

Effect of treadmill training using neuromuscular electrical stimulation on respiratory function of quadriplegic individuals

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Abstract

Quadriplegics present a paralysis of extensive muscle mass, which also affects the respiratory muscles, which decrease the respiratory function and spirometric values similar to those found in restrictive and obstructive respiratory diseases. Nowadays, subjects with obstructive diseases are recommended to perform respiratory training and physical activity, which can increase the endurance and strength of respiratory muscles, consequently improving the respiratory system. To evaluate the effect of 6 months of treadmill gait training (twice a week, during 20 minutes) using neuromuscular electrical stimulation, on spirometric variables, ten complete quadriplegics were studied. Spirometry test was performed before and after training, at rest in the sitting position. Vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in the first second (FEV₁) and maximal voluntary ventilation (MVV) were evaluated. Pulmonary ventilation (V_E), at rest and during gait, was also analyzed. Before training, VC was 3.10 ± 0.78 l, FVC 3.06 ± 0.78 l, VEF₁ was 2.71 ± 0.65 l, MVV was 98.3 ± 24.64 l/min and V_E (during gait) was 18.93 ± 2.95 l/min. After 6 months training, VC was 3.47 ± 0.87 l, FVC 3.41 ± 0.91 l, VEF₁ was 3.09 ± 0.98 l, MVV was 98.4 ± 26.31 l/min and V_E (during gait) was 24.70 ± 4.62 l/min. No significant differences were observed for any analyzed spirometric parameter after training, despite the significant increase of V_E. Thus, the increase of metabolic and respiratory stress did not interfere in the spirometric values, as occurs in normal and obstructive individuals.

1. INTRODUCTION

Quadriplegic subjects present a paralysis of extensive muscle mass, which also affects the

respiratory muscles¹. Individuals with C4 lesion present a preserved activity of diaphragm and sternocleidomastoid muscles. Individuals with C5 to C8 lesion levels also have the scalenus, pectoralis, latissimus dorsi and serratus anterior intact muscles. Intercostal and abdominal muscles activities are not present in quadriplegics with complete lesion^{2,3}.

Treadmill gait, using neuromuscular electrical stimulation (NMES), increase the leg muscle venous pump, the venous return and cardiac output, which improve the oxygen delivery for activated muscles^{4,5}. Also, the contraction of paralyzed muscles thru NMES yields an increase of oxygen consumption by muscles. Those facts are responsible for the increase of oxygen consumption observed during treadmill gait⁶. Moreover, during exercise, even in quadriplegic subjects, an increase of minute ventilation occurs, due to the increase of respiratory rate and deep of breath, associated to the action of respiratory muscles.

Quadriplegic individuals present decrease of respiratory function and spirometric values. Studies have suggested that physical activity can improve the respiratory system and quality of life^{7,8}. However, the positive responses observed in those individuals do not necessarily improve the spirometric values. This lack of changes on spirometric variables is similar to those results obtained in normal individuals who perform endurance training. However, quadriplegic subjects present a dramatic deconditioning, so the increase of intact respiratory muscles activity could alter the respiratory responses after training.

To evaluate the effect of 6 months of treadmill gait training induced by NMES, assisted by partial body weight support (BWS) with 30-50% body weight relief, ten quadriplegic subjects (with complete lesions)

were studied. Training consisted of 6 months, twice a week, during 20 minutes each session.

2. METHODS

Ten complete quadriplegic subjects, all male (mean age 32.5 ± 8.5 yr, mean body mass 67 ± 6.0 kg, mean height 176.9 ± 4.0 cm, mean time postinjury 79.8 ± 45 months) were evaluated. The lesion level varied between C4 and C7. They performed 6 months of treadmill training gait, twice a week, 20 minutes each session. All individuals used the BWS during gait, within 30 and 50% of their weight relief. BWS was provided by a harness suspended from an overhead support and the support vest allowed free movement of the lower limbs. A four channel electrical stimulator (signal of 25Hz of monophasic rectangular pulses with 300μ s duration and a maximum intensity of 200V over a load of $1k\Omega$) was used to provide the stance gait phase thru quadriceps muscle activation and the swing phase triggered by the withdrawn reflex (stimuli to the common peroneal nerve). The study was approved by the local ethical committee.

Spirometry test was performed at rest in the sitting position, using a nasal clip, according to American Thoracic Society⁹ recommendations and using standard techniques. The lung function parameters: vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1) and maximal voluntary ventilation (MVV) were evaluated. The maximal value of three attempts was recorded. Pulmonary ventilation (V_E) was

analyzed during rest and gait. All tests were conducted by the same laboratory technician.

Results were compared to normal subjects and the percentage of normal prediction was obtained. Test was performed using open-circuit spirometry (SensorMedics, Vmax 29c Cardiopulmonary Exercise Testing Instrument). Calibration was performed prior to each test with reference gases.

Statistical comparisons between values obtained before and after training were done using *t* tests. Results are presented as mean \pm standard deviation (SD). Differences were considered significant at 5% ($p < 0.05$).

3. RESULTS

Before training the VC was 3.10 ± 0.78 l, FVC was 3.06 ± 0.78 l, FEV_1 was 2.71 ± 0.65 l, MVV was 98.3 ± 24.64 l/min and V_E during rest was 10.16 ± 2.51 l/min and during gait V_E was 18.93 ± 2.95 l/min. After 6 months training, VC was 3.47 ± 0.87 l, FVC was 3.41 ± 0.91 l, FEV_1 was 3.09 ± 0.98 l, MVV was 98.4 ± 26.31 l/min and V_E during rest was 9.38 ± 1.57 l/min and during gait it was 24.70 ± 4.62 l/min. No significant differences were observed for any analyzed spirometric parameter ($p > 0.05$) after training. Data for VC, FVC, FEV_1 and MVV before and after treadmill training are illustrated in figure 1 (A through D). However, after training during gait, V_E increased significantly ($p < 0.05$), without changes in V_E at rest. V_E at rest and during gait, before and after training is illustrated in figure 2.

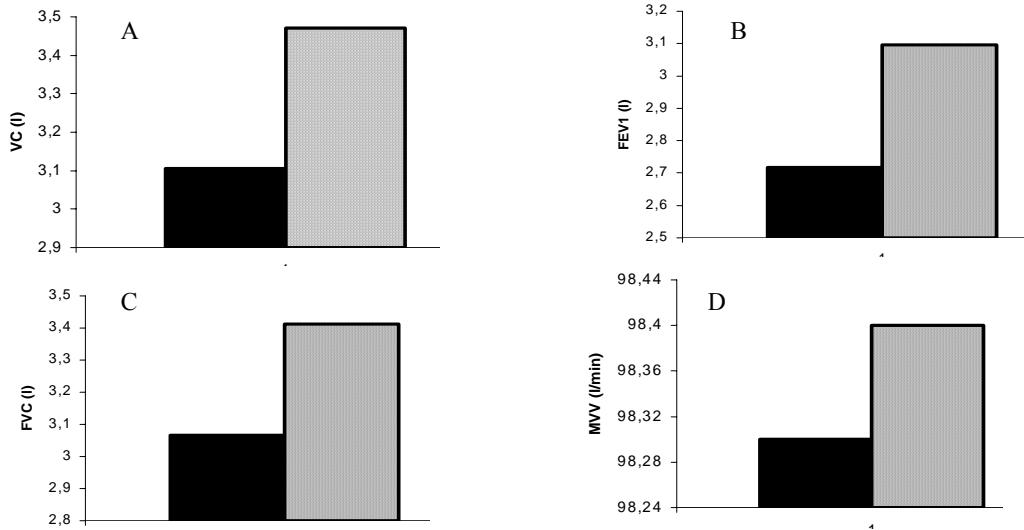


Figure 1: Spirometric values obtained before and after treadmill training in quadriplegic subjects. Values are mean \pm SD. (A) vital capacity (VC l); (B) forced vital capacity (FVC l); (C) forced

expiratory volume in the first second (FEV_1); (D) maximal voluntary ventilation (MVV l/min); before training; ■ after training ▨.

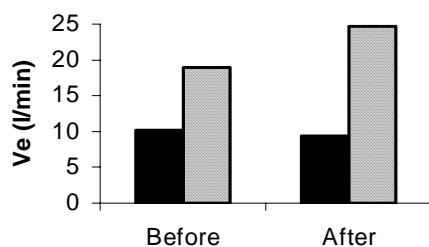


Figure 2: Pulmonary ventilation (V_e) obtained before and after gait training, at rest ■ and during gait ▨.

4. DISCUSSION AND CONCLUSION

Paralysis of intercostal and abdominal muscles in complete quadriplegics interferes negatively in the elastic properties of the lungs, reducing the VC of these individuals¹⁰.

Results have shown that after treadmill gait training, spirometric values did not change. These results are similar to those obtained in individuals with respiratory disease and healthy subjects after exercise training^{7,8}.

Complete quadriplegic subjects have presented spirometric values similar to those found in individuals with restrictive and obstructive respiratory diseases, which indicates a significant impairment of the respiratory function. However, quadriplegic individuals presented a significant increase of minute ventilation during gait (as also observed in our previous study⁶), which is associated to an increase of intact respiratory muscles activity. Despite the increase of minute ventilation, it was not enough for improving spirometric values.

Thus, the increase of metabolic and respiratory stress during gait did not interfere in the spirometric values, as occurs in normal and obstructive diseases.

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