FES-Rowing can alter cardiac structure and function in SCI: a pilot study

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INTRODUCTION

Spinal cord injury (SCI) predisposes individuals to an increased risk of cardiovascular disease. For many with SCI, adding sufficient exercise intensity and volume to a workout is problematic especially for those at the lowest end of the activity spectrum with complete tetraplegia. Functional Electrical Stimulation (FES)-rowing is an exciting new form of cutting edge exercise therapy offering a high-intensity workout for those with SCI and, more crucially, those with tetraplegia. The paralysed legs are activated by small trains of electrical stimulation applied to the quadriceps and hamstring muscles concurrent with voluntary arm exercise resulting in a rowing action. Stimulation is rower or attendant controlled in the case of rowers with tetraplegia (Figure 1). For more information please visit: http://ifess2012.com/papers/secondary_complications_exercise_and_denervated_muscles/ .

Figure 1: *For the first time, subjects with complete tetraplegia up to C4 can now learn to FES-row using Velcro closure gloves (*http://www.activehands.co.uk*) and attendant controlled electrical stimulation.*

PROJECT AIMS

The aims of this project were to examine, for the first time, the differences in structure and function of the heart together with the cardiorespiratory responses to high intensity exercise between people with SCI who regularly engage in FES-rowing (FES-T) and those who have remained sedentary (FES-UT). These data were compared to non-injured controls (non-SCI).

METHODS

Participant groups: ***FES-Trained*** (FES-T) n=3, American Spinal Injury Association Impairment Scale (AIS) A, time post injury (TPI) 7 ± 3 yrs, age 42 ± 15 yrs, stature 1.78 ± 0.08 m Body Mass (BM) 75 ± 7 kg; ***FES-Untrained*** (FES-UT) n=5, AIS A, TPI 7 ± 6 yrs, age 33 ± 7 yrs, stature 1.73 ± 12 m, BM 61 ± 20 kg; ***Non-Spinal Cord Injured*** (N-SCI) n=5, age 41 ± 3 yrs, stature 1.66 ± 0.04 m, BM 62 ± 10 kg.

Experimental design: Cross-sectional to compare cardiac structure and function at rest using echocardiography (Figure 2), diaphragm structure using ultrasound, pulmonary function using spirometry, peak cardio-respiratory responses to arm-crank exercise, and peak cardio-respiratory responses to arm-crank vs. FES-rowing exercise (Figure 5).

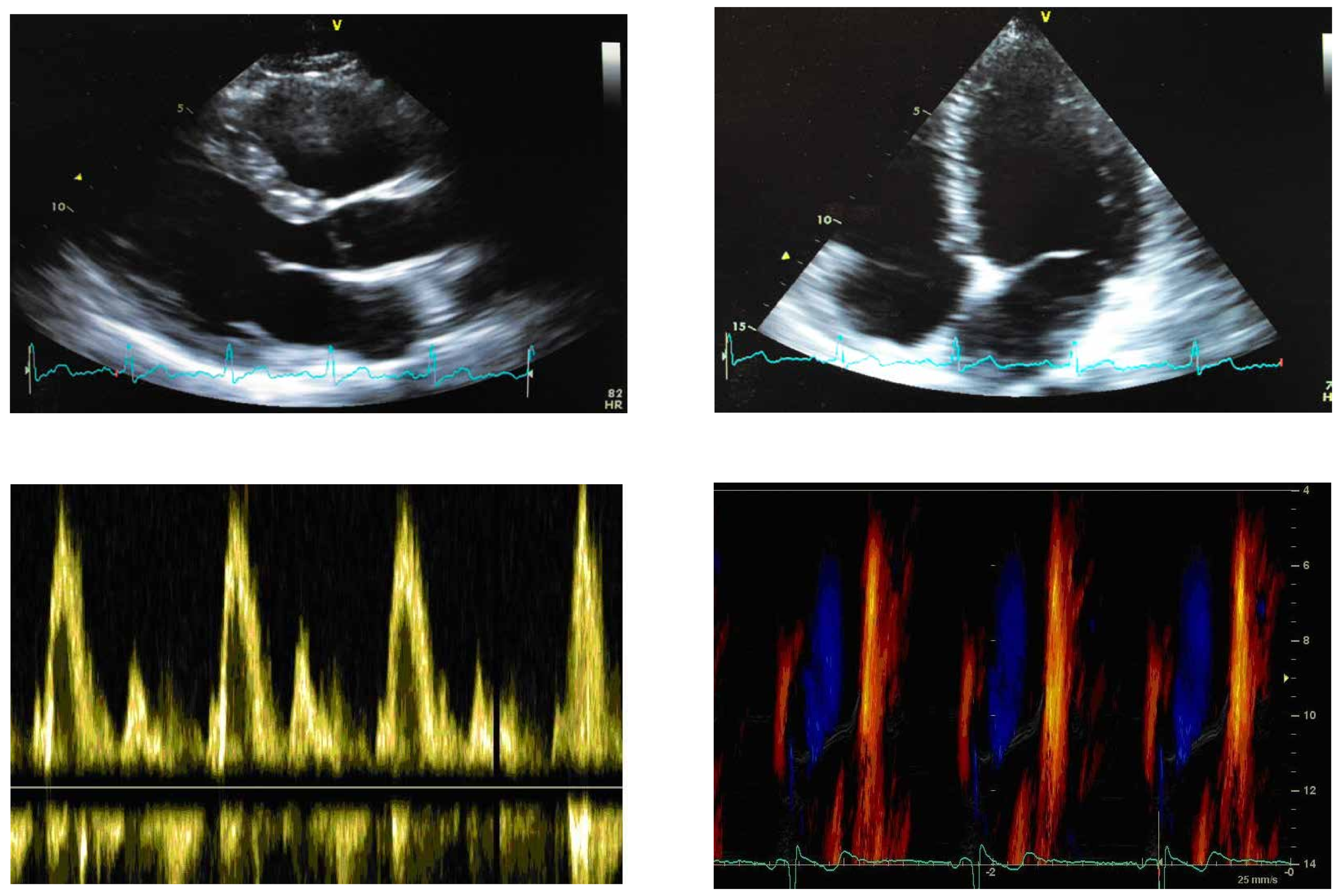

Figure 2: *Here we report for the first time the use of transthoracic echocardiology to examine the heart of FES-trained subjects with tetraplegia and paraplegia. Two-dimensional (2D) parasternal view (top left), apical 4-chamber view (top right), early and late left ventricular filling (bottom left) and left ventricular flow propagation velocity (bottom right) of an expert FES-rower.*

RESULTS

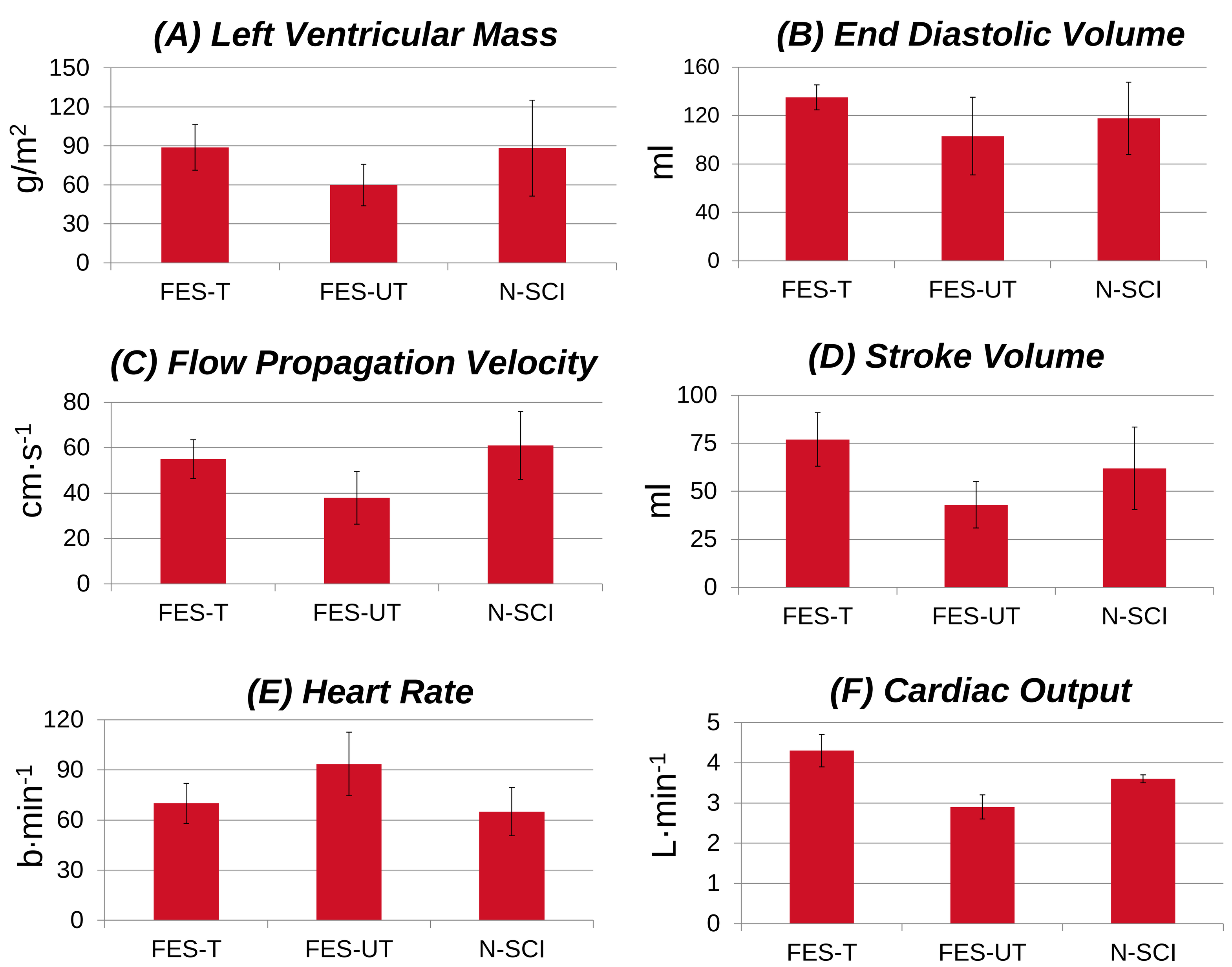

Figure 3: *Comparison of (A) Left Ventricular Mass, (B) End diastolic Volume, (C) Flow Propagation Velocity, (D) Stroke Volume, (E) Heart rate, and (F) Cardiac Output at rest in the three participant study groups. FES-T, Functional Electrical Stimulation-Trained, FES-UT, Functional Electrical Stimulation-Untrained; N-SCI, non-Spinal Cord Injured. Data are means ± SD.* ***Note the differences in heart structure and function in the FES-T vs. FES-UT group.***

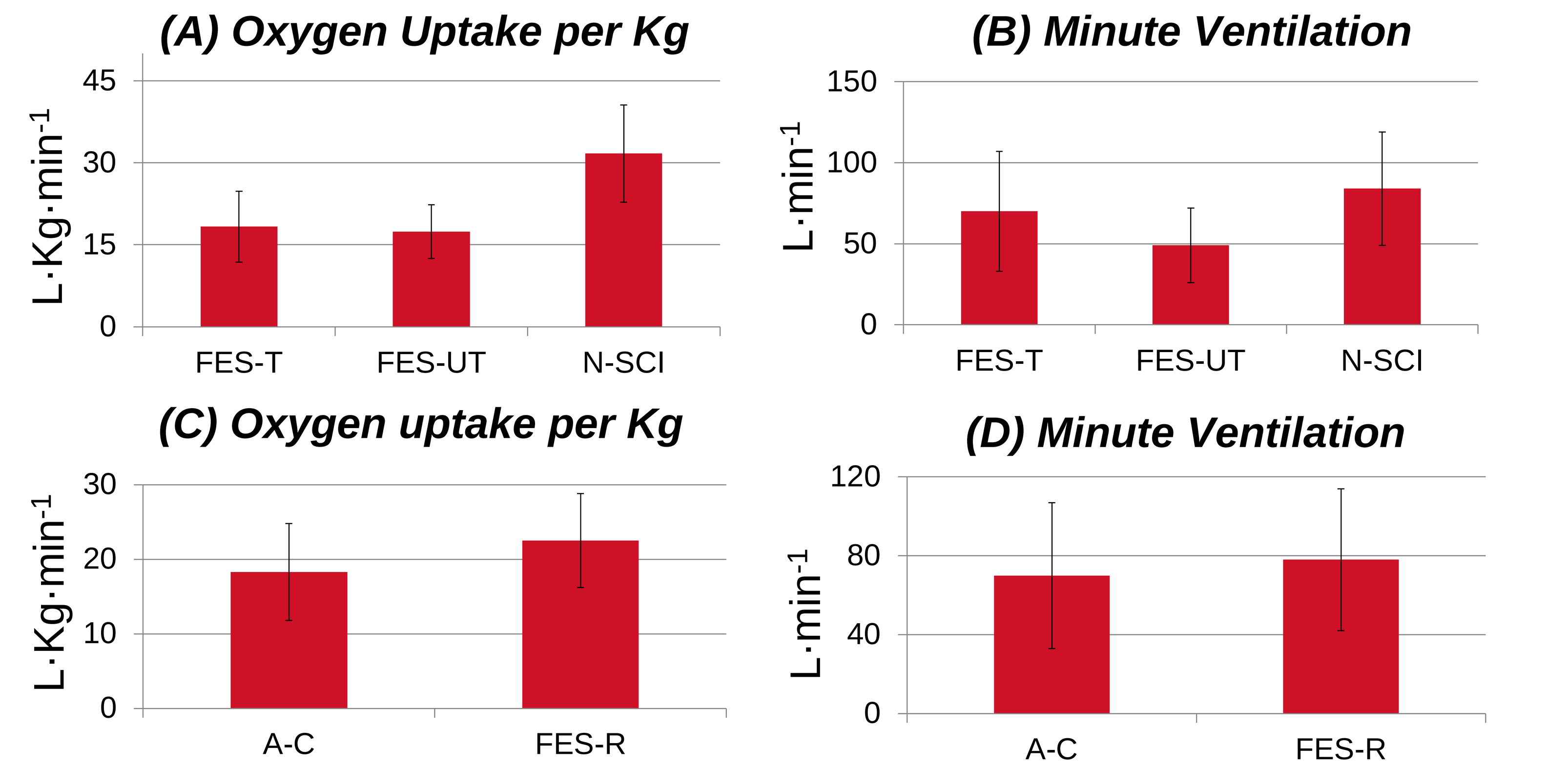

Figure 4: *(A) and (B) cardiorespiratory responses to incremental arm-crank test in three participant groups. FES-T, Functional Electrical Stimulation-Trained; FES-UT, Functional Electrical Simulation-Untrained; N-SCI, non-Spinal Cord Injured.* ***Note the FES-T group data is greater than the FES-UT group.*** *(C) and (D) cardiorespiratory responses to incremental arm-crank test and incremental FES-rowing test in the FES-T group. A-C, arm-crank; FES-R, Functional Electrical Stimulation-Rowing. All data are means ± SD.* ***Note FES-R elicits a greater cardiorespiratory response than A-C exercise.***

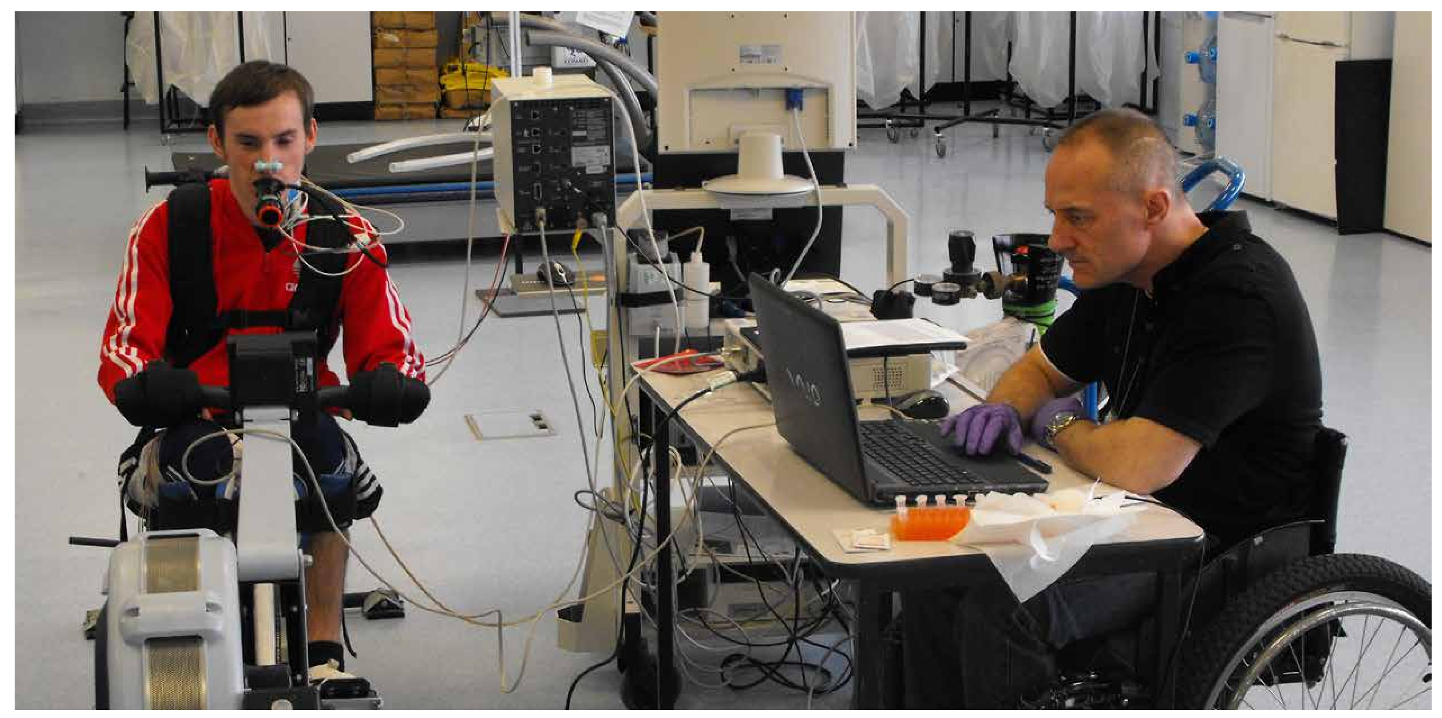

Figure 5: *For the first time is has been possible to conduct an incremental FES-rowing exercise test in subjects with C4 complete tetraplegia.*

SUMMARY & CONCLUSIONS

For the first time we describe and compare cardiac structure and function of FES-rowing trained vs. FES-untrained subjects. Left ventricular mass (~40%) and stroke volume (~43%) at rest was greater in FES-T than FES-UT. Cardiorespiratory response to arm-crank exercise (oxygen uptake per kg ~14%) in FES-T was greater than in FES-UT. These are key findings since improved physical fitness may aid activities of daily living and reduce the risk of cardiovascular disease, particularly those with tetraplegia. We acknowledge the small numbers and large variance in age, gender, injury level and time post injury limits the current interpretation of these findings.

People who engage in FES-rowing appear to have a similar cardiac structure and function to non-injured controls. These individuals also appear to have an improved cardiorespiratory response to high intensity exercise. Further work with greater numbers is now required.