Evaluation of fitness effect on paraplegic patient using the Akita FES-rowing machine

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Abstract

The purpose of this study was to evaluate the cardiovascular fitness effects of FES-rowing for paraplegic patients. We developed the Akita FES-rowing machine, with easier transfer in mind, incorporating a controller for the lower limbs and a trunk stabilizer. A two-channel electrical stimulator using surface electrodes activated the quadriceps femoris muscles for knee extension in drive phases of the rowing cycle. In the process rowing, we measured peak oxygen consumption (L/min) using a portable telemetric system. Comparing pre exercise and post exercise levels, peak oxygen consumption was increased by 12.9%. Our result suggests that FES-rowing exercise is effective for cardiovascular fitness for paraplegics.

1 Introduction

Rowing exercise is effective for the prevention of muscle atrophy in not only healthy people, but also elderly, and even disabled individuals. Functional Electrical Stimulation (FES) is the artificial electrical stimulation of muscle which has lost nervous control and producing a functionally useful movement such as exercise, standing, and walking [1]. Wheeler and colleagues [2, 3] demonstrated that FES-rowing for people with spinal cord injuries were safe and could play a role in decreasing risk factors for cardiovascular disease. In this study, based on a new concept to effectively restrengthen disused muscle and enable whole body exercise in paraplegics, we developed hybrid rehabilitation equipment which included FES technology. The purpose of this study was to evaluate the cardiovascular fitness effects of FES-rowing exercises for paraplegic patient.

2 Methods

Akita FES-rowing machine

The rowing machine used in this study was the Akita FES-rowing machine. We developed this rehabilitation equipment so that paraplegics could use it for safe and effective exercise. The machines total length is about 249.2 cm and it weighs 80kg (Figure 1). We developed this machine with easier transfer for paraplegics and installed a switch on the handle bar so the patient with paraplegia could manually control the electrical stimulation timing.

FES equipment

A 2-channel electrical stimulator (MINATO MEDICAL SCIENCE Co., LTD., Japan), which provides carrier medium frequency pulse (2500Hz) with stimulation frequency at 99Hz, was used to activate the quadriceps femoris muscle on both legs for knee extension using self-adhesive 2.75”x5” surface electrodes (Chattanooga Group Inc., USA) (Figure 2).

Figure 1. The Akita FES-rowing machine
Timing of electrical stimulation during exercise

The basic rowing action is a coordinated muscle action that requires application of force in a repetitive, maximal and smooth manner. Every large muscle group of arms, legs, chest, back, and abs will contribute to this action. The movement cycle of a rowing stroke was set to flexed ready position, drive phase, pull phase, and recovery phase. In the fully flexed ready position, the knee and hip joint start in the maximal flexed position. In the drive phase, the knee and hip joint extend and the upper part of the body inclines. During the pull phase, the lower limbs are in the fully extended position and the subject pulls the handle using their upper extremities. The sequence is initiated from the starting position (fully flexed ready position) by pressing the hand switch, which remains pressed until final extension and throughout the upper-extremity pull phase so that the lower extremities are maintained in an extended position. On completion of the upper-extremity pull, the hand switch is released, and the participant pushes the upper extremities forward. This initiates a return to the starting position (fully flexed position) and the beginning of the rowing stroke in the recovery phase.

Oxygen consumption

The incomplete paraplegic patient (55-year-old male, Frankel grade C, T10 burst fracture) who was injured 4 months ago in a falling accident participated in this study. Three months after the accident he started the FES-rowing exercise. He performed rowing exercise for 4 weeks (20 minutes per day, 5 days per week). During the rowing trial, peak oxygen consumption (L/min) and heart rate data were collected using a portable telemetric system, the K4b2 (COSMED Ltd., Italy) via breath-by-breath methods. The rowing cadence was 12 strokes per minute (Figure 3).

3 Results

\(\text{VO}_2\text{max}\) at the beginning of the patient’s exercise was 1.55 L/min. After four weeks of FES-rowing exercise, his \(\text{VO}_2\text{max}\) was 1.75 L/min (increased by 12.9%).

4 Discussion and Conclusions

Ergometer rowing has become a popular exercise of dry-land training for the sport of rowing. Nowadays rowing is recognized as an aerobic rowing exercise using either an actual boat or a rowing machine improves cardiopulmonary fitness, endurance, and resistance to fatigue. FES-rowing exercise combines voluntary upper-extremity and electrically-stimulated lower-extremity exercises for people with quadriplegia and paraplegia. Based on this concept, we developed the Akita FES-rowing machine that paraplegics can use for safe and effective exercise. A characteristic of this machine is that paraplegics can use it, also, the stimulator using the medium frequency current [4] makes it possible to obtain sufficient muscle contraction without any discomfort, compared with the low frequency current. We did examine cardiovascular effects of the FES-rowing exercise. Our results suggest that safe, effective training is possible for seniors and paraplegics during FES-rowing exercise. We will continue to research the effects of the Akita FES-rowing machine.
References