Energy Expenditure and Fuel Homeostasis During and After Bouts of FES Cycling with Different Devices

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ABSTRACT

Objective: When matched for charge input, determine if caloric (kcal) expenditure and fuel partitioning measured during and immediately following a bout of functional electronic stimulation (FES) cycling differed when performed on two FES devices.

Design/Method: Four males with spinal cord injury (SCI; age: 43±15 yr; weight: 77±6 kg; level of injury: C4-T11) completed 30 min of steady-state FES exercise on four separate occasions using a charge-matched moderate stimulation intensity. Two sessions were completed on a commercially available unit (RT300, Restorative Therapies, MD) and two on a device that is in pre-production testing (MyoCycle, MYOLYN, FL) that employs a different electrical control paradigm. Before, during, and after cycling, energy expenditure and fuel homeostasis were calculated via pulmonary gas exchange (Oxycon, Jeager, CA), and central hemodynamics (for the MyoCycle device only) via impedance cardiography (PhysioFlow, Manatec Biomedical, FR).

Results: Rates of oxygen consumption (VO2) and cardiac output (Q) during FES were 36±18% and 58.7±25.4% of their respective VO2peak and Qpeak achieved during maximal effort arm cycling. Both FES devices elicited similar rates of energy expenditure (1.04±0.18 kcal/min) and fuel homeostasis (83:17 %CHO:%FAT). However, the MyoCycle alone showed a statistically significant increase in energy expenditure at 20-30 min post-exercise (10.2% increase vs pre-exercise, p=.04), with this increase in energy expenditure accompanied by a 48% increase in CHO oxidation during the first 30 min of exercise recovery.

Conclusion: Moderate stimulation intensity FES cycling qualifies as "low intensity" aerobic exercise according to authoritative guidelines, although increases in carbohydrate oxidation during and after cycling might have a meaningful impact on daily glucose regulation. Furthermore, the energetics of the recovery period seem to be influenced by the electrical control system, where the MyoCycle evokes greater use of fatty fuels during and after exercise.

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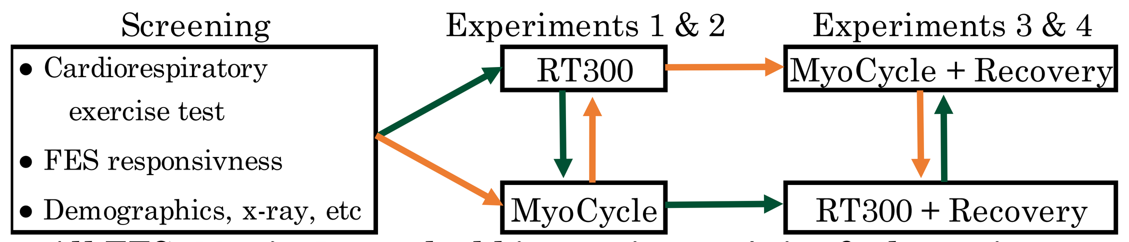
BACKGROUND

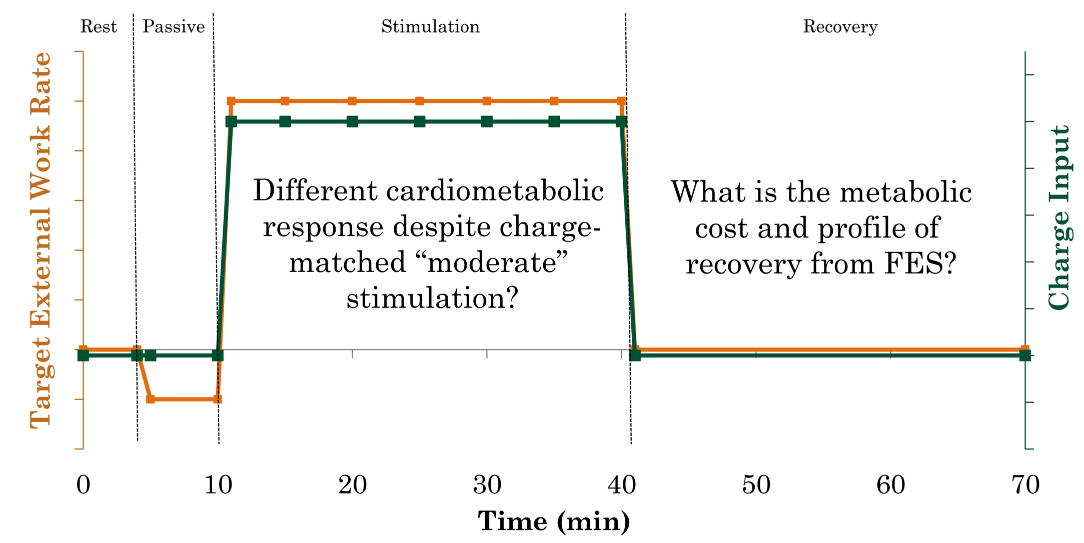
- Functional Electrical Stimulation (FES) cycling elicits acute, steady-state increases in whole body energy expenditure[1] reported to be sufficient to be classified as "moderate intensity aerobic exercise"[2].
- We have reported that commercial FES cycling devices *estimate* implausibly low energy expenditure[3], which might explain why practitioners might overlook the potential cardiometabolic health benefits of FES.[4,5]
- FES cycling has a gross mechanical efficiency (GME) of ~7–13%[6] compared to ~30% for volitional cycling. Mitigation of this inefficiency might be useful in enhancing benefits of FES exercise.
- A FES device in preproduction utilizes a novel electrical control theory that might optimize GME.
- OBJECTIVE: This study examined in eight subjects with SCI the energy cost, GME and fuel partitioning, during and following an acute bout of FES cycling when performed on 2 comparable devices.

DESIGN/METHODS



All FES: 30 min @ matched kinematics, rev/min, & charge input

Timeline



Indirect Calorimetry:

- Energy expenditure
  - kcal/min
  - GME (%)
- Fuel homeostasis
  - g/min
  - % total EE

FES Cycle:

- Matched "moderate" intensity stimulation
- "Useful" power production

Data Processing

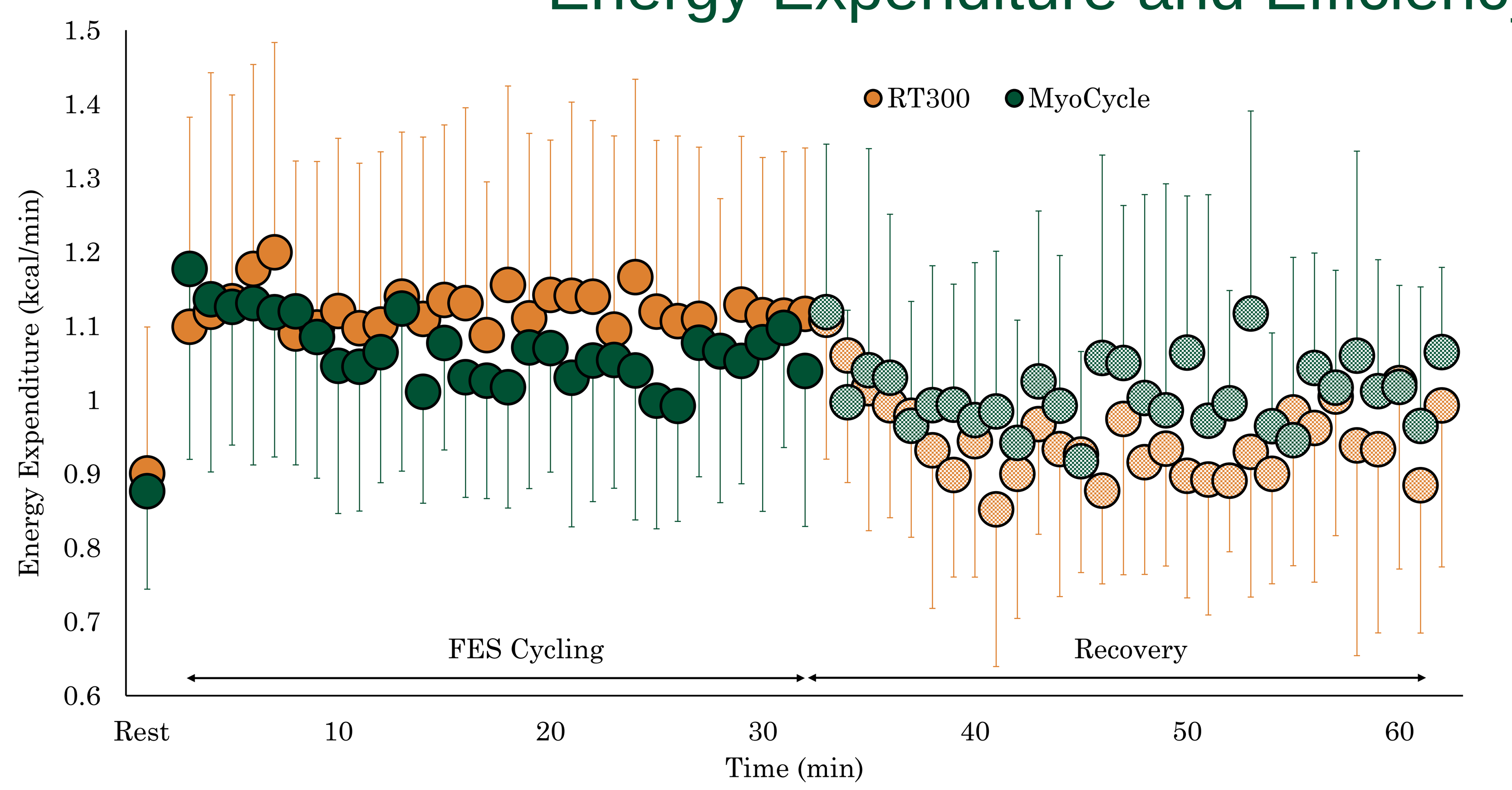
Fat oxidation (g/min) (Jeukendrup 2005)	$= 1.695 \cdot VO_2 - 1.701 \cdot VCO_2$
Lipid Partitioning (% of total EE) (Brooks 1996)	$= 100 - [(RER - 0.707)/0.293] \cdot 100$
Resting EE (kcal/min) (Weir 1949)	$= 3.941 \cdot VO_2 + 1.106 \cdot VCO_2$
Exercise EE (kcal/min) (Jeukendrup 2005)	$= 0.575 \cdot VCO_2 - 4.435 \cdot VO_2$
Gross Mechanical Efficiency (%)	$= \frac{\text{useful work produced}}{\text{metabolic energy cost}} \times 100$

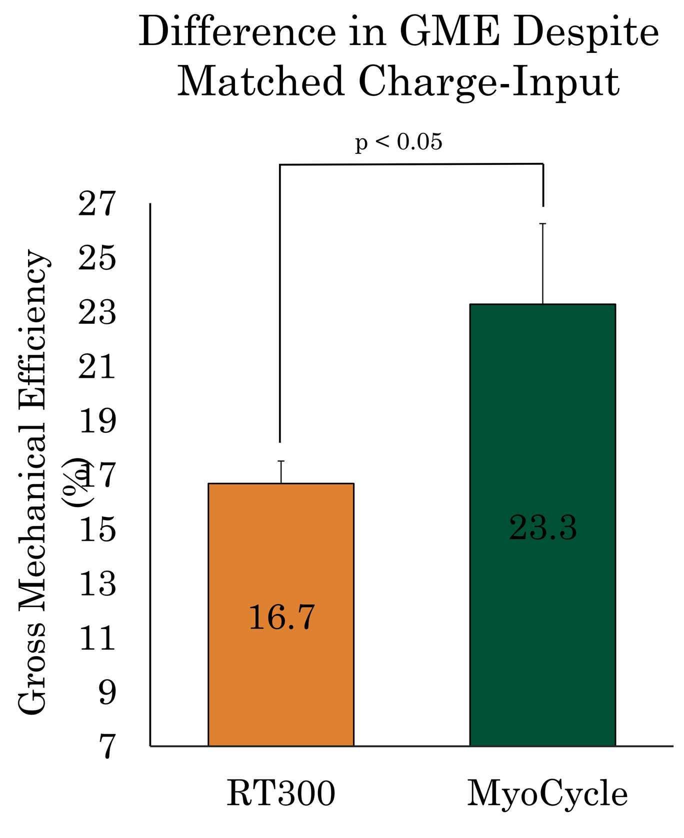
Participants

#	Age (yr)	Mass (kg)	Height (m)	Level of Injury	Complete/ Incomplete	Duration of Injury (yr)
1	35	81.4	1.88	T7	INC	13
2	61	80.5	1.70	T5	COMP	33
3	32	104.0	1.85	C5	INC	2
4	50	68.8	1.65	T12	INC	7
5	28	76.0	1.88	C4	COMP	10
6	74	81.6	1.78	T10	INC	19
7	49	67.6	1.75	C4	INC	14
8	36	104.8	1.88	T5	COMP	18
	46±16	83±14	1.80±0.09	3 Tetra, 5 Para	3 Complete, 5 Incomplete	15±9

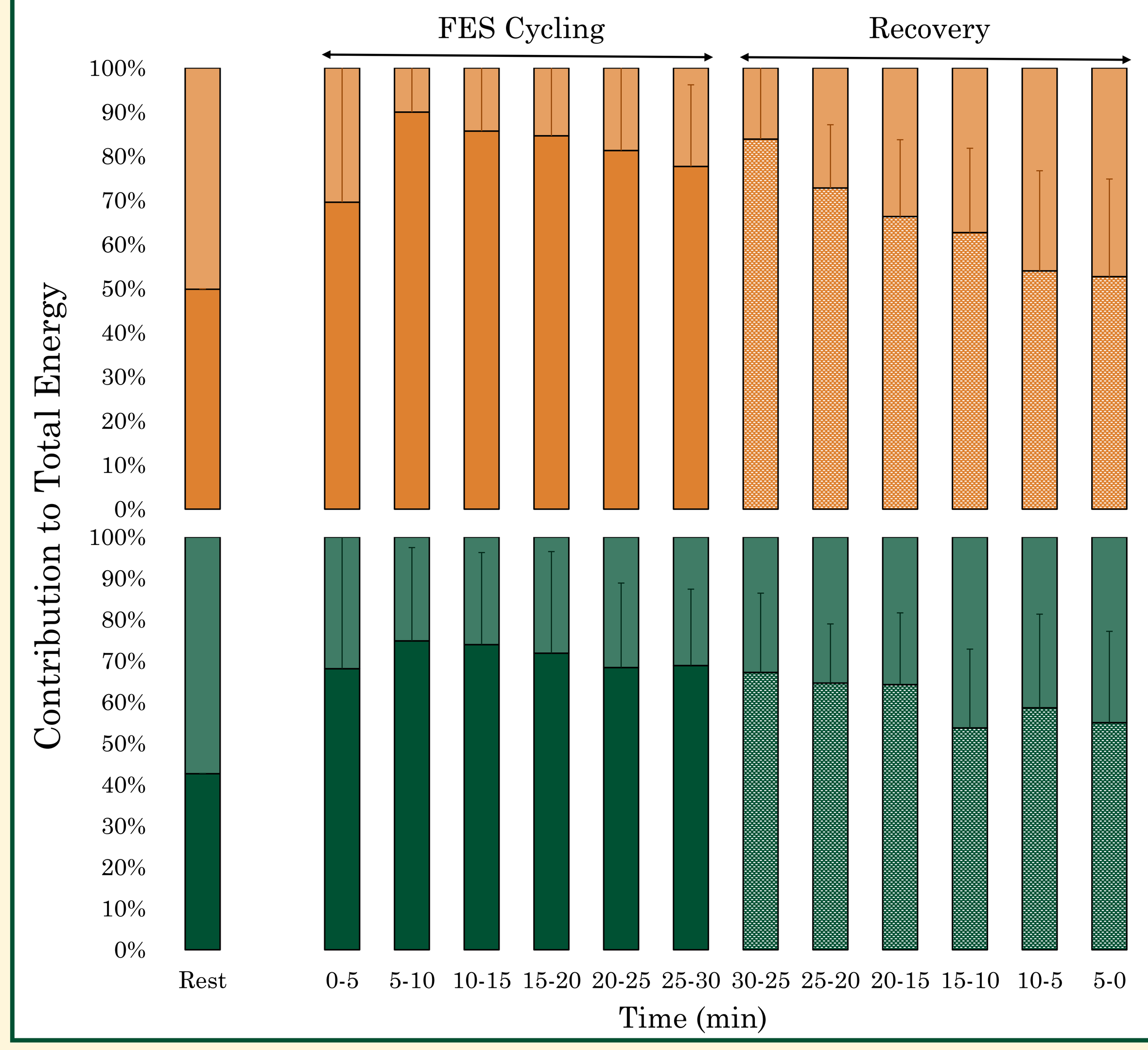
RESULTS

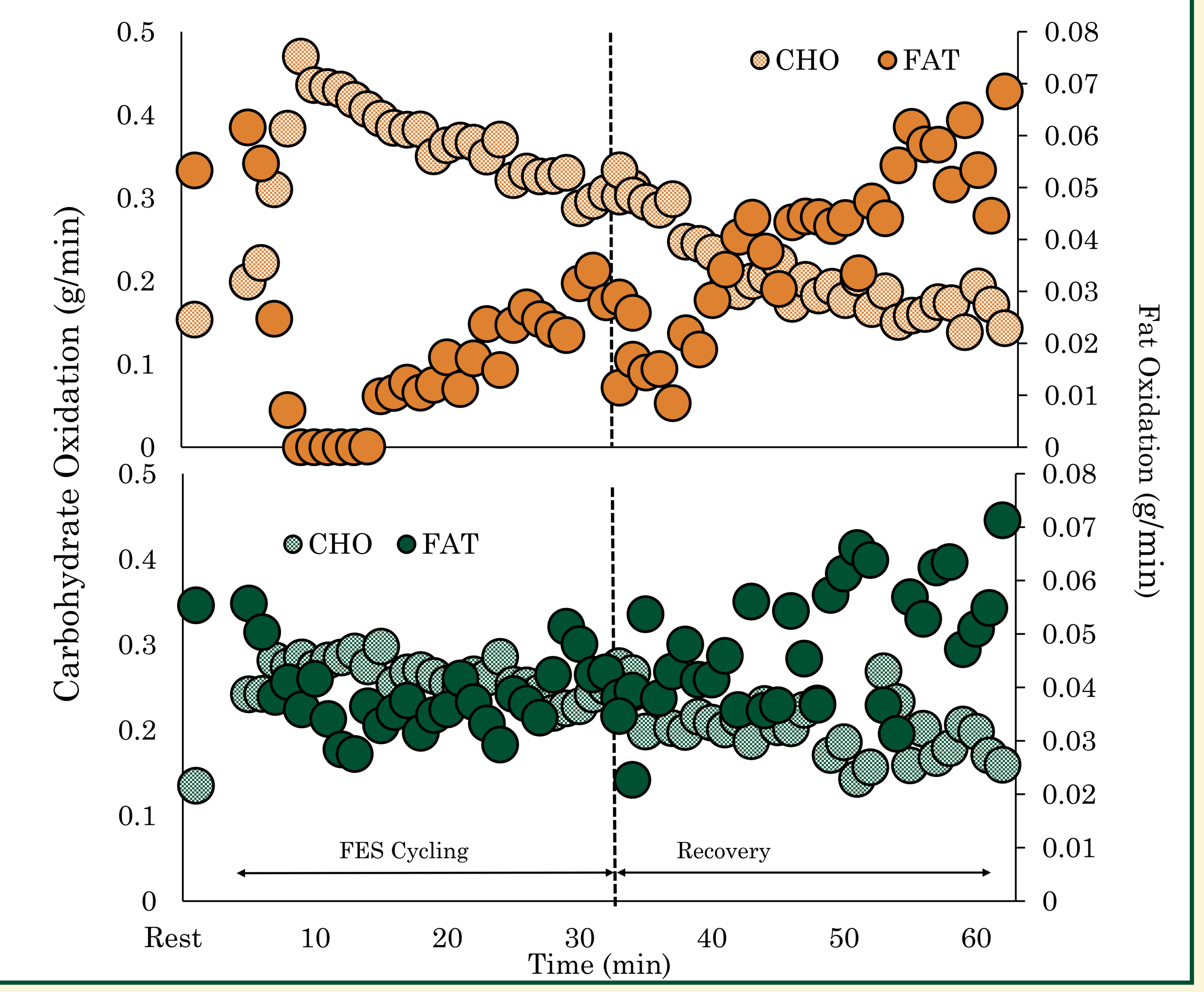
Energy Expenditure and Efficiency





Fuel Homeostasis





CONCLUSION

- Moderate stimulation intensity FES cycling qualifies as "moderate intensity" aerobic exercise according to authoritative guidelines.
- The MyoCycle relies less on carbohydrate fuels and more on fatty fuels at the selected moderate stimulation intensity.
- The MyoCycle promotes a more extensive excessive post-exercise consumption for 30 minutes after termination of stimulation.
- The greater GME observed for the Myocycle may have implications for more substantial sparing of muscle fatigue accompanying FES cycling.

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