Development of a Functional Electrical Stimulation (FES)-Assisted Rowing Machine for Adults with Complete Spinal Cord Injury

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Methods
First, we identified the three main problems with current FES-assisted rowers. These issues were addressed using both off-the-shelf products and components fabricated in house. Finally, we pilot tested the device with adults with SCI who had not previously performed FES-assisted rowing.

Introduction
Adults with spinal cord injury (SCI) have difficulty achieving exercise intensities sufficient to improve aerobic fitness, in part because they are limited to upper body activities. Hybrid exercise, voluntary upper-body exercise with concurrent lower-extremity electrical stimulation, is one mode to increase exercise intensity in adults with SCI. One specific hybrid activity that has been shown to be well tolerated and to increase exercise intensity is functional electrical stimulation (FES)-assisted rowing. Current FES-assisted rowing machines are in need of several improvements to optimize their use.

Purpose
The purpose of this study was to develop an FES-assisted rower that permits a coordinated rowing stroke with adequate seat stability and does not require remedial FES strength training.

Concept 2 Dynamic Rowing Ergometer

The Concept 2 Dynamic Rowing Ergometer (Figure 1) was selected as our base device because its design uses a fixed seat position with the feet moving away from a stationary seat. Standard rowing ergometers use a stationary foot position with a mobile seat.

Problems Addressed:
- Improved seat stability because the seat is fixed in place.
- Reduced knee extension force required to perform rowing stroke reduces or eliminates need for remedial strength training.

Integrated FES-switch System

Two Medtronic Respond II Dual-Channel Neurostimulators were arranged in series with two single-pole double-throw (SPDT) on-on pushbutton switches and a double-pole double-throw (DPDT) on-on toggle switch (Figure 2). When the participant reaches the point of maximal knee flexion or extension, the footplate contacts one of the SPDT switches, alternating the direction of stimulation between quadriceps and hamstrings. The DPDT toggle switch provides a mode of changing stimulation direction by the clinician or trainer during set-up periods. The two SPDT switches are attached to mounting brackets made from 3/8" hot rolled angled structural steel in order to position the switches and provide enough support to withstand repeated impact.

Problems Addressed:
- Improvement in rowing stroke coordination by incorporating the reciprocating stimulation into the motion of the feet.

Conclusions
Improving seat stability and integrating the switch system into the foot motion improved the coordination of the FES-assisted rowing stroke. During pilot testing, the modified FES-assisted rower was well-tolerated and easily utilized by adults with SCI. The current device is a promising mode for high-intensity exercise for adults with SCI.

Future Directions
We plan to utilize this device in an exercise training study to improve the aerobic capacity of individuals with SCI.

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