Swimming Biomechanics in Practice

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What is Biomechanics?

Sport Biomechanics is the application of physics and mechanics to the human body during sport.

Biomechanics is a part of the Movement Science, which also includes Performance Analysis and Skill Acquisition.

“Performance Analysis answers the ‘What’ and ‘When’ whereas Biomechanics answers the ‘How’, whilst Skill Acquisition helps to create the change.”
Tools of the Trade

**Basic Equipment**

Video Equipment
- Video camera,
- Smart phone,
- Tablet

Stop watch

**Advance Equipment and analysis**

Video based kinematic analysis
Inertial sensors
Physical testing using
  - Force plates (Wetplate, KPASS),
  - Drag lines/towing devices
Numerical modelling and analysis of recorded flow lines and vortex patterns
  - Particle Image Velocimetry
Computer-based numerical modelling
  - Computational Fluid Dynamics (CFD)

SPARTA Race Analysis
How do we make Swimmers Faster?

How Do Swimmers Swim?
## The Swimming Race

### Unknown Athlete

100 m Backstroke (LCM)
Age Open - Heat
Australian Championships
Sydney Olympic Park Aquatic Centre, Sydney, Australia
2015/04/04

<table>
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<tr>
<th>Times</th>
<th>First Breakout</th>
<th>Pacing</th>
<th>Summary</th>
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<th>DPS (m)</th>
<th>Strokes</th>
<th>Breakouts (m)</th>
<th>Out (s)</th>
<th>Turn (s)</th>
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Race Averages: 1.67 Vel, 49.4 SR, 2.03 DPS, 3.26 Out, 4.72 Turn, 7.98 TI, 1.13 Split
Swimming Velocity = Stroke Rate \times \text{Stroke Length}
How Do Swimmers Swim?

Buoyancy

Thrust

Weight

Drag
Aquatic Creatures

Killer Whales: 48 kph
Dolphins & Barracudas: 35.2 kph
Penguins: 24 kph
Humans: 7.5 kph

Swimming Speed (kph)
The Swimming Body

- Blunt and smooth at the front and tapered at the back
- Minimises turbulence until well past
So What Is the Problem?

• **Body Shape**
  – Blunt cigar shape
  
  VS

  – Lumpy & irregular human body contour

• No limbs or rough edges to create resistance and, ideally, driven from the rear
Achieved by one of three alternatives:

(1) the swimmer can increase propulsive force, or
Swimming Propulsion

Traditional Ideas of Propulsion Generation:

• Action/Reaction (Drag/Propulsion)

• Lift (Sculling)
Propulsive Force = \( \frac{1}{2} \rho C_D A v^2 + \rho C_M V a \)

- **A** – frontal surface area
- **v** – swimmer’s velocity
- **C_D** – Coefficient of drag
- **\( \rho \)** – density of water
- **V** – Volume
- **a** – swimmer’s acceleration
- **C_M** – Coefficient of inertia
- **\( \rho \)** – density of water

**Drag Effects**

**Unsteady State Inertial Effects**
How to Improve Swimming Performance?

Achieved by one of three alternatives:

(1) the swimmer can increase propulsive force, or

(2) the swimmer can reduce resistive drag (both active and passive), or

(3) some combination of the two (i.e. increased propulsive force and reduced resistance).
Components of drag:

- Frictional drag: friction produced between water and swimmer
- Form drag: a combination of frontal and eddy resistance
- Wave drag: energy loss due to creation of waves
• Is directly proportional to velocity

• Skin with Hair vs Shaved Skin vs Suit
• Combination of
  – Frontal resistance
  – Eddy resistance

• Quadratic relationships
  – Velocity squared
- wave drag: energy loss due to creation of waves
- Bow wave, stern wave & lateral waves
- Most detrimental type of drag – related to the cube of the velocity.
Effect of Depth on Drag Force

Practical Measure of the Drag Force:
Over 25cm extra glide distance in 1s by gliding at 0.4m deep compared with the surface.
Underwater Kick

WAIS Dolphin Kick Study
Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=2.0000e-01)
FLUENT 6.1 (3d, segregated, dynamesh, rke, unsteady)
A 10° increase in plantar flexion created an extra 16N of propulsive force (an extra ~66% peak force).
The 4 H’s

Hand

Head

Hips

Heels

drag force

greater drag force

water surface

water surface

The 4 H’s
Kicking During Swimming

- Aim to keep the feet submerged at all times.
Backstroke
Breaststroke

Traditional

New
Breaststroke
Butterfly
Dive Start
Before and After
Entry: 2.97m

Full Extension in the Air

Entry: 3.36m
Backstroke Start
Sequencing: Arm push / upper body drive (Unfold), Leg drive
Backstroke Start

- Full leg extension
- Head neutral
- Arms streamline
Arms streamline

Head neutral

Full leg extension

Arms streamline
No knee bend/flick

Hands apart = Approx 17% increase in drag
Hold tight body position on entry
Tumble Turns

Projection Clock moon
Skill Development

**Horizontal Velocity m/s**

- **25/06/2008**: 4.76
- **13/10/2009**: 4.96

**15m Start Time**

- **25/06/2008**: 6.52
- **13/10/2009**: 5.95
Thank You