Impact of treadmill gait training with neuromuscular electrical stimulation on the urodynamic profile of patients with high cervical spinal cord injury

Impacto da marcha com estimulação elétrica neuromuscular no perfil urodinâmico em pacientes com lesão raquimedular cervical alta

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ABSTRACT

Objective: To evaluate the impact of gait training with neuromuscular electrical stimulation on urodynamic parameters of patients with neurogenic bladder. **Methods:** Eight male quadriplegic patients with complete cervical injury level ranging from C4 to C7 comprised the study population. They underwent treadmill gait training with neuromuscular electrical stimulation for six months, only after having their quadriceps and tibialis anterior muscles stimulated for five months in order to support at least 50% of their body weight (pre-gait training). Urodynamic testing was performed before the treadmill gait training and six months after. **Results:** The mean time after cervical lesion was 74.63 months. The urodynamic parameters before and after neuromuscular training by electrical stimulation did not show significant difference. **Conclusion:** This study demonstrated that neuromuscular training with electrical stimulation can benefit the urinary tract. This promising minimally invasive field requires further and more complete studies to confirm a possible benefit to the low urinary tract.

Keywords: Spinal cord injuries; Urinary bladder, neurogenic; Urodynamics/physiology; Electric stimulation

RESUMO

Objetivo: Avaliar o impacto do treinamento neuromuscular, por estimulação elétrica da marcha, nos parâmetros urodinâmicos de pacientes com bexiga neurogênica. **Métodos:** A população do estudo compreendeu oito pacientes quadriplégicos do sexo masculino com lesão cervical completa nos níveis C4 a C7. Eles foram submetidos a um treinamento neuromuscular por estimulação elétrica da marcha por seis meses, somente após estimulação dos músculos quadríceps e tibial anterior, por cinco meses, de modo a poder suportar 50% de seu peso corporal (pré-treinamento). Testes urodinâmicos foram feitos antes do treinamento e seis meses depois. **Resultados:** O tempo médio após a lesão cervical foi de 74,63 meses. Os parâmetros urodinâmicos antes e depois do treinamento neuromuscular por estimulação elétrica da marcha não mostraram diferença significante. **Conclusão:** Este estudo mostrou que o treinamento neuromuscular com estimulação elétrica pode ser benéfico para o trato urinário. Esse campo, promissor e minimamente invasivo, requer outros estudos mais completos para confirmar um possível benefício no trato urinário inferior.

Descritores: Traumatismos da medula espinal; Bexiga urinária neurogênica; Urodinâmica/fisiologia; Estimulação elétrica

INTRODUCTION

High cervical spinal cord injury resulting in tetraplegia involves impairment of motor, sensory and sympathetic nervous system (SNS). Quadriplegic patients lose central voluntary and spinal autonomic control of the bladder function, what defines an entity called neurogenic bladder. The spinal cord micturion center is primarily located at the S2-S4 level and it depends on the integrity of spinal neurologic pathways to exert perfect and synchronized control of bladder emptying and storage of urine[1]. After the spinal shock period, complete suprasacral (S2-S4 level) injuries classically result in detrusor hyperactivity and detrusor sphincter dyssynergia. Most cervical spinal cord injuries lead to

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detrusor hyperactivity and/or dyssynergia (42 and 68%), low bladder compliance (44%), and high detrusor leak point pressures (40%)[2]. Urodynamic evaluation is the gold standard for evaluation and definition of lower urinary tract dysfunction[3].

Treadmill gait training with neuromuscular electrical stimulation (NMES) in quadriplegic subjects is capable of improving movements (even quadriplegics with complete lesions), metabolic and cardio respiratory responses and bone mineral density. It was reported that these findings are associated with a better coordination of voluntary and autonomic functions of muscles and nervous pathways; however, there is no unanimous understanding on how and why it happens[4-6].

To date, the effects NMES on the inferior urinary tract have never been studied. The aim of this study was to evaluate the impact of gait training with NMES on urodynamic studies of patients with neurogenic bladder secondary to high cervical spine trauma.

METHODS

After approval of the local Ethics Committee, eight patients were enrolled in the study. All subjects were instructed about the objectives and risks of the investigation and gave written consent for the study.

Eight male quadriplegic patients (mean age: 33.5 years) with complete cervical injury level ranging from C4 to C7 comprised the study population.

All patients performed only conventional physical therapy before the beginning of the investigation. Inclusion criteria were intact lower motor neurons on surface electrical stimulation that would allow muscle contraction and treadmill gait, with 30 to 50% body weight support (BWS) for 20 consecutive minutes, with no skin damage or ulcers; no history of cardiopulmonary disease and radiological and clinical evidence of lower limbs integrity (no signs of fractures, joint degeneration changes or clinical joint instability).

They were submitted to treadmill gait training with NMES for six months, twice a week, 20 minutes per session, only after having their quadriceps and tibialis anterior muscles stimulated for 5 months in order to support at least 50% of their body weight (pre-gait training).

NMES was accomplished with a four-channel electrical stimulator that delivered a 25 Hz signal with monophasic rectangular pulses of 300-μs duration and a maximum intensity of 200 V (1 kΩ load).

Urodynamic testing was performed with a computer-assisted urodynamic unit (Dynamed – Brazil). The patients were positioned in a supine position. The bladder was filled and the intravesical pressure was recorded via a transurethral double-lumen 8 French catheter. Abdominal pressure was registered by a rectal indwelling catheter. Sterile saline solution at body temperature was used as a filling medium, and the bladder was filled at a rate of 20 ml/min until the detrusor leak point was reached or until the patient experienced a sensation that would normally lead voiding of the bladder. The blood pressure was measured during the entire procedure. If signs of vegetative dysreflexia occurred, bladder filling was terminated immediately. Urodynamic testing was done before the treadmill gait training with NMES and six months after the beginning of the training.

Maximal bladder capacity, bladder compliance, involuntary detrusor contractions (IDC), IDC amplitude and the bladder volume that triggered the onset of IDC were the urodynamic parameters assessed in the study pre and post gait training. To compare the urodynamic variables, statistical analysis of repetitive measurements was performed with ANOVA adjusted by time of lesion and patient age. Values were considered significant when $p < 0.05$.

RESULTS

Patient mean age, weight and height were, respectively, 33.5 years (from 22 to 45), 63.52 ± 9.41 kg and 176.28 ± 5.28 cm. Mean post-cervical injury time was 74.63 months. One patient presented with a complete cervical lesion at C4 (12.5%), three at C5 (37.5%), three at C6 (37.5%) and one at C7 (12.5%).

Mean maximal bladder capacity, before and after gait training with NMES, were respectively 247 ± 154 ml and 288 ± 131 ml ($p = 0.5389$).

Mean bladder compliances, pre and post-training with NMES, were respectively 12.33±19.48 cm H_2O/ml and 17.13±12. 96 cm H_2O/ml ($p= 0.6883$).

The average number of IDC during bladder filling phase presented in the pretreatment studies was 6.25 ± 4.4, and it was not significantly different in the post-treatment studies that showed an average of 5.00 ± 5.10 ($p = 0.5840$). According to the above mentioned findings, there was also not significant changes in the bladder volume that triggered the onset of IDC; pre-training studies showed the first IDC with a mean bladder volume of 190 ± 147 ml and post-training studies with 227 ± 125 ml ($p = 0.8797$).

IDC amplitude pre and post-training was 64 ± 25.75 cm H_2O and 58.50 ± 41.19 cm H_2O, respectively ($p = 0.1386$).

DISCUSSION

Many studies showed that the use of NMES during exercise in quadriplegic subjects is capable of improving their physical capacity because of cardiovascular

adaptations[7,8], through increased venous return, cardiac output and heart rate due to the parasympathetic vagal withdrawal and to the muscle contraction. Moreover, many studies reported the effect of NMES in increasing the strength and endurance of paralyzed muscles[9-12].

Moreover, previous studies showed that treadmill gait provided by NMES can raise blood pressure values through increased cardiac output and heart rate[4]. This training increased oxygen output (VO_2) by 36%, CO_2 production by 42.97%, pulmonary ventilation by 30.48% and systolic blood pressure by 4.8%[5]. Subjects with complete quadriplegia suffer from a sympathetic autonomic impairment, changing the normal cardiovascular response during exercise, which includes vasoconstrictor responses and increase in venous return, heart rate and cardiac output. It means that treadmill gait training combined with NMES is capable of increasing the metabolic and cardio respiratory responses in complete quadriplegic subjects, despite autonomic sympathetic deficiencies and extensive muscle paralysis.

These patients also had an efficient increase in bone mineral density – in that, 81.8% of subjects presented a significant increase in bone formation and 66.7% had a marked decrease in bone resorption markers, thus reducing the risk of fractures in osteoporotic bones[6].

Although there is scientific evidence that patients with cerebral and spinal injuries benefit from NMES in the rehabilitation of muscular and cardio respiratory parameters[13], to date there has been no report on the effects of NMES on the low urinary tract function.

Patients with spinal lesions and resulting hyperactive detrusor generally present incontinence, recurrent urinary tract infection, high pressure urine reservoir and autonomic dysreflexia. All these devastating signs and symptoms, if not treated adequately, lead to long-term impairment of renal function.

Several techniques of neuromuscular stimulation have been developed to treat neurogenic bladder secondary to spinal lesions. Sauerwein et al. described their experience with sacral deafferentation and implant of an anterior root stimulator which restored a normal reservoir function and urinary continence by interrupting the reflex activity, and also decreased episodes of urinary infection from 6.3 to 1.2 per year[14]. On the same line, Groat et al. developed a cross-wired skin-central-nervous-system-bladder reflex pathway that allowed patients to initiate voiding voluntarily by scratching the ipsilateral L5 dermatome, with promising results[15].

Other less invasive procedures showed to be effective in improving the consequences of the detrusor hyperactivity. The posterior tibial nerve stimulation is a good example of a minimally invasive technique with significant results on the lower urinary tract function[16].

The present study did not show significant differences in the urodynamic parameters before and after the gait training with NMES. As one may anticipate, one reasonable explanation for the shy response is that the sacral fibers were not directly stimulated with the NMES, and therefore did not directly trigger a response of the urinary bladder.

However, the study showed that the gait training with NMES may be beneficial for the lower urinary tract. It is important to note that the statistical findings were impaired by the small study population and more subjects have been enrolled to the program to date.

It is well known that quadriplegic patients experience improvements in skeletal and cardiorespiratory systems after gait training with NMES. This promising and minimally invasive field requires further and thorough studies to confirm the possible benefits on the lower urinary tract.

CONCLUSION

The study demonstrated that gait training with NMES may be beneficial for the lower urinary tract.

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