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

Jeanne D. Johnston, Joel M. Stager
& Brian V. Wright
Counsilman Center
for the Science of Swimming

Liljestrand & Stenstrom, 1920

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 $m \cdot sec^{-1}$
- 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 ($kcal \cdot min^{-1}$)

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

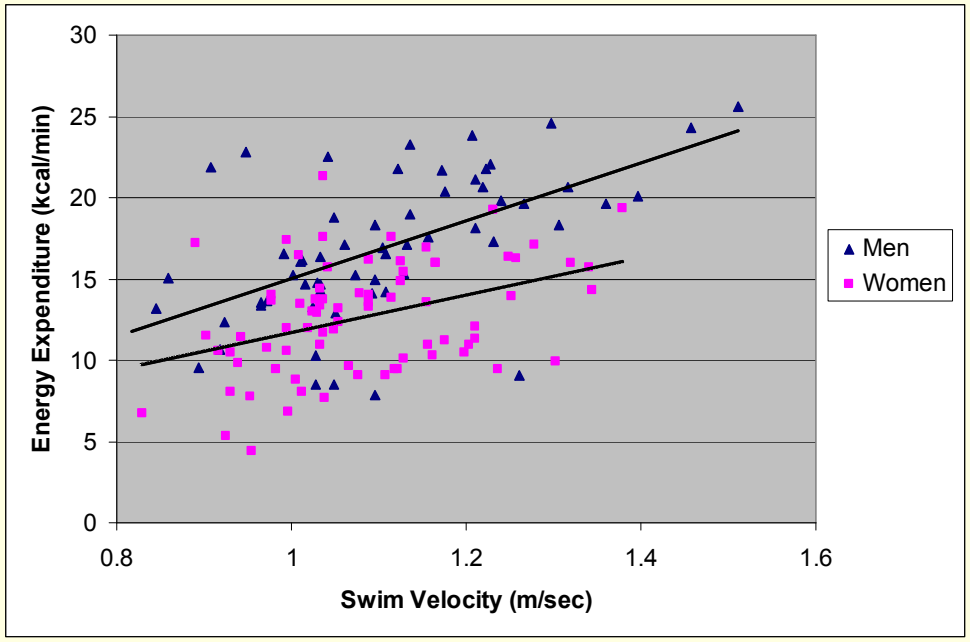


Figure 1. Energy expenditure/swim velocity relationship for men and women

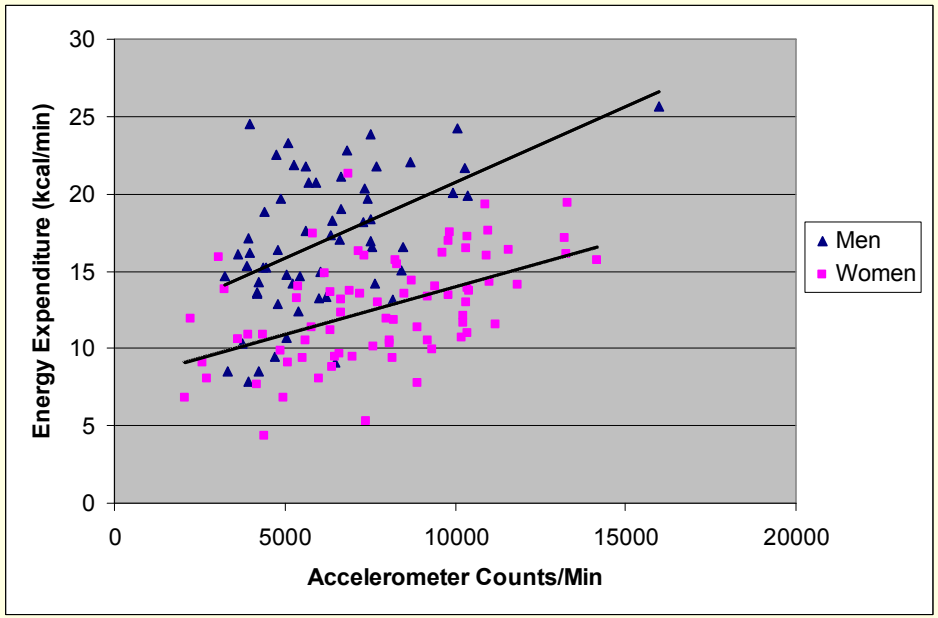


Figure 2. Energy expenditure/leg accelerometer relationship for men and women

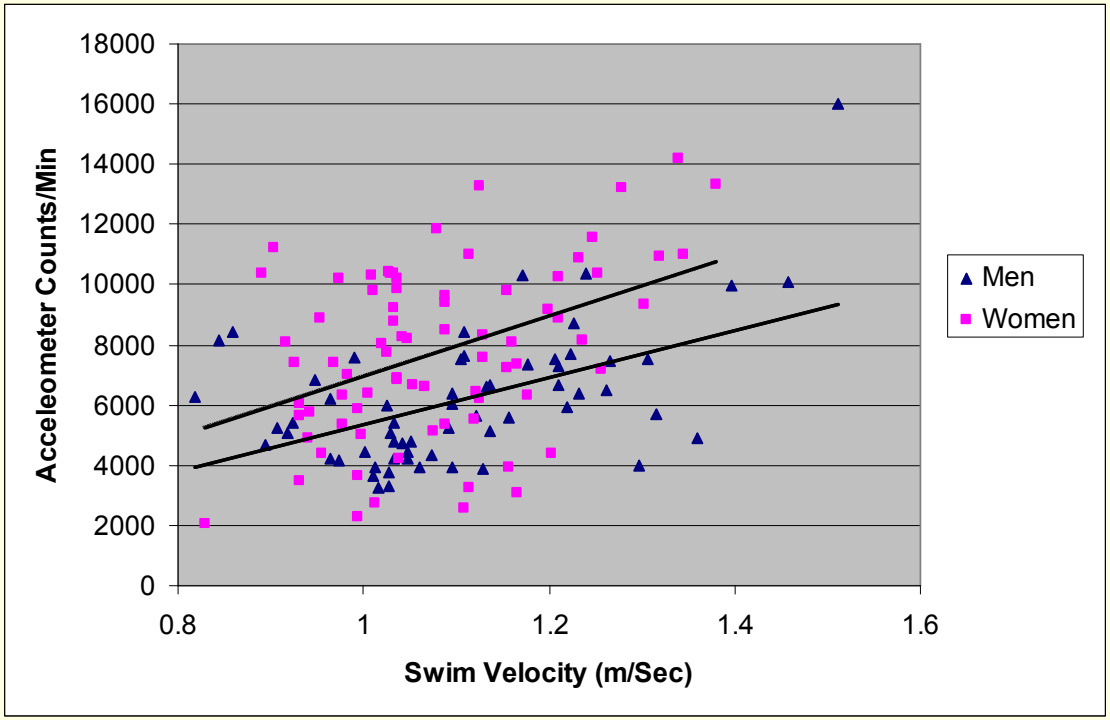


Figure 3. Leg accelerometer counts and swim velocity

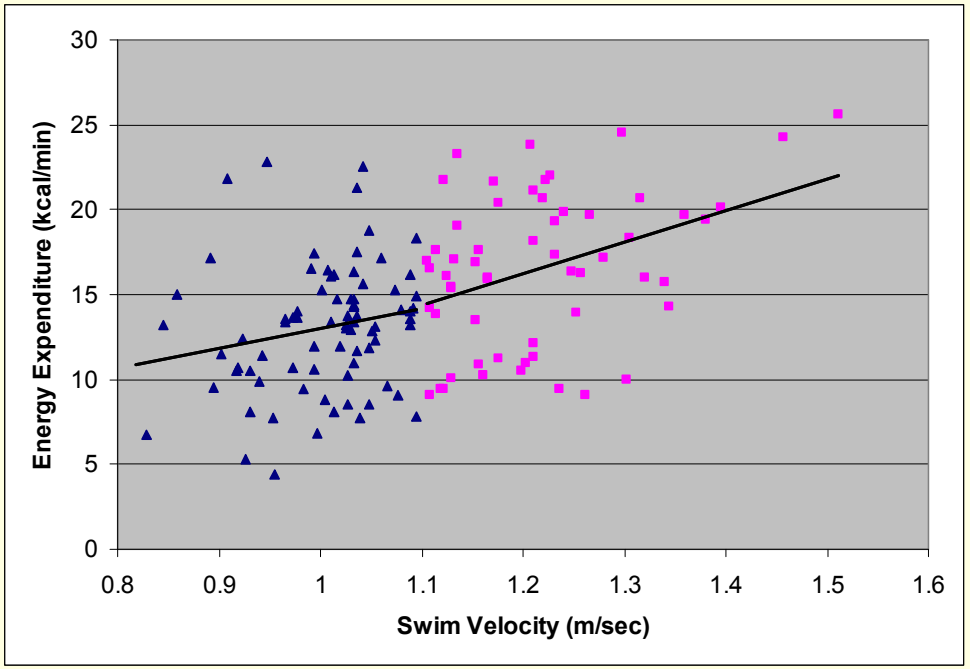
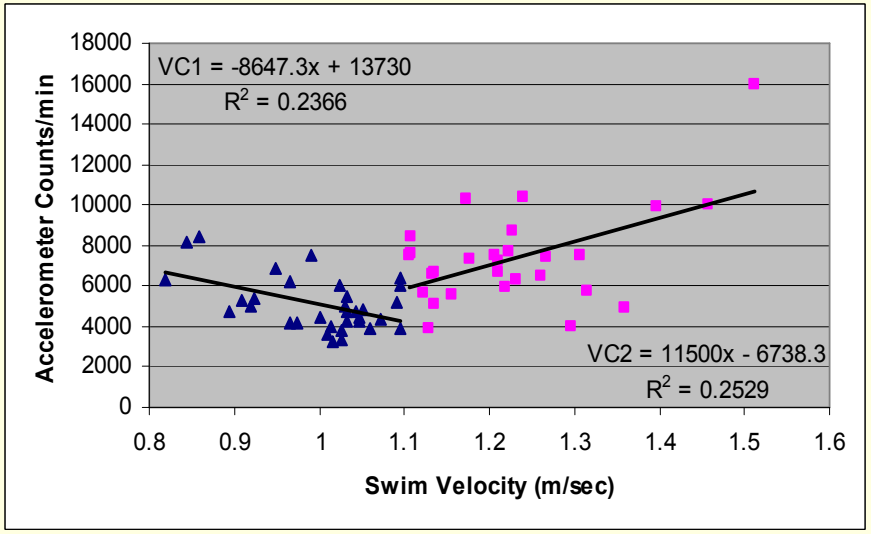
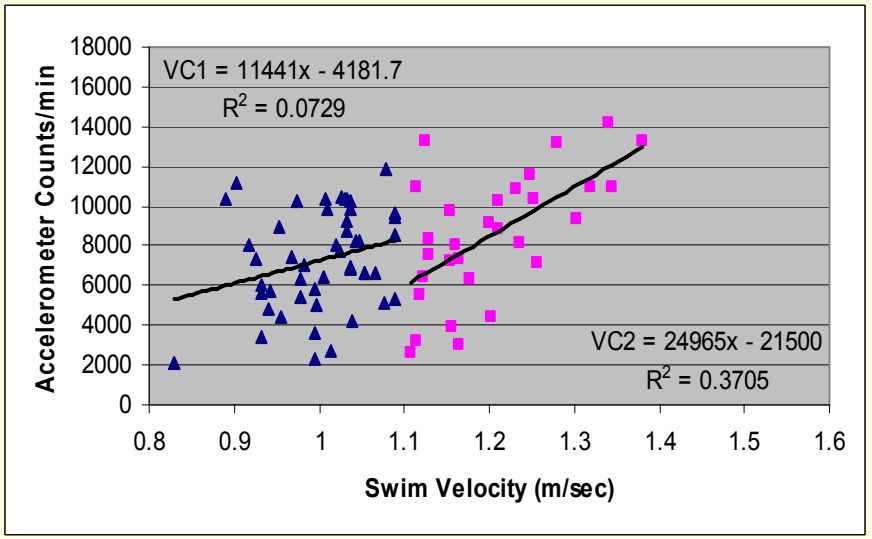


Figure 4. Energy expenditure/swim velocity relationship above and below 1.1 m/sec





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.

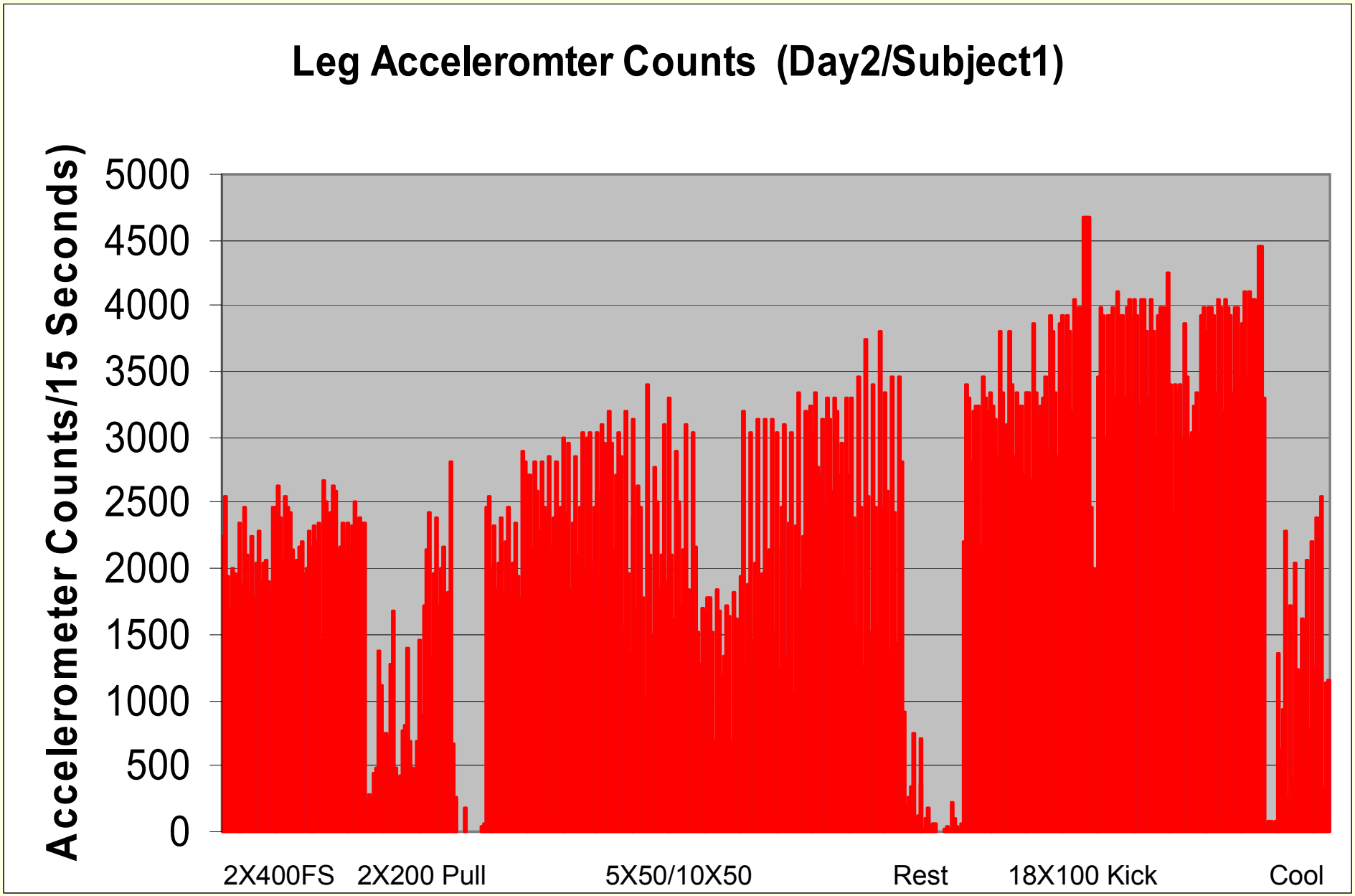
	R^2	SEE	Sig Change
Best Velocity Category (All Subjects)			
BSA	0.35	4.01	0.00
BSA, Leg	0.61	3.18	0.00
BSA, Leg, sex x leg	0.68	2.89	0.01
BSA, Leg, sex x leg, VC	0.73	2.73	0.03
BSA, Leg, sex x leg, VC, Waist	0.76	2.57	0.03
Best Velocity Category Males			
VC x LEG	0.53	3.64	0.00
VC x LEG, BSA	0.65	3.25	0.04
Best Velocity Category Females			
Leg	0.41	2.42	0.00
Leg, BSA	0.63	1.97	0.01

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).

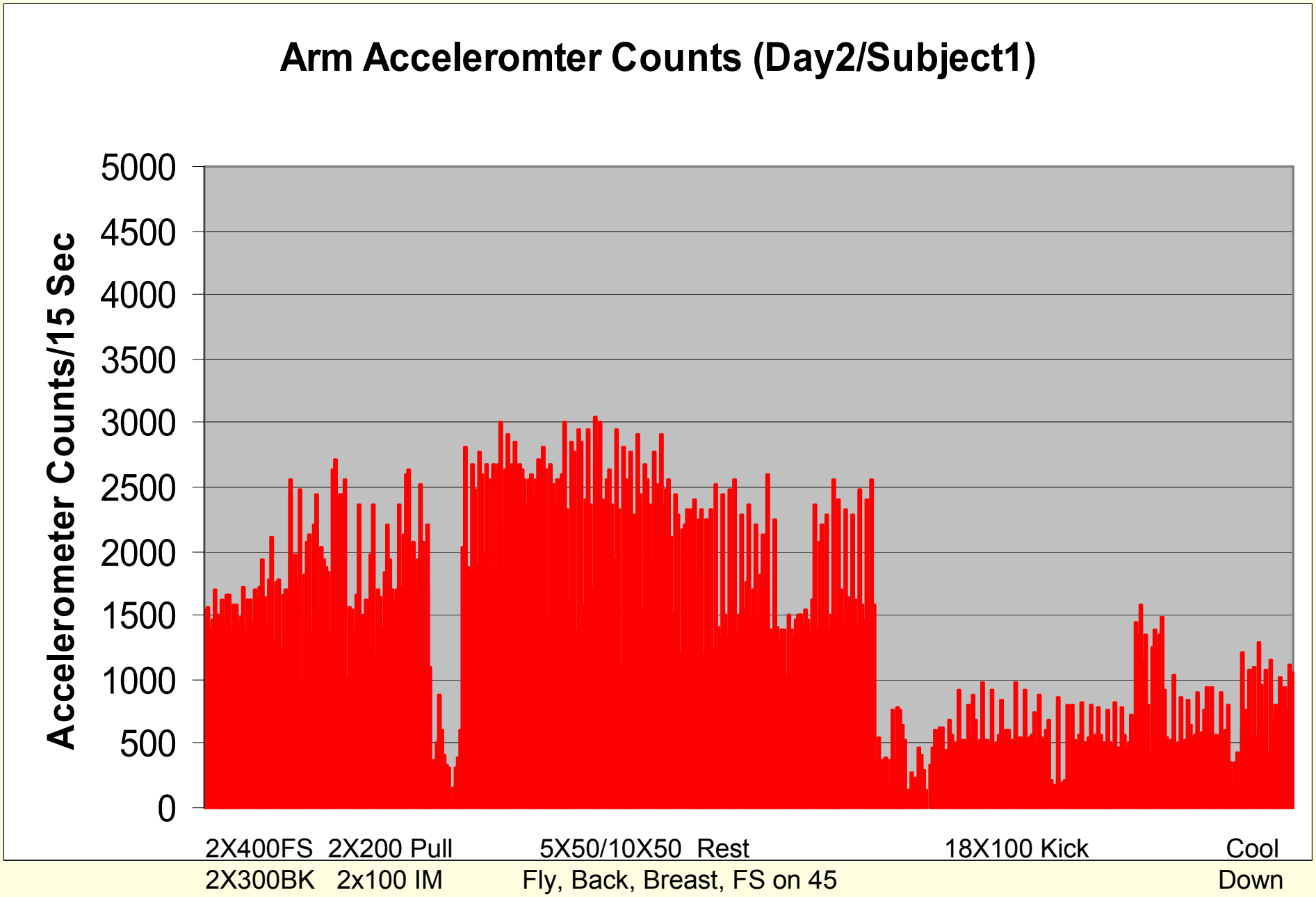
Phase II: Training Dose

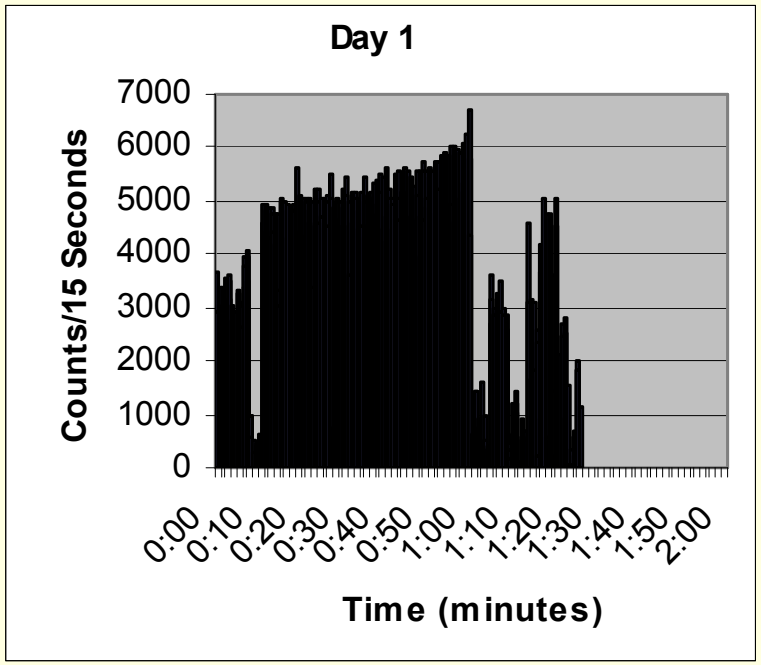
- **Purpose:** Utilize the accelerometer output to quantify “physiological load” of a workout set, workout, and or weekly training plan.
- **Methods**
  - Two female collegiate
  - Monitored 3 days of swim practice
  - Accelerometers were worn on their wrist and ankle
  - Heart rate was recorded throughout practice
- **Practice**s varied in time, distance swam, and intensity

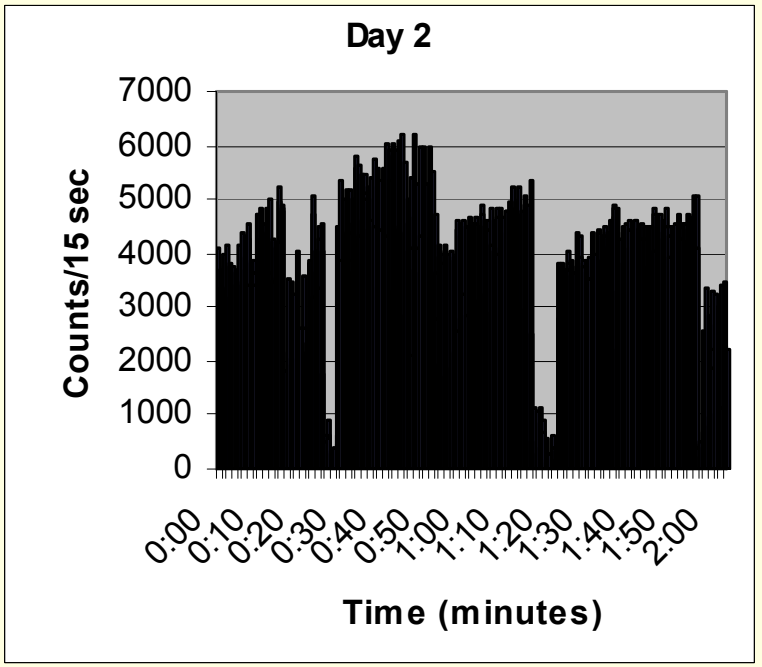
Leg Acceleromter Counts (Day2/Subject1)

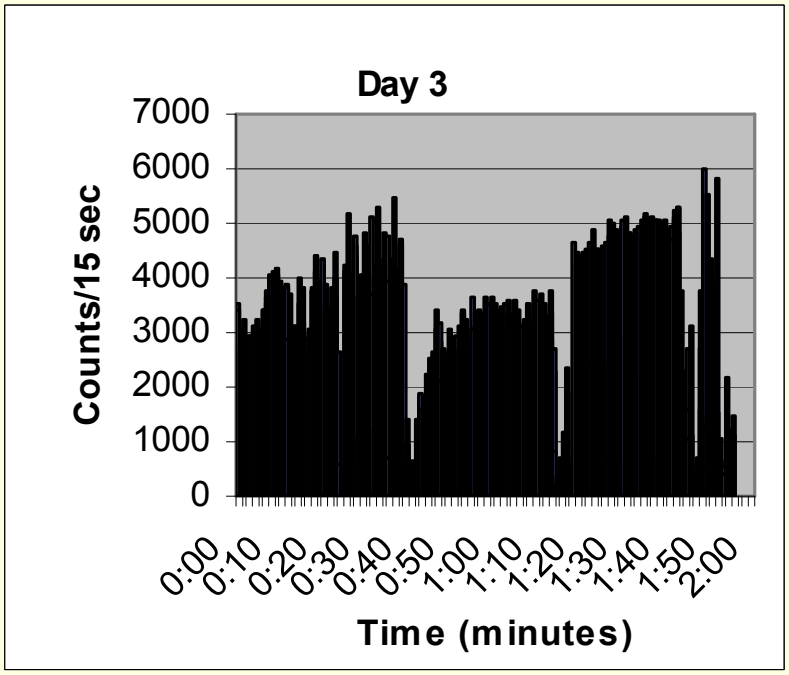


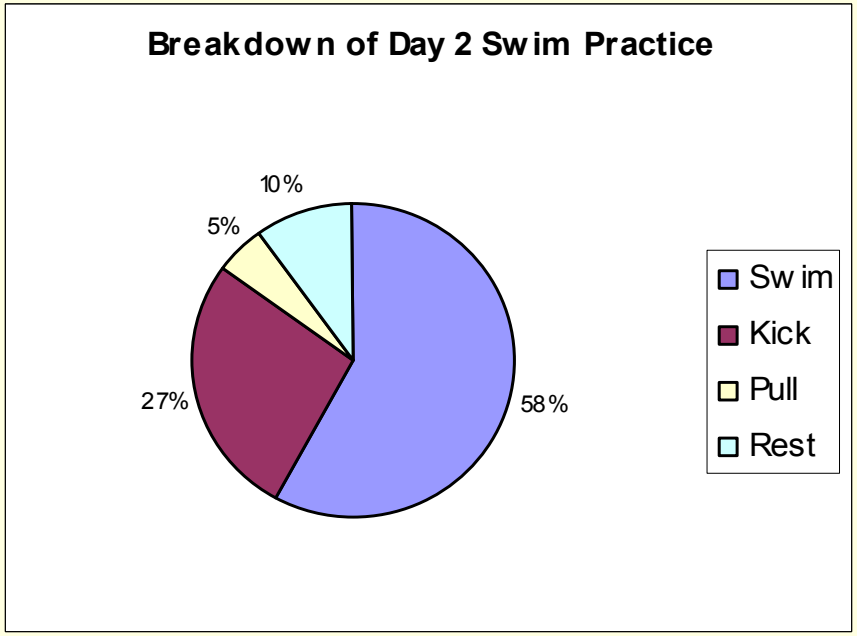
Arm Acceleromter Counts (Day2/Subject1)




Day 1
Counts/15 Seconds
7000
6000
5000
4000
3000
2000
1000
0
0:00
0:10
0:20
0:30
0:40
0:50
1:00
1:10
1:20
1:30
1:40
1:50
2:00
Time (minutes)


Day 2
Counts/15 sec
7000
6000
5000
4000
3000
2000
1000
0
0:00
0:10
0:20
0:30
0:40
0:50
1:00
1:10
1:20
1:30
1:40
1:50
2:00
Time (minutes)


Day 3
Counts/15 sec
7000
6000
5000
4000
3000
2000
1000
0
0:00
0:10
0:20
0:30
0:40
0:50
1:00
1:10
1:20
1:30
1:40
1:50
2:00
Time (minutes)


Breakdown of Day 2 Swim Practice
10%
5%
27%
58%
Swim
Kick
Pull
Rest

	Arm Cts/min	Leg Cts/min	Arm& Leg Cts/min	Arm & Leg Cts/Meter	Total Counts	Distance	Description
Day 1	4984	9339	14383	506	**1226146**	2,424	Short Intense
Day 2	5676	9129	14805	253	**1821043**	7,200	Long Intense
Day 3	3687	8225	11912	229	**1372858**	5,990	Moderate Moderate

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

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_{2max} 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?