Direct Measurement of Stroke Propulsion in Real Swimming by Means of a Non-Invasive Gauge

A. Bottoni, N. Lanotte, S. Bifaretti, G. Gatta, M. Bonifazi, P. Boatto

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Thrust in swimming is “felt” by athletes as an essential factor in their performance but is difficult to assess and measure.

Proposing an innovative, easy-to-use method to measure the thrust of a swimmer.
Direct measurement of forces in swimming is the most appropriate approach to investigating the problem.

Introduction  State of the art

The mechanism of propulsion in a swimming stroke has been investigated in the last 40 years since Counsilman (1971) gave his first important contribution.

There are three basic approaches for measuring or evaluating the hydrodynamic force in swimming propulsion:

- observing water movement and using video analysis techniques
- creating models and performing CFD simulations
- direct measurement of forces

Direct measurement of forces in swimming is arguably the most appropriate approach to investigating the problem.

Ross Sanders
Department of Physical Education Sport and Leisure Studies, The University of Edinburgh, Edinburgh, UK
Adjunct Professor, Edith Cowan University, Perth, Western Australia.
Methods so far used have severe limitations:

- interfere with the swimmer's technique
- require a swimming flume or gauges connected to the poolside (pic: the MAD system)

The method here proposed overcomes most of these downsides.
Swimming propulsion

Direct measurement of stroke propulsion

Measuring the pressure difference

The validity of pressure difference method was demonstrated measuring the pressure distribution on an entire hand model using a wind tunnel (88 measuring point on the surface of the model) and comparing the results to those derived from micro pressure sensors attached to both sides of the hand.

The mean pressure difference can be estimated measuring pressure at point proximal to the metacarpophalangeal II, III, IV and V joints.

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Methods

Sample

5 top swimmers
- International Elite
- Male Freestyle swimmers
- Age 23+/+ 3,2 y.o.
- Altezza 177 +/- 6,5 cm

Homogeneous age and level

Mann - Whitney Test  P ≤ 0,05

4 average swimmers
- Regional swimming rank
- National Ranking Triathletes

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The athlete can swim freely. Data are downloaded via a bluetooth connection.
Hydrostatic pressure is the same on both sides and therefore is not measured.

Force comes from a pressure difference.
Calibration Methods

Hydrostatic pressure: 0 – 100 cm H2O

- paletta sinistra
- paletta destra

Sample

Instrumentation

Calibration

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Does variation in measured pressure correspond to propulsion?

Load cell
Sculling at different intensity

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Methods

Sculling

Sample

Instrumentation

Calibration

Protocol

Sculling at different intensity

Medium Push

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**Methods**

- Sculling

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**Sample**

**Instrumentation**

**Calibration**

**Protocol**

**Sculling at different intensity**

- High Push

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Methods

Sculling

Sample

Instrumentation

Calibration

Protocol

Sculling at different intensity

outsweep

insweep

Maximum Push

cm H2O

Protocol

Sample

Instrumentation

Calibration

Sculling

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Protocol

Sample

Instrumentation

Calibration

Sculling

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Results

Force Vs Pressure

Sculling – Force signal Vs Pressure Signal

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Results

Force - Pressure

- Sculling – Force signal Vs Pressure Signal
  - Maximum force measured 95.6 +/- 12.5 N
  - Maximum Pressure measured 5.85 +/- 0.65 KPa
  - excellent correspondence pressure signal/propulsive force
    - $r = 0.92 +/- 0.03$
    - $p < 0.05$

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Female athlete (expert) – freestyle – right arm
Discussion

Paddles Pressure signal

Female athlete (expert) – freestyle – left arm
Discussion

Paddles Pressure signal

Pressure Signal

FEIMAL ATHLETE (national swimming team)

LEFT ARM

RIGHT ARM

Pa x 10^3

LEFT ARM

RIGHT ARM

ms

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Results - Discussion

Pressure in different swimming styles

<table>
<thead>
<tr>
<th>Pressure in palm</th>
<th>Pressure back</th>
<th>Pressure difference</th>
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Expert Swimmer - Female (National Swimming Team)

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Results - Discussion

Pressure in different swimming styles

- Pressure palm
- Pressure back
- Pressure difference

Expert Swimmer - Female (National Swimming Team)

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NOTEWORTHY RESULTS:
• The shape of the measured pressure for each arm of each swimmer is unique, like a fingerprint
• There is a “family look” in the shapes of each style
• In the same style, sprinters and long distance swimmers have different shapes
• The shapes of an expert swimmer and a novice swimmer are different
• The higher the level of the swimmer, the more repeatable the result
Results - Discussion

Future research and development

- Integration with other sensors (accelerometers, gyroscopes, GPS,..)
- Real time data transmission
- Miniaturisation
- Sensors on legs

- Quantitative analysis (maximum thrust, avg. thrust, frequency,..)
- Qualitative analysis (shape of the curve, faults, symmetry...)
- Study of efficiency
- Effects of training
- Effects of fatigue
Acknowledgements

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