Estimates of Swimming Energy Expenditure and Training Dose Utilizing an Omnidirectional Accelerometer

Jeanne D. Johnston, Joel M. Stager & Brian V. Wright
Counselman Center
for the Science of Swimming
Current Methods to Estimate the Energy Expenditure of Swimming

- Published tables
- Regression equations developed using oxygen consumption and swimming velocity
- Indirect calorimetry
Purpose

- Evaluate the efficacy of an omnidirectional accelerometer (ODA) to quantify swimming energy expenditure (SWE) and assess overall swim training dosage.
  - Phase I: Generation of an algorithm for SWE from ODA output
  - Phase II: Monitor collegiate practice to quantify training dosage.
Methods

- Twenty three men (28.0 years, +/-8.8) and 27 women (26.6 years, +/-8.9)
- 400 yard front crawl swims (light, moderate, and hard intensity)
- Swimming velocity .82-1.51 m·sec\(^{-1}\)
- An ODA was worn on the right wrist, waist, and right leg
- Expired gases were collected for 20 seconds at the completion of each swim
- Multiple regression techniques were utilized to develop the algorithm for SWE (kcal·min\(^{-1}\))
Results

- There were significant correlations between the linear acceleration of limbs (ODA counts) and oxygen uptake.
  - The accelerometer worn on the leg was the best predictor regardless of sex or velocity.
- Degree of correlation depends on
  - Swim Velocity
  - Sex of subject
  - Skill of subject
Figure 1. Energy expenditure/swim velocity relationship for men and women

Figure 2. Energy expenditure/leg accelerometer relationship for men and women
Figure 3. Leg accelerometer counts and swim velocity
Figure 4. Energy expenditure/swim velocity relationship above and below 1.1 m/sec

Figures 5 & 6. Energy expenditure/swim velocity relationship above and below 1.1 m/sec for men (left) and women (right)
**Best Swimming Energy Expenditure (kcal·min⁻¹) Estimates for All Subjects, Men, and Women Utilizing Swim Velocity Categories, Performance Characteristics, and Accelerometer Counts.**

<table>
<thead>
<tr>
<th>Best Velocity Category (All Subjects)</th>
<th>R²</th>
<th>SEE</th>
<th>Sig Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSA</td>
<td>0.35</td>
<td>4.01</td>
<td>0.00</td>
</tr>
<tr>
<td>BSA, Leg</td>
<td>0.61</td>
<td>3.18</td>
<td>0.00</td>
</tr>
<tr>
<td>BSA, Leg, sex x leg</td>
<td>0.68</td>
<td>2.89</td>
<td>0.01</td>
</tr>
<tr>
<td>BSA, Leg, sex x leg, VC</td>
<td>0.73</td>
<td>2.73</td>
<td>0.03</td>
</tr>
<tr>
<td>BSA, Leg, sex x leg, VC, Waist</td>
<td>0.76</td>
<td>2.57</td>
<td>0.03</td>
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</table>

<table>
<thead>
<tr>
<th>Best Velocity Category Males</th>
<th>R²</th>
<th>SEE</th>
<th>Sig Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC x LEG</td>
<td>0.53</td>
<td>3.64</td>
<td>0.00</td>
</tr>
<tr>
<td>VC x LEG, BSA</td>
<td>0.65</td>
<td>3.25</td>
<td>0.04</td>
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</table>

<table>
<thead>
<tr>
<th>Best Velocity Category Females</th>
<th>R²</th>
<th>SEE</th>
<th>Sig Change</th>
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<tbody>
<tr>
<td>Leg</td>
<td>0.41</td>
<td>2.42</td>
<td>0.00</td>
</tr>
<tr>
<td>Leg, BSA</td>
<td>0.63</td>
<td>1.97</td>
<td>0.01</td>
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</tbody>
</table>

Note: BSA (body surface area), VC (0 = <1.1 m·sec⁻¹, 1 = >= 1.1 m·sec⁻¹); arm, leg, waist (counts·min⁻¹), SEE (standard error of the estimate).
Phase II: Training Dose

**Purpose:** Utilize the accelerometer output to quantify “physiological load” of a workout set, workout, and or weekly training plan.

**Methods**
- Two female collegiate
- Monitored 3 days of swim practice
- Accelerometers were worn on their wrist and ankle
- Heart rate was recorded throughout practice

**Practices** varied in time, distance swam, and intensity
Arm Accelerometer Counts (Day2/Subject1)

Accelerometer Counts/15 Sec

- 2X400FS
- 2X200 Pull
- 5X50/10X50 Rest
- 18X100 Kick
- Cool Down

- 2X300BK
- 2x100 IM
- Fly, Back, Breast, FS on 45
- Down
### Future Applications

- Kcals/minute or total kcals per session
- Establish cut-off points based on total counts/session for light, moderate and hard training session

<table>
<thead>
<tr>
<th></th>
<th>Arm Cts/min</th>
<th>Leg Cts/min</th>
<th>Arm &amp; Leg Cts/min</th>
<th>Arm &amp; Leg Cts/Meter</th>
<th>Total Counts</th>
<th>Distance</th>
<th>Description</th>
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<tbody>
<tr>
<td>Day 1</td>
<td>4984</td>
<td>9339</td>
<td>14383</td>
<td>506</td>
<td>1226146</td>
<td>2,424</td>
<td>Short Intense</td>
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<tr>
<td>Day 2</td>
<td>5676</td>
<td>9129</td>
<td>14805</td>
<td>253</td>
<td>1821043</td>
<td>7,200</td>
<td>Long Intense</td>
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<tr>
<td>Day 3</td>
<td>3687</td>
<td>8225</td>
<td>11912</td>
<td>229</td>
<td>1372858</td>
<td>5,990</td>
<td>Moderate</td>
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Conclusions

- ODA may provide a means to quantify daily or weekly energy expenditure.
- ODA may provide a means of quantifying a workout or series of workouts.
- ODA may allow for evaluation of the relative “load” that a segment or cumulative training plan might represent.
- Provides insight into the intensity, repetition and time of a workout.
Potential Applications

- Evaluation of the contribution of leg and arm separately
- Quantification of total swim effort and rest time.
- Monitor stroke technique based on observed insufficient arm or leg counts
- Assessment of inter-individual practice effort
Current Research

- “Accelerometry as a Means of Quantifying Training Load in Competitive Swimmers”

- Funded by USA Swimming
Purpose

Examine the relationship between accelerometer counts and common variables that are currently used to describe and quantify competitive swim training during actual training sessions over the course of a season.
Measurements

- Physiological variables: Heart rate, maximal oxygen uptake, body mass, lean body mass, and height
- Performance variables: Swim velocity, stroke rate, stroke index, stroke length, and training volume.
- Fatigue indices: Salivary cortisol and Iga
- Accelerometer counts per swim session
Protocol

- Subjects: Six competitive high school swimmers
- Accelerometer counts (arm and leg), rating of perceived exertion (RPE), and heart rate are recorded during each training session.
- Measures of body mass, body composition (BIA), and collection of saliva (cortisol and Iga) are taken once a week.
- VO$_{2\text{max}}$ is measured mid-season and post-season.
Research Questions

- Can accelerometers be utilized to track the training load of a competitive swimmer over the course of a swim season?

- Will the output of an accelerometer allow the coach and/or swimmer to evaluate the adherence of the athlete to a particular training protocol?