

Functional Electrical Stimulation (FES)-Rowing for Exercise in the Spinal Cord Injured

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WHY FES-rowing?

Inactivity-Related Health Issues in SCI

- Obesity
- Cardiovascular diseases
- Diabetes
- Osteoporosis

Minimal Exercise Levels To Reduce Risk of Disease

Exercise >21 mL/kg/min (6 MET) is needed to significantly reduce the relative risk for coronary heart disease.
Tanasescu et al., JAMA 2002

Exercise intensity is inversely associated with the prevalence of hypertension, hypercholesterolemia, and diabetes, suggesting that more vigorous exercise results in greater health benefits.
Williams, Med Sci Sports Exerc. 2008

Cardiorespiratory fitness in young individuals is inversely associated with the risk of developing hypertension, diabetes, metabolic syndrome, and hypercholesterolemia in middle age.
Carnethon et al., JAMA 2003

Aerobic Capacity

$$\text{maxVO}_2 = \text{CO} \times \text{a-vO}_2$$

VO_2 Rate of oxygen consumption,
liters of oxygen per minute

CO Cardiac output,
liters of blood per minute

a-vO_2 arterio-venous oxygen difference

Ranges of Aerobic Capacity

Olympic X-country Skiers	82 ml/kg/min
Olympic Rowers	71 ml/kg/min
Competitive Triathletes	65 ml/kg/min
Elite Masters Athlete (aged 63)	61 ml/kg/min
Average 25 year old	50 ml/kg/min
Average 65 year old	32 ml/kg/min
Elite Paraplegic Triathlete (2009 Ironman Winner)	33 ml/kg/min

Limitations to Exercise in SCI

- Limited muscle mass
- Non-weight bearing below lesion
- Impaired vasoconstriction of non-active tissue
- Lack of muscle pump in lower extremities
- Over-use injuries



Advantages of FES-rowing

- Work distributed across large muscle mass to produce high levels of sustained aerobic exercise
- Non-innervated legs initiate a force vector similar to weight bearing
- Hemodynamic profile comparable to the able-bodied via coordinated arm and leg movements
- Avoidance of over-use injuries



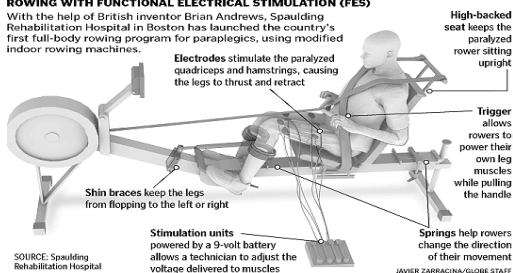
Obstacles to And Practical Application of FES-rowing

Obstacles

- Muscle atrophy
- Spasticity
- Muscle fiber type shift to fast twitch morphology
- Motor unit recruitment pattern

FES-rowing

ROWING WITH FUNCTIONAL ELECTRICAL STIMULATION (FES)
With the help of British inventor Brian Andrews, Spaulding Rehabilitation Hospital in Boston has launched the country's first full-body rowing program for paraplegics, using modified indoor rowing machines.



SOURCE: Spaulding Rehabilitation Hospital

JAVIER ZARRACINA/GLOBE STAFF

Training Paradigm

- Initial quadriceps strength training (2-12 weeks)
- Addition of hamstring strength training (isometric)
- FES-rowing and arms only rowing intervals (2-5 min)
- Continuous FES-rowing ≥ 20 min 3x/week (strength training on non-rowing days, 30-60min)

Current Experience

- 19 enrollees since 2008, 2 dropouts, 6 advanced to continuous rowing (20 min 3x/week)
- Duration of strength training from 0 to 20 weeks
- Duration of interval training from 4 weeks to 32 weeks
- Continuous FES-rowing currently ranges from 20 to 40 min

Additional Obstacles

- Stimulation is ineffective in some individuals
- Incomplete injuries may not tolerate stimulation
- Higher level injury (i.e., tetraplegics) require additional rower modifications and more assistance with transfer
- Rower to staff ratio varies with experience of the participant, from 1:1 to 3:1
- Training may be interrupted due to medical issues (e.g., UTI's, falls, etc.)



***Current Program
Using
FES-rowing***



"The condition of exercise is not a mere variant of the condition of rest, it is the essence of the machine."
- Sir Joseph Barcroft, 1934

MISSION: Provide appropriate exercise to improve health in those with physical disability



- Adults
- ASIA classification A or B or C
- Injury level C4-T12
- Medically stable
- Able to move arms



- To support Military sport programs for the Paralympic Military Program
- Goals:
 - To expand the program through out the New England area by developing a partnership between Spaulding Rehabilitation Hospital and Community Rowing Inc
 - To expand through out the Boston community to include injured service members in the Boston VA Healthcare System
 - To expand beyond Boston, in the last quarter of the grant will include training and expenses to establish the ExPD program at Stanford and the Palo Alto VA

Future Plans

- Bring FES-row training paradigm to other sites
- On water FES-rowing
- Increase muscle mass recruited
- Training for Paralympics?

