FES Rowing After SCI: Health, Sport and Recreation

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Abstract

We have demonstrated FES rowing (indoor ergometer, powered rowing tank, rowing simulator and on-water) in male and female SCI volunteers (ASIA (A/B) C4/5 to T12) using surface electrical stimulation.

Paraplegic and quadriplegic FES rowers have competed alongside able-bodied rowers at major international indoor rowing. The best performance has been achieved by a 23yr male, T12 ASIA(A), in 10 min 28 sec over the Olympic distance of 2,000m. A marathon distance of 50,000m, was achieved in Nov 2006 by a paraplegic male (51yrs,72kg, 1.71m, T4 ASIA(A), 8yrs post injury) in 5 hrs 49min.

FES rowing can enable a range of exercise intensities to be achieved: from recreational use to higher levels of VO_2 in excess of 35 ml/kg/min. High exercise volumes, in excess of 2,000 kcal/week, can also be maintained. These levels of exercise intensity and volume may help to significantly reduce health risks, particularly where dose-response relationships exists, for example in cardiovascular disease.

1 Introduction

It has been suggested that an exercise intensity of at least 6 METs (i.e., oxygen consumption of 21 ml/kg/min) is required to lower the relative risk for coronary heart disease (Tanasescu et al. 2002) and to significantly improve blood lipids fractions, exercise volumes in excess of 1200-2200 kcal/week are required (Durstine et al 2001). However, many persons with SCI can have difficulty achieving these levels (Manns et al. 1999). Although some paraplegics can achieve moderately high peak oxygen consumptions using their upper body muscles alone, however, maintaining sufficient aerobic power with small muscle mass exercise is difficult and may be limited by local fatigue of the highly stressed musculature of the arm.

FES can increase the amount of metabolically active muscle mass and 'hybrid' exercise, that involves both innervated upper body and electrically stimulated lower body, has been shown to produce significantly greater aerobic power and peak oxygen consumption than FES exercise alone. The exercise of wheelchair propulsion and arm-cranking ergometry have been associated with shoulder pain (Jacobs 2004), however, pulling actions have been proposed as therapy for chronic shoulder pain in wheelchair users (Jacobs 2004, Olenik et al. 1995). FES rowing involves arm pulling actions and participants have tolerated it better than standard upper body exercise, even though the latter was conducted at a lower absolute VO_2 (Wheeler et al. 2002).

2 FES-rowing Technology

Indoor Rowing Andrews and colleagues have developed FES rowing with exercise intensities with VO_2 consumption in excess of 35ml/kg/min with volumes greater than 2,000 kcal/week have been achieved by some paraplegics who have competed in international rowing competitions over the Olympic 2,000m distance alongside able-bodied rowers (Hettinga & Andrews 2007). In 2004 two paraplegics using a 4-ch FES system (quads plus hamstrings with a change-over switch mounted on the handle) competed along with over 2,500 other rowers at the British Indoor Rowing Championships www.FESrowing.org The FES equipment is an exhibit at the Rowing Museum http://www.rrm.co.uk/ Since then, paraplegics and quadriplegics (control switch operated either by the attendant or the rower by wrist extension movements with/out velcro closed mitts around the handle grip) have competed in the BIRC and the World Indoor Rowing Championships.

On-Water Sculling Recently, we have further developed FES rowing for a rowing simulator, the

tank and on-water. The Alden 16 (single) and Alden 18 (double) recreational rowing boats were chosen (http://www.rowalden.com/) for their stability and the conveniently removable stateroom module. To facilitate laboratory studies training and systems development a sculling simulator was developed based on the Alden stateroom module Figure 1. The custom seat was similar to that used on the ergometer as was the telescopic leg stabilizer. For some rowers, a bungee cord was attached to the sliding seat to assist the return to catch during the 'recovery' phase. Regular carbon fibre oars with the spoons removed were coupled to two 2-state hydraulic cylinders, i.e. minimal resistance during RECOVERY and adjustable pre-set resistance during DRIVE. In the simplest arrangement 4-ch surface stimulation was used (as with the indoor rower) with the control switch mounted on the oar handle. Training in the simulator followed a similar protocol to that used for rowing on the adapted Concept II.

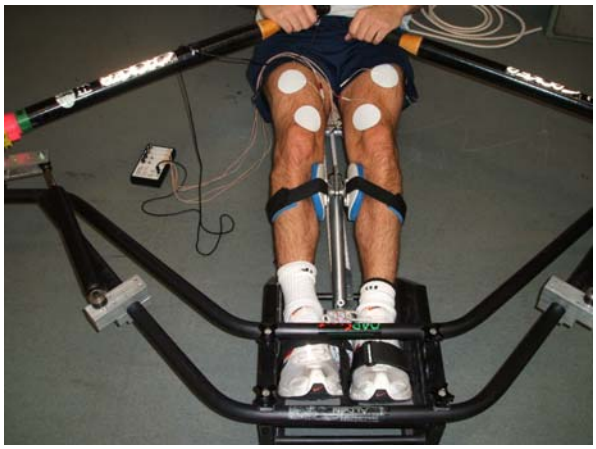

Fig 1(a) The FES rowing simulator: comprising an Alden boat stateroom and fitted with telescopic leg stabilizer with leg cuffs, oar mounted control switch and hydraulic cylinders. The simulator allows laboratory training and systems development.

Case report FES sculling Subject TA (22yrs, 90kg, T12-ASIA(A), 2yrs post injury), shown in figure 1. Following a 3-month period of FES leg strengthening and 12 months indoor rowing ergometry. In Nov 2006 he set the record for FES rowing at the BIRC of 10min 28s for 2,000m. Since then, he regularly works out 2-3 times/week on the FES ergometer. In Dec 2006 he had two additional 1-hour sessions on the sculling simulator (fig 1(a)). This was followed by three one hour sessions in the tank (figure 1(b)), comprising five 8-minute pieces with 3-5 minute rest periods. The turbine was set to simulate a boat speed of 2.3 m/s.

Initial on-water training began following the second tank session using the Alden 18 double with the coach in the bow seat. After three, 30 minute sessions with the coach he began single sculling in the Alden 16, shown in Fig 1(c). He now regularly sculls on-water, typical rowing pieces exceeding 1,000m.

Figure 1(b) Subject TA with the author SG at the adapted station of the 8 seat London Regatta Centre's turbine powered rowing tank. The FES station comprised a modified seat and slide, leg stabilizer and bungee cord assist recovery. The position of the FES control switch is shown being demonstrated. The turbine powered rowing tank at the London Regatta Centre is described in McLean 2002.

3 Discussion

We have observed that all the FES rowers progressively increased their strength and endurance of rowing, beginning with distances of a few tens of meters to many thousands of meters. For example, one of the authors RG (52yrs, T4-ASIA(A), 70kg, 1.71m height) began FES rowing in June 2004 and was only able to attain a few hundred meters before quadriceps were fatigued. In Nov 2004, at the BIRC, he had adopted a 30sec FES row 30 sec arms only split (seat clamped), to allow the quadriceps to recover yet make good time for 2000m. Typically, the split was progressively staged to 40:20 then 50:10 then non-stop for 2000m. In Sept 2006, in an officially timed marathon, 50,000 meters was achieved in 5hrs 49mins. He now routinely trains non-stop at 3-10,000m. Clearly, there have been profound changes in his physical fitness and stimulated muscle endurance. These changes are now the subject of further studies.

FES rowing is now offered at ASPIRE

http://www.aspire.org.uk/index.php?id=101 the Steadward Centre at the University of Alberta http://www.steadwardcentre.org/ and the London Regatta Centre http://www.london-regatta-centre.org.uk/ Internet rowing (RowPro http://www.digitalrowing.com/) is used to link participants. FES rowing offers those with SCI a range of workout intensities and volumes. As in the general population, for many the fun of FES rowing, and the associated social activity, is enough. For others, the competitive element is attractive and has provided the incentive to pursue improved performance and technology.

At the BIRC 2006, medals were awarded based on the average time calculated from an individuals previous 10 attempts at 2000m just prior to the championships. If this time was beaten by 10 secs, the rower achieved Gold, between +/-9 secs Silver, and below 10 secs Bronze. In this way the awards were considered fair but competitive across the widely different exercise capacities'.

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Figure 1(c) Subject TA in the adapted Alden 16 single sculling boat. The floats prevent capsize.