Effects of functional electrical stimulation on body composition and musculoskeletal fitness for patients with incomplete spinal cord injury

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Abstract

A total of eighteen subjects with incomplete spinal cord injury were recruited for testing. Patients received functional electric stimulation cycling exercises (FESCE) 3 times per week for a total of 8 weeks. Body composition, thigh and calf girths of bilateral legs, muscle strength of bilateral knee flexors and extensors were evaluated and measured before the FESCE, after four weeks and eight weeks of FESCE. The results showed that there were significant increases in mean peak torque of bilateral knee flexors and knee extensors after 8 weeks of training. In addition, to assess the effect of 8 weeks FESCE to various degree SCI patients, we found that patients with more residual muscle strength before training would have a higher percentage of strength regained.

Conclusions, the positive effects on body composition and muscular fitness are demonstrated in our study, and more the initial muscle strength the better recovery of muscle strength after FES cycling training.

1. INTRODUCTION

Functional electrical stimulation (FES) is potentially useful in the rehabilitation of patients with SCI [1-2]. Proven benefits included the improvement of contractures, osteoporosis, deep venous thrombosis, edema, and amelioration of spasticity. As a result, functional electrical stimulation cycling exercise (FESCE) involving contracting of the muscles of the paralyzed limbs in individuals with SCI may help to decrease the muscle atrophy [3-4].

However, few reports have discussed the effect of FESCE on muscular strength and body composition in SCI patients with different grades[5-8], therefore we have tried to investigate and the effect of FESCE in patients with various degrees of incomplete SCI, including changes in thigh and calf girth, peak muscular contractile forces, body composition[9], and body mass index (BMI), and the relationship between strength recovery and the spared motor function [10].

2. METHODS

A total of eighteen subjects with incomplete spinal cord injury were recruited for testing. Patients received FESCE 3 times per week for a total of 8 weeks. Each session persisted for 30 minutes with warm-up and cool-down periods lasting 3 minutes. The effects of these exercises were evaluated by changes in thigh and calf girths, body weight, body mass index (BMI), body composition, and muscle peak torque of knee flexors and knee extensors measured with Kin-Com dynamometer [28]. Evaluations were performed before and after 4 weeks and 8 weeks training.

FES-induced cycling exercise was performed by applying 5 x 7 cm surface electrodes to the muscle belly of bilateral quadriceps and hamstrings to achieve a sequential rhythmical cycling motion. As to stimulation patterns, the contraction of the quadriceps produces strength to increase knee angle in the upper cycle; the contraction of the hamstring produces strength to decrease knee angle in the lower cycle. The pulse frequency was set at 20 Hz, pulse duration 300 μsec and current was varied (30-140 mA) and controlled by a microprocessor in order to maintain a pedaling frequency of 45 rpm. The equipment contained the arm-crank structure, it could only be used to help initialize the cycling by an SCI individual and to warm up before electrical stimulation.

3. RESULTS

3.1. Changes in body composition and BMI

Table I showed that the total body weight had the tendency to increase from 73.8 ± 13.9 kg to 75.0 ± 14.3 kg (P=0.062). Mild increase in body lean mass (from 51.6 ± 7.1 to 52.8 ± 8.2) could be found after 8 weeks FESCE (p=0.03). Meanwhile, there were no other marked differences of body composition, including body fat mass, fat percentage, bone mass and BMI.

3.2. Changes of girth in upper and lower legs

(Table II) Thereafter, only mild increase occurred when FESCE continued. A slight increase in girth of calf after 8 weeks of training, which may be owing to the fact that the gastrocnemius and soleus muscles were not stimulated directly during the cycling exercise.

3.3. Changes in mean peak torque

Table III showed the changes in isometric peak torque in bilateral knee flexors and knee extensors. Initially, there was no obvious change in mean peak torque after the 4 weeks of training. Meanwhile, there were significant increases ($p<0.05$) in mean peak torque of bilateral knee flexors and right knee extensors after 8 weeks of training.

3.4. Comparison of outcome in various severity groups

Table IV showed the isometric peak torques and the percentage of torque gains in bilateral knee flexors and knee extensors of these three groups. Although they all revealed peak torque increase, subjects in ASIA D group had a higher percentage of strength gains in bilateral knee extensors and flexors than in ASIA B group and ASIA C group ($p<0.05$) after 8 weeks FESCE, and those in ASIA C group had better results compared with ASIA B group.

3.5. Relationship between the changes of muscle peak torque and those of their initials

Correlations between initial peak torque before training and the percentage of changes in knee muscular strength after 8 weeks of training were analyzed to determine the impact of the initial motor function on potential of recovery. Pearson correlation coefficients were 0.86 ($p=0.013$) (right knee extensor), 0.65 ($p=0.048$) (left knee extensor), 0.5l ($p=0.032$) (left knee flexor), 0.49 ($p= 0.062$) (right knee flexor). These results showed that the percentage of strength gains during FESCE was positively related to the spared muscle function in the beginning. It indicated that patients who previously had higher muscle strength may get a better training effect.

Table I. The changes of body composition after training.

	Before FESCE in SCI subjects	After 4 weeks FESCE in SCI subjects	After 8 weeks FESCE in SCI subjects
Total body weight (kg)	73.8 ± 13.9	73.9 ± 13.7	75.0 ± 14.3
Body fat mass (kg)	18.6 ± 8.6	18.7 ± 8.5	18.7 ± 8.4
Body lean mass (kg)	51.6 ± 7.1	52.3 ± 7.5	52.8 ± 8.2 ‡
Percentage fat mass(%)	25.3 ± 7.1	25.4 ± 6.9	24.9 ± 6.6
Bone weight (kg)	3.5 ± 0.4	3.5 ± 0.4	3.6 ± 0.4
BMI (kg/m^2)	25.4 ± 3.9	25.5 ± 3.8	25.7 ± 3.5

Values shown as mean ± SD
* P<0.05; significant difference between the values before FESCE and those after 4 weeks FESCE in SCI subjects.
† P<0.05; significant difference between the values after 4 weeks FESCE and those after 8 weeks FESCE in SCI subjects.
‡ P<0.05; significant difference between the values before FESCE and those after 8 weeks FESCE in SCI subjects.

Table II. The changes of girth in upper and lower legs.

	Before FESCE in SCI subjects	After 4 weeks FESCE in SCI subjects	After 8 weeks FESCE in SCI subjects
Right thigh girth (cm)	48.2 ± 5.5	49.6 ± 5.2*	50.3 ± 5.1‡
Left thigh girth (cm)	47.4 ± 5.9	49.0 ± 5.4*	49.8 ± 5.2‡
Right calf girth (cm)	34.2 ± 3.8	34.5 ± 3.2	34.6 ± 3.3
Left calf girth (cm)	33.6 ± 4.9	33.8 ± 3.7	34.1 ± 3.9

Values shown as ean ± SD
* P<0.05; significant difference between the values before FESCE and those after 4 weeks FESCE in SCI subjects.
† P<0.05; significant difference between the values after 4 weeks FESCE and those after 8 weeks FESCE in SCI subjects.
‡ P<0.05; significant difference between the values before FESCE and those after 8 weeks FESCE in SCI subjects.

Table III. Isometric peak torques of knee extensors and flexors before and after training.

Peak Torque (Nm)	Before FESCE in SCI subjects	After 4 weeks FESCE in SCI subjects	After 8 weeks FESCE in SCI subjects
Right knee extensors	45.9 ± 32.8	47.6 ± 34.8	52.6 ± 40.7 †‡
Left knee extensors	37.9 ± 26.8	38.3 ± 32.1	38.9 ± 29.9
Right knee flexors	16.1 ± 11.9	16.5 ± 10.2	17.7 ± 11.6 †‡
Left knee flexors	15.1 ± 6.3	15.2 ± 6.1	16.9 ± 6.8 †‡

Values shown as mean ± SD
* P<0.05; significant difference between the values before FESCE and those after 4 weeks FESCE in SCI subjects.
† P<0.05; significant difference between the values after 4 weeks FESCE and those after 8 weeks FESCE in SCI subjects.
‡ P<0.05; significant difference between the values before FESCE and those after 8 weeks FESCE in SCI subjects.

Table IV. Results of isometric torque gains in knee extensors and flexors after training in various severities of SCI patients.

	ASIA B group (n=6)	ASIA C group (n=7)	ASIA D group (n=5)
Right knee extensors (Nm)			
Before FESCE	22.1 ± 11.9	44.6 ± 26.3	76.3 ± 36.4
After FESCE	22.8 ± 9.8	47.4 ± 31.4	95.8 ± 39.7
Strength gains (%)	3.2	6.3	25.6†‡
Left knee extensors (Nm)			
Before FESCE	18.2 ± 6.2	38.7 ± 9.7	52.6 ± 11.3
After FESCE	18.5 ± 5.8	42.5 ± 15.1	58.5 ± 14.4
Strength gains (%)	1.6	9.8 *	11.2†
Right knee flexors (Nm)			
Before FESCE	11.7 ± 5.6	14.4 ± 11.7	21.1 ± 10.9
After FESCE	12.2 ± 9.1	16.7 ± 13.1	25.9 ± 11.8
Strength gains (%)	4.3	15.9 *	22.7†‡
Left knee flexors (Nm)			
Before FESCE	12.1 ± 6.2	16.2 ± 6.3	16.9 ± 5.5
After FESCE	12.6 ± 5.1	17.5 ± 7.8	21.1 ± 5.9
Strength gains (%)	4.1	8.0	24.9†‡

Isometric torques shown as mean ± SD
* $P<0.05$; significant difference of strength gains (%) between ASIA B group and ASIA C group.
† $P<0.05$; significant difference of strength gains (%) between ASIA B group and ASIA D group.
‡ $P<0.05$; significant difference of strength gains (%) between ASIA C group and ASIA D group.

4. DISCUSSION AND CONCLUSION

The positive effects on body composition and muscular fitness are demonstrated in our study. Our study also showed that the initial muscle strength of legs is an effective predictor of recovery of muscle strength after FES cycling training.

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