

# CHARACTERISTICS OF ELITE OPEN-WATER SWIMMERS

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**ABSTRACT.** VanHeest, J.L., C.E. Mahoney, and L. Herr. Characteristics of elite open-water swimmers. *J. Strength Cond. Res.* 18(2):302–305. 2004.—Open-water swimming (5, 10, and 25 km) has many unique challenges that separate it from other endurance sports, like marathon running and cycling. The characteristics of a successful open-water swimmer are unclear. The purpose of this study was to determine the physical and metabolic characteristics of a group of elite-level open-water swimmers. The open-water swimmers were participating in a 1-week training camp. Anthropometric, metabolic, and blood chemistry assessments were performed on the athletes. The swimmers had a  $\dot{V}O_{2\text{peak}}$  of  $5.51 \pm 0.96$  and  $5.06 \pm 0.57$  ml·kg<sup>-1</sup>·min<sup>-1</sup> for males and females, respectively. Their lactate threshold (LT) occurred at a pace equal to 88.75% of peak pace for males and 93.75% for females. These elite open-water swimmers were smaller and lighter than competitive pool swimmers. They possess aerobic metabolic alterations that resulted in enhanced performance in distance swimming. Trainers and coaches should develop dry-land programs that will improve the athlete's muscular endurance. Furthermore, programs should be designed to increase the LT velocity as a percentage of peak swimming velocity.

**KEY WORDS.** anthropometry, physical characteristics, performance

## INTRODUCTION

Open-water swimming is an endurance event that is similar to marathon running or long-distance cycling. Participation in long-distance swimming is growing both nationally and internationally. There are 5-, 10-, and 25-km events in all regions of the United States. Competitors range from developmental or age-group swimmers to masters-level swimmers. The popularity of open-water swimming has grown in the United States; however, it remains a relatively novel sport compared to its popularity internationally (i.e., Australia or Brazil). In addition, the sport has many specific challenges that are unique. Two of these challenges include swimming for long durations in cold water and adverse conditions as well as nutritional/feeding considerations during the open-water swims (2, 8). To date, relatively little is known about these 2 components of open-water swimming compared to its land-based-sport counterparts.

The type of athlete best suited to open-water swimming remains unclear. Anecdotal evidence from coaches and swimmers provides a baseline for the evaluation of athletes; however, it is critical to determine the optimal type of athlete for these events. Open-water swim coaches have suggested that both male and female open-water swimmers must possess (a) an enhanced aerobic capacity, (b) the ability to swim close to maximum pace for long distances, and (c) a higher percentage of body fat than pool swimmers. These characterizations appear to be correct physiologically. Currently, open-water swimming is

growing in popularity in the United States. To date, it is unclear as to the physiological and anthropometrical characteristics of current elite U.S. open-water swimmers. Therefore, the purpose of this study was to characterize an elite group of female and male U.S. open-water swimmers. The swimmers were participating in a training camp in California (Open Water National Team Camp). The data will be compared to known values for elite competitive pool swimmers, when applicable.

## METHODS

### Experimental Approach to the Problem

Four male (mean age = 18.6 years) and 4 female (mean age = 17.8 years) elite open-water swimmers served as subjects for this study. All swimmers were in the top 6 athletes in their event in the United States. The athletes completed 7 days of training during which they completed the training program depicted in Table 1. Training was performed between 0630 and 0930 hours at a local swimming pool and between 1400 and 1700 hours in the Pacific Ocean. Ocean water temperatures ranged between 62 and 68° F. The testing was performed as illustrated in Table 1. All testing occurred in the morning, either prior to or during the workout. Total training distance and the distribution of the training intensity (based on the United States Swimming Training Categories) is illustrated for each of the days of the camp (Table 1). All swimming performance evaluations were performed during the morning pool training sessions. Intraclass *R* values were >0.60 for all tests; therefore, they were considered reliable.

### Measurement Protocols

**Anthropometric Profile.** Body weight was assessed between 0600 and 0630 hours daily. The swimmers were weighed wearing a dry swimsuit on a calibrated scale. All weights were recorded in kilograms (to the nearest 0.5 kg). Height was measured using a calibrated stadiometer and was recorded in centimeters.

Seven skinfold measures (biceps, triceps, abdominal, subscapular, suprailiac, thigh, and calf) were taken on the nondominant side of each swimmer. A calibrated skinfold caliper was placed at each site, and a fold of tissue was measured to the nearest millimeter. Each fold included both skin and the adipose tissue (fat) under the skin in that region. Skinfolds were measured 5 times for each site in the order described previously. All measurements were taken by a single experienced investigator. Percent muscle mass, percent skeletal mass, and sum of skinfolds was calculated as per the methods of Lindsay Carter and Ackland (10). These equations have been described previously in a large-scale study on elite aquatic athletes. Percent body fat was determined for the women using the Jackson, Pollack, and Ward equation (5) and

**TABLE 1.** Training dynamics and testing schedule for the training camp.

Day	Total distance (m)	Training Intensity Category (U.S.S. Intensity Divisions); percentage (out of 100%)					Daily measure
		Near max	Anaerobic	Transition	Aerobic; high intensity	Aerobic; low intensity	
1	12,200	0	0	57	35	8	Anthro
2	14,600	0	10	8	72	10	Blood draw
3	12,800	2	2	2	85	9	
4	6,800	0	0	23	62	15	
5	15,000	0	0	40	58	2	Aerobic
6	11,100	0	0	20	75	5	LT*
7	13,668	0	3	12	77	8	
8	0	0	0	0	0	0	Competition

\* LT = lactate threshold.

**TABLE 2.** Anthropometric data.\*

	Height (cm)	Weight (kg)	% MM	% SM	Sum of skinfolds	% Body fat
Females; open water	168.3 ± 2.83	63.52 ± 5.84	30.73 ± 3.77	8.44 ± 0.73	61.88 ± 11.12	22.8 ± 2.31 (6)
Females; Perth	171.5 ± 7.0	63.1 ± 5.9	42.6 ± 19.6	12.5 ± 1.0	51.2 ± 3.5	
Males; open water	177.3 ± 7.06	71.25 ± 8.08	39.93 ± 8.42	10.24 ± 0.95	53.4 ± 7.53	9.8 ± 2.0 (4)
Males; Perth	183.8 ± 7.1	78.4 ± 7.1	45.8 ± 9.5	13.1 ± 0.9	57.8 ± 2.6	

\* Data represent mean ± SEM. PERTH data from Carter and Akland (2). MM = muscle mass; SM = skeletal mass.

for the men using the equation by Forsyth and Sinning (3). Height, weight, and body composition were compared to data obtained from a group of both U.S. elite pool swimmers and from a large-scale study of elite international pool swimmers (10).

**Lactate Threshold Profile.** The athlete performed a standardized warm-up. The athlete swam 5 200-m freestyle swims with descending times (to a maximal effort) on a 5-minute interval. A blood sample was taken from the earlobe 1 minute following each 200-m swim. Heart rate and stroke rates were measured for each of the 200-m swims. Heart rate was taken continuously from a Polar heart rate monitor strapped to the swimmer's chest. Recovery heart rates were taken immediately following the final swim, 30 and 60 seconds following the final swim. Blood was analyzed for lactate using the YSI Lactate 1500 Sport analyzer (Yellow Springs, Inc., Yellow Springs, OH). Precision of the machine was 0.1 mmol·L<sup>-1</sup>, and intersample variability was 1.7%.

**Aerobic Capacity Profile.** The athlete performed a standardized 10-minute warm-up. Each swimmer swam a maximal 400-m freestyle swim. Peak oxygen consumption ( $\dot{V}O_{2peak}$ ) was measured immediately following the swim using the backward extrapolation method described previously (7, 9). Briefly, the swimmers were instructed to complete a maximal 400-m swim from a push-off start. Prior to beginning the swim, they were fit with an anesthesia mask connected to the metabolic cart (Vmax, SensorMedics, Inc., Yorba Linda, CA). The metabolic cart was calibrated as per the standard methods required by the manufacturer. The swimmer began the swim with a countdown start. They were required to hold their last breath immediately before reaching the final wall. The swimmer's face was placed in the mask, with the back of the head firmly held to make a tight seal on the swimmer's face. Oxygen consumption was measured using open-circuit indirect calorimetry. Expired air was collected during recovery in 20-second collection periods for 2 minutes.  $\dot{V}O_2$  (L·min<sup>-1</sup>) was plotted against time (seconds)

using a semilogarithmic plot.  $\dot{V}O_{2peak}$  (L·min<sup>-1</sup>) was determined from the semilogarithmic plot (7, 9).

**Blood Chemistry and Hematology Profile.** A venous blood sample was collected from each swimmer between 0600 and 0630 hours following an overnight fast. Blood was taken from the antecubital space under sterile conditions. The sample was allowed to clot, was centrifuged at 1,500g for 10 minutes, and was placed into aliquot tubes. All samples were stored at -80° C until analysis. Health markers, muscle damage markers, and iron status markers have been used by our laboratory as a standard test battery in competitive pool swimmers. These markers have been useful in delineating athletes who are maladapted to training and/or who have medical conditions. This battery of test was selected for the present group of athletes to allow for evaluation of problems within the group and to allow for comparison with our existing database on pool swimmers. Glucose, urea, creatinine, cholesterol, triglyceride, iron, creatine kinase (CPK), lactate dehydrogenase (LDH), and aspartate transaminase (AST) were analyzed using colorimetric techniques on an automated blood chemistry machine (Abbott Spectrum, Abbott Laboratories, Abbot Park, IL). Serum ferritin and cortisol were analyzed using colorimetric methods on an automated blood chemistry analyzer (IMx, Abbott Laboratories, Abbot Park, IL). Data were compared to ranges for each parameter developed in our laboratory on elite pool swimmers (13).

## RESULTS

The anthropometric data obtained from the open-water swimmers is shown in Table 2. Comparison data were collected at the World Championships in Perth in 1991 (10). The open-water swimmers in the current study were shorter and lighter than the pool swimmers. Percent muscle mass in open water compared to Perth swimmers was 6.2 and 11.9% lower for males and females, respectively (10).

TABLE 3. Anaerobic threshold profile data.\*

	Males	Females
Velocity (peak) m·s <sup>-1</sup>	1.51 ± 0.36	1.41 ± 0.34
Velocity (at LT) m·s <sup>-1</sup>	1.34 ± 0.23	1.32 ± 0.21
Lactate (peak) mmol	7.38 ± 1.40	7.58 ± 1.10
Heart rate (at LT) b·min <sup>-1</sup>	143 ± 10	161 ± 8
Stroke rate (at LT) cycles·min <sup>-1</sup>	33.88 ± 1.4	44.88 ± 1.6
LT (% velocity peak)	88.75 ± 3.1	93.75 ± 1.5

\* Data represent mean ± SEM. LT = lactate threshold.

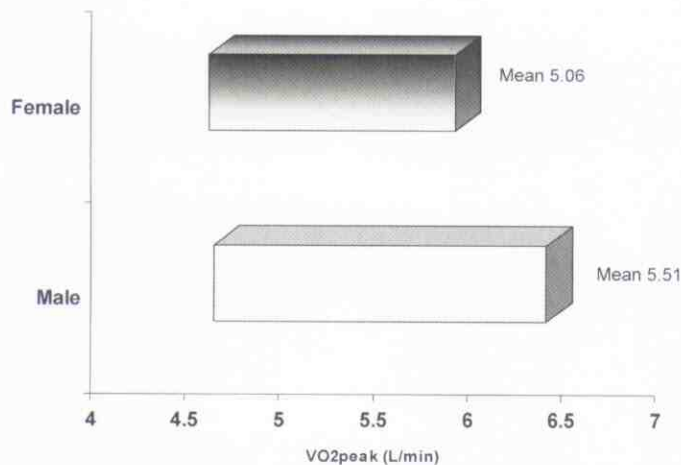


FIGURE 1. Range and mean  $\dot{V}O_{2peak}$  for male and female open-water swimmers.

Table 3 represents the peak velocity and the swimming velocity associated with the lactate threshold (LT) for both males and females in the LT (5 × 200-m free-style) test. Peak velocity was 1.51 m·s<sup>-1</sup> for the males and 1.41 m·s<sup>-1</sup> for the females. Velocity at LT was determined as 1.34 and 1.32 m·s<sup>-1</sup> for the males and females, respectively. These paces are 88.75–93.75% of the peak pace for the test.

The mean and range values for peak oxygen consumption are shown in Figure 1. The data are comparable to other studies assessing elite-level swimmers (4, 5, 9). The current data were converted into a relative value to compare with dry-land athletes. The average  $\dot{V}O_{2peak}$  was 5.51 ± 0.96 and 5.06 ± 0.57 L·min<sup>-1</sup> for males and females, respectively.

Blood chemistry data are represented in Table 4. Group data are presented for the blood chemistry markers. Blood data ranges for U.S. competitive pool swimmers, from our laboratory, are also presented for comparison (13). Stress markers (cortisol, CPK, LDH, AST) were within the range established for pool swimmers. Cortisol was slightly above the normal range (mean = 872.12 ± 15.53; range 165.54–827.7 nmol·L<sup>-1</sup>). Health and metabolism markers (i.e., glucose, triglycerides, and cholesterol) were all within the normal range. However, iron status markers in the women were either at or slightly below the low end of the normal range.

## DISCUSSION

The physical and metabolic characteristics of 8 elite open-water swimmers were evaluated during a 1-week training camp. Data from the current study were compared to other databases on competitive pool swimmers. The results

TABLE 4. Blood chemistry and hematology data.

Parameter	Open-water swimmers, mean ± SD	National pool swimmers, range*
Glucose (mmol·L <sup>-1</sup> )	4.07 ± 0.004	3.61–6.38
Urea (mmol·L <sup>-1</sup> )	5.85 ± 0.11	2.86–7.14
Creatinine (μmol·L <sup>-1</sup> )	87.52 ± 2.65	53.04–106.08
Cholesterol (mmol·L <sup>-1</sup> )	4.44 ± 0.04	3.10–5.69
Triglyceride (mmol·L <sup>-1</sup> )	0.69 ± 0.03	0.34–2.03
Ferritin (pmol·L <sup>-1</sup> )	126.51 ± 5.75	44.94–224.7
Iron (μmol·L <sup>-1</sup> )	12.35 ± 0.35	10.74–28.64
CPK (U·L <sup>-1</sup> )	117.99 ± 7.59	45–235
AST (IU·L <sup>-1</sup> )	37.52 ± 1.15	16–42
LDH (U·L <sup>-1</sup> )	129.09 ± 7.35	100–220
Cortisol (nmol·L <sup>-1</sup> )	872.12 ± 15.53	165.54–827.7

\* Typical ranges for our laboratory (13). Ranges determined from 1,500 blood samples for national-caliber swimmers. Male and female data are pooled. Data represent mean ± SEM.

support the study hypothesis regarding the physiological profile (i.e., aerobic capacity and LT characteristics). However, the male swimmers did not fit the anthropometric profile previously reported by the coaches.

The elite open-water swimmers were both shorter and lighter than competitive pool swimmers (10). Average percent muscle mass was also lower in the open-water swimmers compared to the pool swimmers. The smaller size of the open-water athletes would allow them to endure long-distance events more readily. Distance swimming does not require maximal power outputs typical of those seen in many pool events (i.e., 50- or 100-m free-style). The athlete's size may be a benefit to their swimming performance. However, open-water swimmers train and compete in cold water (2, 8). The smaller size and lower body fat percentage may place the athlete at risk for thermal stress-related events. Additional research is necessary to evaluate the thermoregulatory capacities of competitive open-water swimmers.

The results evaluating anaerobic threshold in endurance athletes are comparable to other work. Work in marathon runners reported values of LT at 76–83% of velocity peak for males and approximately 83% for females (4, 11). The male open-water swimmers appear to respond similarly to other endurance athletes. The females, however, have a higher pace associated with LT relative to peak pace (93.75%) than that reported for land-based female athletes (4, 11). The data support an enhanced ability in the female swimmers to maintain a high percentage of peak velocity during swimming.

A training strategy would be to enhance peak velocity should be employed in conjunction with training that maintains the percentage of peak velocity for LT. Open-water swimming is considered primarily an endurance

event that uses primarily fat as a fuel for energy production. However, more intense swimming at the end of a race and other portions of the race (i.e., tactical sprints) can cause the elevation of lactate in the blood. The data indicate that these swimmers tend to be competing at or near their anaerobic threshold during the course of the competition.

Backward extrapolation procedures provide an effective method to determine peak oxygen consumption in free swimming (7, 9). The oxygen consumption data are comparable to other studies using elite-level swimmers (4, 7, 9). This group of swimmers exhibited both an elevated peak oxygen consumption as well as a lactate threshold that occurred at a pace near-maximal pace. It has been well established that endurance athletes possess increased aerobic metabolic characteristics (4). These characteristics positively affect competitive open-water swimming.

During a season of training, various blood parameters may vary considerably, depending on such things as the intensity of training, diet, stress (physical or psychological), and the amount of training fatigue that the swimmer is under. Our laboratory has tracked blood variables for competitive pool swimmers for many years. The current data are typical of swimmers who are performing large volumes of aerobic work. Muscle damage markers and stress hormones are within the normal ranges.

The iron status markers (ferritin and iron) are near the low end of the normal range. These data appear to be affected by the females who were all below normal in both ferritin and iron values. Poor iron status (low ferritin, iron, red blood cells, hematocrit, and hemoglobin) is typical in U.S. competitive pool swimmers (12). The negative symptoms of poor iron status, such as fatigue, inability to tolerate intense training loads, and a reduced oxygen-carrying capacity, could result in performance impairments (1, 6). Additional evaluation of open-water swimmers is critical to determine those athletes at risk for this problem. Medical and nutritional interventions should be used to aid the athletes in regaining good status.

Open-water swimmers are smaller and lighter than their pool-swimming counterparts. These athletes possess enhanced abilities to perform aerobic work. Additional studies are necessary to evaluate how open-water swimmers respond to training or nutritional interventions. In addition, the thermoregulatory adaptations in these swimmers must be examined to enhance their performance in various environmental conditions.

## PRACTICAL APPLICATIONS

The data collected from this camp provide a description of U.S. athletes currently participating in competitive open-water events. It is clear that open-water swimmers have developed an aerobic capacity that can support the

rigorous training distances involved in this form of swimming. Training programs must be utilized that will increase both aerobic capacity and the velocity that can be maintained for extended durations.

The conditioning programs should include both pool/water training and dry-land cross training that will enhance the lactate threshold as well as increase the aerobic capacity. Strength programs that increase muscular endurance are essential for improving the success of open-water swimmers. In addition, programs should be designed to strengthen shoulder and shoulder girdle musculature. Programs focused primarily on the development of muscular strength and/or hypertrophy are not recommended for this group of athletes.

## REFERENCES

1. BEARD, J., AND B. TOBIN. Iron status and exercise. *Am. J. Clin. Nutr.* 72(Suppl.):594S-597S. 2000.
2. DULAC, S., A. QUIRION, D. DECARUFEL, J. LEBLANC, M. JOBIN, J. COTE, G.R. BRISSON, J.M. LAVOIE, AND P. DIAMOND. Metabolic and hormonal responses to long-distance swimming in cold water. *Int. J. Sports Med.* 8:352-356. 1987.
3. FORSYTH, H.S., AND W.E. SINNING. The anthropometric estimation of body density and lean body weight of male athletes. *Med. Sci. Sports Exerc.* 5:174-180. 1973.
4. HELGERUD, J., F. INGJER, AND S.B. STORMME. Sex differences in performance matched marathon runners. *Eur. J. Appl. Physiol.* 61:433-439. 1990.
5. JACKSON, A.S., M.L. POLLOCK, AND A. WARD. Generalized equations for predicting body density in women. *Med. Sci. Sports Exerc.* 12:175-182. 1980.
6. KARAMIZRAK, S.O., C. ISLEGEN, AND S. VAROL. Evaluation of iron metabolism indices and their relation with physical work capacity in athletes. *Br. J. Sports Med.* 30:15-19. 1996.
7. LAVOIE, J.M., L.A. LEGER, R.R. MONTPETT, AND S. CHABOT. Backward extrapolation of  $\dot{V}O_2$  from the  $O_2$  recovery curve after a voluntary maximal 400-m swim. *Swimming Science* 3: 222-227. 1989.
8. LECLERC, S., V.J. LACROIX, AND D.L. MONTGOMERY. Body temperature homeostasis during a 40km open water swim. *J. Swimming Res.* 14:26-32. 2000.
9. LEGER, L.A., V. SELIGER, AND L. BRASSARD. Backward extrapolation of  $\dot{V}O_{2max}$  values from the  $O_2$  recovery curve. *Med. Sci. Sports Exerc.* 12:24-27. 1980.
10. LINDSAY CARTER, J.E. AND T.R. ACKLAND. *Kinanthropometry in Aquatic Sports*. Human Kinetics Sports Science Monograph Series, Vol. 5. Champaign, IL: Human Kinetics, 1994.
11. TANAKA, K., AND Y. MATSUURA. Marathon performance, anaerobic threshold, and onset of blood lactate accumulation. *J. Appl. Physiol.* 57:640-643. 1984.
12. VANHEEST, J.L., AND K. RATLIFF. Incidence of poor iron status in national caliber swimmers. *Med. Sci. Sports Exerc.* 29:S217. 1997.
13. VANHEEST, J.L., AND K. RATLIFF. Normative blood chemistry and hematology data on US national calibre swimmers. Unpublished data. 1998.

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