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Predicted and Actual Pre-Competition Anxiety in College Swimmers

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Abstract

State anxiety was evaluated in male college swimmers in order to contrast predicted pre-competitive anxiety values with actual ratings. Ss completed the state version of Spielberger's State-Trait Anxiety Inventory under a baseline condition as well as 1-hr prior to two dual meets. Anxiety was also assessed 24-hr prior to the easy meet and 48-hr prior to the difficult meet with instructions for Ss to imagine how they would feel 1-hr prior to each competition. The team won both dual meets, and individual performance ratings were obtained from the coach. Actual state anxiety increased (P < .01) prior to both meets, and the increase was significantly greater (P < .05) for the difficult compared to the easy meet. The predicted and actual anxiety scores did not differ and were significantly correlated for the easy (r = .60, P < .01) and difficult (r = .72, P < .001) meets. Actual pre-competitive anxiety was not related to performance ratings, but swimmers rated as performing above average were more accurate in predicting pre-competitive anxiety (P < .05). These findings offer no support for the popular view that relaxation leads to enhanced performance, since this team experienced success with elevated pre-competition anxiety. It is concluded that college swimmers can accurately predict their pre-competitive anxiety levels 24 to 48-hr in advance of actual competition.

A number of theories have been advanced in an attempt to explicate the relationship between anxiety and athletic performance (3, 5). The majority of these theories contend that anxiety is related to performance at a group level. That is, for every athlete on a particular team anxiety should be at the same absolute level prior to competition (e.g., low, moderate, or high depending on the theory) in order to optimize performance. A somewhat related view argues that optimal pre-competition arousal levels vary as a function of task demand (i.e., gross vs fine motor task) within a sport. These theories predict that decrements in performance occur when anxiety is either lower or higher than a given absolute level.

In contrast to these theories, Hanin (1) has presented evidence that anxiety is related to athletic performance at an individual level. Hanin has made multiple assessments of anxiety, utilizing the Russian version of the State-Trait Anxiety Inventory (STAI) (8) on numerous athletes in various sports. These assessments have been performed prior to competitions ranging from relatively unimportant meets to world championships. From these investigations Hanin has concluded that each athlete possesses a particular anxiety level where performance is maximized, and the absolute level may be low, medium, or high depending on the individual. This level has been termed the “zone of optimal function” (ZOF), and the ZOF has been operationalized as each athlete's mean anxiety score prior to successful performances, plus or minus 4 raw score units on the STAI. Hanin (1) reported that pre-competition anxiety levels which were either lower or higher (+4) than the athlete's ZOF have been associated with decrements in performance. Hanin (1) has also found that athletes can accurately predict, up to several weeks prior to a competition, how anxious they will feel immediately prior to that event. In addition, athletes have been more accurate in predicting pre-competitive anxiety prior to difficult than easy competitions.

The primary purpose of the present investigation was to extend Hanin's work with Soviet athletes to a group of American male, college varsity swimmers by determining if swimmers could predict their own pre-
competitive anxiety in advance of two dual meets. An easy and difficult competition were chosen in an effort to evaluate whether or not the relative difficulty of competition would affect the ability to predict pre-competitive anxiety. A secondary purpose of the study was to evaluate the relationship of pre-competition anxiety and performance.

Method

Subjects
Members of the University of Wisconsin-Madison Men’s Swimming Team were recruited to serve in the present investigation, and 32 Ss completed all phases of the testing. The swimmers completed an informed consent document prior to participating in the investigation and it was emphasized that they would be free to discontinue participation in the study at any time. All data were number coded for identification purposes and treated confidentially.

Materials
State anxiety was assessed by means of the state version of the State-Trait Anxiety Inventory (STAI-X) (8). This 20-item questionnaire has well established validity in sport settings (1, 5). All testing was performed under environmentally controlled conditions in a windowless room free of distractions, and it was adjacent to the pool. The room was maintained at 25°C, 45% relative humidity, and a sound pressure level of 48 decibels.

Design and Procedure
The team’s coach identified upcoming meets that were anticipated to be either easy or difficult. Two dual meets were selected and the final scores were 70-45 (easy meet) and 58-55 (difficult meet) in accordance with the coach’s predictions.

Predicted pre-competitive anxiety was assessed for 14 Ss 24-hr prior to the easy meet, and for 18 Ss 48-hr prior to the difficult meet. Each swimmer was instructed to respond in terms of “how you think you will feel 1-hr before the upcoming meet”. The swimmers again completed the state anxiety questionnaire 1-hr prior to both meets with instructions to respond in terms of “how you feel right now at this moment”. Each swimmer also completed the state anxiety questionnaire at the beginning of the season in a non-competitive context, and this assessment was utilized as a baseline for comparison purposes.

The team’s coach rated each swimmer’s performance following both meets and these assessments were made without knowledge of the anxiety scores. The swimmers were assigned one of three ratings and these were: (I) performed better than expected for this point in the season; (II) performed as expected for this point in the season; or (III) performed worse than expected for this point in the season. These ratings were then given a numeric value (4, 3, or 2, respectively) to aid in grouping the swimmers according to relative success. Most swimmers performed in several events during each meet and in these cases the performance ratings were averaged to derive a single value. These values were then used to divide the swimmers into above average, average, and below average performance groups. The mean scores for these groups were 3.97 (SD = 0.07), 3.36 (SD = 0.07), and 2.58 (SD = 0.53) respectively.

While it may be argued that performance ratings based on a subjective assessment (i.e., coach’s ratings) would be inferior to objective measures such as place of finish or performance time, it is our view that a coach’s assessment should be more accurate because it incorporates input based on objective and subjective criteria. That is, a coach’s rating involves objective information such as place of finish and time (i.e., products), as well as subjective factors such as the start, pace, and turns (i.e., process). Also, the coach’s rating could account for factors such as the swimmer’s recent health and training status, as well as additional factors not amenable to quantification (e.g., optimal event selection).

Descriptive statistics and correlation coefficients were computed for all conditions. Pearson product-moment correlations were computed for the predicted and actual anxiety values. Baseline, predicted, and actual pre-competition anxiety scores for the meets were analyzed by means of ANOVA for repeated measures (9).

Results
The mean anxiety data for the baseline and both meets are displayed in Figure 1. Separate analyses with repeated measures ANOVA were performed for both meets and

![Figure 1. State Anxiety Values (± SE) for the Easy and Difficult Meets (* = P < 0.01, ** = P < 0.001).](image-url)
significant main effects were observed for the easy (F = 5.46, P < 0.01) and difficult competitions (F = 38.91, P < 0.001). Comparison of the mean predicted and actual pre-competition anxiety scores did not differ significantly (P > 0.05) for either meet. Significant correlations were observed between the predicted and actual anxiety ratings for both the easy (r = 0.60, P < 0.01) and difficult meets (r = 0.71, P < 0.001). Also the mean pre-competition anxiety level was greater (t = 3.16, P < 0.002) for the difficult meet in comparison to the easy meet.

The pre-competition anxiety scores for the above average, average, and below average groups were found to be significantly greater (P < 0.05) than baseline values for the difficult meet, but in the case of the easy meet, only the average and above average groups experienced a significant increase (P <.05) in pre-competition anxiety. A two-way ANOVA was performed contrasting the actual pre-competition anxiety values for the above average, and below average groups for both meets. No main effect for groups was observed (F = 1.55, P > 0.05) nor was the group by meet interaction significant (F = 0.62, P > 0.05), but a significant main effect for meets (F = 11.99, P < 0.01) did occur.

In an effort to compare the accuracy of the above average and below average groups in predicting actual pre-competition anxiety, the absolute difference score between the predicted and actual pre-competition anxiety (the positive value of predicted minus actual anxiety) was computed for each swimmer in both groups. The mean values for the groups are displayed in Figure 2, and an independent t-test of these scores was significant (t = 3.4, P < 0.05), indicating that the above average group was more accurate in predicting their actual pre-competition anxiety levels compared to the below average group. That is, while the discrepancy between predicted and actual pre-competition anxiety group means did not differ between the above average and average groups (P > 0.05), the above average swimmers were more accurate in predicting pre-competition anxiety when the absolute error between predicted and actual pre-competition anxiety was examined.

Discussion

The results of the present investigation support Hanin's (1) findings with Soviet athletes. This sample of American collegiate swimmers was able to accurately predict 24- and 48-hr prior to competition how anxious they were going to be 1-hr before dual meets. Pre-competition anxiety was higher in the difficult meet compared to the easy meet, and the mean increase in pre-competition anxiety observed in the present group of college swimmers is consistent with that found with college athletes in various sports (5) and elite male (6) and female (7) long-distance runners.

While the predicted and actual pre-competition scores of the above average and below average groups did not differ significantly (P > 0.05) when analyzed via independent t-tests, the above average group was found to be more accurate in predicting pre-competition anxiety (P < 0.05) when the mean absolute difference between predicted and actual pre-competition anxiety was compared. Hence, an individualized approach to investigating anxiety and physical performance demonstrated a relationship between the variables, whereas the approach at the group level did not.

Morgan and Ellickson, (5) have recently reviewed the major theories employed in explanation of the relationship between anxiety and athletic performance. These theoretical views include: 1) drive theory, where increases in anxiety are thought to be associated with improvements in performance; 2) inverted-U theory, where increases in anxiety are viewed as being associated with increases in performance up to a particular point, but if anxiety increases beyond that point performance declines; and 3) relaxation theory, where performance is thought to improve as anxiety is lowered.

Although each of these hypotheses may seem tenable, there is little support for these theories in terms of athletic performance. Investigations designed to test these theories have usually suffered from one or more of the following design problems: 1) non-athlete subject pools; 2) learning (not performance) of novel tasks and 3) performance under controlled laboratory conditions. Investigations showing a relationship between anxiety and the learning of a novel motor task in the laboratory cannot be generalized to the performance of well learned motor tasks in field settings. Thus, the data in support of group theories of anxiety and learning of novel tasks in unskilled non-athletes should not be generalized to the skilled athlete.

The present investigation does not support the relaxation hypothesis because the team displayed significant

![Figure 2: Mean Absolute Difference Scores (± SE) for the Above Average and Below Average Swimmers.](image-url)
(P < 0.05) increases in anxiety prior to competing, and the increase in anxiety was even greater in the case of the difficult meet. The inverted-U and drive theories of physical performance were not supported either since no significant differences were observed in the mean values of pre-competition anxiety between the above average and below average groups, and large differences in individual pre-competition anxiety scores were also observed (range = 28-66).

While the present results suggest that swimmers who can accurately predict their levels of pre-competition anxiety are rated as performing better than swimmers who are less accurate, more work is needed before pre-competition anxiety interventions can be performed utilizing ZOF theory. At this time, the performance effects of manipulating pre-competition anxiety higher or lower than the ZOF are not known. Hence, coaches or psychologists should not routinely attempt to manipulate swimmers’ anxiety levels in an effort to enhance performance. Overarousing or relaxing groups of athletes may worsen performance in some cases, and relaxation strategies can result in paradoxical increases in anxiety, as well as panic attacks in some individuals (2). Also, while elevated anxiety prior to performance may often be due to the competition per se, in some instances the anxiety may be a secondary symptom of an underlying physical or psychological illness. Anxiety is associated with a variety of illnesses, and it has been shown that athletes suffer from psychological problems at the same rate as the general population (4). By routinely treating elevated anxiety as an athletic performance problem, the existence of a serious underlying illness may be ignored. This example reinforces the need for the use of properly trained personnel when performing psychological monitoring or intervention strategies with athletes.

Conclusions
1. State anxiety increased significantly above baseline for both an easy and difficult competition.
2. Actual pre-competition state anxiety was greater for the difficult meet than the easy meet.
3. Swimmers were able to accurately predict their pre-competition anxiety levels 24 to 48 hours prior to competition.
4. Swimmers tended to be more accurate in predicting their levels of pre-competition anxiety for a difficult meet than an easy meet.
5. Swimmers rated as performing above average were more accurate in predicting their pre-competition anxiety level prior to a difficult meet than were swimmers who were rated as performing below average.

References

Breaststroke Economy, Skill, and Performance: Study of Breaststroke Mechanics Using a Computer Based "Velocity-Video" System

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Abstract
The first phase of this study examined the validity of a computer based "velocity-video" recording system. This system directly assessed forward body velocity and corresponding changes in body position while swimming. The velocity values derived from the velocity-video system were correlated with velocity values derived from standard biomechanical film analyses. These variables were found to have a correlation coefficient of 0.95, suggesting that the velocity-video system is a valid method for measuring fluctuations in horizontal velocity during swimming. In the second phase of the study seventeen trained college male (n = 7) and female (n = 10) breaststroke swimmers were used to study the relationship between swimming economy (ml 02/meter/LBW), skill, and performance during breaststroke swimming. Subjects were grouped according to their best 100 yd (91.4m) breaststroke time. Swimming economy was found to vary for male and female swimmers, 0.67 to 0.86 ml 02/meter/LBW and 0.75 to 1.03 ml 02/meter/LBW, respectively. Analysis of the velocity-video recordings for breaststroke indicated that during sub-maximal swimming the "superior" swimmers spend a greater amount of time during the glide and leg recovery phases of the breaststroke cycle, thereby covering a greater distance per stroke cycle than the less talented swimmers (P < 0.05). The results of this study indicate that the velocity-video system is a practical and valid method of evaluating swimming technique through the analysis of intrastroke velocity fluctuations.

Introduction
The application of propulsive force in swimming results in velocity fluctuations within a stroke cycle (9,10,11). In breaststroke, for example, the arm pull and leg kick result in acceleration. In contrast, the glide, the arm recovery, and the leg recovery result in deceleration. The potential to improve stroke efficiency can be increased if the coach is given immediate and reliable feedback of the changes in body position during the stroke cycle. In this light, a computer based "velocity-video" system for simple and rapid analysis of swimming technique has been developed (3). The purpose of the following investigation was (1) to validate the velocity-video system as a method for assessing swimming velocity, and (2) to illustrate the application of the system by examining the relationship between swimming economy, mechanical skill, and performance among "superior" and "good" breaststroke swimmers.

Methodology
The velocity video system has previously been described by Costill et al. (3). Briefly, this system consists of a "swim-meter" (5), video camera, Apple Ile computer, Microkey overlay system, video camera recorder, and monitor. The swimmers wear a belt around their waist, which is attached a fine stainless steel wire. As the swimmer moves through the water the wire is pulled from the swim-meter, thereby driving a DC generator wheel, which produces voltage in proportion to the swimmer's instantaneous velocity. The voltage output is then con-
ditioned and relayed into the computer. An underwater video image is recorded using a VHS or beta camera. The video output is fed into the computer and processed by the Microkey overlay system. A software program allows for the velocity recording to be displayed and synchronized with the swimmers movements.

To test the accuracy of the instrument, velocity measurements obtained from the velocity video system were compared to the velocities calculated from biomechanic film analysis. A breaststroke swimmer was filmed simultaneously with a 16 mm Locam camera and a video camera from an underwater viewing window. A light, which was in sight of both cameras, flashed as the swimmer entered the field of view. This allowed for synchronization of the two cameras so that comparison of velocities from the same breaststroke cycle could be made. A sonic digitizer interfaced to a VAX computer was utilized to reduce the 16 mm film data. The belt point (swimmers waist) was digitized every second frame for one breaststroke cycle. The forward velocity of the swimmer, as measured at the belt point, was computed via a computer program. The velocity graph from the video system was printed out on graph paper, time matched and correlated to the velocity-time curve obtained from digitized film.

**Breaststroke Economy, Skill and Performance**

Seventeen trained college male and female breaststroke swimmers (nine "superior" and eight "good") participated in this study. Subject characteristics are presented in Table 1. The swimmers were grouped according to their best 100 yd performance time (Table 1).

| Table 1. Characteristics of male and female breaststroke swimmers (mean ± SE). |
|---------------------------------|-----------------|-----------------|--------------|-----------------|
| Age (yrs) | Height (cm) | Weight (kg) | %Body Fat | VO<sub>2</sub> Max (L/min) | Best Perf. (seconds/100 yd) |
| Males: | | | | | |
| Superior | 20.3 | 181.8 | 75.9 | 11.1 | 4.26* | 59.96* | 130.97* |
| | (0.8) | (5.8) | (4.9) | (2.70) | (0.06) | (0.41) | (1.38) |
| Good | 19.3 | 182.0 | 75.3 | 11.7 | 3.91 | 57.33 | 149.33 |
| | (0.9) | (1.0) | (3.8) | (0.05) | (0.05) | (0.59) | (2.90) |
| Females: | | | | | | |
| Superior | 19.4 | 165.8 | 62.0 | 22.3 | 3.08 | 71.80* | 157.60* |
| | (0.4) | (1.5) | (3.4) | (1.7) | (0.26) | (1.10) | (4.70) |
| Good | 18.8 | 167.0 | 63.6 | 23.0 | 3.86 | 80.10 | 175.40 |
| | (0.2) | (2.3) | (2.1) | (1.4) | (0.12) | (1.10) | (2.00) |

*P < 0.05 between the superior and good breaststroke swimmers.

Estimates of oxygen uptake during a 400 yd (365.8 m) submaximal breaststroke swim were determined from 40 sec gas collections taken immediately after the swim (4, 12). A series of computer controlled lights on the bottom of the pool were used to aid in pacing the swimmer. Males performed at 1.02 m/s and females at 0.92 m/s. In order to gauge the swimmer’s economy oxygen uptake was expressed in the following relative units; ml 02/meter/LBW. A blood sample was drawn one minute post exercise for lactate determination (2), giving an indication of the metabolic demand of the swim. Heart rate was monitored every 15 sec during the swim using radiotelemetry (Quantum XL monitor).

To determine the swimmer’s VO<sub>2</sub> max, respiratory gas was collected after an all-out swim. The swimmer’s stroke distance was determined from mean swimming velocity (m/sec) and the mean time required to complete one stroke cycle. It was assumed that the swimmers who covered the greatest distance per stroke, at a constant velocity, were the most efficient (5).

Velocity curves and video recordings were obtained while the swimmers performed a series of 25yd (22.86m) swims at different velocities. A series of computer controlled lights were used to pace the subjects at the various speeds, 0.8, 0.9, and 1.0m/s. Since the swimmers were not able to keep perfect pace with the lights the actual speed of the trials was determined using the software developed for the velocity-video system (Ball State University, Human Performances Laboratory). In order to make comparisons of stroke mechanics between the superior and good swimmers for the male and female groups, a common velocity for analysis was selected: males, 0.97 ± 0.02 m/s; for females, 0.92 ± 0.03 m/s.

The velocity data for one breaststroke cycle was divided into propulsive (arm pull and leg kick) and non-propulsive phases (glide and leg recovery; Figure 1). To provide some insight on movement economy the following variables were examined: 1) distance per stroke, 2) peak and minimum velocities within the stroke cycle (Figure 1), 3) time spent and distance traveled (Displacement Index,
DI (meters)), during the propulsive and non-propulsive phases of the breaststroke cycle. Displacement was determined by measuring the area (Hi Pad digitizer; Houston Instruments, DT-11A) under the velocity time curve.

Statistics
Mean, standard error, and correlation coefficients were determined using conventional statistical methods. A student's t-test was applied for statistical comparison between the "Superior" and "Good" breaststroke swimmers. Level of significance was set at the 0.05 level.

Findings
Validation. The breaststroke velocity-time profiles of the two systems (video and film) are shown in Figure 2, \( r = 0.95 \).

Swimming Economy, Skill, and Performance in Breaststroke:
Mean values (± SE) for performance time, oxygen uptake, heart rate, distance per stroke and stroke rate for the submaximal and maximal swims are presented in Tables 2 and 3, respectively. Lactate values (mM/1) for the submaximal effort are also presented (Table 2). In terms of 1 02/min, the superior male swimmers had a significantly greater oxygen uptake than the good swimmers (\( P < 0.05 \)). No significant differences in maximum oxygen uptake between the superior female and good female swimmers was observed. During the maximal 365.8m swim, no statistical differences in mean stroke rate (SR) and distance covered per stroke (d/s) between

| Table 2: Mean (± SE) values for oxygen uptake (1/min, ml O₂/m/LBW), stroke rate (SR, sec/stroke), distance per stroke (d/s, meters/stk), heart rate (HR, bt/min) and lactate (mM/1, during 400yd (365.8m) submaximal swim (males, 1.02 m/s; females, 0.92m/s). |
|-----------------|--------|----------|--------|--------|--------|
| Males:          |        |          |        |        |        |
| Superior        | 3.10   | 0.17     | 2.29   | 1.13   | 143.0  | 1.85*  |
|                 |         | (0.01)   | (0.14) | (5.6)  | (0.39) |
| Good            | 3.20   | 0.24     | 1.97   | 1.70   | 150.0  | 4.49   |
|                 |         | (0.06)   | (0.18) | (5.0)  | (0.36) |
| Females:        |        |          |        |        |        |        |
| Superior        | 2.40   | 0.11     | 2.02   | 1.83   | 164.0  | 3.59   |
|                 |         | (0.05)   | (0.16) | (5.0)  | (1.11) |
| Good            | 2.38   | 0.05     | 1.89   | 1.73   | 173.4  | 3.96   |
|                 |         | (0.04)   | (0.07) | (3.6)  | (0.53) |

\*P < 0.05 between superior and good breaststroke swimmers.

| Table 3: Mean (± SE) values for oxygen uptake (1/min, ml O₂/min/LBW) stroke rate (SR, sec/stroke), distance per stroke (d/s, meters/sec), heart rate (HR, bt/min) during 400yd maximal breaststroke swim. |
|-----------------|--------|--------|--------|--------|--------|
| Males:          |        |        |        |        |        |
| Superior        | 1.18   | 0.01   | 4.26   | 3.47   | 1.55   | 1.82   | 170.8 |
|                 |         | (0.06) | (0.23) | (0.26) | (5.7)  |
| Good            | 1.08   | 0.02   | 3.91   | 1.80   | 1.40   | 1.30   | 175.0 |
|                 |         | (0.05) | (0.10) | (0.08) | (2.5)  |
| Females:        |        |        |        |        |        |        |
| Superior        | 1.00   | 0.02   | 3.08   | 3.20   | 1.51   | 1.50   | 185.2 |
|                 |         | (0.26) | (0.10) | (0.08) | (1.7)  |
| Good            | 0.96   | 0.01   | 2.86   | 1.80   | 1.37   | 1.40   | 186.6 |
|                 |         | (0.12) | (0.08) | (0.08) | (2.2)  |

\*P < 0.05 between superior and good breaststroke swimmers.

the superior and good swimmers (males and females) was observed. Significant differences were not observed in swimming economy (ml 02/meter/LBW) between the superior and good male and female breaststroke swimmers (Table 2). There was a 14% difference in mean d/s values between the superior and good male breaststrokers during the submaximal effort. For females, a 6.5% difference in d/s between the superior and good swimmers was noted. A statistically significant difference in d/s, however, was not obtained. Although there was a lower HR value for the superior male and female compared to the good male and female swimmers during the submaximal effort, statistical significance was not reached. Lactate values were significantly lower in the superior compared to the good male swimmers: 1.85 ± 0.39 mM/l versus 4.49 ± 0.86 mM/1, respectively, at a given speed.

Velocity Time Curves
The Displacement Index (DI, meter) for the arm recovery (A) and leg recovery (LR) phases were significantly greater in the superior compared to the good male breaststroke swimmers at a given speed (0.97 ± 0.02 m/s; Table 4). There was no significant difference in displacement between the superior and good males during the kick (K) and glide (G) phase. Although observable differences in displacement were noted during the K,G,A and LR phase, statistical significance between the superior and good female swimmers was not obtained.

Table 5 presents the minimum velocity (MV), peak kick (PK), peak arm (PA) velocities, minimum velocity between PK and PA (MV2). The superior males were found to have a greater PA value than the good males (P < 0.05). No significant differences for any of the velocity points.
Table 4. Mean (± SE) values for area (expressed as a Displacement Index, meters(m)) under the velocity-time curve for breaststroke. Total area (TA), kick (K), glide (G), arm (A), and leg recovery (LR).

<table>
<thead>
<tr>
<th></th>
<th>Velocity (m/s)</th>
<th>Area (m)</th>
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<tr>
<td></td>
<td>TA</td>
<td>K</td>
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<tr>
<td>Males:</td>
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<td></td>
<td>Good</td>
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<td>Females:</td>
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* P < 0.05 between superior and good breaststroke swimmers.
**P = 0.07

Table 5. Mean (± SE) values for peak and minimum velocity points within the breaststroke velocity-time curve. Minimum vel. (MV), peak kick (PK), peak arm (PA), minimum vel. between PK and FA (MV2), drop in vel. from PK (DV; PK-MV2).

<table>
<thead>
<tr>
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<th>Velocity (m/s)</th>
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<td>of 25yd swim</td>
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<tr>
<td></td>
<td>MV  PK  PA  MV2 DVF</td>
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<td>Females:</td>
<td>Superior</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P < 0.05 between superior and good breaststroke swimmers.

There was a significant difference in time spent during the total cycle (TC), arm pull (AP), and leg recovery (LR) between the superior and good male swimmers (Table 6). There was no significant difference between the superior and good male swimmers in time spent during the kick (KP) or glide (GP) phases of the stroke cycle. Significant differences between the superior and good females for the KP, GP, AP, and LR time phases, was not reached. Time spent for the TC phase, however, was significantly greater for the superior female swimmers.

The superior males covered 2.13 ± 0.18 meter per stroke, whereas the good males only covered 1.42 ± 0.10 meters per stroke (P<0.05), a 33% difference (Table 6). The superior female swimmers covered 1.60 ± 0.80 meters compared to 1.39 ± 0.03 meters per stroke by the good swimmers (P<0.05), a 13% difference.

Discussion

Part I. Validation

The results of this investigation indicate that the velocity video system is an accurate method of monitoring horizontal swimming velocity. As noted in Figure 2, a correlation coefficient of 0.95 was obtained between the velocity-time curves derived from the velocity-video system and digitized film. Furthermore, the velocity recordings are synchronized and displayed simultaneously with the video image of the swimmer. This is of practical importance since it allows the coach and swimmer
to identify technical faults and to offer suggestions that may be helpful for improving the swimmer's stroke mechanics.

**Part II**  
Swimming Economy, Skill, and Performance in Breaststroke

Performance in swimming is primarily governed by two factors. The first is the total energy output, a product of aerobic and anaerobic power. The second is technical skill, which is reflected by how much oxygen a swimmer uses to swim a given distance (6, 7, 8). In the present study, VO₂ max for the male and female swimmers varied from 2.52 to 4.36 L O₂/min. The correlation between VO₂ max and best performance time for 400 yd (365.8m), 200 (182.9m) and 100 yd (91.4m) breaststroke was 0.83, 0.88, and 0.87, respectively. These relationships emphasize the importance of aerobic capacity to performance. The high correlation between max VO₂ and performance, however, should not overlook the importance of mechanical skill as a major determinant of swimming success.

The present study measured swimming economy in terms of ml O₂/meter/LBW consumed at a given velocity (males, 1.02 m/s; females, 0.92 m/s). No significant differences in physiological economy between the superior and good swimmers for both the male and female groups was noted (Table 2). This contrasts with previous investigators who have shown a difference in oxygen uptake between swimmers of varied mechanical ability (6, 13). The most interesting finding in swimming economy, however, was the large variation found among the superior as well as the good breaststrokes. Swimming economy for males varied from 0.67 to 0.86 ml O₂/m2/LBW, whereas, for females the range was from 0.75 to 1.03 ml O₂/m2/LBW.

Variations in swimming economy can be attributed to differences in mechanical skill (6, 7). In order to gauge mechanical swimming economy, investigators have chosen to measure the distance covered per stroke at a given velocity (5, 13). The basis being that the swimmer who takes the fewest strokes at a given velocity is mechanically more economical (5). During the submaximal swim, the superior swimmers covered a greater distance per stroke than the good swimmers (Table 3). This suggests that the superior swimmers were more effective in terms of applying force and/or were more streamlined than the less talented swimmers (5, 14). Craig and Pendergast (5) have suggested that swimming at a slower stroke rate would possibly result in reduced local muscular fatigue. This may account, in part, for a lower lactate level for that given speed. The superior male swimmers were found to have significantly lower blood lactate levels than the good male swimmers, 1.85 ± 0.39 and 4.49 ± 0.86 mM.L-1, respectively (Table 2). Although the superior females had a mean lactate value which was 10% lower than the good female swimmers, statistical significance was not reached. Similar findings in lactate values between the superior and good swimmers have also been reported by Holmer (6), who showed that elite swimmers tend to have lower blood lactate levels at a given speed than do less proficient swimmers.

Velocity patterns derived from the video system showed that at a given speed, (0.97 ± 0.02m/s for males, and 0.92 ± 0.03m/s for females), the superior male and female swimmers covered 33 and 13% greater distance per stroke than the good breaststokers, (P <0.05), indicating better mechanical skill (5). A significant correlation between the time spent during the non-propulsive phases of the stroke cycle (glide plus leg recovery) with distance covered during the stroke cycle was found: for males, 0.84; for females, 0.68. It has been suggested that the longer the time of the cycle in the non-propulsive phases the less drag and therefore the lower the negative acceleration (1). It should be noted, however, that the trial performed by the swimmers in this study was a sub-maximal effort and that at the higher speeds the time spent during the glide and leg recovery decreases (1).

The superior male and female swimmers were found to cover a greater distance during the glide phase than the good swimmers, 33% and 20% difference, respectively. The greater distance covered during the glide was not a consequence of generating a higher peak kick velocity, since values were similar between the groups (Table 6). This suggests that the superior swimmers were more streamlined during the latter stages of the arm recovery and during the glide phase of the stroke cycle than the good swimmers.

A correlation of 0.76 between peak arm pull velocity and distance covered per stroke for the male swimmers was observed. This high correlation was not found to exist for the female swimmers. A common trait for both the superior males and females was their ability to cover a greater distance during the arm pull phase of the stroke cycle than the good swimmers (Table 4). Consequently, a high peak velocity and the effective application of force during the arm pull phase of the stroke cycle are important components of stroke efficiency.

The velocity-video system employed in the present investigation is a less complicated and less time-consuming procedure for diagnosing stroke mechanics than traditional biomechanical analysis. Consequently, the coach, swimmer and researcher can evaluate stroke mechanics in a more practical and efficient manner. As a result, the ability to evaluate and correct faults in swimming technique is enhanced.

**References**


The Prediction of Tethered Swimming $\dot{V}_{o2}^{max}$ from $\dot{V}_{o2}^{max}$
On a Biokinetic Swim Bench

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Abstract

The purpose of this study was to develop a regression equation for predicting the maximum oxygen consumption ($\dot{V}_{o2}^{max}$) of an elite swimmer during tethered swimming from the $\dot{V}_{o2}^{max}$ attained on a Biokinetic Swim Bench. Thirteen national and varsity swimmers volunteered to perform tethered swimming (TS) and continuous swim bench (SBC) tests to obtain $\dot{V}_{o2}^{max}$. A stepwise load increase every two minutes was used in both TS (by adding weights) and SBC (by increasing tension). Expired gases were measured every 30s using the Beckman Metabolic Measurement Cart (MMC). $\dot{V}_{o2}^{max}$ and HRmax were higher in TS than SBC ($p<0.001$ and $p<0.005$ respectively). The $\dot{V}_{o2}/\dot{V}_{o2}$ ratio at $\dot{V}_{o2}^{max}$ was lower in TS compared with SBC ($p<0.01$). There was no difference in $R_{max}$ for the two tests. These data suggest that SBC $\dot{V}_{o2}^{max}$ was not a valid measure of TS $\dot{V}_{o2}^{max}$. A positive correlation ($r=0.59$, $p=0.017$) was found between TS $\dot{V}_{o2}^{max}$ (ml$\cdot$kg$^{-1}$$\cdot$min$^{-1}$) and SBC $\dot{V}_{o2}^{max}$ (ml$\cdot$kg$^{-1}$$\cdot$min$^{-1}$). A stepwise regression analysis yielded the following prediction equation (ml$\cdot$kg$^{-1}$$\cdot$min$^{-1}$): TS $\dot{V}_{o2}^{max} = 0.593$ SBC $\dot{V}_{o2}^{max} + 35.8$ ($s_{yy}=4.74$). Although the prediction equation was statistically significant, the correlation coefficient accounted for only 35% ($r^2=0.35$) of the common variance. Therefore, SBC $\dot{V}_{o2}^{max}$ was a poor predictor of TS $\dot{V}_{o2}^{max}$ in elite swimmers.

Introduction

Maximum oxygen consumption or maximum aerobic power ($\dot{V}_{o2}^{max}$) is the most widely used indicator of the endurance potential of an individual (Cardus, 1979; Shephard, 1984). Physiologically, $\dot{V}_{o2}^{max}$ reflects the efficiency of the body to transport oxygen via the circulatory system (central component) and the efficiency of the muscle to utilise that oxygen in the ATP resynthesis process (peripheral component) (Holloszy, 1975; McCafferty and Horvath, 1977; McKenzie et al., 1978).

$\dot{V}_{o2}^{max}$ has been shown to be specific to the mode of exercise performed (Roberts and Alsopough, 1972; Magel et al., 1975; Pate et al., 1978). The more specific the test to the actual exercise, the more accurate the measure of $\dot{V}_{o2}^{max}$ (Bonen et al., 1980; Magel et al., 1975). Tethered swimming (TS) is one such test procedure that has been shown to be both specific to swim trained individuals (Magel and Faulkner, 1967; Magel, 1970), and valid when compared to flume or free swimming (Bonen et al., 1980). However, technical problems can impede data collection in the water environment. It may be advantageous, therefore, to have a dry-land testing device that could be used in a controlled laboratory setting.

The Biokinetic swim bench (Isokinetics, Inc.) was developed as a dry-land training machine for swimmers. The use of this swim bench as a testing device is prevalent in the literature, and has been used to monitor fatigue (Thornton and Flavell, 1981), power output (Costill et al., 1980; 1985), or for prediction of performance, especially in sprint swimming (Sharp et al., 1982). Armstrong and Davies (1981) used the Biokinetic swim bench to predict $\dot{V}_{o2}^{max}$ in age-group swimmers, but no validation was made with TS.

The purpose of this study, therefore, was two-fold: 1) to determine whether swim bench $\dot{V}_{o2}^{max}$ was a valid measure of tethered swimming $\dot{V}_{o2}^{max}$, and, 2) to determine whether $\dot{V}_{o2}^{max}$ elicited by a swimmer when using the Biokinetic swim bench could be used to predict the $\dot{V}_{o2}^{max}$ in a tethered swimming test.
Methods
Thirteen elite swimmers (male = 8, female = 5), signed informed consent forms and were familiarized with the testing procedures. The subjects performed two separate tests to determine $V_{O2\text{max}}$: 1) tethered swimming (TS), and, 2) Biokinetic swim bench ergometry continuous test (SBC).

The TS test required a pulley system allowing the swimmer to remain in a stationary position, yet work in a swimming mode at maximum rate (Bonen et al., 1980). During TS, a marker was placed on the pool floor, over which the subjects were required to swim, and remain in a stationary position. A metal framework was used to hang hoses from the Beckman Metabolic Measurement Cart (MMC) to the mouth piece on the swimmer.

The TS procedure required two separate swims. The first was to determine the maximum tether load (TL_max), where weights (in kilogrammes) were rapidly added to the bucket until the subject was pulled back from the mark. The load was added in 0.25kg increments, with the rest duration between one and two minutes. Following a ten minute test, the subject performed a progressive maximum test until exhaustion (i.e., until the weight bucket touched the base of the TS apparatus). The load progressions were based on the TL_max of each swimmer, and increments were made every two minutes. The TL_max was divided into six loaded progressions. The warm-up load was approximately 1/5 of TL_max (1/5TL_max), followed by increments of 1/6TL_max (load 2 and 3), 1/8TL_max (load 4 and 5), and a final load increment of 1/12TL_max. The freestyle swimming stroke was performed by the swimmers during TS.

During SBC, subjects were strapped to the swim bench to limit body movements, and hand gloves were worn for protection (Figure 1). Stroke rate (SR) was set by a metronome at 76 strokes per minute (spm), but dropped at the higher resistance settings. The SBC SR was based on the mean swimming SR of the swimmers from four varsity swim meets. SBC consisted of a 2 minute warm-up at setting 6 (low tension) followed by a setting increase every 2 minutes until setting 3 (high tension) was reached. A 15 minute rest was taken to reduce the effects of fatigue (MacDougall et al., 1982), followed by a final load at setting 2. An alternate arm pulling action, with an under-arm recovery, was used during SBC.

During the exercise tests, subjects breathed through a low resistance respiratory valve. Oxygen (O2) and carbon dioxide (CO2) were collected and analysed by the MMC, previously calibrated with gases of known concentrations. Physiological measures, including volume of expired air ($V_e$), oxygen consumption ($V_{O2}$), respiratory exchange ratio ($R$) and heart rate ($H_r$), were recorded every 30s. Prior to testing, body fat estimations were performed according to procedures by Yuhasz (1982).

A correlated 't' test was employed to determine whether any significant differences in mean scores existed between the two tests for $V_{O2\text{max}}$ and HR_max, ventilatory equivalent ($V_e/V_{O2}$) at $V_{O2\text{max}}$ and maximum respiratory exchange ratio ($R_{max}$). In addition, a stepwise regression analysis was performed to determine whether SBC $V_{O2\text{max}}$ could predict TS $V_{O2\text{max}}$.

Results
The physical characteristics of the subjects (means ±SE) are shown in Table 1. Presented in Table 2 are the mean TS and SBC scores (±SE) and the 't' test prob-

Table 1. Mean Age, Weight (Wt), Height (Ht), Total Body Fat (TBF) and Lean Body Mass (LBM) of the Swimmers

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Wt</th>
<th>Ht</th>
<th>TBF</th>
<th>LBM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>yrs</td>
<td>kg</td>
<td>cm</td>
<td>(%)</td>
<td>kg</td>
</tr>
<tr>
<td>Women (n = 5)</td>
<td>18±6</td>
<td>64±4</td>
<td>172±4</td>
<td>15±1</td>
<td>54±4</td>
</tr>
<tr>
<td></td>
<td>(0±6)</td>
<td>(1±6)</td>
<td>(3±6)</td>
<td>(1±6)</td>
<td>(3±2)</td>
</tr>
<tr>
<td>Men (n = 8)</td>
<td>19±0</td>
<td>73±1</td>
<td>177±9</td>
<td>7±4</td>
<td>67±7</td>
</tr>
<tr>
<td></td>
<td>(0±6)</td>
<td>(1±1)</td>
<td>(1±8)</td>
<td>(0±5)</td>
<td>(1±1)</td>
</tr>
<tr>
<td>Group (n = 13)</td>
<td>18±8</td>
<td>69±7</td>
<td>175±7</td>
<td>10±3</td>
<td>62±5</td>
</tr>
<tr>
<td></td>
<td>(0±4)</td>
<td>(2±3)</td>
<td>(1±8)</td>
<td>(1±3)</td>
<td>(2±3)</td>
</tr>
</tbody>
</table>

Note: Standard errors shown in parentheses

Table 2. $V_{O2\text{max}}, HR_{max}, V_e/V_{O2}$, Ratio and $R_{max}$ Results for Tethered Swimming (TS) and Swim Bench Continuous (SBC) Ergometry (n = 13)

<table>
<thead>
<tr>
<th></th>
<th>TS</th>
<th>SBC</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{O2\text{max}}$</td>
<td>4±14 (0±6)</td>
<td>2±79 (0±6)</td>
<td>*0.001</td>
</tr>
<tr>
<td>(lit*min⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{O2\text{max}}$</td>
<td>59±4 (0±6)</td>
<td>39±8 (0±6)</td>
<td>*0.001</td>
</tr>
<tr>
<td>(ml<em>kg⁻¹</em>min⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR_max</td>
<td>184 (2)</td>
<td>172 (2)</td>
<td>*0.05</td>
</tr>
<tr>
<td>(b*min⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_e/V_{O2}$</td>
<td>29±1 (1±1)</td>
<td>35±6 (1±4)</td>
<td>*0.01</td>
</tr>
<tr>
<td>$R_{max}$</td>
<td>1±16 (*04)</td>
<td>1±10 (*02)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Note:
Group means shown
Standard error in parentheses
'p' indicates significance of 't' test

A = BECKMAN METABOLIC MEASUREMENT CART
B = TENSION SETTING
C = GAS ANALYSIS HOSE
D = HAND PADDLE ATTACHMENT
E = STRAPPING

Figure 1. Side view of the experimental setup for the Biokinetic swim bench protocol.
abilities for $V_{\text{O}_2, \text{max}}$, HRmax, $V_E/V_{\text{O}_2}$ ratio and Rmax. The mean TS $V_{\text{O}_2, \text{max}}$ was $1.35 \text{ l.min}^{-1}$ or $19.6 \text{ ml.kg}^{-1}$ higher than the mean SBC $V_{\text{O}_2, \text{max}}$ ($p<0.001$).

The mean HRmax was $12 \text{ b.min}^{-1}$ lower in SBC than TS ($p<0.005$). The $0.04$ higher mean Rmax for TS compared to SBC was non-significant, but indicated maximal effort by the swimmers (MacDougall et al., 1982) in both tests. The SBC $V_E/V_{\text{O}_2}$ ratio at $V_{\text{O}_2, \text{max}}$ was $6.5$ higher than the TS $V_E/V_{\text{O}_2}$ ratio ($p<0.001$).

At the lower submaximal loads, as the exercise intensity increased, the TS $V_E/V_{\text{O}_2}$ ratio decreased, but then increased at higher submaximal intensities (Figure 2). An opposite trend occurred during SBC, but the observed muscular tension (motor unit recruitment), elevated the load whereas in TS, the load was elevated by SR and speed of contraction. The isokinetic muscle contraction that occurred during SBC resulted in a longer contractile period (especially at high tension, slow speed settings), as indicated by SR. However, during TS, contraction time became shorter as the load was increased. Furthermore, in accordance with stroke mechanic theories (Counselman, 1971; Barthels, 1978; Counselman, 1981), the application of the hand of the swimmer in a sculling motion at a given velocity results in an exponential increase in force (F). Under these conditions, as the TS test progressed, small increases in motor unit recruitment were adequate to hold the swimmer in a stationary position.

Clausen (1971) states that the optimum ratio of muscle contraction-relaxation (C-R) to facilitate a muscle pump action is $1:0.3$. Once this value has been surpassed, blood pressure and local vascular occlusion reduce muscle blood flow (MBF). The reduction in MBF ultimately inhibits $V_{\text{O}_2, \text{max}}$ (Matsui et al., 1978). In the present study, a high C-R during SBC probably impaired MBF, whereas the muscle pump action during TS would have enhanced it. Thus, increasing $V_{\text{O}_2, \text{max}}$.

TS HRmax was significantly higher than SBC HRmax ($p<0.001$), and mean scores were representative of other trained swimmers (Magel, 1971; Holmer, 1974b; Gergley et al., 1984). According to Rowell (1980), the circulatory response to exercise is proportional to the motor unit recruitment. Greater HRmax scores have been demonstrated in arm-leg work compared with arm work (Bergh et al., 1976; Millerhagen et al., 1983), and during full-stroke compared with legs or arms only freestyle swimming (Holmer 1974a). Therefore, in the present study, the maximal circulatory capacity may have not been met during SBC (Saltin, 1971), resulting in a lower HRmax compared with TS.

The $V_E/V_{\text{O}_2}$ ratio is an index of the efficiency of ventilation (Bhambhrami and Singh, 1985). The ability of $V_E$ to increase is proportionally greater than $V_{\text{O}_2}$ during exercise, primarily due to an increase in anaerobic metabolism (Whipp, 1978; Brooks and Fahey, 1984). Hence it is unlikely that $V_E$ limits $V_{\text{O}_2, \text{max}}$. The $V_E/V_{\text{O}_2}$ ratio for SBC decreased until a deflection point (Figure 2), where it showed a slight increase until maximal levels were reached. This was opposite to the TS $V_E/V_{\text{O}_2}$ and to the data of Bhambhrami and Singh (1985). It has been demonstrated that breathing frequency is synchronised with SR or arm revolutions (Holmer, 1974b; Vokaei et al., 1975). The SBC SR began at 76spm at a low $V_{\text{O}_2}$, then remained at 76spm or dropped towards the end of the test, as the increments in $V_E$ fell during periods of high $V_{\text{O}_2}$. Moreover, the mean TS SR increased from 54spm to 102spm, with $V_{\text{O}_2}$ rising from $0.4 \text{ l.min}^{-1}$ to $5.0 \text{ l.min}^{-1}$ (Figure 3). The deflection point during TS coincided with the dramatic increase in SR, hence $V_E$.

Figure 2. Diagrammatic representation of the changes in ventilatory equivalent ($V_E/V_{\text{O}_2}$) during tethered swimming (TS) and swim bench ergometry (SBC).

Discussion

The mean TS $V_{\text{O}_2, \text{max}}$ score in the present study was in agreement with some previous TS studies (Magel and Faulkner, 1967; Magel, 1970; 1971), but lower than in other studies (Holmer, 1974b) involving elite swimmers. When expressed as an absolute value, the mean SBC $V_{\text{O}_2, \text{max}}$ was higher than previous work (Armstrong and Davies, 1981; Gergley et al., 1984). However, when expressed relative to body weight, SBC $V_{\text{O}_2, \text{max}}$ was lower than other studies (Armstrong and Davies, 1981). In the latter study, the mean weight of the subjects was $55.5 \pm 13.4$ kg, lower than the swimmers in the present study.

The $V_{\text{O}_2, \text{max}}$ for SBC was significantly lower than for TS. During SBC, increased resistance and hence increased
would have increased at a proportionally higher rate than \( V_{O_2} \), thereby reducing the \( V_{E}/V_{O_2} \) ratio. In the present study, therefore, SBC SR imposed a restriction on \( V_{E} \) which increased the SBC \( V_{E}/V_{O_2} \) at \( V_{O_2\text{max}} \), whereas the higher \( V_{E} \) during TS may have enhanced TS \( V_{O_2\text{max}} \) (Figure 3).

The stepwise regression analysis revealed a positive correlation \( (r = 5.59, p = 0.017) \) between TS \( V_{O_2\text{max}} \) and SBC \( V_{O_2\text{max}} \), when expressed relative to body weight. It should be stated that the correlation coefficient \( (r = 0.59) \) represented only 35% of the common variance. The data from the swimmers in the present study produced the following prediction equation:

\[
TS V_{O_2\text{max}} \text{ m}^3\text{kg}^{-1}\text{min}^{-1} = (0.595 \text{ SBC } V_{O_2\text{max}} \text{ m}^3\text{kg}^{-1}\text{min}^{-1}) + 35\text{S} (S_{\text{asy}} = 4.74)
\]

From a practical viewpoint, the standard error of prediction for the equation was too high to be of use for monitoring training progress, due to the low \( r^2 \) value.

The above evidence suggested that SBC \( V_{O_2\text{max}} \) was not a valid measure of TS \( V_{O_2\text{max}} \), this being the result of restrictions imposed by the circulatory and ventilatory systems. In addition, SBC \( V_{O_2\text{max}} \) was not a useful predictor of TS \( V_{O_2\text{max}} \) in swimmers, and where possible, the TS protocol should be used.

**References**


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EDITORIAL STYLE: The author should submit three copies of a manuscript, typewritten and double-spaced with 1 1/2" margins on all edges. A short running title should be repeated at the top right corner of each page followed directly below by the page number. Authors should avoid all information which will identify human subjects.

English will be the language of this publication. As a general rule, only standardized abbreviations and symbols should be used. The first time an uncommon abbreviation appears it should be preceded by the full word or name it represents. The author is encouraged to refer to the Publication Manual of the American Psychological Association, 3rd edition, for editorial style concerning punctuation and abbreviations, construction of tables and figures, presentation of statistical symbols or mathematical equations, and use of standard units of measurement.

Manuscripts should contain the following elements placed in the following order:

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2. ABSTRACT. The abstract (200 words or less) should summarize the study’s purpose, methodology, results, and conclusions. It should include a summary statement that provides some interpretation of the findings and their implications to the on-deck coaching and training of swimmers.

3. TEXT—The text should contain separate sections for the:
   a. Introduction. This section should state the purpose, the rationale, and the essential related literature.
   b. Methodology. This section should include a clear description of the experimental subjects and their controls. The description of the methodology should provide enough detail for others to duplicate the study. References should be provided for established methods and statistical procedures should be supported with rationale.
   c. Findings. The findings presented in the text, tables, and figures should follow a logical and parallel sequence. The statistical significance of appropriate results should be acknowledged.
   d. Discussion. This section should emphasize the study’s important and original aspects while avoiding a repeat of data presented in the findings section.
   e. Conclusion. The author should conclude with explicit conclusions supported by their data. This section of the manuscript is of particular importance to the purpose of the journal. It should be of at least 500 words in length and provide in simple, laymen terms, an interpretation of findings and implications to the on-deck coaching and training of swimmers.

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