Peak Oxygen Consumption with Implanted Stimulation-Driven Cycling

Lok W Lei Valentas, Rudi Kobetic, M.S.E, Lisa Lombardo, MPT, Kevin Foglyano, B.S.E, John McDaniel, Ph.D, Ronald J. Triolo, PhD

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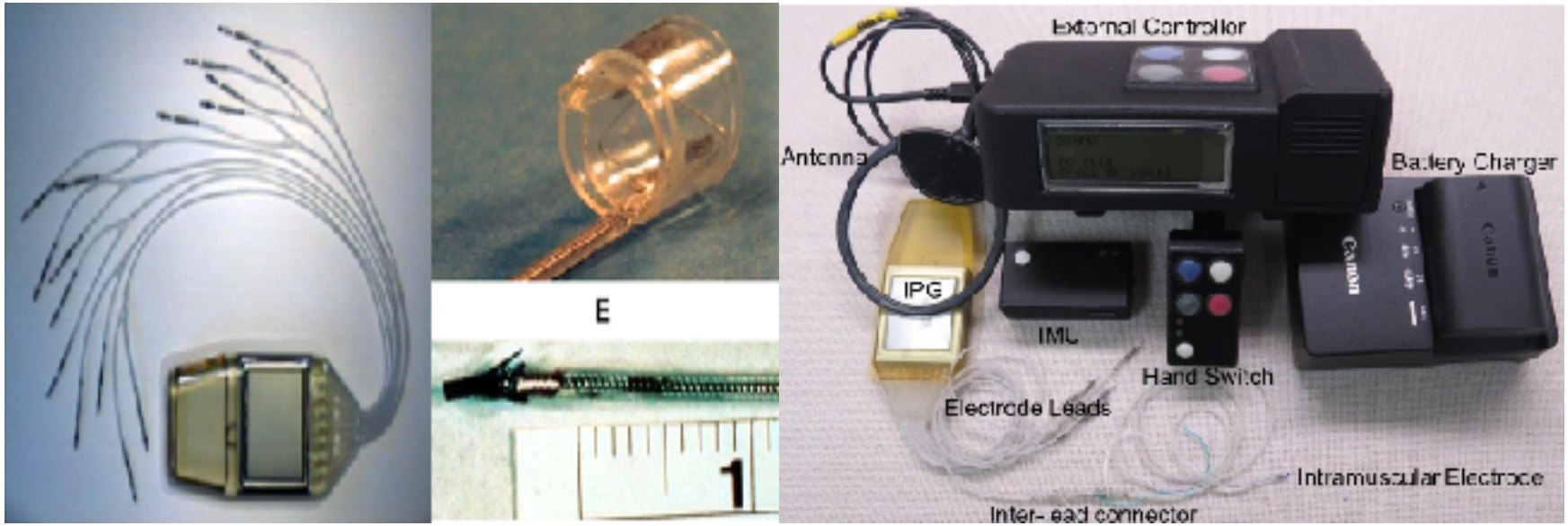
Introduction

- Cardiovascular disease is a leading cause of mortality in spinal cord injury (SCI) patients
- Numerous benefits of exercise
- Oxygen consumption (VO2): measurement of aerobic exercise intensity
- American College of Sports Medicine (ACSM) recommendations:
  - Aerobic exercise at 50-80% peak VO2
  - 20-60 minutes
  - 3-5 times/week
- Previous studies focused on VO2 and stationary cycling
- Evaluate modality for recreational use

Study Overview

- 3 subjects
- Catrike 700 with neuroprostheses
  - Nerve cuff implantation
  - Stimulation program with sensor
- Part of larger study to aid standing and stepping in SCI patients
- Measured peak oxygen consumption

Nerve cuff implantation



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Instrumentation

- Catrike 700 recumbent trike
- Custom pulley keyed to crank
- 3D printed gears with 1:1 ratio
- Off-crank encoder
- Sensor output acquired by external controller
- Cycling stimulation pattern program

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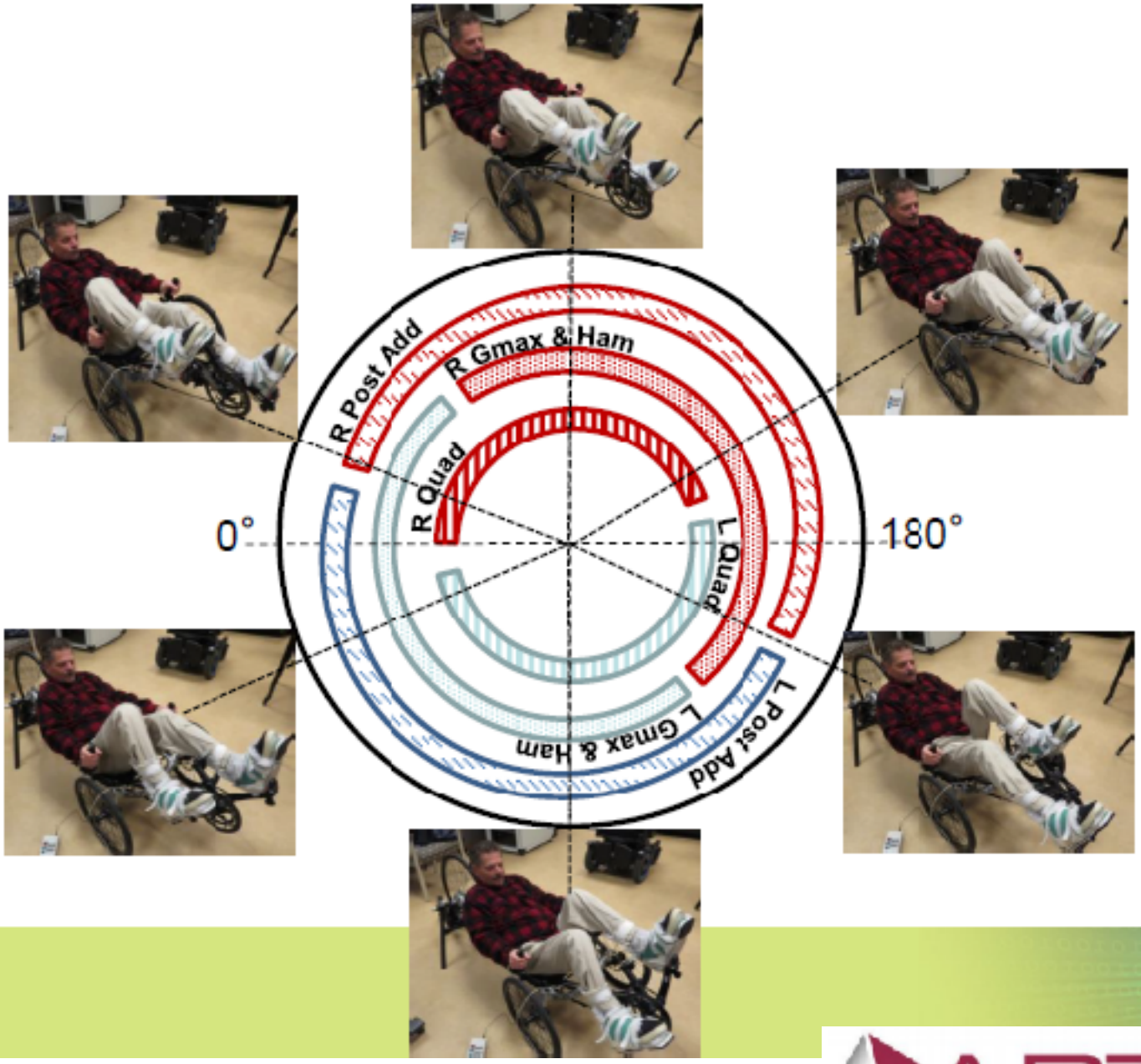

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Methods

- 3 subjects
- Catrike 700 with neuroprostheses
- K4b2 system
- 5 min rest, cycling until fatigue, 5 min recovery

Subjects

Subject	Age	Height (cm)	Weight (kg)	Level of Injury	Date of Injury	Cycling Start Date	Muscles stimulated
1	59	175	79	T4 ASI B	3/9/2008	8/2015	Bilateral gluteus maximus, posterior portion of adductor magnus, quadriceps, hamstrings, Bilateral glut max, posterior portion of the adductor magnus, quadriceps, hamstrings
2	53	175	66	T7 ASI A	11/27/1983	5/2016	Bilateral gluteus maximus, posterior portion of the adductor magnus, quadriceps, gracilis, sartorius, right tensor fasciae latae
3	51	175	68	T3 AIS A	3/30/2013	9/2015	Bilateral gluteus maximus, posterior portion of the adductor magnus, quadriceps

Subject with K4b2 system cycling on the Catrike® 700
Photo credit: Rudi Kobetic

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Peak VO2 estimation

Table 4.1 Cardiorespiratory Fitness Classifications: $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})

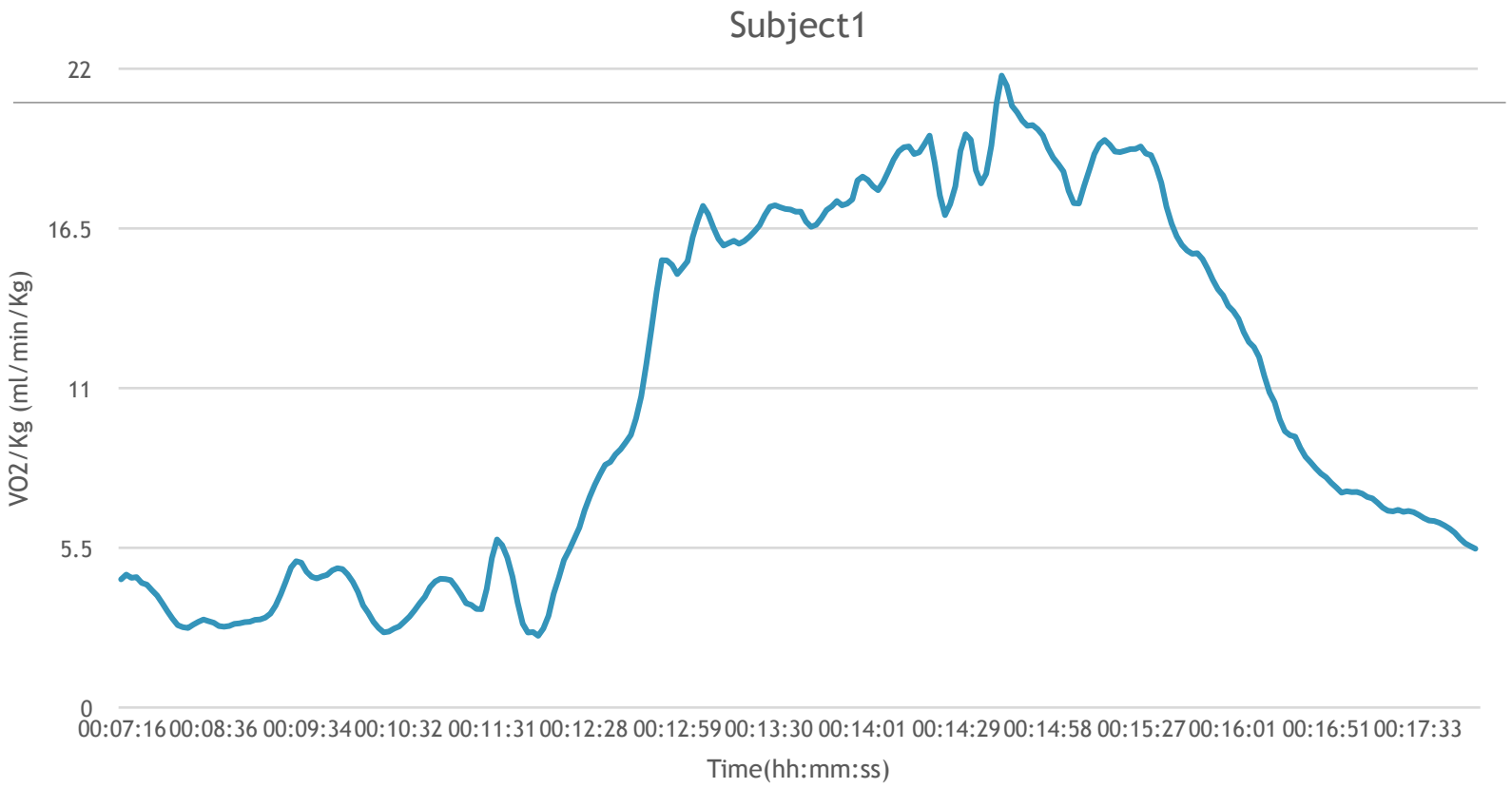
Age (yr)	Poor	Fair	Good	Excellent	Superior
WOMEN					
20-29	≤35	36-38	40-43	44-48	49+
30-39	≤33	34-36	37-41	42-46	47+
40-49	≤32	33-35	36-38	39-44	45+
50-59	≤28	29-31	32-35	36-40	41+
60-69	≤26	27-28	29-32	33-36	37+
70-79	≤25	26-27	28-29	30-36	37+
MEN					
20-29	≤41	42-45	46-49	51-55	56+
30-39	≤40	41-43	44-47	48-53	54+
40-49	≤37	38-41	42-45	46-52	53+
50-59	≤34	35-38	39-42	43-48	49+
60-69	≤31	32-34	35-38	39-44	45+
70-79	≤28	29-31	32-35	36-42	43+

Data from Cooper Institute for Aerobics Research 2005.

- Table from Heyward et al., Method as done by Asselin et al.

Results

Subject	Predicted VO2 based on age	Peak VO2	Percentage of predicted VO2
1	35-38	21.79	62.2%
2	35-38	15.52	44.3%
3	35-38	17.36	49.6%



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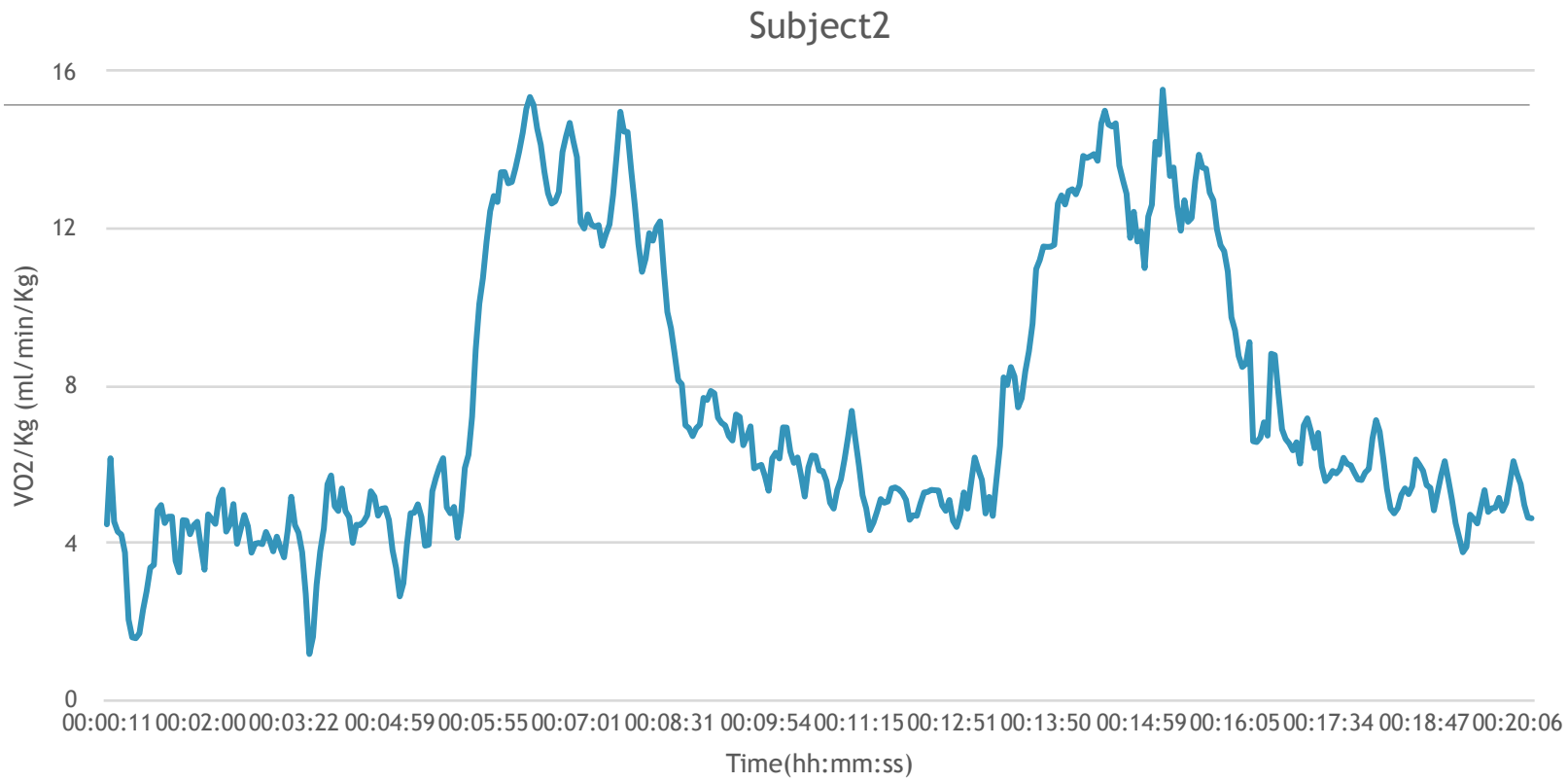

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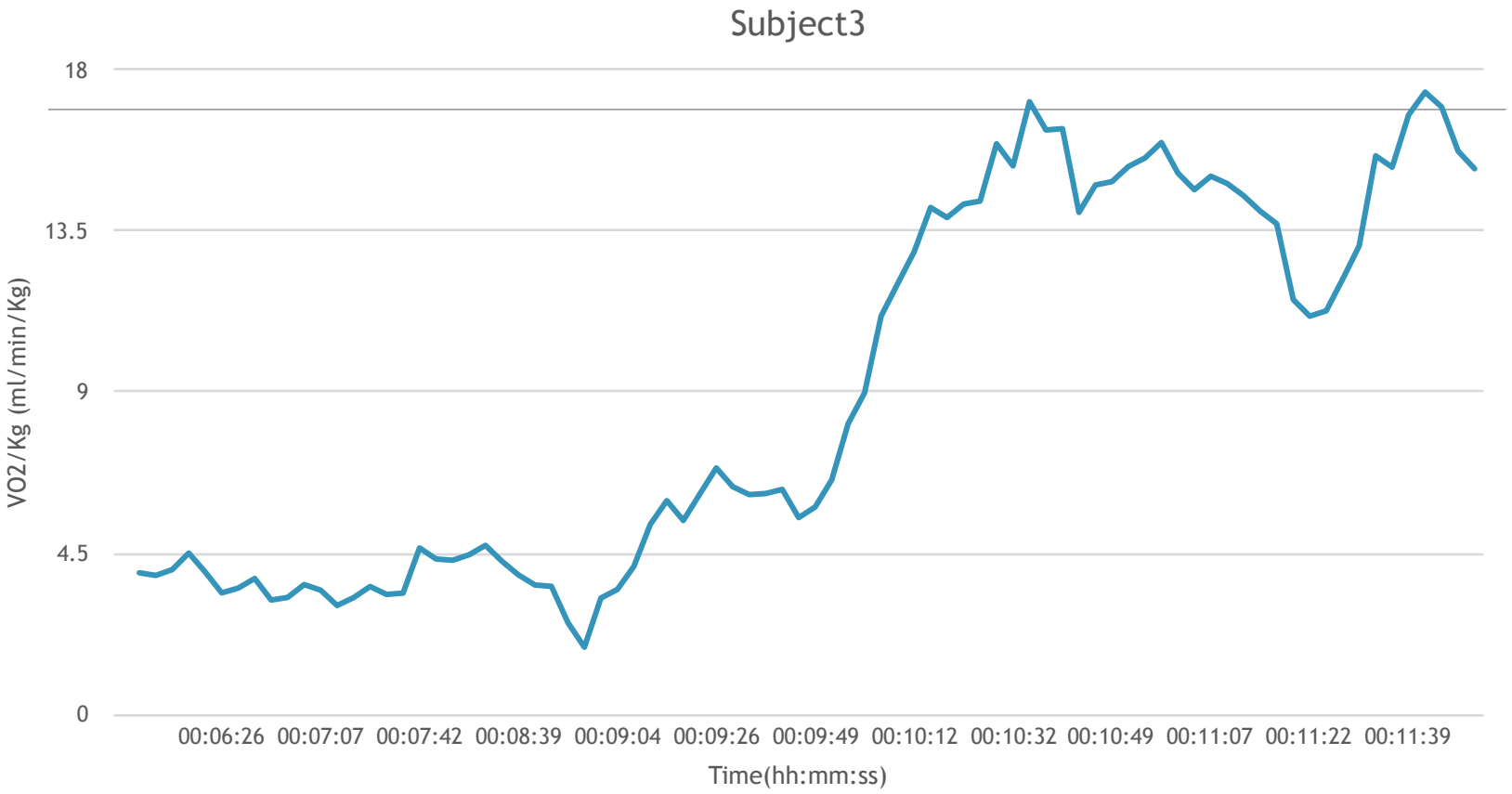

Conclusion

- Higher peak VO2 compared to 14.3ml/min/kg documented for cycling with surface stimulation by Hettinga et. al·
- One of three peak VO2s below ASCM recommendations
- Results thus far suggest tested modality can offer superior level of exercise
- Overground capabilities may provide additional motivation
- Physical and psychological benefits

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Limitations

- Small subject number
- VO2 peak estimation
- Cycle fatigue
- Physiological differences

Future directions

- Further evaluation of portable activities as modalities for recreational exercise
  - Additional muscle recruitment
  - Additional electrophysiology studies (ex: blood lactate)
  - Incorporate both upper and lower extremities
- *Surface* stimulation in overground cycling
- Power assistance in case of fatigue
- Subject conditioning

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Thank you