The Contribution of the Arm Stroke and Leg Kick to Freestyle Swimming Velocity & Metabolic Cost, Controlling for Stroke and Kick Rate: A Pilot Study

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Swimming Performance

• Determined by velocity, generated by the propulsive actions of the upper and lower limbs

• Velocity = Metabolic Power ÷ Mechanical Cost (di Prampero, 1986)

• Influenced by rate of muscular contractions

  Stroke Rate & Kick Rate
Physiology

Performance (Velocity)

Metabolic Power
- VO₂
- [La⁻]
- PCR

Mechanical Costs
- Drag
- Kinetic Energy
- Internal Power

Velocity of the limbs

Mechanics

Stroke Rate

Kick Rate

C_{INT} (Legs) = 6.9KR³
C_{INT} (Arms) = 38.2SR³

(Zamparo et al., 2002; 2005; 2006; 2012)
Previous Research
Contributions of the Limbs

**Velocity:**
- Arms = 85-90%
- Legs = 10% or 60-65%

**Aerobic energy metabolism:**
- Arms = 70-95%
- Legs = 70-155%

**Anaerobic energy metabolism:**
- Arms = 60-75%
- Legs = 60-100%

(Major limitation)
No control or measurement of stroke and kick rate across trials = Uncontrolled internal mechanical power across trials

Aims:

• Determine the contribution of the legs and arms to velocity and metabolic cost in submaximal, steady-state freestyle swimming, while controlling for stroke and kick rate

Hypotheses:

• The relative contributions will be lower than previously reported, due to the control of stroke and kick rate
Method Overview

Participants

- 3 male and 2 female trained age group swimmers

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Training Age (y)</th>
<th>Mass (kg)</th>
<th>Stature (cm)</th>
<th>200 m PB (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.2 ± 1.6</td>
<td>9.0 ± 1.9</td>
<td>72.9 ± 8.7</td>
<td>173.3 ± 7.5</td>
<td>129.2 ± 14.0</td>
</tr>
</tbody>
</table>

Anthropometry

- Stature, body mass

Warm-up & Familiarisation

Swim Tests

- 2 x whole body
- 2 x arms only
- 2 x legs only
Sub-maximal Swimming Trials

Sub-maximal trials:

400m @ 70%
Whole body (SR & KR)

200m @ SR70%
Arms only

200m @ KR70%
Legs only

400m @ 80%
Whole body (SR & KR)

200m @ SR70%
Arms only

200m @ KR70%
Legs only

Measures: VO$_2$, [La$^-$], velocity, C, HR, RPE, SR, KR
Equipment
# Results – VO₂ and Velocity

<table>
<thead>
<tr>
<th></th>
<th>VO₂</th>
<th>Velocity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Whole body</td>
<td>Arms only</td>
</tr>
<tr>
<td>70%</td>
<td>2.7 ± 0.6</td>
<td>2.02±0.4^</td>
</tr>
<tr>
<td>%</td>
<td>100.0</td>
<td>74.5</td>
</tr>
<tr>
<td>80%</td>
<td>3.3±0.9</td>
<td>2.28±0.5^</td>
</tr>
<tr>
<td>%</td>
<td>100.0</td>
<td>70.2</td>
</tr>
</tbody>
</table>

Abs: Absolute value

*: Significant difference

^: Percentage of maximum

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Results – Metabolic Cost

Absolute Metabolic Cost (J · m$^{-1}$)

- WB
- AO
- LO

70% 80%

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Results

Stroke Rate:
- 70%: 29.2 vs. 28.6
- 80%: 34.0 vs. 33.3

Kick Rate:
- 70%: 72.7 vs. 77.5
- 80%: 87.9 vs. 94.3

Blood Lactate:
- No difference
- Average value: 2.7 mmol/L

Heart Rate:
- 70%:
  - AO lower than WB
- 80%:
  - AO and LO lower than WB

RPE:
- 70% & 80%:
  - AO lower than WB
Limitations

Mechanics of different swimming conditions:
• Whole body
• Arms only + pull buoy
• Legs only + kickboard

Velocity differences and drag:
• Drag dependent on velocity
• Drag affects metabolic cost
• Influence of drag not taken into account while interpreting metabolic data

Subject group:
• Small sample size
• Combining male and female participants to report group data
Control of stroke and kick rate reduced the difference between whole body swimming and the sum of arms only and legs only swimming for velocity and metabolic cost

Future research:

• Measure and control stroke and kick rate
• Measure stroke length and kick depth - internal mechanical power demands
• Measure trunk angle, frontal surface area and active body drag
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Thank You
References


