, 2]

[1]*Biomechanics and Rehabilitation Lab., Department of Orthopedics and Traumatology, Faculty of Medical Sciences, University of Campinas – Unicamp, Campinas, Brazil*

[2]*Biocybernetics and Rehabilitation Engineering Lab., Department of Electrical Engineering, University of São Paulo, São Paulo, Brazil*

Keywords: Spasticity, Tetraplegia, Pendulum Test, Neuromuscular Electrical Stimulation.

Abstract: Objective: To analyze the effects of different neuromuscular electrical stimulation (NMES) protocols on spasticity improvement in subjects with tetraplegia. Methods: 13 patients with tetraplegia went through the pendulum test evaluation before and after NMES treatment. During tests an electrogoniometer was placed on a leg to measure leg oscillations and knee angles. Individuals were divided in two groups according to the treatment: gait group with NMES (n=6) and exercise group with NMES (n=7) Results: Relaxation index, test duration in seconds, angle of the first swing and rest angle of the leg in both legs were assessed before and after the treatment for both groups. Most differences were observed in the gait group. Conclusion: Both treatments with NMES have shown to be effective treatments for spasticity improvement in individuals with tetraplegia.

1 INTRODUCTION

The spinal cord injury brings many complications to the patients such as recurrent urinary infections, osteoporosis, cardiovascular defects, muscle atrophy and spasticity (Carvalho et al, 2001; Carvalho et al, 2006; Carvalho et al 2005; Sepulveda et al, 1997). Treatments with neuromuscular electrical stimulation (NMES) can minimize these complications.

Different NMES techniques have been used from 12 channel stimulation down to 4 channel, which is considered the minimum to generate gait after a complete spinal cord injury. In this case, NMES is applied to quadriceps muscles to promote knee extension and fibular nerve which generates the flexion withdrawal reflex (Rose J Gamble JG, 1993).

The spinal cord injury paralyzed muscle is mainly composed by fast atrophied fibers. And when it is electrically activated produces smaller force and goes into fatigue quickly. So, it is necessary to condition the atrophied and paralyzed muscle before gait training (Rose J Gamble JG, 1993).

Besides muscle atrophy, spasticity is also minimized by the use of NMES. Spasticity impacts on the patients' quality of life. It is easy to be detected but difficult to be quantified. A subjective assessment often used is the Modified Ashworth Scale (Leitão et al, 2006).

Another assessment that also measures spasticity but as an objective way is the pendulum test, created by Wartenberg in 1951. This test version was modified using an electrogoniometer to capture variations in range of motions and oscillations of the knee and has been used in individuals with spasticity (Badj et al, 1982; Badj et al, 1984).

Recently, a device to perform the pendulum test, consisting of an electrogoniometer and software for visualization and data processing was built (Maria et al, 2013).

Therefore, it becomes rather important to analyze the effects of different NMES treatments on spasticity improvement in subjects with tetraplegia.

Regina Ferreira Braga Machado de Azevedo E., Manzano Maria R., Varoto R., Cristina Alonso K. and Cliquet Junior A..
Spasticity Assessment through Pendulum Testing in Individuals with Tetraplegia Undergoing Rehabilitation with Neuromuscular Electrical Stimulation.
DOI: 10.5220/0004731100910094
In *Proceedings of the International Conference on Biomedical Electronics and Devices* (BIODEVICES-2014), pages 91-94
ISBN: 978-989-758-013-0

2 METHODS

Thirteen patients, all male with tetraplegia and lesions over two years old were recruited. The injury level ranged from C3 to C7. This study was approved by the local Ethics Committee.

All individuals went through pendulum test evaluation before and after the treatment at The Biomechanics and Rehabilitation Laboratory of the UNICAMP Clinical Hospital. They were positioned on a chair with the trunk at an angle of 60□ flexion (figure 1). During tests, a flexible fiber optic electrogoniometer was placed (model Shape Sensor S700Joint Angle, Meancurand Inc. figure 2a) on a leg of the patients in order to measure the oscillations of the leg and angles of the knees (figure 2b).

Figure 1: Patient test position on a chair with the trunk at an angle of 60º flexion.

The individuals were divided in two groups according to the treatment: a gait group with NMES (GG: n=6) and exercise group with NMES (EG: n=7).

All subjects had their quadriceps femoris and fibular nerve stimulated by a 4 channel electrical stimulator with 25Hz, monophasic rectangular pulses with 300µs duration and a maximum intensity of 150V. In the EG group each patient was trained for 20 minutes of knee extension under quadriceps stimulation and 15 minutes under fibular nerve stimulation.

In the GG group, individuals went through a treadmill gait using NMES and body weight support (40% of body weight reduction) at a speed of 1.2 km/h for 20 minutes. Physiotherapists helped move the legs through the gait cycle.

All the measurements were performed three times on both legs before and after the treatment for subsequent data analysis (mean and standard deviation).

Figure 2: a) Electrogoniometer Shape Sensor S700, b) Electrogoniometer positioning.

3 RESULTS

In table 1 and 2 the anthropometric data of gait group and exercise group, respectively, can be observed (age, body mass index – BMI, neurological level, duration of injury and medication).

Through the pendulum test were evaluated: relaxation index (RI), obtained by the end angle of the leg divided by the angle of the first swing of the leg; test duration in seconds; angle of the first swing that is, the first angle of knee flexion (Fang) and end angle or angle of rest of the leg (Restang).

All data were analyzed before and after the two different treatments on both legs and are shown in tables 3 and 4.

Most differences were observed in the gait group.

Table 1: Gait group anthropometric data.

Patients	Age (years)	BMI	Neurological level	Injury duration (years)	Medication/ day
1	27	20.78	C5B	8	---
2	29	24.66	C4A	7	Baclofen 1pill
3	39	22.59	C4B	16	---
4	25	16.12	C5C	6	---
5	34	21.65	C7A	11	---
6	45	23.59	C4B	16	---
Mean/ Sd	33.17/ 7.7	21.57/ 3.0	-------	10.67/ 4.46	

Abbreviations: SD, standard deviation; BMI, body mass index.

Table 2: Exercise group anthropometric data.

Patients	Age (years)	BMI	Neurological level	Injury duration (years)	Medication/ day
1	31	22.34	C3A	8	Baclofen 8 pills
2	37	28.35	C4A	17	Baclofen 2 pills
3	42	26.12	C4A	11	Baclofen 2 pills
4	24	22.4	C6A	5	Baclofen 8 pills
5	49	26.16	C5A	13	Baclofen 1 pill
6	30	21.85	C5B	10	Baclofen 3 pills
7	42	22.59	C4A	12	Baclofen 3 pills
Mean/ Sd	36.42/ 8.62	24.26/ 2.56	-------	10.85/ 3.8	------

Abbreviations: SD, standard deviation; BMI, body mass index.

Table 3: Right knee pendulum test results.

Groups mean/ sd	RI	Time (s)	Fang (º)	Restang (º)
GG before	0.82/ 0.32	8.7/ 4.06	88.56/ 33.22	61.82/ 14.48
GG after	0.6/ 0.09	9.14/ 3.27	117.29/ 11.13	69.95/ 13.15
EG before	0.65/ 0.06	10.27/ 1.27	117.71/ 10.57	77.06/ 12.59
EG after	0.62/ 0.08	11.31/ 3.36	113.02/ 12.75	69.31/ 9.11

Abbreviations: SD, standard deviation.

Table 4: Left knee pendulum test results.

Groups mean/ sd	RI	Time (s)	Fang (º)	Restang (º)
GG before	0.69/ 0.12	7.8/ 2.09	78.74/ 13.58	52.46/ 4.66
GG after	0.63/ 0.06	7.48/ 1.14	106.48/ 11.74	66.83/ 4.75
EG before	0.63/ 0.08	9.77/ 3.37	105.45/ 14.17	65.65/ 8.54
EG after	0.6/ 0.08	10.84/ 2.83	117.99/ 13.59	71.66/ 9.88

Abbreviations: SD, standard deviation.

4 DISCUSSION

The pendulum test is fast and easy to apply and in addiction has an objective assessment.

In this study all patients showed some improvement in spasticity in both legs after treatments with NMES, evidenced by at least two different variables. This improvement may have occured due to neuromodulation, which happens through the stimulation of agonist muscle directly to the quadriceps femuralis and indirectly to the antagonist (hamstrings) through fibular nerve with flexion withdrawal reflex.

However in EG group this improvement was more discret, which may have occurred due to all individuals in this group take antispastic drug (baclofen) and most aplenty, so the quadriceps femuralis were more relaxed than in GG group.

Besides that, in GG group, only one patient takes baclofen and one pill per day. The baclofen is a gamma-aminobutyric acid (GABA) agonist that is used to reduce muscle tone. GABA is an important inhibitory neurotransmitter in the central nervous system.

Before treatment EG individuals have already presented better results when compared to GG group. However, when results after the treatment are compared between groups both have similar results in all variables.

Granat et al (1993) analyzed spasticity through pendulum test after gait with NMES in patients with incomplete paraplegia and also showed improvement in spasticity, observed by RI, like in the present research.

5 CONCLUSIONS

NMES and treadmill gait with NMES are effective treatments for spasticity improvement in individuals with tetraplegia. However, further studies would be interesting towards differentiating the baclofen use and NMES.

ACKNOWLEDGEMENTS

The authors would like to thank CAPES (Ministry of Education, Brazil).

REFERENCES

Barbeu, H., Ladouceur, M., Norman, K.E., Pépin, A., 1999. Walking after spinal cord injury: evaluation, treatment, and functional recovery. *Arch Phys Med Rehabil*. v. 80, p.225-235.

Badj, T, Bowman, R.G., 1982. Testing and modeling of spasticity. *Journal of Biomedical Engineering*. n. 4, p.90-96.

Carvalho, D.C., Carvalho, M.M., Cliquet, A. Jr., 2001. Disuse ostoporosis: its relationship to spine cord injuried patient rehabilitation. *Acta Ortop Bras.* n. 3, v. 9, p. 34-43.

Carvalho, D.C., Garlip, C.R., Bottini P.V., Afaz S.H., Moda M.A., Cliquet, A. Jr., 2006. Effect of treadmill gait on bone markers and bone mineral density of quadriplegic subjects. *Braz J Med Biol Res.* n. 39, v. 10, p. 1357-1363.

Carvalho, D.C., Zanchetta, M.C., Sereni, J.M., Cliquet, A. Jr., 2005. Metabolic and cardiorespiratory responses of tetraplegic subjects during treadmill walking using neuromuscular electrical stimulation and partial body weight support. *Spinal Cord.* n. 43, v. 7, p. 400-405.

Granat, M.H., Fergunson, A.C.B., Andrews, B.J., Delargy, M., 1993. The role of functional electrical stimulation in the rehabilitation of patients with incomplete spinal cord injury- observed benefits during gait studies. *Paraplegia.* n. 31, p. 207-215.

Leitão, A.V., Muss, C.A.I.,Granero, L.H.M., Rossetto, R., Pavan, K., Lianza, S., 2006. Spasticity: Clinical evaluation. *Brazilian Association of Physical Medicine and Rehabilitation.*

Maria, R.M., Alonso, K.C., Azevedo, E.R.F.B.M., Varoto, R., Cliquet, A.Jr., 2013. Custom built device for spasticity evaluation associated to spinal cord injury – a reredundant signal to electrogoniometer in pendulum test. *BIODEVICES 2013 – International Conference on Biomedical Eletronics and Devices.* p.120-126.

Sepulveda, F., Granat, M.H., Cliquet, A.Jr., 1997. Two artificial neural systems for generation of gait swing by means of neuromuscular electrical stimulation. *MedEng Phys*. n. 19, v. 1, p. 1357-1363.