Muscle oxygenation responses during a 400-Meter Open Water Swim Time Trial

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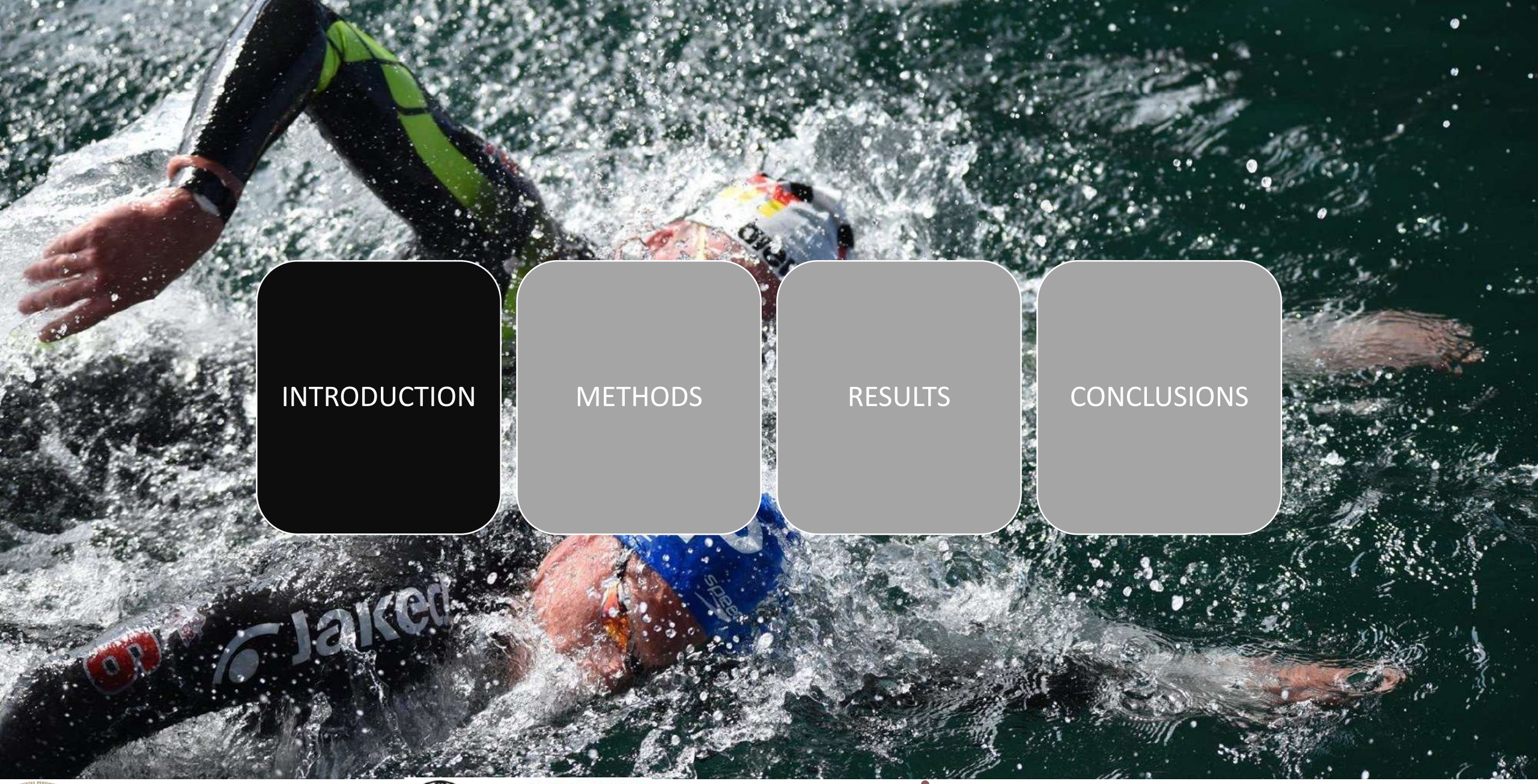

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Open water swimming

- Open water swimming is a swimming discipline which takes place in outdoor bodies of water such as open oceans, lakes or rivers.
- The 10km open-water event has been included in the Olympic Games since 2008.
- International open water races range from 5km to 25km.

Bradford, C.D., et al. (2019)

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RESEARCH Open Access

Analysis of 10 km swimming performance of elite male and female open-water swimmers

Pascale Vogt[1], Christoph Alexander Rüst[1], Thomas Rosemann[1], Romuald Lepers[2] and Beat Knechtle[1,3,4*]

Abstract

This study investigated trends in performance and sex difference in swimming speed of elite open-water swimmers at FINA 10 km competitions (*i.e.* World Cup races, European Championships, World Championships and Olympic Games). Swimming speed and sex difference in swimming speed of the fastest and the top ten women and men per event competing at 10 km open-water races between 2008 and 2012 were analysed using single and multi-level regression analyses. A total of 2,591 swimmers (*i.e.* 1,120 women and 1,471 men) finished 47 races. Swimming speed of the fastest women (1.35 ± 0.9 m/s) and men (1.45 ± 0.10 m/s) showed no changes across years. The mean sex difference in swimming speed for the fastest swimmers was 6.8 ± 2.5%. Swimming speed of the top ten female swimmers per event was 1.34 ± 0.09 m/s and remained stable across the years. The top ten male swimmers per event showed a significant decrease in swimming speed over time, even though swimming speed in the first race (*i.e.* January 2008, 1.40 ± 0.0 m/s) was slower than the swimming speed in the last race (*i.e.* October 2012, 1.50 ± 0.0 m/s) ($P < 0.05$). To summarize, swimming performances remained stable for the fastest elite open-water swimmers at 10 km FINA competitions between 2008 and 2012, while performances of the top ten men tended to decrease. The sex difference in swimming speed in elite ultra-swimmers (~7%) appeared smaller compared to other ultra-distance disciplines such as running. Further studies should examine how body shape and physiology of elite open-water ultra-distance swimmers influence performances.

Keywords: Elite swimmer; Open-water; Ultra-distance; Performances; Sex difference

Open Water Swimming in Elite Triathletes: Physiological and Biomechanical Determinants

Óscar López-Belmonte, Ana Gay, Jesús J. Ruiz-Navarro, Francisco Cuenca-Fernández, Roberto Cejuela, Raúl Arellano

Performance in a 1500m time trial correlated with:

- Exercise VO_2 (r = 0.51; p = 0.030)
- Swim index, a marker related to swimming efficiency (r = 0.70; p = 0.002)

López-Belmonte et al. (2024)
Vogt et al. (2013)

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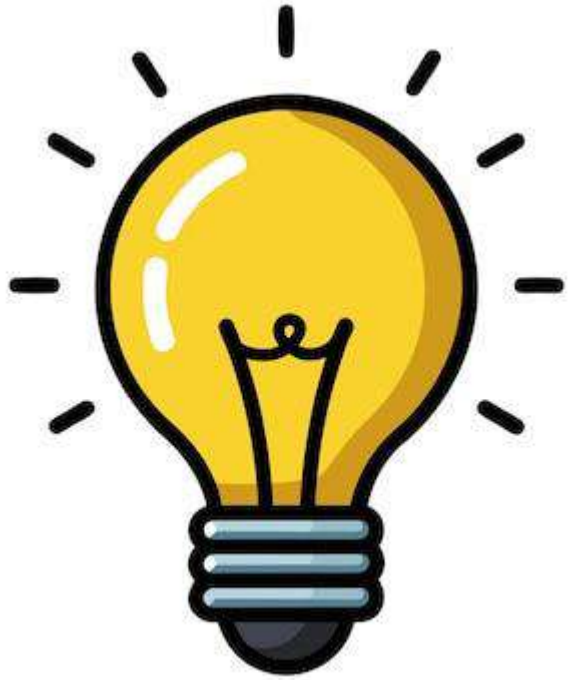
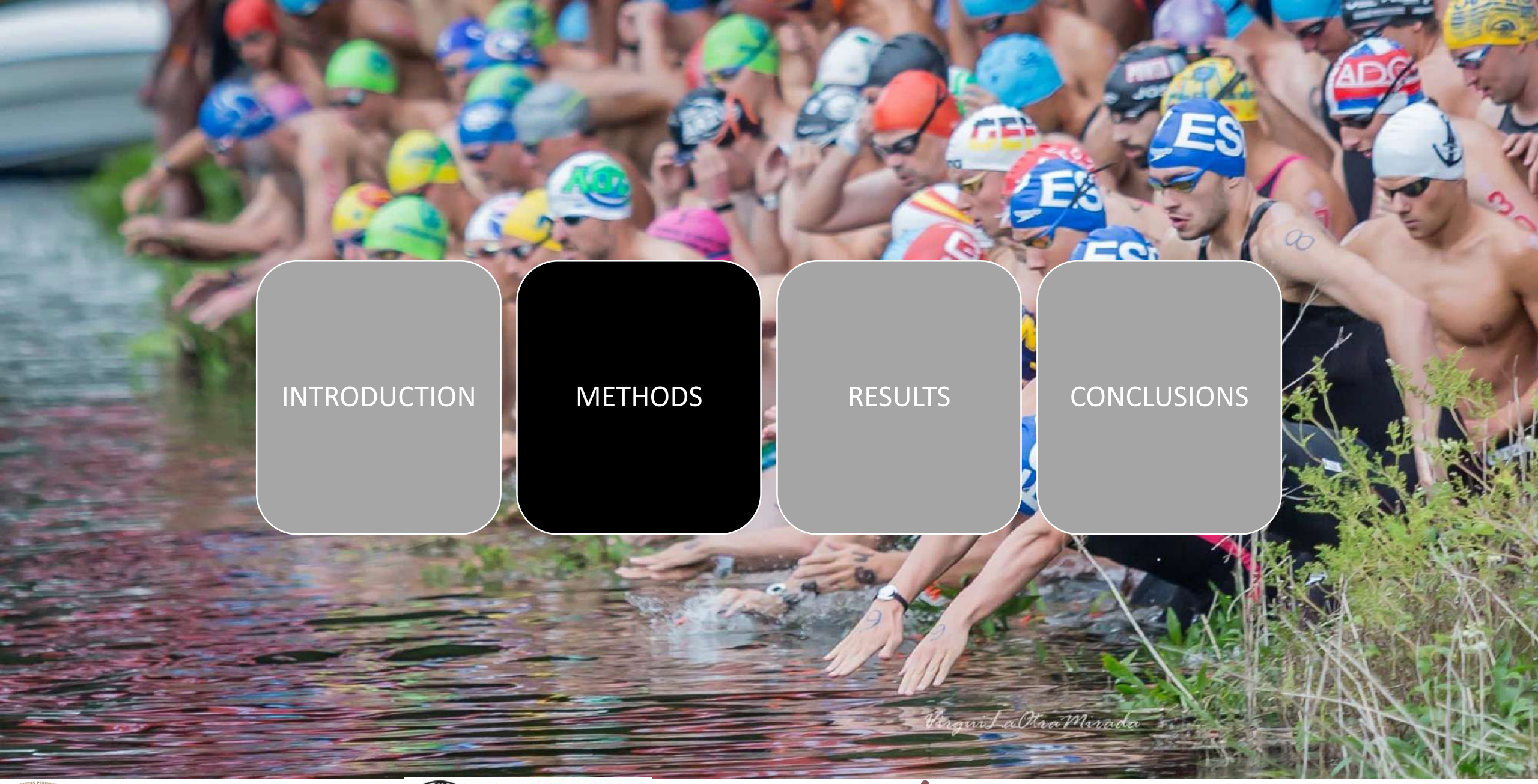


Objectives

- Assess changes in SmO_2 and THb during a 400m open water swim on the vastus lateralis (**VL**) and latissimus dorsi (**LD**).
- Compare SmO_2min and desaturation slopes between **VL** and **LD**.
- Evaluate the correlation between SmO_2min and performance in the 400m time trial.
- Study the correlation between adipose tissue thickness (ATT) and SmO_2min in both muscles.



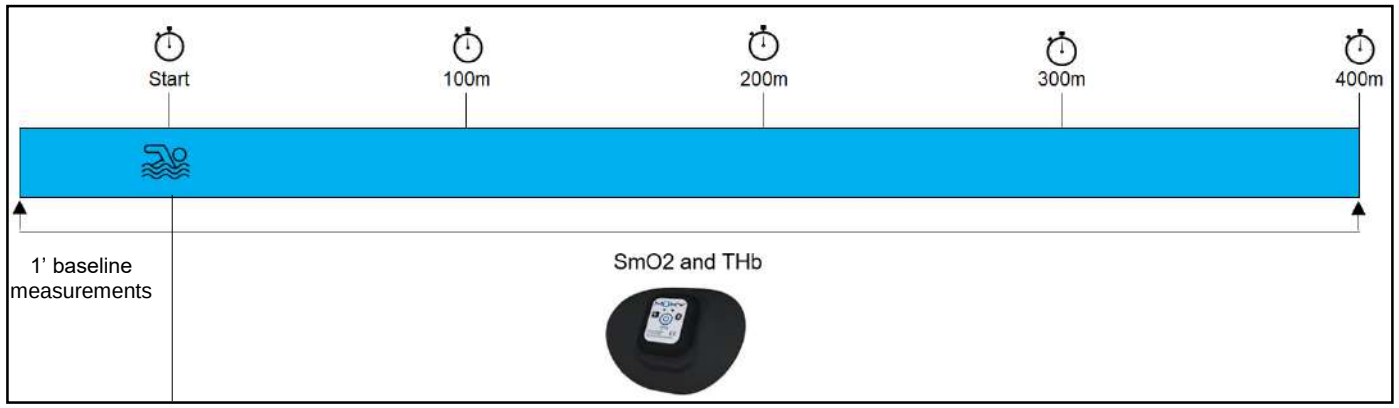
INTRODUCTION

METHODS

RESULTS

CONCLUSIONS

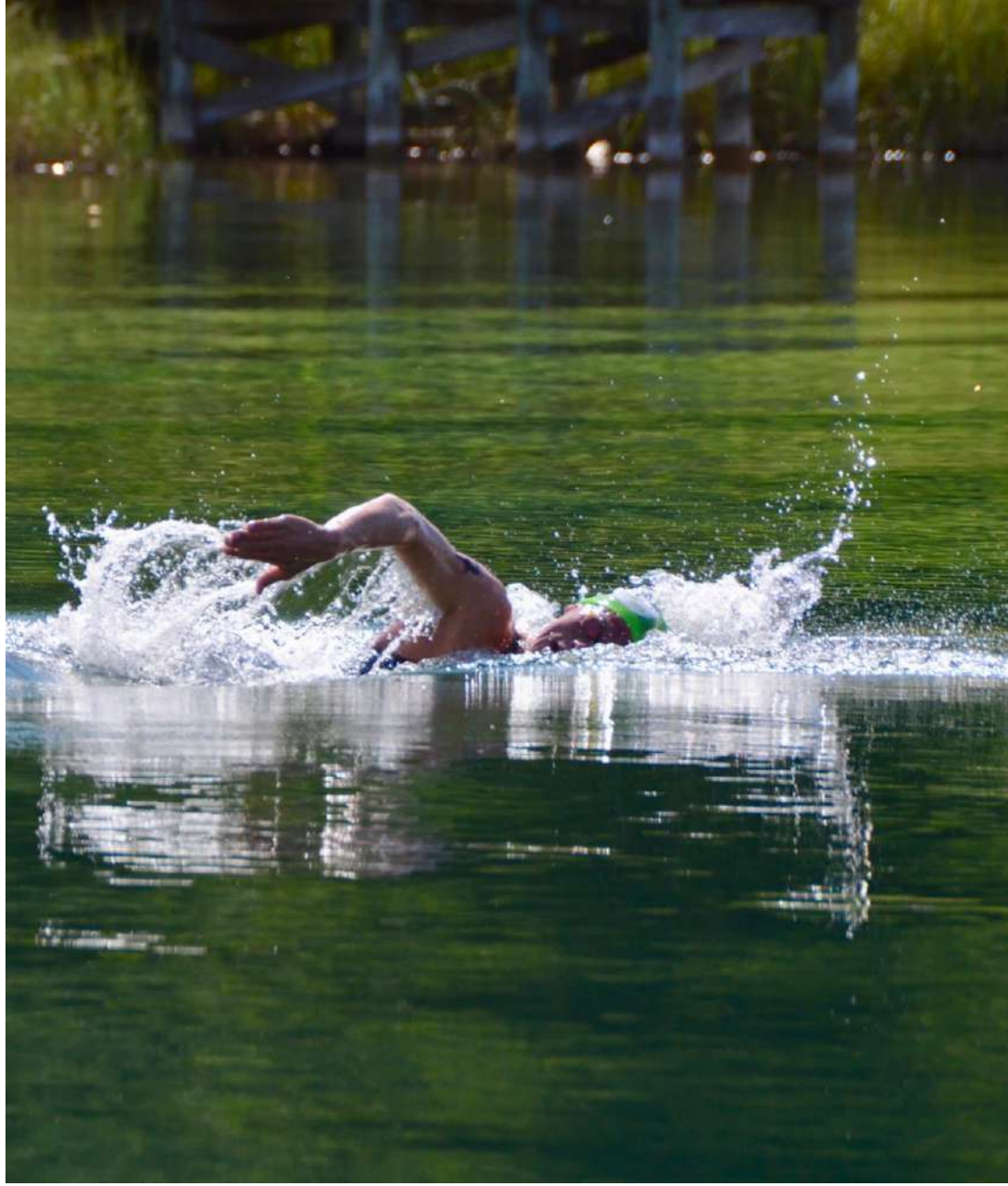
Protocol and participants



11 international swimmers
5 men
6 women
400m time: 04:33 ± 00:14 (mm:s)
Wetsuit: Sailfish Ignite 2

ATT = 6.3 ± 2.7 mm

ATT = 3.6 ± 0.8 mm



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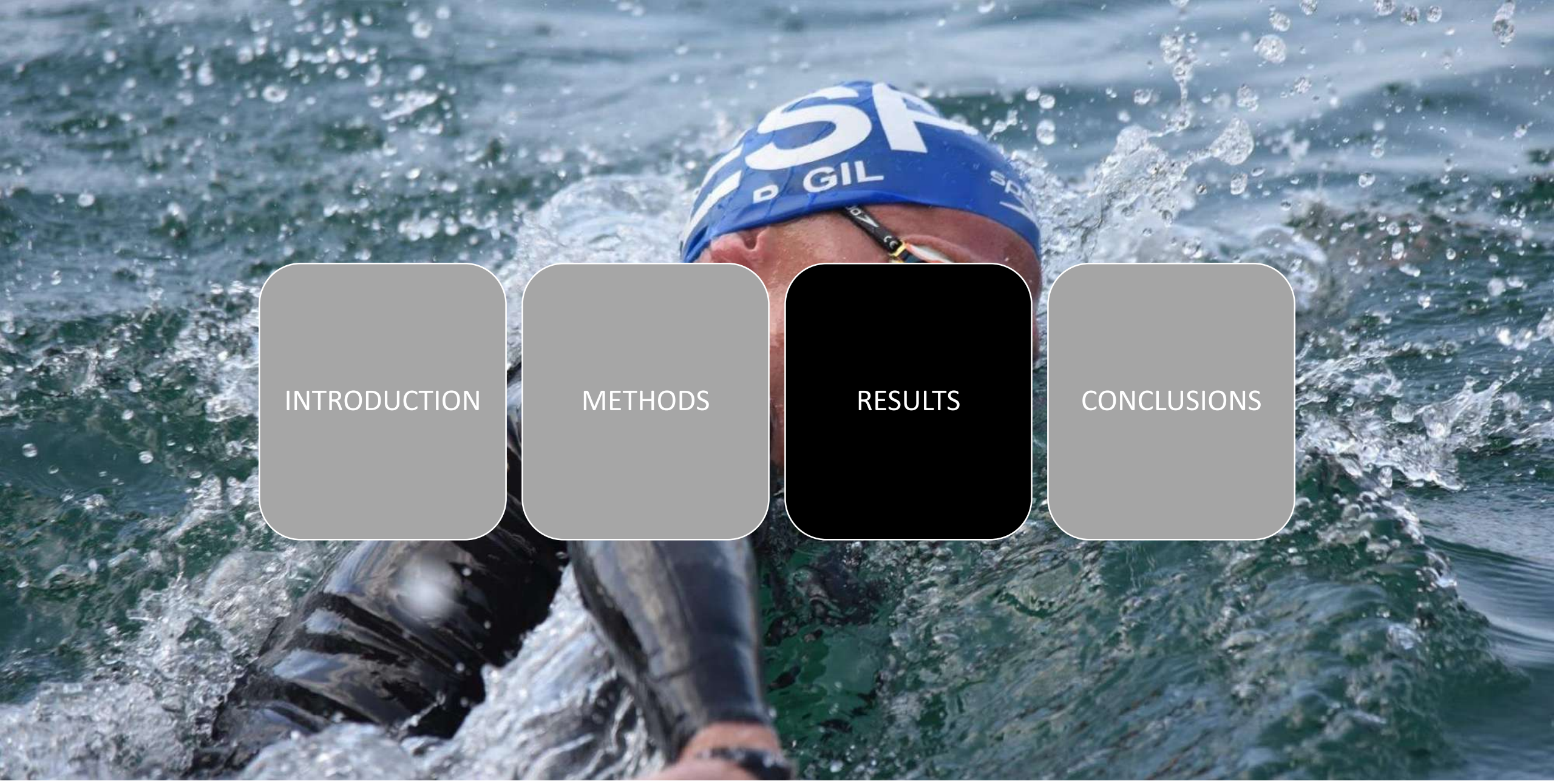

INTRODUCTION

METHODS

RESULTS

CONCLUSIONS

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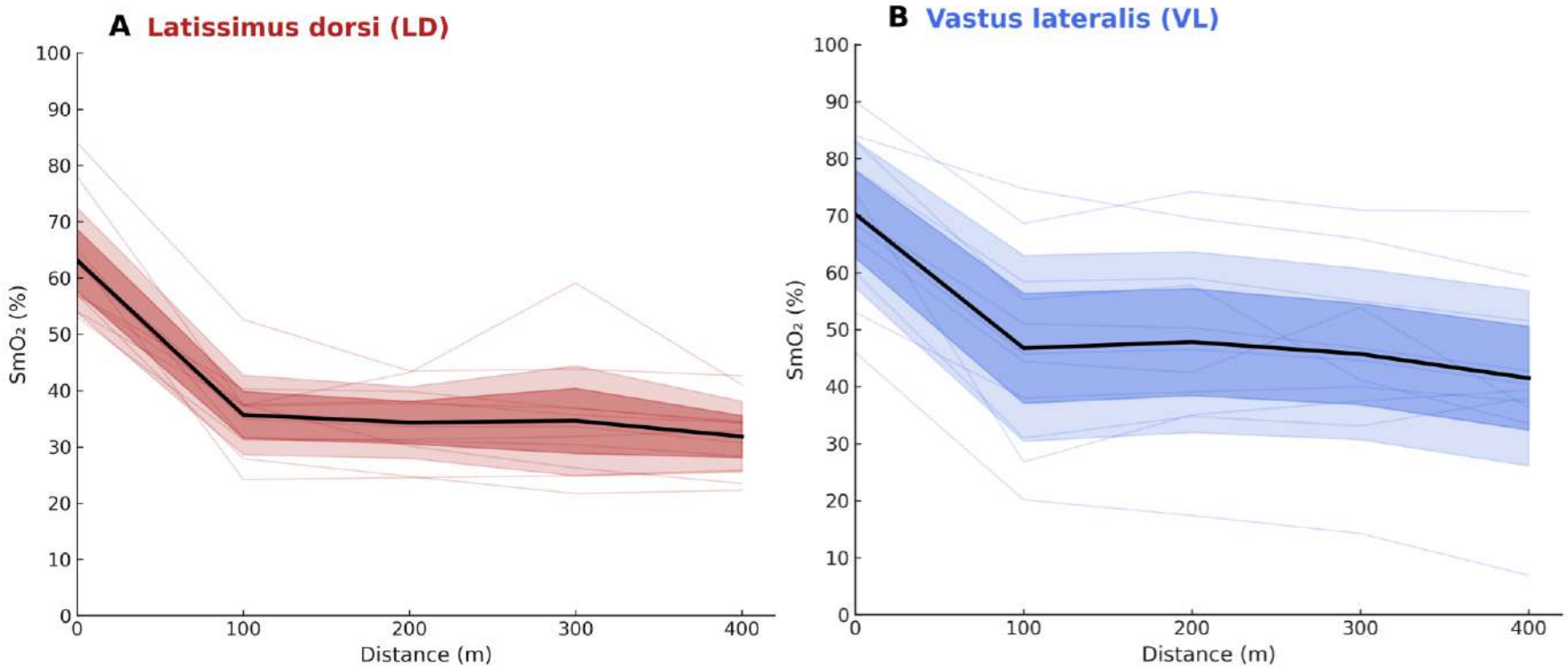
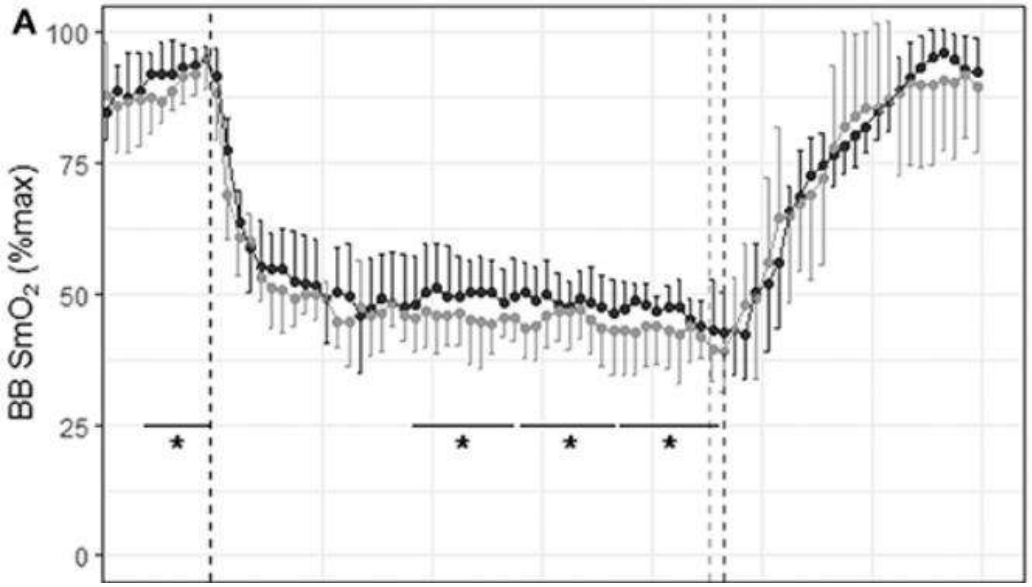
SmO_2

- SmO_2 values changed significantly across the 400 m trial ($p < 0.001$).
- No significant differences in SmO_2 values between muscles ($p = 0.073$).
- SmO_2 changed across segments similarly for both muscles ($p = 0.151$).



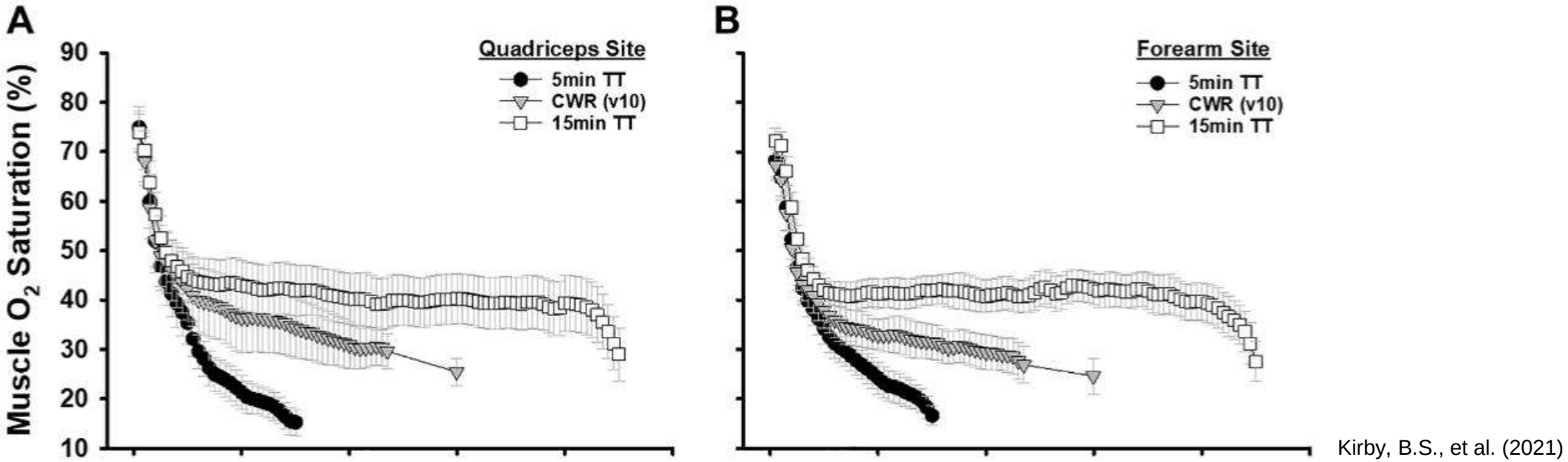
The thick black lines represent group mean; the thin background lines represent individual responses. The darker shaded areas indicate the 95% confidence intervals (CI), while the lighter shaded areas represent standard deviations (SD).



Paquette, M., et al. (2020)

SmO_2 <u>biphasic response</u> during the time trial

- Paquette et al. (2020): Kayak (biceps braquii).
- Kirby et al. (2021): Running (vastus lateralis and forearm).



Kirby, B.S., et al. (2021)

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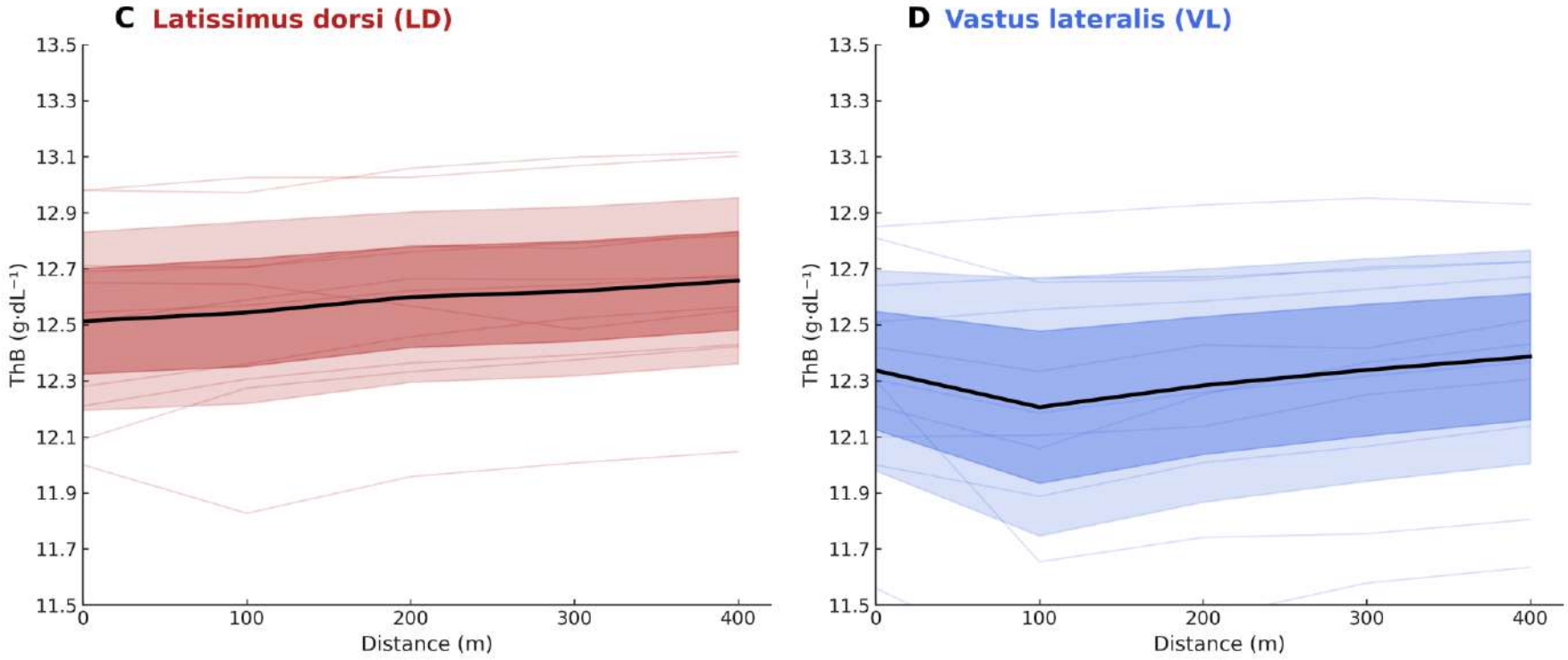
THb

- THb values changed significantly across the 400 m trial ($p < 0.001$).
- No significant differences in THb values between muscles ($p = 0.057$).
- THb changed across segments similarly for both muscles ($p = 0.156$).



The thick black lines represent group mean; the thin background lines represent individual responses. The darker shaded areas indicate the 95% confidence intervals (CI), while the lighter shaded areas represent standard deviations (SD).

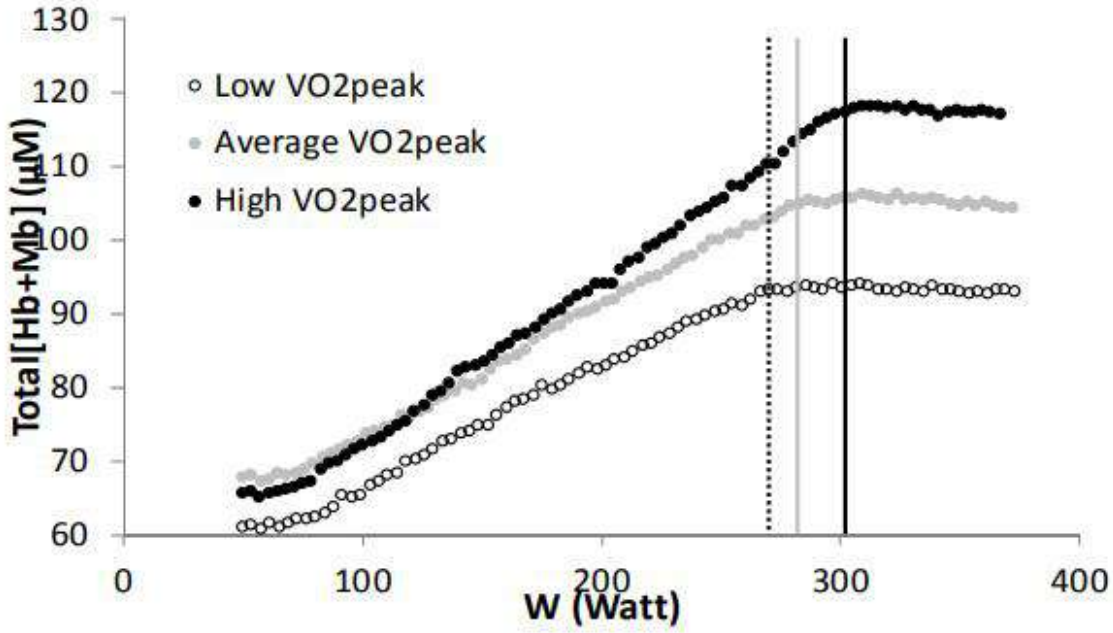
Table I. Average values for physiological variables measured during the exercise protocol.

	100 W	150 W	200 W	250 W	300 W	350 W
SmO_2	52 ± 6	45 ± 9*	36 ± 11*	26 ± 11*	20 ± 8*	15 ± 6*
THb	12.7 ± 0.2	12.7 ± 0.3	12.7 ± 0.3	12.7 ± 0.3	12.8 ± 0.3	12.7 ± 0.3
HR	112 ± 12	130 ± 14*	146 ± 17*	162 ± 17*	171 ± 14*	175 ± 14*
VO_2	27 ± 4	36 ± 5*	45 ± 6*	55 ± 7*	64 ± 8*	71 ± 9*

Notes: Data are presented as mean ± SD. SmO_2, muscle oxygen saturation expressed as %; THb, total haemoglobin content in g dL^{-1}; HR, heart rate in bpm, VO_2, whole-body oxygen uptake in ml $min\ kg^{-1}$.
*$p \leq .05$ compared to the previous stage.

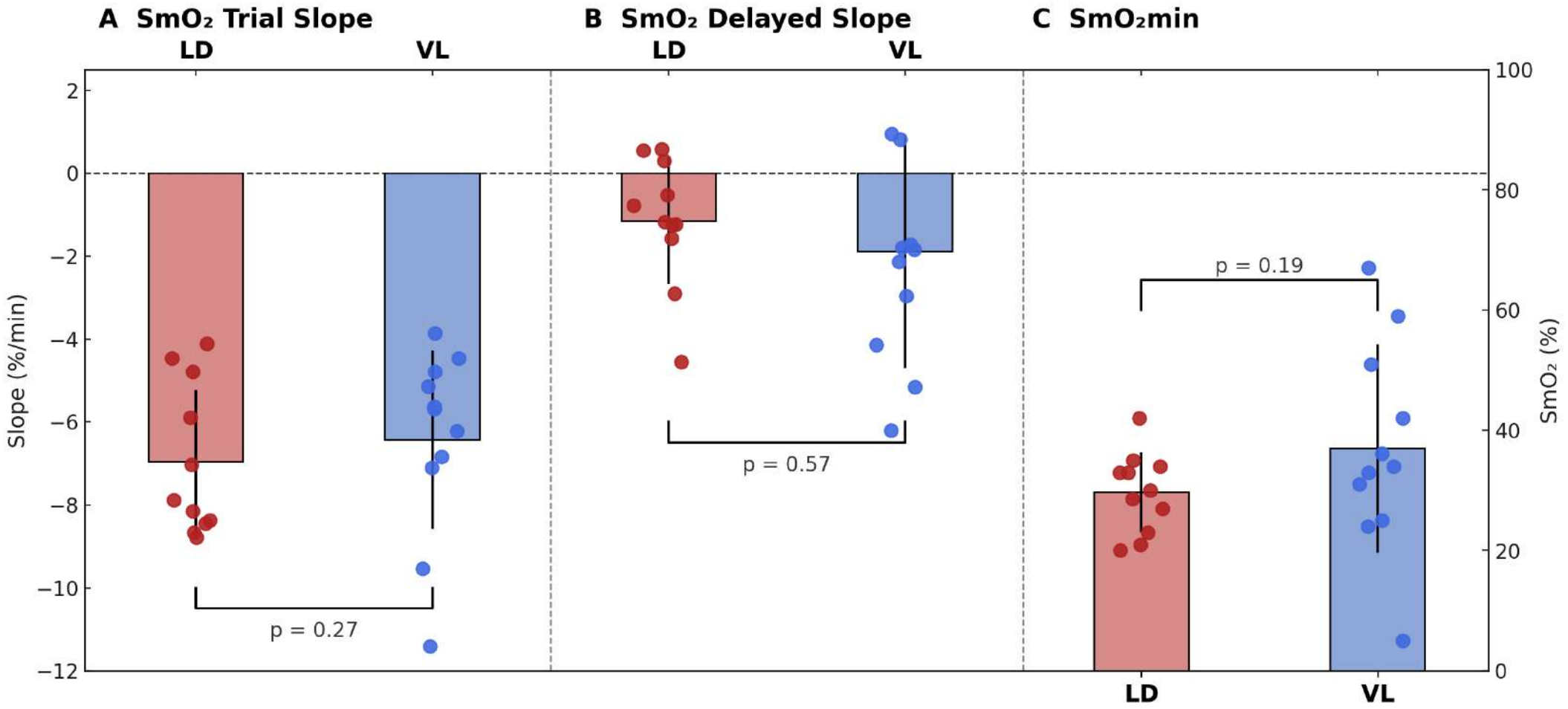
SmO_2 ($p < .01$). THb showed little variation throughout each trial and was not significantly associated with changes in exercise intensity ($p = .29$).

Crum, E.M., et al. (2017)



Boone, J., et al. (2016)

SmO_2 slopes and SmO_2min



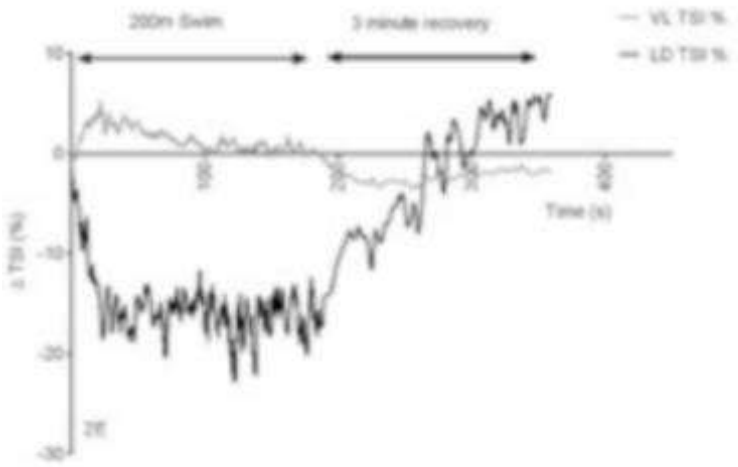
Bars represent the mean values for the LD and VL muscles; individual data points are overlaid. Error bars indicate standard deviations.

Chapter 4
Underwater Near-Infrared Spectroscopy: Muscle Oxygen Changes in the Upper and Lower Extremities in Club Level Swimmers and Triathletes

B. Jones and C.E. Cooper

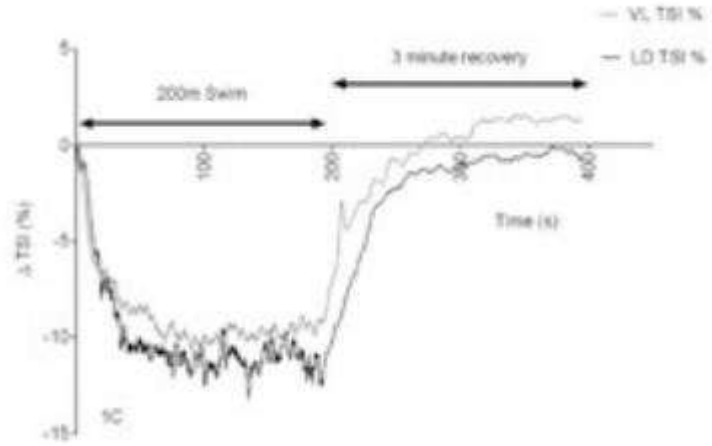
- Higher level swimmers use both the upper and lower muscles to a similar extent in time trials up to 400 m.
- Incorporating leg kick into arm action results in approximately a 10 % increase in swim speed.

Triathletes



Δ SmO_2 **LD** vs Δ SmO_2 **VL** **p = 0.043**

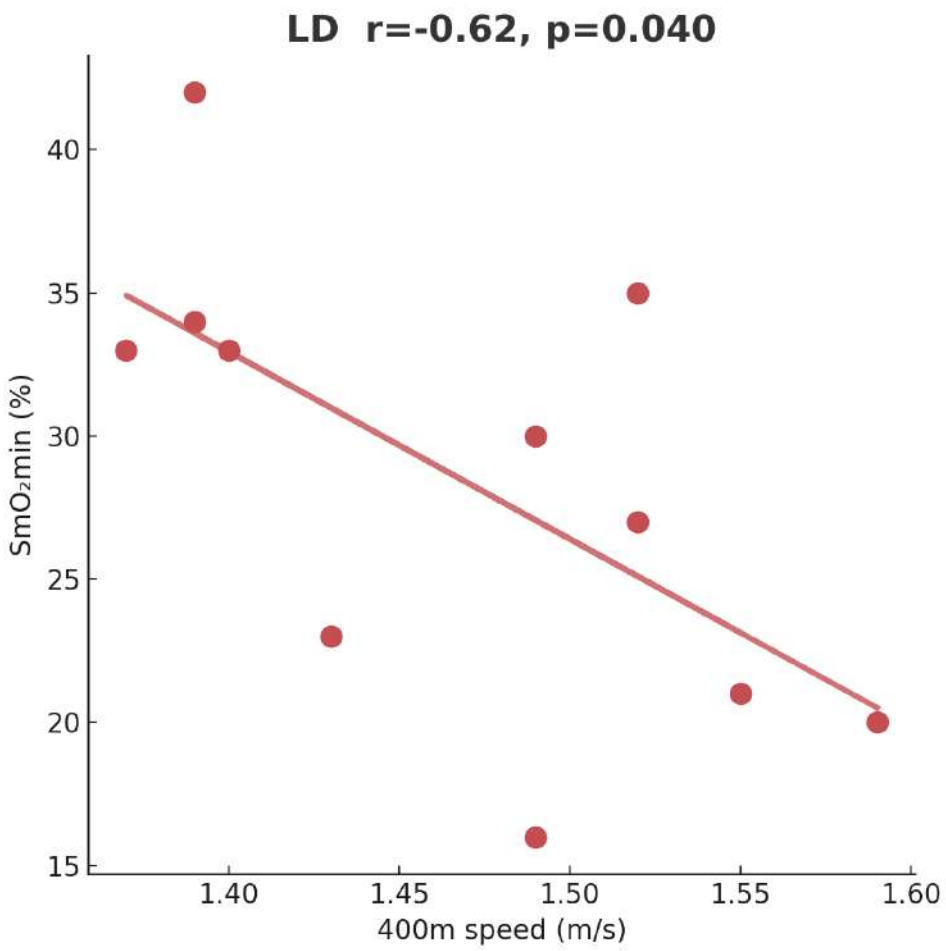
Club-swimmers

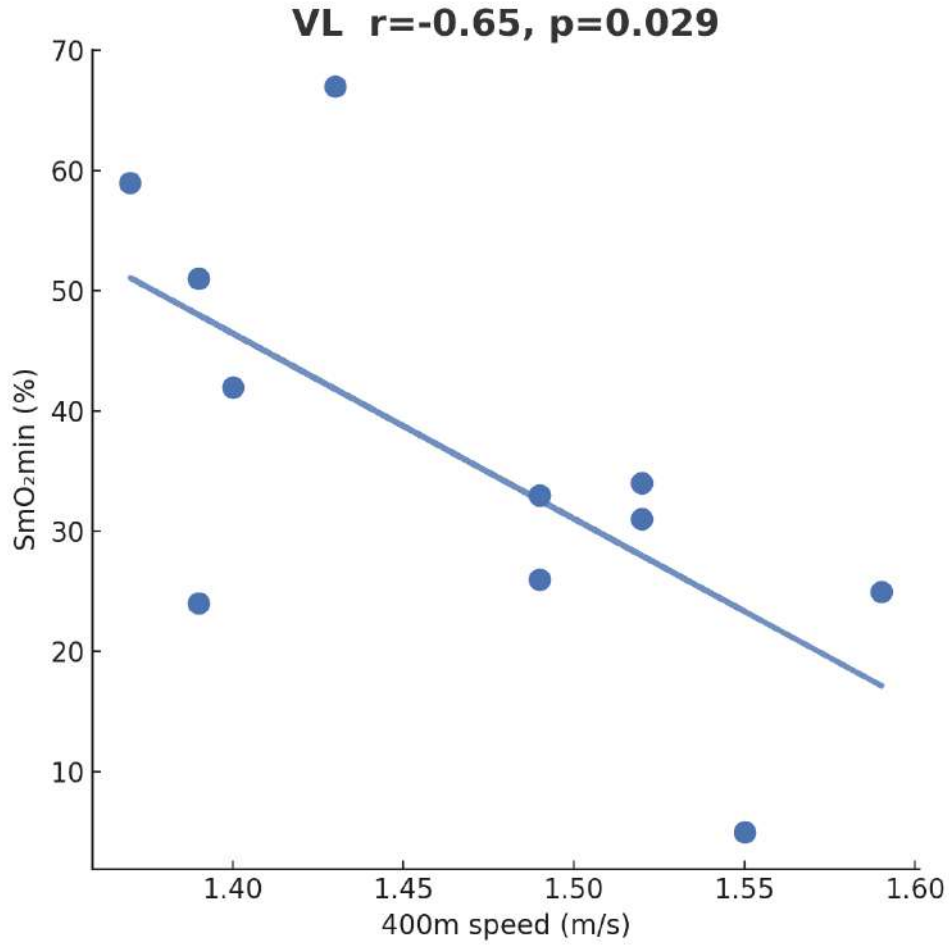


Δ SmO_2 **LD** vs Δ SmO_2 **VL** **p = 0.686**

Jones, B., & Cooper C.E. (2016)

SmO_2min and performance





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Furno Puglia, V., et al. (2024)

Characterization of muscle oxygenation response in well-trained handcyclists

Veronica Furno Puglia[1,2] · Myriam Paquette[2] · Andreas Bergdahl[1]

TT mean power (W/kg) was highly associated with BB ΔSmO_2min measured in the incremental test and in the Wingate sprint. In addition, the best physiological predictor of TT mean power was the BB ΔSmO_2min, while BB ΔSmO_2min measured in the Wingate sprint was also the best physiological predictor of a strong MAP. Since

TT mean power – SmO_2min
(r= −0.998 p = 0.002)

SmO_2min was related to performance in canoeists

(r= −0.5 to -0.6 p = < 0.05)

Paquette, M., et al. (2020)

Muscle Oxygenation Rather Than VO_2max as a Strong Predictor of Performance in Sprint Canoe–Kayak

in International Journal of Sports Physiology and Performance

Click name to view affiliation

Myriam Paquette, François Bieuzen, and François Billaut

DOI: https://doi.org/10.1123/ijspp.2018-0077

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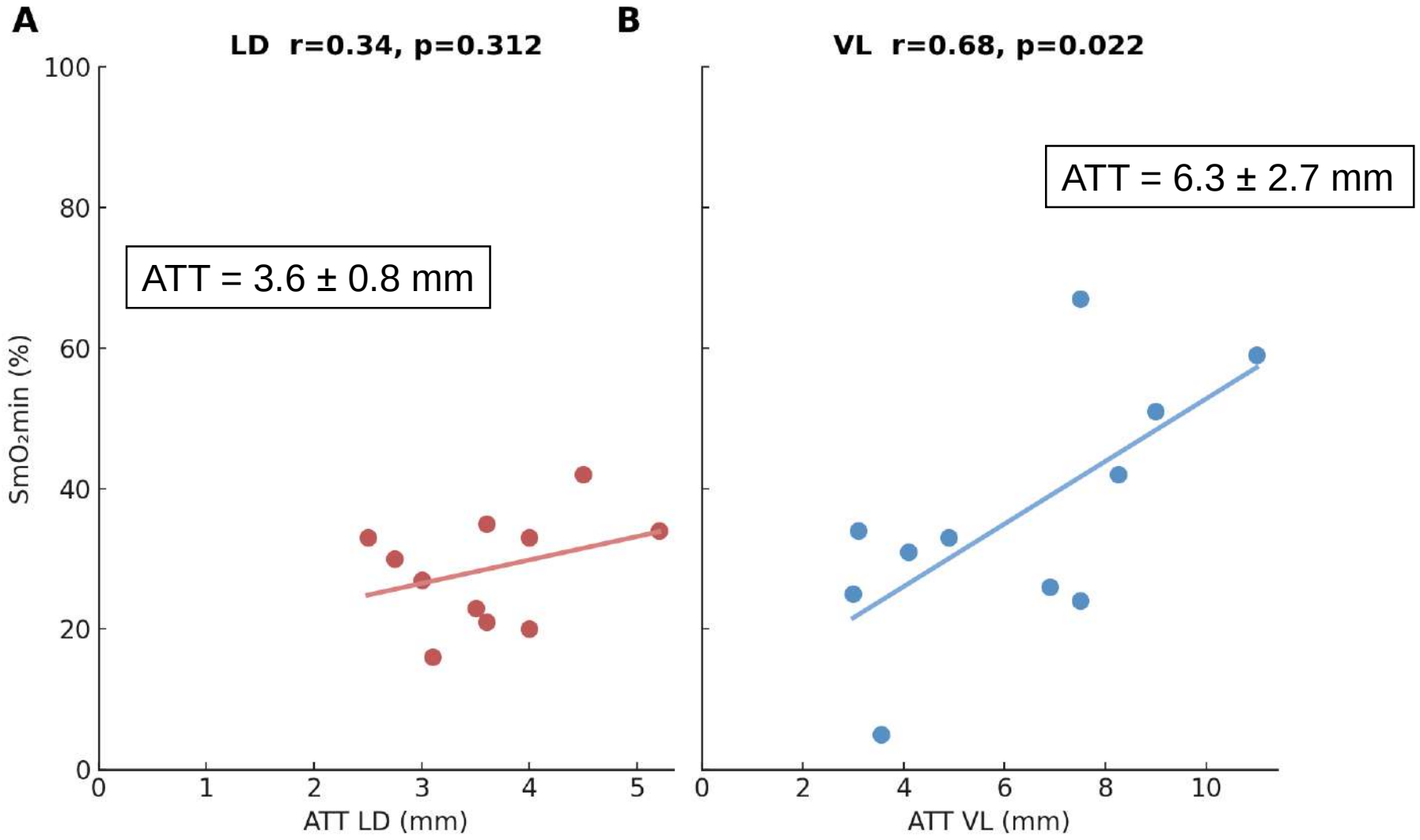
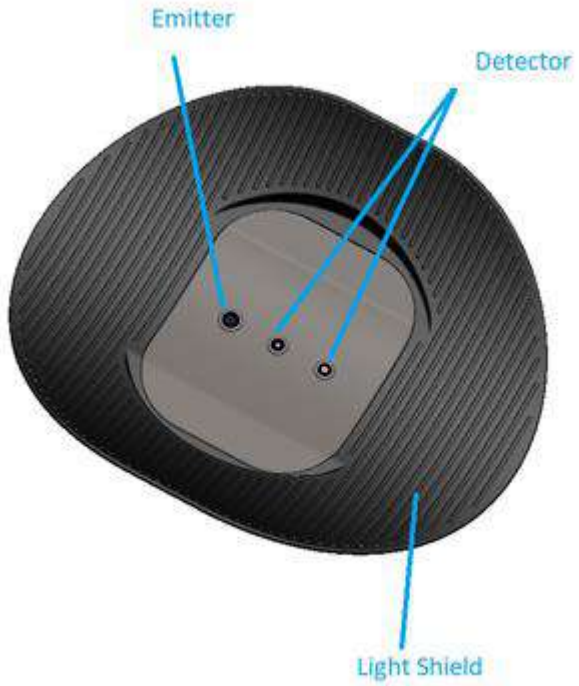
SmO_2min and ATT





Barstow, T.J. (2020)
McManus, C., et al. (2018)

MOXY

maximum source:detector separation of 25 mm

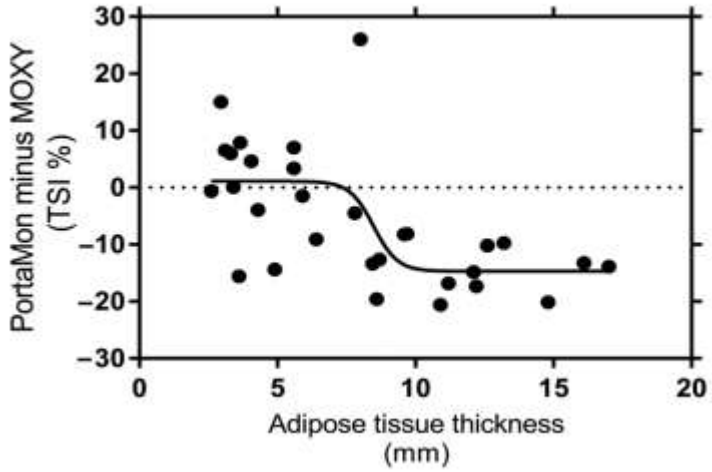
Review | Cores of Reproducibility in Physiology

Understanding near infrared spectroscopy and its application to skeletal muscle research

Thomas J. Barstow

16 MAY 2019 // https://doi.org/10.1152/japplphysiol.00166.2018

‘’mean path length of photons is typically estimated as one-half the source-detector ‘’
ATT up to 12.5mm



Performance comparison of the MOXY and PortaMon near-infrared spectroscopy muscle oximeters at rest and during exercise

Chris J. McManus,* Jay Collison, and Chris E. Cooper
University of Essex, School of Sport, Rehabilitation and Exercise Sciences, Colchester, United Kingdom

Caution is advised when using the MOXY monitor in individuals with adipose tissue thickness (ATT) exceeding 7 mm, as measurement accuracy may be compromised.

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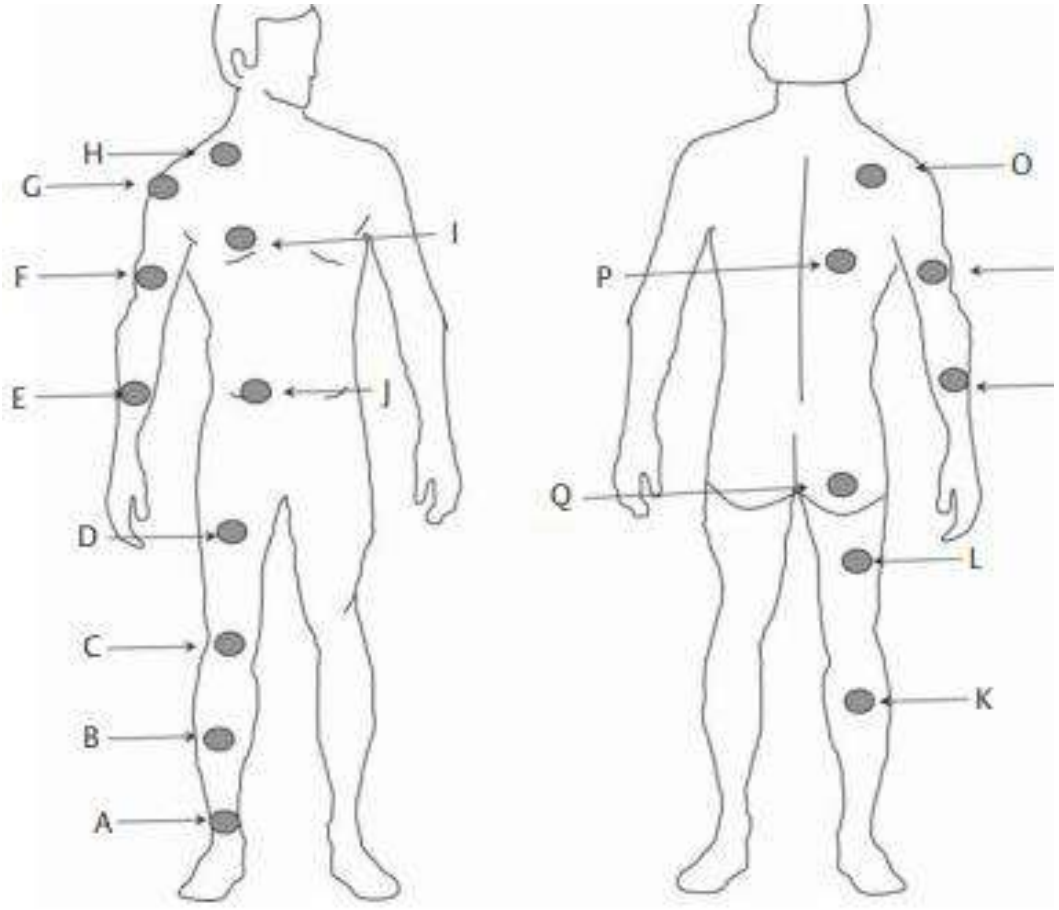
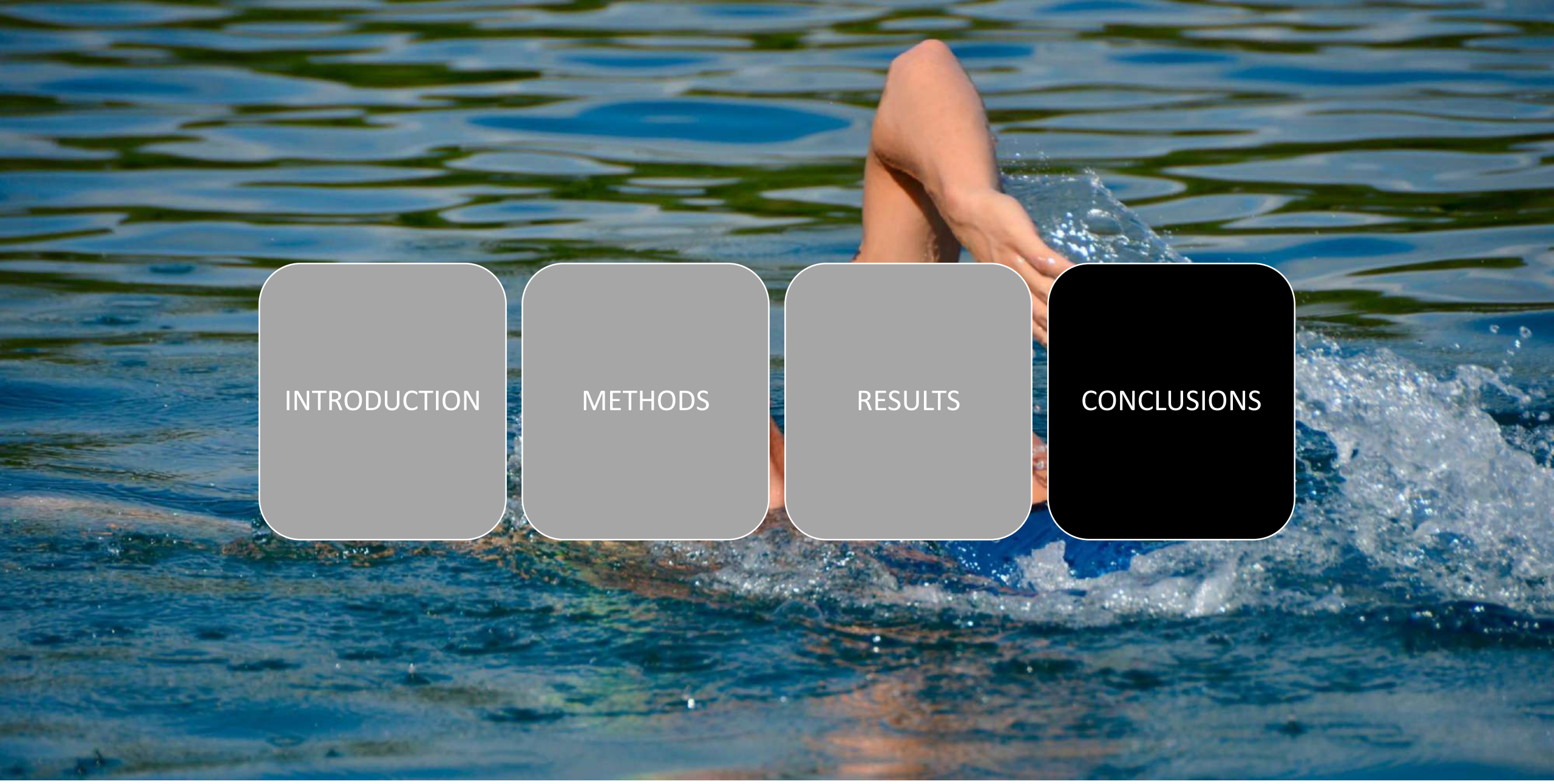
Limitations

- We did not measure the interface pressure applied by the wetsuit into the skin.
- Above 20 mmHg MOXY reports declining SmO_2 values (McManus et al., 2018).
- Interface pressures of ≈ 25 mmHg have been measured under a 5 mm neoprene wetsuit (Castagna et al., 2013).
- Wetsuits used in the current study: 3 mm thickness in legs and trunk.



Castagna, O. (2013)
McManus, C., et al. (2018


INTRODUCTION
METHODS
RESULTS
CONCLUSIONS

Conclusions

1. NIRS offers valuable insights into the muscle-specific internal load in open water swimming.

Next steps

- Longer time trials
- Replicate specific race situations
- Drafting
- Leg kick patterns

2. SmO_2min appears to be a useful marker to predict performance.

3. ATT should be monitored by coaches for better interpretation of the data.

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THANK YOU

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