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Case Report
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Effects of Functional Electrical Stimulation-Cycling on Muscle Thickness and Blood Glucose Level in Neuromuscular Disease Mechanically Ventilated Patient: Case Report

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Abstract

Details of the clinical case: This is a case of a 49-year-old male patient diagnosed with severe chronic inflammatory demyelinating polyradiculoneuritis. At the beginning of the study, the patient was in a good general condition and breathing under mechanical ventilation through tracheostomy. Muscle ultrasound and blood glucose were evaluated before and after 10 sessions of Functional Electrical Stimulation (FES)-cycling. An isokinetic FES-cycling mode (20 rotations per minute) was used and the FES parameters were: 75 Hz frequency, 800 µs to 900 µs pulse width and 170 mA to 210 mA intensity. Rectus Femoris thickness increased 12% after FES-cycling (138 *vs*. 154 mm). Vastus Intermedius thickness was almost unchanged (96 *vs*. 98 mm, +2%). Mean blood glucose level reduced 21% after FES-cycling (162 *vs*. 128 mg/dL). There was a 27% reduction at 6:00 am (132 *vs*. 96 mg/dL), 15% reduction at 12:00 noon (166 *vs*. 142 mg/dL), and 21% reduction at 06:00 pm (187 *vs*. 147 mg/dL).

Discussion: To our knowledge, this is the first time that FES-cycling has been reported in a neuromuscular disease. It contributed to preventing/reducing the effects of physical inactivity. Due to huge impairment in the neuromuscular pathway, the patient needed high levels of electrical charge (high pulse width and intensity). The therapy was safe (no adverse events were reported during treatment), feasible and well tolerated.

Summary: It was demonstrated that 10 sessions of FES-cycling prevented muscle mass wasting and improved blood glucose control in a neuromuscular disease mechanically ventilated patient.

Keywords: FES-cycling; Exercise; Muscle; Blood glucose

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Case Presentation

This is a case of a 49-year-old male patient diagnosed with severe Chronic Inflammatory Demyelinating Polyradiculoneuritis (CIDP). Electroneuromyography demonstrated the presence of a diffuse neuropathic process with clear motor predominance, in addition to signs of acute degenerative activity. The patient's comorbidities included type 2 diabetes mellitus, chronic respiratory failure, and anemia. He was taking several drugs for his condition (escitalopram, quetiapine, insulin, and enoxaparin) and received infusions of Rituximab as part of the CIDP treatment.

The patient was admitted to the intensive care unit due to symptoms of dysphagia, choking, progressive worsening of the breathing pattern, and oxygen saturation reduction. Intubation, mechanical ventilation, and gastrostomy were necessary. After proper management and stabilization, the patient was transferred to the ward. At the beginning of the study, he was in a good general condition, breathing under mechanical ventilation through tracheostomy.

The patient received FES-cycling therapy, in addition to the usual care (all previous therapeutic conduct were maintained). Muscle ultrasound and blood glucose were evaluated (single day) before and after 10 sessions of FES-cycling. The study was approved by the Lauro Wanderley University

Figure 1: Patient attached to the FES-cycling equipment.

Hospital ethics committee (opinion number 6.055.353/23).

The muscular thickness was assessed using a portable equipment (Mobissom, Mobissom, São Paulo, Brazil) with linear transducer. The rectus femoris and vastus intermedius of the dominant lower limb was evaluated, with the patient lying down. The transducer was positioned at 2/3 of the distance between the anterior superior iliac spine and the upper border of the patella. The images were collected and sent to a computer for analysis, using the ImageJ software.

The patient received 150 mL of a hyperprotein normocaloric industrialized diet every 3 h from 5:00 am to 11:00 pm during all evaluation/intervention period. Blood glucose data were recorded during hospital routine monitoring. Fingertip blood collections were performed at 6:00 am, 12:00 noon, and 6:00 pm. Blood was analyzed in a portable device (Accu-Chek Active, Roche, Switzerland).

The patient was positioned on the FES-cycling equipment (MOBITRONICS®, INBRAMED, Brazil) (Figure 1). Self-adhesive electrodes (size 5 cm × 5 cm) were placed bilaterally on the bellies of the quadriceps (vastus lateralis and vastus medialis), hamstrings, and tibialis anterior muscles, and then connected to the cables of the stimulation device. Eight channels of electrical stimulation were used. The FES was triggered and stopped according to the position of the cycle ergometer pedals. The equipment has a sensor to detect the position of the pedals in 360º. FES triggering/stopping was defined according to the physiological positions of the joints during the cycling movement. The isokinetic FES-cycling mode (20 rotations per minute) was used.

One adaptation and ten therapeutic FES-cycling sessions (once a day) were performed. Before starting each session, one electrical stimulation channel was activated to detect the highest tolerable parameter sets without pain. The FES parameters were: 75 Hz frequency, 800 µs to 900 µs pulse width and 170 mA to 210 mA intensity. The adaptation session was performed with 75 Hz frequency, 400 µs pulse width, and 80 mA intensity. The patient initially performed 10 min of FES-cycling in the adaptation and first therapeutic session, followed by increases of 2 min every 2 sessions (reaching 18 min at the final session).

After 10 FES-cycling sessions, Rectus Femoris thickness increased 12% (138 *vs.* 154 mm). Vastus Intermedius thickness was almost unchanged (96 *vs.* 98 mm, +2%). Mean blood glucose level reduced 21% after FES-cycling (162 *vs.* 128 mg/dL). There was a 27% reduction at 6:00 am (132 *vs.* 96 mg/dL), 15% reduction at 12:00 noon (166 *vs.* 142 mg/dL), and 21% reduction at 06:00 pm (187 *vs.* 147 mg/dL) (Figure 2).

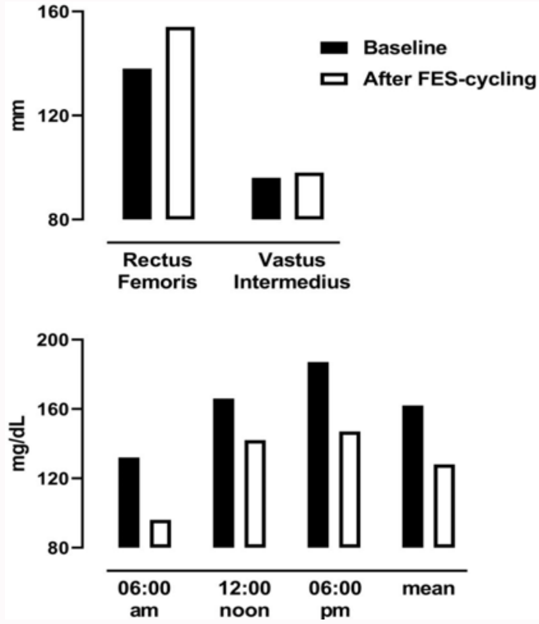

Figure 2: Muscle thickness (top panel) and blood glucose level (bottom panel).

Discussion

Neuromuscular diseases are a broadly defined group of disorders that all involve injury or dysfunction of peripheral nerves or muscle and often patients progress to respiratory failure, requiring mechanical ventilation [1]. Disuse or bed rest itself also accelerates the onset of combined changes in neuromuscular control and muscle protein synthesis [2,3]. In addition to progressive muscle mass wasting, weakness, and sensory dysfunction caused by the disease, mechanical ventilation reduces muscle thickness [4]. Even short-term rest reduces the cross-sectional area in all fiber types [5]. Physical inactivity also impairs insulin sensitivity [6], contributing to increased blood glucose levels in bedridden patients.

To our knowledge, this is the first time that FES-cycling has been reported in a neuromuscular disease. It contributed to preventing/reducing the effects of physical inactivity. Functional Electrical Stimulation (FES)-cycling has increasing evidence of therapeutic use. The technology is being used in various pathological disorders that reduce patients' physical activity levels, including neurological [7], chronic cardiorespiratory [8] and critical illness [9].

Due to huge impairment in the neuromuscular pathway, the patient needed high levels of electrical charge (high pulse width and intensity). Even with high levels of electrical charge, the therapy was safe (no adverse events were reported during treatment), feasible and well tolerated. The parameters adjustments were not enough to induce very visible muscle contractions (pain threshold was respected). Although muscle contraction was barely visible, muscle thickness improved and blood glucose levels reduced. Very visible muscle contractions may not be the main target for this population.

FES-cycling promotes muscle contraction against resistance, increasing the external work. It not only reduces the loss of lean body mass, but causes moderate increases, preventing muscle atrophy [10]. Tension-producing activity is essential for muscle trophism. Without tension, muscle fiber disorganization starts within a period of days [11]. The atrophy results from a combination of decreased muscle protein expression and increased activity of intramuscular Ca^{2+} activated proteases that can be reversed if the muscles produce tension. For the first time FES-cycling technology was used to prevent/attenuate muscle mass reduction in neuromuscular disease. Although a barely visible muscle contraction was achieved, the muscle tension produced during the therapy was enough for reverse/attenuate the muscle atrophy mechanisms.

A previous physiological study [12] suggested higher glycolytic pathway activation during FES-cycling, with higher respiratory exchange ratio and energy expenditure. The blood glucose reduction demonstrated in this case report may be explained by this higher glycolytic pathway use. Muscle contraction is essential for blood glucose control. Contraction-induced molecular signaling involves a variety of signaling molecules. While acute regulation of muscle glucose uptake relies on GLUT4 translocation, glucose uptake also depends on muscle GLUT4 expression which is increased following exercise. Exercise training is the most potent stimulus to increase skeletal muscle GLUT4 expression, an effect that may partly contribute to improved insulin action and glucose disposal and enhanced muscle glycogen storage following exercise training [13].

Application to Practice

FES-cycling can be a tool to perform exercise on patients with neuromuscular disease breathing under mechanical ventilation. It can contribute to preventing/reducing the effects of physical inactivity.

Summary

It was demonstrated that 10 sessions of FES-cycling prevented muscle mass wasting and improved blood glucose control in a neuromuscular disease mechanically ventilated patient.

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