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D. A. Tanner

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THE JOURNAL OF SWIMMING RESEARCH

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"The truth is out there....."

Life can be confusing at times in these last days of the 20th century. It seems as if it is becoming ever more difficult to determine what is the truth about anything. It's not that we as a people or culture no longer value the truth. Telling the truth is one of the first social constructs taught in virtually every culture and every society. Parables and allegories from early childhood repeatedly emphasize the importance of telling the truth. The truth is sacred and that which lies at the center of every enduring intimate relationship. Despite all this, it is getting to the point where all too frequently the truth has taken on qualitative traits. There are degrees of truth. The truth appears to be for sale, or the truth is not always what it is advertized to be.

What does my musing about the truth have to do with The Journal of Swimming Research and the science of swimming you ask? It provides me with an opportunity to express several timely opinions. First, science and scientists, above all else, should be of, and about, the truth. An elaborate system consisting of multiple reviewers and referees, editors, associate editors, and publishers has evolved within the scholarly community to help identify, promote and permit communication of the truth. As cumbersome as it may be, if everyone does his or her job well, (and with a little luck thrown in), a manuscript expressing a reasonable version of the current truth is produced. At stake are credibility and reputation, two of the most valued assets of any individual, certainly any good scientist. But in the end, the truth should be in plain sight.

Secondly, much of this effort is accomplished with little or no monetary reward involved. At most, these volunteers consider their contribution professional service. At its least, the contributed hours are considered pay back in order to balance the positives accrued through years of participation within the sport. A heartfelt thanks goes out to all those who were involved in the process which culminated in the issue you are currently holding in your hand. Truth be praised!

Finally, something needs to be said about capitalizing from the truth. This more than anything else, in my view, is the primary cause for the lack of clarity concerning swimming truths today. Because of the dependence upon Corporate America's dollar, the truth is sometimes filtered, not by those who discover or pursue the truth, but by those who wish to market it. Or worse, our administrators and executives suppress the truth so as not to dissuade potential sponsors. By our attorneys and our accountants, the truth is doctored, so as not to jeopardize binding, legal, or financial obligations. And finally, our coaches and our elite athletes sell the truth in as many versions as the current market will bear. And all of this is permissible for when it comes to dollars and cents, it's easy to rationalize. But if there is a lack of direction, a dearth of perceived leadership within the national and international competitive-swimming community, it is because the truth has been sold and resold such that unquestioned credibility and esteemed reputation are as hard to identify today as is the truth. The truth is intrinsic, essential, and inherent. It should be unaffected by contracts or potential sponsorship and should be independent of endorsement value. As we move into the 21st century, competitive-swimming must chart its future carefully so as not to lose sight of its truths.

Which brings us to the current issue of the JSR. This issue is a wonderful blend of topics, diverse in nature and of wide interest. Topics range from recovery protocols... to freestyle and butterfly turns, and from potential benefits of workshops focusing on pre-race strategies... to the age of women swimmers. In addition, another tremendously useful installment of "In print" is included. Once again, our appreciation is extended to all authors, co-authors, reviewers, associate editors, sponsors, the ASCA leadership and membership for their support and varied contributions. As always, your input is appreciated and until next time, I challenge you to engage your colleagues in debate concerning the truth(s) which hopefully lie here within.

J. M. Stager
Fall 1997

Correction to Vol. 11 Fall 1996 of The JSR

The sequence of authors for the manuscript entitled "Recovery from maximal swimming at the predicted onset of blood lactate accumulation" was listed incorrectly on the front cover and also on the first page of the manuscript. The correct sequence is as follows:

M. T. Richardson, K. F. Rinehardt, N. Bouchier, D. Zoerink, M. Cordill, and C. Latham
Swimming performance following different recovery protocols in female collegiate swimmers

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Abstract

This study was designed to compare lactate levels and subsequent swim performance following a maximal swim using three different recovery protocols: swimming; rowing; and passive rest. Female participants from a Division III swim team (N = 10) were tested under each recovery protocol. Experimental sessions were separated by at least one day. Each session consisted of two maximal effort 200-yd freestyle swims, separated by 14 min of recovery. The 14-min recovery period was broken into three sections: 2 min to prepare for the recovery, 10 min of active/passive recovery, and 2 min to prepare for the second trial swim. Variables measured were blood lactate concentrations across time and the time difference between trial swims. Blood samples were drawn pretest and at 2, 7, and 12 min during the recovery period. Significantly (p < .05) lower mean lactate levels and smaller mean time differences were reported for swim recovery as compared to passive rest. No significant (p > .05) difference was reported for mean lactate levels and mean time differences between swimming and rowing recovery. In conclusion, recovery that incorporates exercise, regardless of mode, appears to be more effective in maintaining performance than passive rest.

INDEX TERMS - Anaerobic, post-exercise, blood lactate, exercise recovery

Introduction

Competitive swimmers may be required to swim successive events that are separated by short time intervals. Repeated events lead to elevations in plasma lactate levels (18). Repeated events lead to elevations in plasma lactate levels as well as other metabolic and physiological disturbances which may adversely affect subsequent performance (7, 18). The need to hasten recovery and restore metabolic capacity is crucial.

The recovery from lactate accumulation is a time related event (9, 11). Researchers studying cycling and running have demonstrated that active recovery hastens the rate of lactate removal following maximal exercise (1, 3, 5, 16).

High lactate concentrations following an initial event may be one factor leading to poorer performances in subsequent events. Lactate accumulation may only be a marker or reflection of multiple metabolic disturbances which accompany intensive exercise. Nevertheless, the restoration of metabolic equilibrium or homeostasis may favorably impact subsequent performance. Aerobic exercise during recovery from bouts of high intensity cycling, running, and swimming has been clearly shown to impact on the rate of lactate removal (1, 3, 5, 10, 11, 16). However, limited evidence exists demonstrating that active swimming recovery following maximal swimming reduces the decrement in subsequent performance.

McMaster et al. (10) examined the effect of passive recovery versus an active aerobic swim recovery on blood lactate levels. A 20-min swimming recovery was performed after a maximal swim. Active swimming decreased the time needed to return lactate levels back to resting levels as compared to recovery consisting of passive rest (10). Siebers and McMurray (15) found that a 15-min swim recovery led to lower blood lactate levels than a similar period of walking; however, performance in a subsequent 200-yd freestyle event was similar between the two recovery protocols. The amount
of muscle mass that is active during the recovery will have a
direct impact on the uptake of lactate by skeletal muscle (1, 6,
15, 19). Siebers and McMurray (15) indicated that the speed
maintained by the subjects during walking recovery did not
allow the subjects to recruit as many large muscle groups as
during the swim recovery.

Since there has been limited attention given to the effect of
different types of recovery on subsequent swimming
performance, research is needed to determine the appropriate
recovery protocol, specific to swimming, that facilitates the
best performance in subsequent swimming events. In this
study, swimming and rowing recovery protocols were
compared to passive rest. Rowing was chosen as an
alternative recovery protocol since it is an activity that
involves large muscle mass and can be done pool side using
a rowing ergometer. This may be an important alternative
activity particularly if a warm-down pool is not available.

Our working hypotheses were then: Both active recovery
protocols (swimming and rowing) were expected to result in
less decrement in performance in a subsequent swimming
event, in comparison to passive rest recovery. No difference
in the subsequent event time was expected following
swimming recovery as compared with rowing recovery. And
finally, lactate concentrations were expected to be lower in
swimming and rowing recovery than following passive
recovery.

Methodology

A repeated measures design was used to determine the
differences across recovery protocols and the impact of each
recovery protocol on lactate levels and subsequent swimming
performance. Subjects were tested under three recovery
protocols: swimming recovery, rowing recovery, and passive
rest recovery. Mean blood lactate levels were compared
across the three recovery protocols at rest and at 2, 7, and 12
min into each recovery period. The differences in time
between the two 200-yd time trials, separated by the recovery
period, were compared across the three recovery protocols.

Subjects

The subjects in this study were 10 female swimmers, from
a NCAA Division III varsity swim team. There were 2
seniors, 3 juniors, 2 sophomores, and 3 freshmen. Their best
times for the 200-yd freestyle ranged from 1:57.48 to 2:11.48
(min,sec). Prior to testing, subjects were provided with
written and verbal instructions regarding testing procedures.
Subjects completed a written consent form and a medical
history form prior to testing. All methods and procedures
were approved by the Institutional Review Board of
Springfield College.

Subjects recorded dietary intake in list form prior to and
during the days of exercise testing. Each subject was
instructed to attempt to duplicate dietary intake the day prior
to and the day of each testing session.

Apparatus

The research was conducted at the Springfield College
swimming complex. All testing procedures were conducted
in the short course, 25-yd, competition pool. A Concept II
Model C rowing ergometer, from Concept II, Inc., Morrisville
VT, was used for the rowing recovery protocol. A 3-mm
automated lancet was used, by the researcher and research
assistant, to draw blood, via capillary puncture. The Original
Mini Hand Warmer, from Grabber Warmers, Grand Rapids,
MI, was used to heat the finger prior to blood extraction.
After the swim trial, it took approximately 15-20 sec to obtain
the blood sample.

Measurement Instruments

The metabolic variable measured was blood lactate. Lactate
concentrations were measured using a 1500 YSI Sport Lactate
Analyzer (Yellow Springs, OH). The 1500 YSI Sport Lactate
Analyzer was calibrated according to the specifications of the
manufacturer prior to the testing of each subject. Heart rates
were monitored with a portable Polar Vantage XL Pulse
Monitor (Stamford, CT Model #43900). Times for each trial
swim were measured using the Colorado Timing System 4
(Colorado Timing, Colorado Springs, CO).

Testing Procedure

Testing was conducted on three separate days, with at least
one day between testing sessions. Two 200-yd freestyle
events separated by 14 min were swum by each subject at
each session. Subjects were verbally instructed to perform a
maximal effort for each trial swim. The 200-yd freestyle is a
common competitive event at the collegiate level. Performance in an event of this duration has the potential to
be adversely affected by muscle fatigue associated with
elevated blood lactate levels. The 14-min recovery protocol,
while representative of a short rest period for collegiate meets,
was chosen to maximize the possible effects of metabolic
disturbances on a subsequent swim event. Maximal lactate
values are usually obtained within the first 5 minutes
following an all-out effort (4,11,16).

The testing procedures were conducted in the following
manner. Resting blood lactate measures were taken prior to
the warm-up activity after each subject sat quietly for 5 min.
Swimmers performed a typical meet warm-up of 2000-yd.
The warm-up activity was identical, by subject, for each
testing session. The warm-up period was followed by a 10-
minute rest period. The subject performed the first 200-yd time
trial, following the 10-minute rest period.

Subjects were randomly assigned to one of the six possible
sequences for completing the three recovery protocols. Since
10 subjects were tested, 4 of the orders were used twice.

Swimming recovery velocities were 65% of the lifetime best
velocity for each subject on the 200 yd freestyle. This
velocity has been found to be optimal for facilitating lactate clearance(4,10). Stopwatch time checks and large pool side pace clocks were used to verify recovery velocities. A research assistant walked on deck to oversee that each of the subjects maintained the appropriate velocity. Prior to testing, subjects were educated on individual pacing techniques specific to calculated recovery swim velocity for each subject.

The intensity for the rowing ergometry recovery protocol represented 60% of the age-predicted maximal heart rate of the subject. The age-predicted maximal heart rate was calculated by subtracting the age of the subject from 220 (220-age). Heart rates were monitored for the 10-min recovery period. Intensity was adjusted to maintain the allocated workload. For the passive recovery protocol each subject was seated in a chair at pool side. Towels were available for warmth during the recovery period.

The recovery session was broken into three sections. The first 2 min allowed for each of the subjects to be positioned at the appropriate recovery modality. The following 10 min was designated for the recovery protocol. The remaining 2 min allowed for each of the subjects to prepare for the second 200-yd swim. The second time trial was conducted 14 min after completion of the first time trial. Each testing session was identical except that the type of recovery used was varied.

Prior to each testing session the YSI blood lactate analyzer was calibrated according to the guidelines of the manufacturer. Blood lactate values were obtained four times: after a 5-min rest period prior to the warm-up activity, 2 min after the first time trial, 7 min into recovery, and at 12 min (representing the end of the active recovery period). Subjects were stopped for about 45 s to 1 min, during active swimming and rowing ergometry recovery to allow for blood extraction. Blood was drawn from a peripheral finger stick using a 3-mm automated lancet. The finger was pre-warmed for 15 s prior to each blood extraction.

Statistical Analysis

A 3 x 4 (3 recovery protocols and 4 testing times) repeated measures factorial analysis of variance (ANOVA) was computed to compare lactate levels. If a significant main effect for testing time was reported, a polynomial trend analysis was calculated which analyzed the data for potential linear and curvilinear patterns in lactate levels over the recovery period. If a significant interaction effect was found, a simple effects test for testing time and a polynomial trend analysis for each recovery protocol were calculated.

A 3 x 2 (3 recovery protocols and 2,200-yd swim times) repeated measures factorial ANOVA was computed to evaluate the effect of the recovery protocol on the 200 yd swimming time. A difference contrast was done to compare the three recovery protocols. The repeated measures procedure from the SPSS Windows Statistical Package was used to compute the repeated measures factorial(12). The .05 alpha level was used.

Findings

All data are represented as means ± SD. The present study was conducted to determine the recovery protocol that elicited the least difference in time between two subsequent swimming performances. Lactate levels during the recovery period and the times to complete two consecutive 200-yd freestyle time trials were examined. The subjects averaged in age of 19.5 ± 1.8 years. Subject characteristics may be found in Table 1.

Table 1
Descriptive Statistics for the Subjects (N = 10)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>19.50</td>
<td>1.18</td>
<td>18.00</td>
<td>21.00</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.39</td>
<td>5.92</td>
<td>160.02</td>
<td>177.80</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.09</td>
<td>8.34</td>
<td>59.09</td>
<td>84.09</td>
</tr>
</tbody>
</table>

A one-way repeated measures ANOVA was used to analyze dietary intakes the day prior to each testing session for each recovery protocol. No significant (p ≥ .05) differences were found across each of the testing sessions for total daily calories; grams of carbohydrates, fats, and proteins; and percentage of calories from carbohydrates, fats, and proteins.

Lactate Measures

A 3 x 4 repeated measures ANOVA was used to analyze the data from three recovery protocols and four testing times for lactate levels during the 14-min recovery period. The Mauchly Sphericity test (12) was computed and no significant (p ≥ .05) differences were found in the treatment differences of lactate levels across the three recovery protocols as well as across the four testing times. A significant (p ≤ .05) main effect was found for recovery protocols and a significant (p ≤ .05) main effect was found in mean lactate levels across the lactate testing times.

A significant interaction for recovery protocol by testing time was found for lactate levels [F = 5.04, Table F (6, 54) = 2.29, p ≤ .05]. Graphical representation of the mean lactate levels across the recovery time period may be found in Figure 1. After computing a simple effects test, no significant (p ≥ .05) difference for mean lactate levels was found for the baseline and the 2-min testing time periods. A significant (p ≤ .05) difference was found in the mean lactate concentrations at the 7 and 12-min testing time.

No significant (p ≥ .05) difference was found for the mean lactate level of swimming recovery protocol and rowing recovery protocol at the 7-min testing time. Significantly (p ≤ .05) lower mean lactate levels were found when the rowing recovery protocol and the swimming recovery protocol were compared to the passive rest recovery at the 7-min testing time. Furthermore, the mean lactate value for the passive rest recovery was significantly (p ≤ .05) higher than an average of
both active recovery protocols at the 7-min testing time. In addition, with the exception of the comparison between the rowing recovery and rest (in which there was no difference), the relationship between the lactate response at 12-min was similar to what was observed at the 7-min testing time (see Figure 1).

Further analysis of lactate levels without baseline rest lactate values were computed to determine the trend in the lactate levels over the three testing times during recovery. The mean lactate levels by testing time were tested with orthogonal polynomial analysis and a significant \( (p \leq .05) \) linear trend was found across time periods when the baseline values were eliminated from the analysis. The orthogonal polynomial analysis was used to test the trend of the data for each recovery protocol. A significant \( (p \leq .05) \) linear trend was found for each recovery protocol.

\[ \text{200-ys Swim Times} \]

The mean times and standard deviations for trial 1 and trial 2, and the mean time differences between the trials for each recovery protocol may be found in Table 2. A 3 X 2 repeated measures ANOVA was computed to compare the effect of the three recovery protocols on the time to swim 200-ys. There was no significant recovery protocol by 200-ys swim time interaction but there was a significant main effect for recovery protocol with the time to complete the 200-ys swim being slower following the passive recovery than following either the swimming recovery or the rowing recovery. However, there was no difference in 200-ys times following the swimming and rowing recoveries. The time to complete the second 200-ys was significantly slower than the first \( (138.02 \pm 7.04 \text{ vs } 136.89 \pm 7.28 \text{s}) \) \( (p \leq .05) \) (See Table 2).

\[ \text{Discussion} \]

The most important observation of this study was that active recovery, regardless of the exercise mode, was more effective than passive recovery following a maximal swim. During the swim recovery, lactate concentrations were lower and faster
Table 2
Means and standard deviations for trial times and time difference between trials (N= 10)

<table>
<thead>
<tr>
<th></th>
<th>Swimming</th>
<th>Rowing</th>
<th>Passive Recovery</th>
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<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>137.27</td>
<td>136.10</td>
<td>137.29</td>
</tr>
<tr>
<td>SD</td>
<td>7.23</td>
<td>6.84</td>
<td>7.99</td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>137.27</td>
<td>137.09</td>
<td>*139.71</td>
</tr>
<tr>
<td>SD</td>
<td>7.16</td>
<td>6.78</td>
<td>7.71</td>
</tr>
<tr>
<td>Time Difference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2 - T1 Mean</td>
<td>0.00</td>
<td>.99</td>
<td>*2.42</td>
</tr>
<tr>
<td>SD</td>
<td>1.36</td>
<td>1.64</td>
<td>2.54</td>
</tr>
<tr>
<td>Lifetime Best 200- yd Swim Times</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>126.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>4.41</td>
<td></td>
<td></td>
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</tbody>
</table>

All values are in seconds. * = Passive recovery slower than swimming or rowing recovery (p ≤ .05).

Times were recorded in a subsequent 200-yd time trial, as compared with the prior 200-yd time trial, when compared to passive rest. Furthermore, rowing and swimming recovery resulted in equal times in a subsequent swimming event and similar lactate levels after 14 min of recovery. Researchers (2,4,10,19) have reported that blood lactate reduction during recovery is magnified by moderate submaximal exercise following a maximal effort. Moderate aerobic exercise during the recovery period promotes a continuous steady blood flow to the liver and kidney where lactate is converted to glucose via gluconeogenesis (14). Furthermore, the heart has the capacity to utilize lactate as a fuel source (13).

The amount of reduction in lactate over a recovery period will primarily depend on the intensity of the recovery (3,6), and the amount of muscle mass that is active (1,6,15,19). The intensity of the activity during the recovery period optimal for lowering blood lactate concentrations are specific to the individual. Stamford et al.(16) found that recovery intensities below the lactate threshold promote lower blood lactate concentrations during recovery when compared with intensities above the lactate threshold (16).

The intensity of the swim recovery in the current investigation was the same as that used by Cazorlita et al. (4) and McMaster et al. (10) who found that, following maximal swimming performance, a velocity representing 65% of the maximal swimming velocity is optimal for facilitating lactate clearance. Cazorlita et al. (4) suggested that this velocity is well below the lactate threshold in trained competitive swimmers. Furthermore, as long as the intensity is below the lactate threshold, disappearance will be optimal.

The impact of recovery on subsequent swimming performance following a maximal effort exercise is relatively unexplored. Swimming often requires athletes to compete in various events with limited rest periods. Active recovery during a recovery period promotes the least decrement in subsequent performance (17,19). Siebers and McMurray (15) reported no difference in walking and swimming recoveries on subsequent performances. They did observe a significant difference in lactate levels, which suggests that lactate levels had a limited impact on subsequent performance (15).

The current research is in agreement with the study conducted by Siebers and McMurray (15) in that active recovery, by either swimming or rowing, elicited equal performance in subsequent swimming events. However, passive rest recovery resulted in significantly slower times in a second 200-yd time trial than the swimming recovery protocols. The lactate concentrations following the passive rest recovery were almost two times greater than those in the swimming recovery. This implies that lactate concentrations may have a larger role than Siebers and McMurray (15) suggested.

In conclusion, swimming recovery produces a smaller decrement in subsequent swimming performance as compared to passive rest, perhaps due to an enhanced lactate removal. Rowing recovery and swimming recovery prevent a decrement in subsequent swimming performance and promote similar lactate concentrations following a recovery period. Furthermore, swim recovery results in lower lactate concentrations than passive rest recovery.

Applications
Based upon the findings of this study, it is recommended that coaches convey to their athletes the importance of an active recovery during recovery periods. Peak lactate levels reflect metabolic status within 5 minutes following the completion of maximal exercise. Following this, active recovery leads to a linear reduction in lactate levels. The findings of the current study are particularly important to the swimmer who may be required to compete with limited rest intervals between events. Maximizing these rest intervals psychologically will have a significant impact on the success of subsequent swimming efforts that are held on the same day. In situations where space is not available for swimming recovery during competition, rowing recovery at an intensity that represents at least 60% of the age-predicted maximum heart rate (i.e., 220-age) of the individual swimmer produces similar results to swimming recovery, and may be a valid substitute. Swimmers are encouraged to experiment on their own to determine the optimal intensity to use. However, this research reinforces previous findings that an effective intensity for swimming recovery is 65% of maximal velocity. If at all possible, a period of swimming recovery within the specified range (i.e., 65% max velocity) is preferred to being passive.
Finally, many small colleges and YMCA facilities only have 6 to 8 lanes with no warm-down swimming facilities. Swimmers competing in these facilities would benefit from an alternate recovery protocol. Coaches are encouraged to determine which alternate recovery protocol apart from swimming, may be appropriate for their facility.

Acknowledgments

The authors thank Kelly Clemente for her assistance during data collection. We would also like to thank those members of the Springfield College swim team who participated in this study.

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References

A kinematic and kinetic analysis of the freestyle and butterfly turns

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Australia

Abstract

Swim turns represent an integral factor in determining the final outcome of a swimming race. The aim of this study was to provide a comprehensive analysis of the kinematic and kinetic parameters which affect the turning performance of elite swimmers in a freestyle flip turn and a butterfly turn. Four butterfly (age: 21.3 ± 2.6 yrs; height: 1.85 ± 4.13 m; weight: 82.6 ± 1.9 kg) and three freestyle (age: 19.0 ± 1.0 yrs; height: 1.88 ± 9.42 m; weight: 77.5 ± 3.6 kg) elite male swimmers performed seven complete turns with key kinetic and kinematic variables recorded for each turn. The kinetic analysis was performed using a 3D Kistler force plate mounted on the wall under the starting block. The kinematic analysis was performed through the use of the Kinex Swimming Analysis System which involved underwater and above-water video analysis of the approach, push-off and glide phases of the turn. Due to the limited subject population, the analysis was restricted to descriptive statistics of means and standard deviations for each of the kinetic and kinematic variables. A comparison of the present results demonstrated that the butterfly turn exhibited a greater average impulse (369.1 ± 35.4 vs 247.3 ± 29.0 Ns) and peak force (1406.7 ± 117.2 vs 1345.3 ± 236.5 N) and a longer average time on the wall (0.40 ± 0.03 vs 0.29 ± 0.05 s) than the freestyle turn. This longer time on the wall for the butterfly turns led to a slower push-off speed (1.33 ± 0.11 vs 1.47 ± 0.19 m/s) compared to the freestyle turns. Despite the case study approach, it was demonstrated that the collection of the kinematic and kinetic variables used in this study allowed a more comprehensive analysis of the freestyle and butterfly turns.

INDEX TERMS - Swimming, Biomechanics, Hydrodynamics

Introduction

Turning in a swimming race can comprise over a third of the total event and, therefore, is an integral factor in determining the outcome in a sport where hundredths of a second can separate placings (6). Improvements in turn times can lead to substantially improved event times. This is especially so in short course (25 m or yd pool) competitions and for longer freestyle events where the average velocity-out from the wall significantly correlates with the event time (3). Despite the obvious importance, and the availability of anecdotal evidence to that fact, there has been a paucity of quantitative research conducted on this aspect of competitive swimming. This is especially apparent for turns other than the freestyle turn.

Differences in the distances between the commencement and completion of turns have made direct comparisons between studies difficult. Previous research has represented the turn with respect to the timing of the stroke (3). For example, the distance-in was taken from the last hand entry before the wall and the distance-out was at the end of the first stroke (5,3). The turn has also been defined with respect to the fixed arbitrary distances of 3m in to 6.5m out (12), or 5m in until 5m out (7). In addition, the Australian Institute of Sport adopted a definition of 7.5m in until 7.5m out to encompass the turn preparation, rotation, gliding and stroke preparation phases of the turn.

Early research in this field of swimming performance has typically involved the comparison of times taken to perform different turning techniques (4,10). More recently, studies have collected kinematic and kinetic data (11,5,6,1,2). However, these studies have usually lacked a comprehensive analysis of the kinematic parameters associated with turning performance. In addition, the evolutionary changes in techniques and turning rules have resulted in a dearth of knowledge of the kinematic profile for the different turns currently employed in competition.

Of the few researchers investigating aspects of the kinematic profiles of the turn, Takahashi et al. (11) examined the range of knee flexion that occurred during push-off in a flip turn, and reported no significant difference between the elite and recreational swimmers. Further, Huehlhorst et al. (6) analyzed the displacement and velocity characteristics of the center of gravity in a breaststroke turn using eight elite swimmers. This pilot study demonstrated a high degree of similarity in the displacement curves despite individual differences in turning technique. Chow et al. (3) also investigated selected kinematic variables of the turning technique employed by elite swimmers in the 1982 Commonwealth Games. These variables included the
distance in/out, time in/out, average speed in/out and total turn time. These studies form the total extent of kinematic analysis that have been performed on swimmers during a turn and, as such, many parameters essential to a thorough kinematic analysis of the turn are lacking.

The kinetics of swimming turns have been an area which has undergone more substantial research (8,11,1). Takahashi et al. (11) investigated the propulsive forces generated by swimmers during a flip turn and during a push-off the wall for both elite and recreational swimmers. Force profiles were produced with results showing no significant differences in the peak force and duration of push-off between the flip turn and the concentric glide, however the total impulse was significantly higher for the flip turn (11). In addition, the elite swimmers demonstrated greater total impulse and a shorter push-off duration than the recreational swimmers.

Nicol and Kruger (8) employed a time measuring device and underwater force plate to investigate swimming speeds and impulses generated by 5 competent swimmers (4 females and 1 male). The authors reported that the complete turn time for the freestyle flip turn was significantly shorter than that of the open turn (orthodox freestyle turn). No significant difference was discovered between the turns for the return swimming velocity, impulse and duration of impulse, indicating the differences were limited to different turn preparation times. The researchers concluded that the velocity in the flip turn is maintained, but the kinetic energy is converted from forward movement to rotation before push-off.

Blanksby et al. (2) employed force plate and video analysis to determine characteristics of freestyle turns which enhance performance in 17 male and 19 female age (11-13 y.o.) swimmers. A high correlation was discovered between the 50m swim time and 5m round trip time (RTT) and 2.5m RTT, reinforcing the importance of the turns in swimming performance. Results of this study also indicated that high peak forces and low wall contact times were required to reduce the time taken to perform the RTT's (5m in to 5m out; 2.5m in to 2.5m out).

The lack of any comprehensive kinetic and kinematic swimming turn analysis is largely due to problems in designing accurate and reliable equipment for the aquatic environment. The kinematic analysis is also hindered by the lack of a consistent definition of the total turn time, while in the kinetic analysis, the exact time of hand/foot contact is difficult to ascertain due to the presence of a bow wave. The aim of this study was to provide a more comprehensive analysis of both the kinematic and kinetic parameters that affect the turning performance of elite swimmers performing a freestyle flip turn and a butterfly turn. The butterfly and freestyle strokes were chosen as they represent the two current methods of performing a turn, namely, a pivot turn preceded by a hand touch (as in butterfly and breaststroke) or a somersault turn (as in freestyle and backstroke).

### Methodology

The subjects were seven national and international level male swimmers (four butterfliers and three freestylers) between the ages of 17 and 24 years. Subject characteristics for age, height, weight and years of national competition are listed in Table 1. Each subject performed a minimum of seven complete turns at maximum speed in either freestyle or butterfly. These trials were then averaged to allow a typical turn profile of the swimmer to be realized.

<table>
<thead>
<tr>
<th></th>
<th>AGE (yrs)</th>
<th>HEIGHT (m)</th>
<th>WEIGHT (kg)</th>
<th>YEARS OF NATIONAL COMPETITION (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUTTERFLY</td>
<td>21.3 ± 2.6</td>
<td>1.85 ± 0.13</td>
<td>83.6 ± 1.9</td>
<td>5.59 ± 2.56</td>
</tr>
<tr>
<td>FREESTYLE</td>
<td>19.9 ± 1.0</td>
<td>1.81 ± 0.42</td>
<td>77.5 ± 3.6</td>
<td>3.07 ± 1.25</td>
</tr>
</tbody>
</table>

### Kinetic Analysis

The kinetic analysis was achieved through the use of a turning board (designed by GHD Pty Ltd, Canberra, Australia) which incorporated four Kistler tri-axial force transducers (Kistler type 9251A, Winterthur, Switzerland) mounted in each corner directly in front of the starting block. The force plate was installed with preset calibration range and offset files were recorded for each subject to allow for the pressure of the water against the plate. All force data were collected at a sampling rate of 500 Hz. Analysis of the raw data involved transducer processing and digital filtering at 20 Hz. The orientation of the force plate axis was such that the Z forces were directly perpendicular to the force platform, Y forces resulted from impacts up and down the force platform and X forces were a result of forces either left or right on the forceplate. The propulsive forces perpendicular to the forceplate (Z forces) were then used to develop a force profile for each turn with the absolute peak force (N), total propulsive impulse (Ns) and time on the wall during push-off (s) being recorded. Relative (to bodyweight) peak force (bw) and total impulse (bws) was also recorded as a more practical measure of the forces. Figure 1 illustrates a typical force profile recorded during a freestyle turn.

Figure 1. Sample force profile for freestyle turn.
To determine hand/foot touch, a manual trigger was enacted when a subjective judgment of touch was made. During analysis, this trigger tended to coincide with an increase in both X (left-right) and Y (up-down) forces. For consistency, hand/foot touch during analysis was deemed to occur with an increase in these X and Y directional forces. As such, the time on the wall began with an increase in the X and Y forces and finished when a zero propulsive force (Z force) was reached.

**Kinematic Analysis**

The kinematic analysis was performed through the use of the Kinex Swimming Analysis System (Kinex, Estonia). The program highlights parameters that describe the various phases of the turn. These parameters are beneficial for coaches in detecting any weaknesses that swimmers may have. Kinematic parameters obtained for the butterfly turn through the use of the Kinex Swimming Analysis System included the duration of rotation, push-off speed, glide duration, glide speed, speed for the first stroke cycle and Kinex turn speed (see Table 2). In addition to these variables, the freestyle turn analysis also included the distance from the wall when the head commences its downward motion. The average speed from 7.5m before the wall until 7.5m out from the wall was also recorded as a measure of total turn speed.

<table>
<thead>
<tr>
<th>FREESTYLE</th>
<th>DISTANCE FROM WALL BEFORE TURN</th>
<th>PUSH-OFF SPEED</th>
<th>GLIDE TIME</th>
<th>GLIDE SPEED</th>
<th>SPEED OF THE FIRST STROKE</th>
<th>KINEX TURN SPEED</th>
<th>TOTAL TURN SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from when head is submerged until the feet touch the wall</td>
<td>Time from when feet leave the wall until the start of the first arm stroke</td>
<td>Average velocity during the push-off phase.</td>
<td>Average velocity over the glide duration.</td>
<td>Average velocity over the glide duration.</td>
<td>Average speed from the start of the first arm stroke until the start of the firstbek of the second cycle.</td>
<td>Average speed from the wall until 7.5m after the wall.</td>
<td>Average speed of the swimmer from 7.5m before the wall until 7.5m after the wall.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BUTTERFLY</th>
<th>ROTATION TIME</th>
<th>PULL-OFF SPEED</th>
<th>GLIDE TIME</th>
<th>GLIDE SPEED</th>
<th>SPEED OF THE FIRST STROKE</th>
<th>KINEX TURN SPEED</th>
<th>TOTAL TURN SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from when the hands touch the wall until the feet touch the wall</td>
<td>Time from when feet leave the wall until the start of the first arm stroke</td>
<td>Average velocity during the pull-off phase.</td>
<td>Average velocity over the glide duration.</td>
<td>Average velocity over the glide duration.</td>
<td>Average speed from the start of the first arm stroke until the start of the firstbek of the second cycle.</td>
<td>Average speed from the wall until 7.5m after the wall.</td>
<td>Average speed of the swimmer from 7.5m before the wall until 7.5m after the wall.</td>
</tr>
</tbody>
</table>

A Panasonic underwater camera and JVC Super VHS camera operating at 25 Hz, were used in conjunction with a video timer. These were positioned on a moveable trolley at the side of the pool to allow an above/below water view of the swimmer to be realised throughout the approach, pull-off and glide phases of the turn. Markers were positioned underwater every 1m for the first 4m, and every 2m thereafter, to form the scaling factor for the Kinex program. The turn was filmed from 15m before the wall to 15m out from the wall, and required the subject to be in view at all times. The underwater view was utilised for the Kinex analysis while the above/below water split view was used for both qualitative analysis by the coaches and to determine the total turn time (7.5m in until 7.5m out). The Kinex program requires that fixed points on the swimmer are digitised at various phases of the turn cycle and incorporated with the underwater markers to enable the kinematic data to be realised.

### Table 4. Means and standard deviations for the butterfly groups.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>SUBJECT 1</th>
<th>SUBJECT 2</th>
<th>SUBJECT 3</th>
<th>SUBJECT 4</th>
<th>OVERALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROTATION TIME (s)</td>
<td>0.85 ± 0.02</td>
<td>0.90 ± 0.04</td>
<td>0.89 ± 0.03</td>
<td>0.91 ± 0.03</td>
<td>0.90 ± 0.03</td>
</tr>
<tr>
<td>PULL-OFF SPEED (m/s)</td>
<td>1.34 ± 0.07</td>
<td>1.42 ± 0.09</td>
<td>1.34 ± 0.09</td>
<td>1.30 ± 0.08</td>
<td>1.32 ± 0.11</td>
</tr>
<tr>
<td>GLIDE TIME (s)</td>
<td>2.94 ± 0.27</td>
<td>2.92 ± 0.26</td>
<td>2.93 ± 0.25</td>
<td>2.92 ± 0.32</td>
<td>2.92 ± 0.43</td>
</tr>
<tr>
<td>GLIDE SPEED (m/s)</td>
<td>1.79 ± 0.05</td>
<td>1.81 ± 0.04</td>
<td>1.79 ± 0.03</td>
<td>1.86 ± 0.05</td>
<td>1.81 ± 0.05</td>
</tr>
<tr>
<td>SPEED OF 1ST STROKE (m/s)</td>
<td>3.69 ± 0.05</td>
<td>3.67 ± 0.05</td>
<td>3.67 ± 0.03</td>
<td>3.65 ± 0.02</td>
<td>3.66 ± 0.06</td>
</tr>
<tr>
<td>KINEX TURN SPEED (m/s)</td>
<td>1.73 ± 0.03</td>
<td>1.59 ± 0.04</td>
<td>1.68 ± 0.03</td>
<td>1.65 ± 0.03</td>
<td>1.65 ± 0.03</td>
</tr>
<tr>
<td>TOTAL TURN SPEED (7.5m in until 7.5m out) (m/s)</td>
<td>1.60 ± 0.04</td>
<td>1.62 ± 0.03</td>
<td>1.72 ± 0.04</td>
<td>1.67 ± 0.03</td>
<td>1.68 ± 0.04</td>
</tr>
<tr>
<td>MAXIMUM FORCE (N)</td>
<td>1453.42 ± 132.41</td>
<td>1320.50 ± 89.60</td>
<td>1333.51 ± 68.54</td>
<td>1446.71 ± 92.22</td>
<td>1408.74 ± 117.18</td>
</tr>
<tr>
<td>MAXIMUM FORCE (bw)</td>
<td>1.85 ± 0.16</td>
<td>1.84 ± 0.10</td>
<td>1.86 ± 0.09</td>
<td>1.72 ± 0.11</td>
<td>1.72 ± 0.14</td>
</tr>
<tr>
<td>TIME ON WALL (s)</td>
<td>0.40 ± 0.03</td>
<td>0.39 ± 0.03</td>
<td>0.44 ± 0.03</td>
<td>0.38 ± 0.03</td>
<td>0.40 ± 0.03</td>
</tr>
<tr>
<td>IMPULSE (Ns)</td>
<td>376.43 ± 32.35</td>
<td>335.95 ± 22.35</td>
<td>405.81 ± 10.82</td>
<td>384.37 ± 24.35</td>
<td>369.10 ± 25.44</td>
</tr>
<tr>
<td>IMPULSE (bw)</td>
<td>0.48 ± 0.04</td>
<td>0.47 ± 0.02</td>
<td>0.49 ± 0.03</td>
<td>0.48 ± 0.03</td>
<td>0.49 ± 0.04</td>
</tr>
</tbody>
</table>

A Panasonic underwater camera and JVC Super VHS camera operating at 25 Hz, were used in conjunction with a video timer. These were positioned on a moveable trolley at the side of the pool to allow an above/below water view of the swimmer to be realised throughout the approach, pull-off and glide phases of the turn. Markers were positioned underwater every 1m for the first 4m, and every 2m thereafter, to form the scaling factor for the Kinex program. The turn was filmed from 15m before the wall to 15m out from the wall, and required the subject to be in view at all times. The underwater view was utilised for the Kinex analysis while the above/below water split view was used for both qualitative analysis by the coaches and to determine the total turn time (7.5m in until 7.5m out). The Kinex program requires that fixed points on the swimmer are digitised at various phases of the turn cycle and incorporated with the underwater markers to enable the kinematic data to be realised.

### Findings

Due to the limited subject population, the analysis was restricted to descriptive statistics. The means and standard deviations of the kinematic and kinetic parameters are presented in Tables 3 and 4.

The butterfly turn was initiated at hand contact and followed immediately by rotation about the frontal axis lasting just under 1 s. Wall push-off lasted an average of 0.4 s and the swimmers produced an average of just over 1400 N for the peak force and 369 Ns for total impulse. The average velocity during wall push-off (push-off speed) reached 1.33 m/s. The glide time recorded was approximately 2.3 s with an average glide speed of 1.81 m/s and an average speed during the first stroke of 1.61 m/s. The Kinex turn speed (hand touch to end
of the first stroke cycle) and total turn speed (7.5 m in until 7.5 m out) were similar in magnitude indicating constant turn approach speeds.

The freestyle turn began with the swimmer's head flexing to initiate a somersault-style rotation at an average of just under a meter from the wall. The somersault rotation, from when the head was submerged to when the feet hit the wall, lasted an average of 0.72 s, which was substantially faster than the average rotation time for the butterfly turns. Average push-off force recorded by the forceplate was 1345N with an average impulse of 247 Ns. The time on the wall for the freestyle turns, however, was considerably lower than for the butterfly turns (0.29 vs 0.4 s). The push-off was performed at an average speed of 1.47 m/s and led to an average glide speed of 1.85 m/s. The lower average glide times (1.33 vs 2.29 s) and faster glide speeds (1.85 vs 1.81 m/s) also led to a greater average speed during the first stroke (1.74 vs 1.61 m/s) for the freestyle turns.

The initial hand touch in the butterfly turn recorded forces of up to 200 N (perpendicular to the forceplate) which tended to remain relatively constant for approximately 0.5 s as the swimmer maintained hand contact with the turning board. This is then followed by the main force curve (average peak force of 1406.7 ± 117.2 N) as a result of push-off approximately 1 s later. The freestyle force profile consisted of a bi- or tri-modal force curve resulting from the foot contact (average peak force of 1345.3 ± 236.5 N) and subsequent push-off which lasted approximately 0.3 s.

Discussion

A comparison of the kinetic and kinematic parameters highlight essential technique differences between the freestyle and butterfly turns. As to be expected, the force profiles of the butterfly and freestyle turns demonstrated marked differences. The average impulse, peak force and time on the wall are notably higher in subjects performing the butterfly turn as compared to those performing the freestyle turns. This may be due to the butterflyer positioning himself for optimum push-off whereas the freestyler must judge the wall after the tumble. Comparisons between the present study and previous research for various force parameters occurring in the freestyle turn are listed in Table 5.

The average peak force and impulse in the freestyle turns represented substantially higher values than those reported for the 36 competitive age-group swimmers by Blanksby et al. (1) and the 3 recreational swimmers in Takahashi et al. (11). This may be attributed to the lower age, height and weight of the subjects in the former study, and the novice level of the swimmers in the latter study. However, the current findings are lower than for the 3 highly trained swimmers reported by Takahashi et al. (11).

The present study demonstrated the lowest average time on the wall during push-off with an average of 0.18 s faster than those reported in previous studies (8,11,11). This may partially be due to the allowance in the present study for the presence of a pre-touch force resulting from the swimmer's bow wave. Previous studies have neglected this wave force effect. In the current study, the peak forces prior to the start of X and Y directional forces (initial contact) reached up to 500 N. The magnitude of this proposed wave force is, therefore, significant in the kinetic analysis.

The kinematic data realised through the Kinex analysis have not previously been reported in swim turn studies. Examination of the kinematic variables provided by the Kinex program, in conjunction with the force variables, enable a more comprehensive analysis of the turn to be made. For instance, a large impulse during push-off and low wall contact time should be related to a high average push-off speed which, in turn, affects the glide speed.

A comparison between subject 5 and subject 7 in the freestyle group is presented as a practical example in the interpretation of the results. At push-off, all of the kinetic variables were higher, while time on the wall was lower for subject 5. This manifested itself in a higher push-off and glide speed for this subject. Subject 7 still maintains a similar total turn speed (7.5 - 7.5 m) as subject 5, presumably from a superior approach phase of the turn. As such, subject 5 may require turn preparation work to ensure swimming velocity is maintained during the approach phase. Subject 7 should focus on improving the total impulse and decreasing wall contact time during the push-off phase. This may be achieved through a specific dry-land training program to develop leg extensor power.

### Table 5. Comparison between studies.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>TURN</th>
<th>SUBJECT POPULATION</th>
<th>PEAK FORCE (N)</th>
<th>TIME ON WALL (sec)</th>
<th>IMPULSE (Ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Study</td>
<td>Butterfly</td>
<td>2 National level males</td>
<td>1345 ± 236.5</td>
<td>0.18 ± 0.01</td>
<td>247 ± 236.5</td>
</tr>
<tr>
<td></td>
<td>Freestyle</td>
<td>2 National level males</td>
<td>1345 ± 236.5</td>
<td>0.18 ± 0.01</td>
<td>247 ± 236.5</td>
</tr>
<tr>
<td>Blanksby et al. (1990)</td>
<td>Freestyle</td>
<td>36 competitive age swimmers (15 females, 17 males)</td>
<td>1345 ± 236.5</td>
<td>0.18 ± 0.01</td>
<td>247 ± 236.5</td>
</tr>
<tr>
<td>Takahashi et al. (1992)</td>
<td>Freestyle</td>
<td>3 highly trained males</td>
<td>1345 ± 236.5</td>
<td>0.18 ± 0.01</td>
<td>247 ± 236.5</td>
</tr>
<tr>
<td></td>
<td>Freestyle</td>
<td>3 recreational level males</td>
<td>1345 ± 236.5</td>
<td>0.18 ± 0.01</td>
<td>247 ± 236.5</td>
</tr>
<tr>
<td></td>
<td>Freestyle</td>
<td>5 University trained swimmers (4 female, 1 male)</td>
<td>1345 ± 236.5</td>
<td>0.18 ± 0.01</td>
<td>247 ± 236.5</td>
</tr>
</tbody>
</table>

Practical Applications

As with any aspect of swimming, it is essential to be able to quantify elite swimmers’ turning technique. This involves examining a wide variety of performance variables that may be important to a successful turn. The collection of this information assists coaches to determine any potential areas for improvement in the turning technique of their swimmers.
A close examination of the interrelationship between the kinetic and kinematic variables allows performance to be monitored during the various phases of the turn. As an example, the difference between the Kinex turn speed and total turn speed gives an indication of the approach and preparation phase of the turn. Likewise, a high impulse and push-off speed, but low glide speed, may indicate problems in streamlining. Information of this type will allow the coach to concentrate on areas which require improvements.

The split-view video footage is also an important tool to be used in conjunction with the collected data to identify the problems in technique which may have lead to poor Kinex results. In this study, it was found that, in trials with a high push-off speed but low glide speed, the subjects tended to push off the wall on their backs. This required almost a 180° rotation during the glide phase which, in turn, may have caused an increase in the hydrodynamic drag experienced by the swimmer. The coach can then use this information to target specific technique problems.

Specifically, the swim coaches should concentrate on the following key aspects of the turn:

**For freestyle** -

a) Swimmers should maintain speed into the wall during the approach phase of the turn. A slow approach will result in a large difference between the Kinex turn speed and the total turn speed, while incorrect timing of the rotation will lead to low push-off impulse.

b) A streamline position throughout the glide phase is important. Minor changes in the streamline position result in large form drag measurements which slow the glide velocity (9). This is especially true for swimmers who demonstrate excessive rotation (to achieve a prone position) after wall push-off.

**For butterfly**:

c) A high impulse and short wall contact time assists in achieving a high push-off speed (requires a force platform to measure). There is an optimal trade-off between the impulse achieved during push-off and the time spent on the wall.

d) Ensure the swimmer begins stroking at race speed. Extra time is consumed if the swimmer begins stroking too early or too late in the glide phase (1).

Unfortunately, the scope of this study was limited to a case study approach due to subject numbers. Further study in this area using larger subject numbers could provide a greater insight into the parameters which contribute most to successful turns. The hydrodynamics of the swim turn is also an area which has received little attention. Establishing drag profiles for swimmers throughout the turn phases would enable the merits of different turning styles to be examined. An extensive analysis of the kinetics, kinematics and hydrodynamics of the swim turn would therefore allow the turn technique to be optimised.

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**References**

The effect of swim training, reduced training, and retraining on velocity-blood lactate relationships

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Abstract

This study investigated changes in swimming velocity at the initial onset of blood lactate accumulation (Vo2Lac), and at fixed blood lactate concentrations of 2, 4, and 6 mmol.l-1 (V2, V4, V6) during 19 weeks of a collegiate swim season. Fourteen male division II swimmers age 19.7±2.3 yrs and body fat 12.4±3.4% served as subjects. Lactate profiles were developed, and the above velocity-lactate data points were measured at time (T) 0, 4, 12, 15, and 19 weeks. A period of interrupted and reduced training during semester break occurred from T13 to T15. V2 was the only velocity to increase during T0 to T4, (p<0.05). From T0 to T12, Vo2Lac, V2, V4, and V6 increased, respectively, 9.5%, 12.2%, 11.9%, and 17.0%, (p<0.05). Following the break (T13 to T15), velocities changed -2.0%, 0.0%, -1.2%, and -7.1%, and then increased during retraining (T16 to T19) 1.0%, 3.3%, 1.6% and 1.5%, respectively, with only V2 and V4 retaining significance compared to T0. The results indicate a routine swim training program of 12 weeks was effective for increasing swimming velocity at blood lactate concentrations corresponding to mild aerobic to intense anaerobic exercise. Furthermore, four weeks of retraining was ineffective in reversing the loss in swimming velocity during reduced training.

INDEX TERMS - IOBLA, FBLC, mechanical efficiency, metabolic efficiency, overtraining

Introduction

Blood lactate concentrations during sub-maximal exercise are strongly related to physiological capacity and competitive performance. The velocity corresponding to the aerobic threshold or initial onset of blood lactate accumulation (IOBLA), typically 1-2 mmol.l-1, is related to running performance and aerobic capacity (5), and is an optimal swimming intensity for clearing blood lactate during recovery from maximal exercise (18). The velocity approximating the 4 mmol.l-1 anaerobic threshold has been shown to be the maximal steady state lactate concentration during a maximal 3000 m swim (7,12,16), and is conceived as an optimal training intensity to improve both aerobic and anaerobic capacities (7,11,22). Swimming velocities above 4 mmol.l-1 lactate are not associated with "thresholds"; however, training velocities corresponding to lactate concentrations of 6-10 mmol.l-1 are recommended by the United States Swimming Sports Medicine Program for improving swimming power and lactate tolerance. Although, excessive training at these lactate levels may lead to potential training overload and subsequent decrements in performance (15).

Blood lactate accumulation during sub-maximal exercise appears to be more sensitive in its response to training than VO2max and therefore is suggested as a better indicator of how well athletes respond to training (22). However, several investigators have shown that reductions in blood lactate concentration occur only at intensities where training occurs. In other words, to increase performance velocity at a given
blood lactate concentration, one must train specifically at that intensity (1,22). This type of training is atypical of routine swimming programs in which swimmers are exposed to training sets ranging from mild aerobic endurance to high intensity interval swimming.

Improvement in swimming velocity-lactate relationships is dependent on training consistency. Training seasons are often interrupted by external factors like injury, illness, vacation, planned breaks, etc., consequently, sub-maximal blood lactate increases at specific velocities often with concomitant reductions in swimming performance (13). Neufeld et al. (13) reported significantly higher sub-maximal blood lactate concentrations from 200 yd (183 m) swims and decreased tethered swimming power following four weeks of reduced training. Furthermore, Prins et al. (17) investigated changes in swimming velocity-lactate relationships during two successive competitive seasons and reported increases in blood lactate accumulation per velocity during periods of reduced training. This leads one to ask, "Does a typical swim training regimen that includes a range of training intensities improve swimming velocity-lactate relationships throughout a season? Moreover, what are the effects of interrupted or reduced training on these relationships?" The purpose of this study, therefore, was to investigate changes in swimming velocity corresponding to the relative VOBLA (VOBLA) and fixed blood lactate concentrations (FBLC) of 2, 4, and 6 mmol·L⁻¹ (V₂, V₄, V₆) during 19 weeks of a collegiate swimming season which included a period of interrupted/reduced training.

**Methods and Procedures**

Fourteen division II college, male swimmers who had a minimum of six years of competitive experience prior to competing at the college level were informed verbally and in writing about the conduct of the study. The swimmers then voluntarily signed an Informed Consent Form approved by the Institutional Research Board of the University to serve as subjects in the study. Classification of subjects by primary competitive distance revealed there were; seven sprinters, six middle distance swimmers and one distance swimmer. When classifying subjects by primary stroke, there were three backstrokers, four breaststrokers/cfers, two butterflies, and five freestylers. Further descriptive information of the subjects is shown in Table 1.

**Table 1. Descriptive information of subjects. (Mean ± S.Dev, n=14)**

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Body Fat (%)</th>
<th>Swim Times (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.7</td>
<td>±2.1</td>
<td>±12</td>
<td>±10.4</td>
<td>±3.5</td>
</tr>
<tr>
<td></td>
<td>179</td>
<td>80.2</td>
<td>12.4</td>
<td>2.1 (200 yds, 183m)</td>
</tr>
<tr>
<td></td>
<td>±12</td>
<td>±10.4</td>
<td>±3.5</td>
<td>±0.1</td>
</tr>
<tr>
<td></td>
<td>5.8 (500 yds, 457m)</td>
<td>±0.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Design**

The design of the study is depicted in Figure 1. V̇OBLA, V₂, V₄, and V₆ were determined from lactate profiles: prior to the start of formal training (T₀), at 4 and 12 weeks of predominately easy and hard aerobic training (T₄ and T₁₂), and following three weeks of reduced training (T₁₅) that included one week of final examinations when swimmers swam on their own and two weeks when swimmers swam with their local United States Swimming team during semester break. Final data collection occurred at the end of four weeks of retraining in preparation for championship competition (T₁₉). All training with the exception of the three week reduced training period was directed by the coaching staff, and workouts were recorded daily. Workouts during the two week semester break were reported to the investigator by the swimmers.

![Figure 1. Design of a 19 week swim training study with data collection occurring at weeks T₀, T₄, T₁₂, T₁₅, and T₁₉.](image)

Training intensity was quantified by matching swimming times to corresponding lactate concentrations from the individual lactate profiles taken across the season. Easy aerobic training was classified as swimming times performed at lactate levels slightly above the VOBLA from 1.8-3.2 mmol·L⁻¹ (avg 2.2±0.6 mmol·L⁻¹), whereas hard aerobic training was performed between 2.3-5.2 mmol·L⁻¹ (avg 3.1±1.3 mmol·L⁻¹) with intense anaerobic training performed well above the 4 mmol·L⁻¹ lactate concentration at accumulations of 7.5-10.7 mmol·L⁻¹ (avg 8.7±1.1 mmol·L⁻¹).

**Data Collection Procedures**

Lactate profiles were developed by each swimmer completing 5×366 m (400 yds) freestyle swims with one each at 50, 60, 70, 80, and 90% of his pre-determined maximal 366 m swim time. A one minute period separated the profile swims. Prior to beginning the profile swims subjects performed a warm-up of 457 m (500 yds) which was followed by 5 minutes of rest. At the completion of each profile swim, subjects exited the water and 25 microliters of capillary blood was obtained from the finger tip within the one minute time period. Blood lactate concentration was measured using a YSI 1500 Sport automated analyzer (Yellow Springs, Ohio).

Lactate and corresponding velocity data points from individual profiles were graphed and V̇OBLA, V₂, V₄, and V₆, were then determined from the graphs for each data collection date. To locate V̇OBLA, a line was interpolated between the first 2 data points above baseline lactate, then extrapolated to
baseline lactate and dropped vertically to the corresponding velocity on the x-axis (18), (Figure 2). Data from our laboratory and others (5,18) have shown the velocity-lactate relationship is significantly linear above the IOBLA. $V_2$, $V_4$, and $V_6$ were located by drawing horizontal lines from the respective lactate values on the Y-axis until it intersected the velocity-lactate curve. A line was then dropped vertically to the corresponding velocity on the x-axis, (Figure 3). The manual selection of velocities as described above was made independently by two investigators and compared to curvilinear regression analysis with no significant difference existing between the investigators or between the manual and regression method, ($p \geq 0.05$).

![Location of Velocity at IOBLA](image)

**Figure 2.** Swimming velocity at the IOBLA is located by interpolating the initial two data points above baseline lactate then extrapolating to the corresponding velocity.

**Statistical Analysis**

A MANOVA with repeated measures was performed on $V_{\text{EMG}}$, $V_2$, $V_4$, and $V_6$ to establish if a significant change occurred during the season. Once significance was established, an ANOVA with repeated measures was performed to detect significance across time. A Tukey post hoc test was then performed to locate significant changes between T0, T4, T12, T15, and T19. The significance level was set at $p \leq 0.05$. All values are expressed as mean±SD.

**Results**

Analysis of the amount of easy and hard aerobic and anaerobic swimming during each training period is shown in

![Blood Lactate](image)

**Table 2.** Mean±SD in meters of total daily swimming distance and amount of easy aerobic (EA), hard aerobic (HA), and anaerobic (AN) training performed during each training period.

<table>
<thead>
<tr>
<th>Period</th>
<th>Total</th>
<th>EA</th>
<th>HA</th>
<th>AN</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1-T4</td>
<td>5275</td>
<td>2879</td>
<td>1789</td>
<td>608</td>
</tr>
<tr>
<td>±845</td>
<td>±1059</td>
<td>±708</td>
<td>±455</td>
<td></td>
</tr>
<tr>
<td>T5-T12</td>
<td>4504</td>
<td>2801</td>
<td>935</td>
<td>758</td>
</tr>
<tr>
<td>±1133</td>
<td>±652</td>
<td>±816</td>
<td>±591</td>
<td></td>
</tr>
<tr>
<td>T13-T15</td>
<td>5760</td>
<td>1890</td>
<td>3108</td>
<td>761</td>
</tr>
<tr>
<td>±585</td>
<td>±239</td>
<td>±630</td>
<td>±158</td>
<td></td>
</tr>
<tr>
<td>T14-T15</td>
<td>2588</td>
<td>1174</td>
<td>1166</td>
<td>229</td>
</tr>
<tr>
<td>±1160</td>
<td>±904</td>
<td>±561</td>
<td>±172</td>
<td></td>
</tr>
<tr>
<td>T16-T19</td>
<td>5794</td>
<td>2953</td>
<td>1859</td>
<td>959</td>
</tr>
<tr>
<td>±2699</td>
<td>±975</td>
<td>±1627</td>
<td>±923</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4, with the mean±SD shown in Table 3. Inspection of Figure 4 shows the training effectiveness on $V_4$ in the T4 curve and for all velocities in the T12 curve by a shift downward and to the right relative to T0, indicative of increased velocity at the selected blood lactate concentrations. The effect of reduced training is observed by a shift to the left in the T15 curve and a shift to the right, again, in the T19 curve after retraining. The swimming velocity corresponding to the relative IOBLA significantly increased 0.084±0.073 m$s^{-1}$ during the initial 12 weeks of continuous training (T0-T12). Blood lactate concentration at the IOBLA did not significantly change and was 2.10±0.69, 1.88±0.55, 1.65±0.47, 1.38±0.43, and 1.50±0.45 mmol$l^{-1}$, respectively, at T0, T4, T12, T15, and T19. $V_2$, $V_4$, and $V_6$ significantly increased, respectively, 0.113±0.089 m$s^{-1}$, 0.123±0.071 m$s^{-1}$, and 0.189±0.097 m$s^{-1}$ during T0-T12. These changes represent an increase in swimming velocity of 9.3%, 12.2%, 11.9%, and 17.0%, respectively, at the $V_{IOBLA}$, $V_2$, $V_4$, and $V_6$ during the initial 12 weeks of training. During T0-T4, only $V_4$ demonstrated a significant increase, 0.068±0.048 m$s^{-1}$ or 6.5%, and likewise significantly increased 0.055±0.059 m$s^{-1}$ during T5-T12.

![Image](vol.12_training_retraining.png)

Figure 4. Changes in swimming velocity at IOBLA, 2, 4, and 6 mmol$l^{-1}$ lactate at weeks 0, 4, 12, 15, and 19.

At the end of the three week interrupted/reduced training period (T13-T15), $V_{IOBLA}$ and $V_6$ decreased, respectively, -2.0% and -7.1% and were no longer significantly faster compared to T0 velocities; however, $V_2$ and $V_4$ did not change significantly during detraining and were still significantly faster than T0 velocities. Moreover, following four weeks of retraining all velocities were statistically unchanged relative to T15.

Table 3. Mean±SD swimming velocities (m$s^{-1}$) at selected blood lactate concentrations during a 19 week collegiate swim training season.

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>T4</th>
<th>T12</th>
<th>T15</th>
<th>T19*</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IOBLA}$</td>
<td>0.892</td>
<td>0.919</td>
<td>0.976*</td>
<td>0.961</td>
<td>0.968</td>
</tr>
<tr>
<td></td>
<td>±0.118</td>
<td>±0.117</td>
<td>±0.112</td>
<td>±0.094</td>
<td>±0.097</td>
</tr>
<tr>
<td>$V_2$</td>
<td>0.928</td>
<td>0.981</td>
<td>1.040*</td>
<td>1.037*</td>
<td>1.072*</td>
</tr>
<tr>
<td></td>
<td>±0.126</td>
<td>±0.098</td>
<td>±0.075</td>
<td>±0.083</td>
<td>±0.081</td>
</tr>
<tr>
<td>$V_4$</td>
<td>1.038</td>
<td>1.106*</td>
<td>1.161*</td>
<td>1.147*</td>
<td>1.164*</td>
</tr>
<tr>
<td></td>
<td>±0.106</td>
<td>±0.084</td>
<td>±0.054</td>
<td>±0.072</td>
<td>±0.046</td>
</tr>
<tr>
<td>$V_6$</td>
<td>1.112</td>
<td>1.162</td>
<td>1.300*</td>
<td>1.209</td>
<td>1.226</td>
</tr>
<tr>
<td></td>
<td>±0.095</td>
<td>±0.078</td>
<td>±0.072</td>
<td>±0.074</td>
<td>±0.071</td>
</tr>
</tbody>
</table>

a T0, T4, T12, T15, T19 represent the weeks in the season when data collection occurred.

* denotes significant increase compared to T0, (P≤0.05)

Discussion

The swimming athlete whether sprinter, middle distance, or distance competitor is trained using swimming sets of multiple intensities and distances. Consequently, throughout a typical collegiate swimming season, all competitors swim endurance as well as high intensity interval sets. The present training regimen followed a similar pattern of training as described above. Excluding the two weeks of reduced training (T14-T15) in which swimmers trained at home with their USS teams, easy aerobic swimming including warm-up and cool-down swims comprised 51-62% of total distance, hard aerobic swimming totaled 21-32%, and intense anaerobic or sprint training totaled 11-17%.

Analysis of the effect of training, reduced training, and retraining show that all four swimming velocities increased significantly during the initial 12 weeks, $V_2$ and $V_4$ decreased minimally during reduced training while maintaining a significant increase relative to T0, and only $V_2$ and $V_4$ slightly increased beyond T12 during retraining. It would appear the 2-4 mmol$l^{-1}$ lactate range of training intensity seems to be more sensitive to training/retraining and less sensitive to reduced training than slower and faster swimming velocities. An explanation could be that the majority of training occurred at moderate velocities, typically in the aerobic to anaerobic transitional range (2-4 mmol$l^{-1}$ lactate), and not at very slow or very fast velocities. Mean blood lactate concentrations of 2.7 mmol$l^{-1}$ from easy to moderately hard swimming (366 to 1101 m) across the entire study support this theory. Although this study shows that typical non-specific swim training is effective for increasing swimming velocity at different lactate concentrations, the results may suggest that coaches intuitively utilize a majority of moderate training intensities at
or slightly below the 4 mmol·l⁻¹ maximal steady state lactate during a training season.

Further analysis indicate \( V_4 \) was the only velocity to significantly increase during T0-T4, which agrees with unpublished results from our lab on elite collegiate runners who improved their \( V_4 \) in the same length of time during initial cross country training. However, the lack of significant improvement at the \( V_{OBLA} \) and \( V_2 \) is dissimilar with findings by Rogers et al. (19) where sedentary middle-aged men significantly improved walking or running velocities corresponding to 1.5, 2.6, and 3.1 mmol·l⁻¹ lactate. Differences in subject age and initial physical condition could explain the differing results between the two studies.

The athletes in the current study significantly increased all four swimming velocities as a result of 12 weeks of training. Our findings agree with running and cycle ergometry studies that demonstrated velocities or work outputs are increased similarly by training at different intensities. Weltman et al. (24) trained previously untrained women for 16 weeks at either the lactate threshold (LT), our \( V_{OBLA} \), or above the LT at a running velocity corresponding to 50% of the intensity between the LT and maximal oxygen uptake. The quantity of training was equal in both groups. Similar improvements in velocity at the LT and at FBLCs of 2.0, and 2.5 mmol·l⁻¹ were reported, with neither group improving the 4 mmol·l⁻¹ velocity. Casaburi et al. (2) in a five week cycle ergometry study, reported statistically similar increases in work output at the lactate acidosis threshold (LAT) in sedentary young men who trained at intensities of 80% of LAT, or at 25% or 50% of the difference between LAT and maximal power output.

A trend of possible importance to coaches occurs in both Weltman's and Casaburi's study. Weltman's study continued for a year with the subjects who trained above the LT continuing to improve their LT velocity, whereas the group that trained below the LT demonstrated no significant improvement after the initial 16 weeks. Similarly, Casaburi's group that trained 50% above the LAT doubled the work output compared to the group that trained below the LAT, although as reported above the difference was not significant. This may suggest that intensity of training should be increased across time for continued improvement, which fits nicely with typical swimming programs in which training intensity is increased throughout the season, particularly during taper.

Other investigators have reported decreased swimming velocities at specific blood lactate concentrations during reduced training (13,17). In the present study, \( V_{OBLA}, V_2, V_4, \) and \( V_6 \) all decreased from T12 values, with \( V_{OBLA} \) losing significance compared to T0. This could be attributed to decreased muscle respiratory capacity and/or decreased metabolic efficiency (3,9). Ivy et al. (9) reported a highly significant correlation (\( r=0.94 \)) between muscle respiratory capacity and the intensity at which blood lactate begins to accumulate, with lesser trained individuals possessing lower respiratory capacities. The implication for the present study is that as the swimmers' training decreased during reduced training, their ability to oxidize pyruvate decreased and blood lactate accumulation was increased at the measured velocities. Results from Costill et al. (3) indicate that the increase in sub-maximal blood lactate during reduced training can also be attributed to a decreased buffering capacity of bicarbonate ion as well as decreasing muscle respiratory capacity; indicative of decreased metabolic efficiency.

Although all velocities seemed to improve during retraining, significant improvements beyond the velocities achieved at T12 were not observed. Furthermore, the decrease during retraining in \( V_{OBLA}, V_2, V_4, \) and \( V_6 \), respectively, was 1.0%, 3.3%, 1.6%, and 1.5%, compared to an increase of 3.1%, 5.7%, 6.5% and 4.5% observed during the initial four weeks of training. This agrees with findings from a 21 week training, inactivity, and retraining (seven weeks each) study by Pedersen et al. (16) in which the \( VO_{2max} \) of sedentary females during retraining only attained a similar capacity as during the initial training period. The findings from Pedersen's study and the present study suggest that within a training season, an individual's ability to increase his/her physiological capacity may be retarded following a period of reduced training.

The above are probable explanations for changes in swimming velocity during reduced training and retraining. We additionally suggest that a loss in mechanical swimming efficiency during reduced training coupled with a blunted improvement in efficiency from an abrupt increase in retraining distance, is in part responsible for the less than expected gains in velocity during retraining. Mean training distances for weeks T14 and T15 of reduced training and daily distances during retraining are depicted in Figure 5.

![Reduced vs. Retraining Distance](image_url)

Figure 5. Swim training distance during two weeks of reduced training and retraining.
deGroot et al. (4) have shown that propulsive efficiency of arm stroke mechanics and swimming propulsion are related. In addition, results from Fitts et al. (6) and Schmidtleicher (21) have shown that repeated high resistance exercises similar to that produced during high velocity swimming are required to increase the coordination and activation (mechanical efficiency) of prime movers, synergists, and antagonists during muscular contractions. To that end, analysis of the two week period of reduced training shows that only 229 m or 9% of total distance was devoted to intense anaerobic training. This may have been an insufficient amount of high velocity training to maintain mechanical swimming efficiency, particularly at velocities like \( V_6 \). Furthermore, analysis of the retraining period shows that swimmers swam 8714±1871 m, daily, in the first eight training days compared to 2588±1160 m, daily, during the previous two weeks of reduced training. This abrupt increase in training distance may have physiologically fatigued the swimmers from which they could not recover. Consequently, the improvement in swimming stroke efficiency observed during the retraining period may have been blunted. Although two weeks of tapered training followed the abrupt increased training, it appears this was not enough time for a significant increase in the velocity-lactate ratio to occur.

Application

This study has demonstrated that a typical routine swim training program was effective in increasing training velocity at blood lactate concentrations corresponding to mild aerobic to intense anaerobic swimming. This was exemplified by the improvement in the \( V_4 \) 100 yd freestyle training pace from 1:28.4 to 1:23.0 min:sec in only four weeks of training. The rapid improvement and strong relationship between the \( V_4 \) training intensity and physiological capacity and competitive performance, assures the coach that an early season training program of multiple training intensities is appropriate for and effective in preparing the athlete for more rigorous training later in the season.

In 12 weeks, the 100 yd training pace increased at all measured velocities, with \( V_{IOBIA} \) improving from 1:44.9 to 1:34.0, \( V_5 \) from 1:38.9 to 1:28.2, \( V_6 \) from 1:28.4 to 1:19.1, and \( V_7 \) from 1:22.3 to 1:10.6. Of note, is the gain of 17.0% in swimming velocity at the 6 mmol\( \cdot l^{-1} \) lactate and the progressive rate at which \( V_6 \) increased; 4.5% from T0 to T4 and 12.5% from T5 to T12. This is evidence that predominately aerobic training (83-89%) coupled with increases in intense anaerobic training, 11% during T0-T4 (607 m daily) and 17% from T5-T12 (758 m daily), is probably effective for improving division II athletes' physiological capacity at relatively fast swimming velocities. This is important since it is suggested that excessive training at intensities equal to or above the 4 mmol\( \cdot l^{-1} \) maximal steady state lactate concentration, particularly during early season, may encourage a state of overtraining later in the season. With aerobic training as a foundation, the amount of intense anaerobic swimming can then be increased later in the season, particularly during taper, to elicit a "physiological peak" for championship competition without the threat of overtraining.

The three week interrupted/reduced training period significantly decreased improvements in swimming velocity at \( V_{IOBIA} \) and 6 mmol\( \cdot l^{-1} \) lactate; regardless of the increased training volume during the first week of the period (T13). Analysis of total training distance showed an approximate 50% reduction in training volume during T14-T15 compared to that of T0-T12. As a result, the 100 yd freestyle pace changed from; 1:34.0 to 1:35.5 at \( V_{IOBIA} \), 1:28.2 to 1:28.5 at \( V_5 \), 1:19.1 to 1:20.0 at \( V_6 \), and 1:10.6 to 1:16.0 at \( V_7 \). The magnitude of decrease in velocity at \( V_6 \) coupled with \( V_7 \) not re-attaining T12 velocity during retraining makes it apparent the reduced training period had a lasting impact on the effectiveness of retraining.

If reduced training is inevitable and a loss of mechanical efficiency contributed to these decreases as proposed in the discussion, it would be practical to increase the proportion of intense anaerobic training to maintain coordination and activation (neural efficiency) of muscle contraction as explained above from Fitts et al. (6) and Schmidtleicher (21). Therefore, intense anaerobic swimming could be a viable, integral, and effective method of training to maintain physiological capacity and high velocity swimming during periods of reduced training. Further support for this suggestion are data from Kame et al (10) which demonstrate that primarily high intensity training is effective for improving physiological capacity and performance across a swimming season. With this in mind, initial retraining distance does not need to be increased to the extent it would overly fatigue and "break down" the athlete as suggested above. The coach could gradually increase the distance and intensity of training thus permitting swimmers to physiologically and biomechanically adapt to the more rigorous training. Consequently, significant improvements in velocity-lactate relationships beyond those observed before the training break may then occur.

Acknowledgements

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References


Effects of a workshop intervention on competitive performances of age-group swimmers: two investigations

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Abstract

Volunteer swimmers and parents in two swimming clubs were exposed to resource materials and a workshop explaining the development and use of pre-race and race strategies prior to the commencement of state age-group (10-12 and 13-17 yr) championships. Strategy use in the championships was advocated. The number of competition swims that bettered entry times was the dependent variable. No compulsion for compliance with or use of the strategies existed. Parents were encouraged to assist their children in the completion of described tasks.

In Investigation One, swimmers within the clubs who did not experience the treatment served as a within-club control group. The remainder of swimmers at the championships served as a larger control group. Both sex groups of Workshop Attendees produced a significantly greater percentage of improved performances than did Non-Attendees and the Rest of the Field control groups at the 13-17 yr championships. Male swimmers were more successful than females. This simple educational procedure was associated with the elevation of performances of age-group swimmers at a championship meet.

Investigation Two compared the use and non-use of race strategies in nine swimmers at the 10-12 yr championships. Parents assisted in developing the strategies. When strategies were used, 85.7% of swims improved but when they were not used the rate fell to 19.1%. Race strategy use beneficially affected the championship performances of very young swimmers.

Both investigations supported the use of strategies as being important for age-group swimmers. Their implementation resulted in improved championship performances. Race strategy development and parental involvement could be an effective addition to age-group swimming programs.

INDEX TERMS - Workshop attendance, age-groups, race strategies, racing

Introduction

The conscious development and use of pre-competition and competition strategies has been proposed as being effective and a pre-requisite for modern competition preparations (15, 17, 19). A substantial amount of work to verify these assertions has been conducted with elite athletes (4, 16, 21). Less attention has been paid to the feasibility of such approaches with young athletes although basic strategy elements have been investigated (1, 2, 24).

Research reports of the general value of performance strategies in sports have been published (e.g., wrestling (3); basketball (7), running (23), skiing (13), swimming (14), rowing (6)). Thus, the preparation of what is to be done and thought of during a sporting contest seems to have validity for enhancing performance as it does in other human endeavors (e.g., music (5)).

Assessing the effects of competition strategy development and use in young athletes would be a valuable contribution to coaching knowledge. This paper relates two studies that evaluated the effects of a workshop designed to instruct about pre-race and race strategy development and use on the performances of age-group swimmers.

In early 1995, the Forbes and Ursula Carlile Swimming Organization of Sydney, Australia, made its two member swimming clubs (Ryde and Carlile) available for the implementation of a pre-race and race strategy development program. The timing of this opportunity was in close proximity to two New South Wales state age-group swimming championships (13-17 yr and 10-12 yr). It was decided to assess the effectiveness of attending a workshop on strategy use on the two separate occasions with these two age-groups of swimmers.

Investigation One

Purpose

The purpose of this study was to determine whether attendance at a competition strategy workshop by age-group
(13-17 yr) swimmers and their parents affected subsequent championship performances.

**Rationale**

Swimming coaches are required to perform a multitude of managerial and coaching duties. As the demands and number of such tasks are increased, coaching effectiveness can decline. It is understandable that coaches might be hesitant to adopt a new and extra coaching responsibility. A coach's instruction and monitoring of the development of individual swimmers' pre-race and race strategies may be too demanding in age-group swimming because of the normally large number of competitors.

The involvement of parents in swimmers' competitive activities is a possibility that rarely is contemplated by coaches. Considering the number of "how to handle parents" articles (e.g., 10, 11, 25) it is reasonable to assert that parents usually are considered to be more of a nuisance rather than to have contributive value. However, in the opinion of world-champion athletes, the roles played by parents in their development and lives are admirable and essential (18). There is possible dissonance between coaches' and athletes' opinions of the value and roles that could be performed by parents in the sport setting. If a new program is needed, but a coaching staff is unable to institute it because of resource limitations, parents could fill a valuable role in assisting athletes provided that adequate instructions were made available.

The development of age-group swimmers' pre-race and race strategies were deemed desirable by the coaching staffs of the Ryde and Carlisle Swimming Clubs. It was decided to test the effects of swimmers and parents attending a pre-race and race-strategy workshop on swimmers performances at the subsequent 13-17 yr Age-group Championships.

**Methods and Procedures**

**Instructional process**

Two forms of instruction were developed to improve mental strategies in age-group swimmers.

1. A detailed swimmer-friendly manual that indicated the justifications, structures, and procedures for pre-race and race strategy formulations and use was produced (20). It contained brief treatments of experimentally verified essential elements of pre-race and race preparations and conduct. Those factors were then interpreted into the swimming setting. Step-by-step procedures for developing the two forms of strategy were described. This product was the basic source of information and instructions intended to supplement and/or replace a possible coaching role. Copies of this manual were provided to every swimmer who attended an associated workshop.

2. A three-hour workshop for swimmers and their parents was conducted to cover the implementation of pre-race and race strategies. It consisted of attendees experiencing a verbal and visual presentation and completing a structured workbook as the information delivery progressed (a form of interactive learning). Questions and answers were also entertained. This workshop occurred seven days prior to the first day of competition at the New South Wales State Age-group (13-17 yr) Championships. The investigator also attended two afternoon workouts at each club on two occasions after the workshop and prior to the competition to answer questions about, and to review strategies that were being formed.

It was advocated that parents work with their children using the instructional materials and develop appropriate competition strategies for use in the ensuing Age-group championships. No attempt was made to ensure that all swimmers and parents formulated strategies for every race to be contested. Each swimmer or swimmer-parent group decided upon the degree of compliance with this direction.

**Subjects**

Participants were volunteers from within the two clubs. Not all championship qualifiers or their parents attended the workshop, and not all received the resource materials. Each club was divided into two groups: an experimental group (Workshop Attendees) of those who attended the workshop and were encouraged to use strategies, and a within-club control group (Non-Attendees) comprised of those who did not attend and would not use strategies of the particular type advocated. No randomization of the groups was possible. As well as swimmers from the two clubs, it also was possible to monitor the performances of all other contestants at the Championships, the "Rest of the Field" group, which served as a further control group. It was assumed that all groups were equivalent in performance capability prior to the commencement of the championships.

**Dependent variable**

The measure of effect was whether or not a championship performance in a heat or final bettered the entry time of a swimmer. An Improved swim was one that improved on the entry time, and one that did not was Unimproved. An entry time traditionally was the best time recorded by the swimmer in the event up to the closing date for entries or a converted best short-course time recorded in the previous short-course season. These times were verified by the New South Wales Swimming Association as part of the entry procedure. The Association records and files all performance times of all registered swimmers in all sanctioned meets. For championships, the best time recorded over the previous 12 months is automatically used as the entry time to assist in seeding for each event. Any championship performance time
that bettered the entry time is officially recognized as a “personal best” (improved) performance.

**Data analysis**

The number of Improved and Unimproved performances were counted for the three different swimmer categories — Workshop Attendees, Non-Attendees, and the Rest of the Field. Each category was further divided on the basis of sex. The count data were also converted to percentages.

Tests of differences in percentages/proportions for independent groups were used to determine whether the percentages of Improved and Unimproved swims differed between the groups. There were three two-group comparisons, namely for (a) Workshop Attendees vs Non-Attendees, (b) Workshop Attendees vs Rest of the Field, and (c) Non-Attendees vs Rest of the Field. A one-tailed test was appropriate for the first two of these comparisons and a two-tailed test for the third. Where N’s were relatively small (in the first comparison), the correction for discreteness — equivalent to the Yates’ correction for small N in the related χ² test — was applied. This allowed the safe use of the Normal approximation in all tests. It is noted that in all cases the minimum criterion usually recommended for application of this approximation, namely N_{min} > 5 and N_{min}q being greater than 5, was met.

The fact that some of the swim performances were by the same swimmer meant that the assumption of independence inherent in the statistical test was somewhat violated. Neither experimental control nor statistical adjustment could feasibly be incorporated into the study to control for this feature. Since swims were performed over five days in different events and often with different expectations it is likely that correlation between swims was low.

**Results**

Table 1 lists the percentages of occurrence of Improved and Unimproved swims for Workshop Attendees, Non-Attendees, and the Rest of the Field. Table 2 shows the results of the six comparisons that assess whether the proportions of Improved and Unimproved Swims Differ Between Groups Within Sexes.

<table>
<thead>
<tr>
<th>Swimmer Category</th>
<th>Performances</th>
<th>Males</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop Attendees</td>
<td>Improved</td>
<td>68.7% (N = 68)</td>
<td>51.3% (N = 51)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Attendees</td>
<td>40.9% (N = 9)</td>
<td>59.1% (N = 13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of the Field</td>
<td>48.9% (N = 717)</td>
<td>51.1% (N = 759)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workshop Attendees</td>
<td>Improved</td>
<td>43.9% (N = 43)</td>
<td>56.1% (N = 55)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Attendees</td>
<td>19.2% (N = 5)</td>
<td>80.8% (N = 21)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of the Field</td>
<td>34.4% (N = 496)</td>
<td>65.6% (N = 948)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Comparisons That Assess Whether the Proportions of Improved and Unimproved Swims Differ Between Groups Within Sexes.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Observed Z</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workshop Attendees vs Non-Attendees</td>
<td>2.21*</td>
<td>SIG</td>
</tr>
<tr>
<td>Workshop Attendees vs Rest of the Field</td>
<td>3.82*</td>
<td>SIG</td>
</tr>
<tr>
<td>Non-Attendees vs Rest of the Field</td>
<td>0.75**</td>
<td>Not SIG</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workshop Attendees vs Non-Attendees</td>
<td>2.08*</td>
<td>SIG</td>
</tr>
<tr>
<td>Workshop Attendees vs Rest of the Field</td>
<td>1.92*</td>
<td>SIG</td>
</tr>
<tr>
<td>Non-Attendees vs Rest of the Field</td>
<td>1.61**</td>
<td>Not SIG</td>
</tr>
</tbody>
</table>

* Test incorporated correction for discreteness.
** Critical Z for two-tailed test (p < 0.05) is 1.96.

Tests of differences in the percentages of Improved and Unimproved swims for the three groups in both sexes.

There were notable differences in percentages of Improved and Unimproved performances between Workshop Attendees and the other two groups within sexes. Male Attendees exhibited an improvement rate of 68.7% while in the other two groups the rates were less than 50%. Among females, a lower percentage (43.9%) of Workshop Attendees improved. However, the percentages of improved performances were even less f or Non-Attendees (19.2%) and the Rest of the Field (34.4%).

Regardless of sex, Workshop Attendees performed significantly more Improved swims than either Non-Attendees or the Rest of the Field. There was no difference between Non-Attendees and the Rest of the Field.

**Discussion**

In an applied setting it is very difficult to create conditions that suit all the features of ideal experimentation. To employ random selection could be construed as unethical, particularly if a paying club member was denied the benefits to be derived from some effective procedure. Thus, this study was hampered by two design elements: subjects were volunteers; and all subjects made multiple swims, leading to a concern about the independence of measures.

Male and female age-group swimmers were notably different in the percentages of Improved and Unimproved performances they achieved at the New South Wales 13-17 yr Age-group Championships. In each of the three studied categories, Workshop Attendees, Non-Attendees, and Rest of
the Field, males produced a greater proportion of Improved performances than females.

Within the like-sex groups, the success rates of the experimental groups were notably better than those who did not attend the strategy-development workshop and the remaining swimmers at the championships. This is an interesting effect when it is considered that: (a) attendees were not required to formulate strategies (that was left to the strength of the message in the workshop presentation); (b) swimmers who did formulate strategies most probably did so for "favored" events rather than all events; and (c) there was no control or monitoring over the standard or form of strategy formulation. It was observed that some Workshop Attendees did not formulate any strategies and that some who did did so without parental assistance. On the other hand, a number of parents were very involved with assisting their children. These features would introduce variability into the responses to the workshop and into the conduct of swimmers in applying the content in the critical championships situation. This investigation supports the conclusion that the mere experience of a workshop and provision of resource materials was sufficient to markedly improve the performances of age-group swimmers relative to those of non-participants. The replication of this effect between the two sexes strengthens this assertion.

It was related to the senior author by significant officials of the New South Wales Swimming Inc. that the general improvement of Rest of the Field swimmers of both sexes were unacceptably low and that actions should be taken to produce better levels of accomplishment at such important meets. The relative improvements demonstrated by the two experimental groups in this study suggest some actions to improve performances:

(a) the provision of resource materials that guide users to develop pre-race and race strategies;
(b) enlist parents to assist young swimmers to understand and prepare strategies recommended in the resource materials; and
(c) provide a workshop or alternative information presentation as a means of informing and motivating swimmers and parents to employ this form of competition preparation.

These features can be instituted without requiring a coach to take on another time-consuming task.

A workshop is often perceived to be a "weak" intervention technique for effecting behavior change. However, it is a popular program within swimming environments. Weekend workshops on topics such as stroke-development, training programs, nutritional practices, etc., are often scheduled. In this investigation it is not possible to determine if the workshop experience, the strategy-focused content of the workshop, or a combination of both of these factors was associated with the improvements observed in attendees. In this instance, a workshop that emphasized pre-race and race-strategy development was related to improved performances in swimmers exposed to its setting and content.

Conclusions for Investigation One

The provision of a workshop experience covering pre-race and race strategy development and use was shown to be significantly related to improvement rates of age-group swimmers in a championship. Effects were consistent between the sexes although the two sex populations of swimmers were notably different. Given the limitations of the applied-field-research nature of this investigation, the obtained results were significant and further replications of this manipulation are warranted.

Investigation Two

Purpose

The purpose of this investigation was to compare championship performances for which race strategies were and were not prepared in swimmers aged 10 to 12 years.

Rationale

In this second investigation, young swimmers from the Ryde and Carlisle Clubs who attended the same workshop described in Investigation One were encouraged to develop and use race strategies in the New South Wales State Age-group (10-12 yr) Championships. These Championships occurred 14 days after the workshop experience. Race strategies were a significant topic of the workshop. The identified group was monitored for performances and whether or not a race strategy was developed for each race contested. The intention of this evaluation was to determine if performances for which formal strategies had been prepared were different to those for which no formal strategy was prepared.

Methods and Procedures

Subjects and training

Three females and six males served as subjects. They represented performers in each of the three (10, 11, and 12 yr) competition age-groups. Subjects attended an instructional workshop in the company of one or both parents and received resource materials on pre-race and race-strategy formation.

Subjects were instructed to prepare as many race strategies as they wished for events to be contested at the age-group championships. The coaches encouraged them to at least form a strategy for their most important event(s). All subjects developed race strategies with the assistance of one or both parents. No emphasis was placed on developing pre-race strategies.

After the workshop, the investigator attended both swimming clubs on three occasions to answer questions about and review race strategies being prepared. Five swimmers, each with at least one of their parents, sought evaluation and assistance.
Compliance

On the day of, but prior to the commencement of the first session of the championships, the investigator asked the swimmers’ parents whether or not their children had prepared race strategies with their assistance and for what events. Their responses served as categorization criteria for strategy and no-strategy events.

Dependent variable and data analysis

The dependent variable was whether or not a championship performance in a timed-final bettered the entry time of a swimmer. As in Investigation One, an Improved swim was one in which the swimmer’s event time was better than the entry time and an Unimproved swim was one which was not better. The numbers of Improved and Unimproved swims were determined for races for which a strategy was prepared and for those that were swim without a formal strategy.

The statistical comparison of the overall effects of Strategy and No Strategy conditions on rates of Improved and Unimproved performances can be made in several ways. For these data of Investigation 2 the N’s are clearly a good deal smaller than in Investigation 1, and concerns about the counts of Improved and Unimproved swims being from the same swimmers (and thus not independent) are still pertinent, too. In the light of these, the most conservative non-parametric test was chosen — a variant of the sign test. Of the 9 subjects, 8 had a higher percentage of Improved performances under the Strategy condition than under the No Strategy condition. Using the exact binomial test, the probability of a like or more extreme result (one-tailed test) is 0.02. The pattern of Improved performances being associated with the Strategy condition is clearly significant in the statistical sense.

Results

Table 3 lists for each swimmer the frequencies of Improved and Unimproved swims in both the Strategy and No Strategy conditions. Of the nine subjects, eight had a higher percentage of Improved performances under the Strategy condition than under the No Strategy condition. Using the exact binomial test, the probability of a like or more extreme result (one-tailed test) is 0.02. The pattern of Improved performances being associated with the Strategy condition is clearly significant in the statistical sense. The number of Improved swims was notably higher than the Unimproved swims in Strategy events (18 vs 3). However, for No Strategy events, the number of performances that were Unimproved was higher than the Improved (17 vs 4). The enhancement effect of strategy preparations on the championship performances of the subjects was marked.

Since the preparation of strategies was left to the discretion of each individual, the number of events for which preparations were made varied between swimmers. Generally, the older the swimmer, the greater the number of strategies developed (2 of 6 for 10 year-olds, 7 of 20 for 11 year-olds, 12 of 16 for 12 year-olds).

<table>
<thead>
<tr>
<th>Swimmer</th>
<th>Age</th>
<th>Strategy</th>
<th>No Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Improved</td>
<td>Unimproved</td>
</tr>
<tr>
<td>F1</td>
<td>11</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>F2</td>
<td>12</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>F3</td>
<td>12</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>M1</td>
<td>12</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>M2</td>
<td>10</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>M3</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>M4</td>
<td>10</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>M5</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>M6</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Percentages</td>
<td>85.7</td>
<td>14.3</td>
<td>19.1</td>
</tr>
</tbody>
</table>

Discussion

Strict experimental design conditions were not possible in the applied setting of this investigation. However, associations and some effects were still demonstrated. The experimental variable in this investigation was a package of factors: attendance at a workshop, parental involvement, and the development of formal race strategies along recommended guidelines.

Every subject performed some events for which no strategy had been developed. Eight of nine subjects demonstrated Improved performances when using strategies, six of them only recording Improvements when strategies were used. Only two subjects demonstrated Improved swims under the No Strategy condition. Strategy use produced only three Unimproved swims in two subjects. When no formal race strategies were used, all subjects experienced at least one Unimproved swim.

The role and extent of influence of parental involvement in the race-strategy formulation was not determined. That remains for future investigations. Neither the investigator nor any of the five coaches involved were made aware of any problems experienced by a swimmer with regard to the parental activity. It is possible that this type of activity might be a beneficial procedure in which parents could be involved in their children’s swimming.

Perhaps the most significant finding was the effect on the group. Coaches often are interested in what happens to a team. When strategies were used 85.7% of swims improved.
When strategies were not used, 19.1% of swims improved. These results suggest that strategy use was associated with improved championship performances in these young swimmers. Most coaches would be very interested in promoting the effects demonstrated in this second investigation. A strategy development and implementation program could be a very beneficial addition to a young age-group swimming program.

Conclusions for Investigation Two

Young swimmers (10-12 yr), with parental assistance and guidance, developed race strategies for some events contested at a state age-group championship. When strategies were formed and used, 85.7% of swims improved on entry times. In comparison, when strategies were not used only 19.1% of performances improved on entry times. The use of race strategies by swimmers as young as these appears to be feasible for improving championship performances in age-group swimmers.

General Discussion

Two major factors associated with improved championship performances in age-group swimmers were revealed in these investigations. Attendance at a workshop focusing on the formation of pre-race and race strategies, and the use of formal race strategies, were both associated with improved championship performances. However, one should be cautious about generalizing from these demonstrations. At best, they suggest domains which are worthy of more intensive investigation.

Attending a workshop involves many influential factors: the dynamism/influence of the presenter, the content advocated, the relevance of the content to the audience, the degree of audience understanding, etc. are some possibilities. In this instance the workshop presented content and principles that had been largely verified in objective settings (e.g., 1, 2, 24) although in some cases the application to swimming was unique. As much as possible, unsubstantiated opinions were avoided. A multi-presentation method was designed to increase the understanding of the audience. Verbal and visual presentation with workbook completion was used to focus the audience’s attention on the content and to create a greater degree of understanding, as well as to construct a permanent record of the experience. The associated text, Personal Best (20), provided a source of more extensive knowledge and examples of how to proceed with strategy development. These features may have been associated with the findings in Investigation One. On the other hand, the workshop itself may have been a catalyst for more significant self-directed experiences which promoted improved championship performances.

It is difficult to imagine that it was the workshop attendance alone which was the significant causative factor in Investigation One. It is contended that more influential variables which were part of the “workshop experience” were probably of greater effect. Further research will need to be conducted to determine the actual influential variables that were associated with improved championship performances in age-group swimmers in this setting.

Investigation One demonstrated that a workshop involving selected psychological factors can positively influence participants’ performances. It showed this was possible with age-group swimmers and is not restricted to sophisticated or mature individuals.

One feature of the content of the workshop was the presentation of a “smorgasbord” of information which allowed participants to select those items with which they were most comfortable. This promoted individualized structuring of any formal strategies as well as fostering choice and personal decisions. This was done in the belief that there is no one specific set of content necessary for pre-race and race strategies for all swimmers.

Investigation Two attempted to answer some questions that were not embraced in the first study. It focused on swimmers’ use of the materials from the original workshop. As a follow-up to that workshop, the presenter/senior investigator made himself available to swimmers and their parents to answer questions regarding race strategy formulation. In subsequent interactions no attempt was made to direct what should be done. Only suggestions about ways to improve what had already been prepared, if necessary, were entertained.

The young swimmers’ strategies were collaborative efforts with their parents. Very notable performance improvements were associated with race-strategy formulation. The question is raised whether young swimmers in the 10-12 yr age-group could complete adequate strategies on their own? That needs to be answered by other research. It does appear that the content of the workshop and associated materials were related to performance improvements when used in strategies developed by the young athletes with the assistance of their parents. This suggests a productive and beneficial role for parents to play in age-group swimming.

A number of theoretical constructs could be proposed to explain the results of these two investigations. Detailed, specific behavioral plans reduce the amount of uncertainty involved with a performance. As task uncertainty is reduced, performance is enhanced. Strategy formulation and implementation reduces uncertainty. The specter of increased self-efficacy also arises as a result of strategy formation. Since it is the athlete who constructs the strategy, it usually is a plan to do what the athlete believes can be done with a high degree of confidence. Efficacy strength is high when implementing a self-developed strategy and improved performances should result (8). Attentional skill may be enhanced by constructing, learning, and implementing race strategies. As such skill improves, so do performances (9). If age-group swimmers generally are unskilled in how to race effectively, then strategy use should produce performance
improvement because of the higher degree of mental skill that should result. The significant performance improvements of the young swimmers in Investigation Two under the strategy condition when compared to the no-strategy condition gives support to such an interpretation.

One of the major complexities of a swimming race is its demands for different types of skills. Performances with changing demands for sequences and routines require different conscious attentions at various stages. If a performer is not prepared to accommodate to such changes, but rather reacts (sometimes in a delayed manner), then a performance will be less than optimal (12, 26). Pre-race and race strategies prepare athletes for changing task demands in a proactive and usually beneficial manner.

As a recommendation for future research based on this investigation two factors that were not controlled here need to be considered.

a. Whether or not the groups differed in performance capability was not determined. If that variable was associated with the dependent variable it may have influenced the results.

b. Those who attended the workshop may have been differentiated from non-attenders by degree of motivation. If a difference existed, the applied implications of this investigation would not generalize beyond the "type" of swimmer that attended.

Explanations for why strategies work, and in particular why they work in young swimmers, deserve more exposure in another forum. What has been shown in these two investigations is that despite the complications and restricting circumstances of introducing and employing race strategies in real-life championship settings, as well as involving parents, substantial beneficial effects on performance were demonstrated. Race strategies and parental assistance should be considered for inclusion in age-group swimming programs.

Investigation Two used very young (10-12 yr) age-group swimmers as subjects. Parents assisted them in the formation of race-strategies for use at the 10-12 yr age-group championships. In races for which strategies were formed, the success rate of improving on entry times was very high (85.7%). However, in races where no strategy was prepared or used, the success rate was quite low (19.1%).

Both sets of results indicated that the introduction to and use of race strategies and parental involvement were beneficial for improving swimming performances in age-group championship competitions. The benefits of strategy use in competitions appear to be as real for age-group swimmers as they are for elite athletes.

Acknowledgement

This project could not have been completed without the support of the swimmers, parents, coaches, and principals of the Forbes and Ursula Carlile Swimming Organization, and the cooperation of the officials and officers of New South Wales Swimming Association Inc. Their contributions are gratefully acknowledged.

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References


...On the age of elite U. S. women swimmers

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Abstract

The present study consists of an analysis of the ages of elite women competitors in the United States Long Course National Championships between the years 1972 and 1996. Data obtained from official meet results allowed assessment of the women’s ages at their last birthday. The results indicated that there is a general trend toward older competitors and finalists. Age was youngest for competitors in the early 1970’s averaging about 15 yrs and increased until the 1990’s, in which the mean age was approximately 19 yrs. The range in mean age for competitors during this time was 15.7 yrs in 1973 to a high of 19.2 yrs in 1992. Athletes tended to be older during Olympic years (1984, 1988, 1992, 1996; 18.9 yrs) than in the subsequent years (17.8 yrs). In addition, age differences were noted between entrants and finalists and between competitive events with sprinters being significantly older than endurance athletes (example, 1988; 50 freestyle, 21.4 yrs ± 4.2 yrs versus 800 freestyle, 17.7 yrs ± 1.5 yrs). In conclusion, the age of elite competitive women swimmers is appreciably older now than it was two decades ago. The sport is no longer dominated by high-school athletes; rather, it is now one that is dominated by college-age or older competitors. As a result of the age differences, caution must be used when generalities are made relative to the nature and developmental characteristics of women swimmers. The population traits such as maturation rate and age of menarche today may be distinct from those of 10 or 20 years ago.

INDEX TERMS - Maturation, development, menarche, swimming, athletes

Introduction

Clearly, the cause of success of an athlete in a competitive sport is multifactorial. Elements of biomechanics, anatomy, physiology, nutrition and psychology all contribute to an athlete’s performance. It is also evident that the specific characteristics necessary for athletic success may be prescribed by the nature of the sport. An obvious example is that above-average height tends to be an advantage in basketball and volleyball. However, it is also possible that traits necessary for success in a sport may be determined by the athletic population participating in it. It has been suggested that for certain sports, the age of the competitors may influence the desirable traits which are coincident with success. Thus, it has been observed that when all participants in a sport are primarily adolescents, early maturation rate may be an important determinant of competitive success (10).

For women, the sport of swimming has generally been perceived as an “early entrance - early exit” sport because competitors are introduced to the sport well before puberty and relatively few compete beyond the junior-high or high-school level (3). This suggestion has so frequently been made that it is nearly accepted as dogma that, with the possible exception of gymnastics, most people believe that elite women swimmers are younger than women competing in most other sports (Time, page 61, Sept 19, 1988) and much publicity was generated over the “older women” competing in the recent Atlanta Olympic Games (USA Today, page 12C, June 14, 1995).

The initial component of the “early entrance - early exit” label has been documented; the age at initiation of formal competitive swim training for women in the U. S. is estimated to be approximately 9 yrs (23). This is in contrast to estimates of the age at initiation of training for competitive women runners (15 yrs) (8). Participants in team sports such as basketball or volleyball generally do not begin formal training until the junior-high or senior-high school years (15). Thus, it appears that on the average, women swimmers train earlier than competitors in many sports. Comprehensive data on the mean age of elite women competing in swimming are lacking and therefore documentation of the “early exit” assumption is incomplete.

Since it was thought for many years that the majority of women swimmers were peri-pubertal, a more rapid advance towards maturity was proposed as a competitive advantage for women swimmers (13). Data collected by Astrand and colleagues in 1963 on the age of menarche (AOM), a widely used index of maturity status for women, suggested that elite swimmers were younger at menarche than their
noncompetitive contemporaries (12.9 yrs versus 13.6 yrs) (2). Other literature at this time (13) reported that indices of development such as skeletal maturity, breast and pubic hair development were advanced in swimmers when compared to nonathletes of similar age supporting the hypothesis that early maturity represented a competitive advantage to the woman swimmer. In other words, during the 1960's and early 1970's, because the competitors were generally young, girls who matured early were bigger, stronger, and thus faster swimmers than those who had yet to mature.

More recent data on developmental traits of swimmers, however, conflict with these early reports. In 1988, competitive swimmers were shown to represent the later-maturing population, significantly older at menarche than nonathletic controls (14.3 yrs versus 12.9 yrs respectively) (20). These data are similar to what has been reported for women in other sports and at one time were interpreted as demonstrating the maturation process may be delayed by pre-adolescent physical training (9). This hypothesis has been challenged, and the data suggest that later onset of puberty appears to be associated with enhanced athletic performance in swimming (23). In simple terms, women with a slower developmental pace may ultimately become better competitive swimmers.

The true nature of this relationship and an explanation as to why the more recent data on menarche in swimmers conflict with the early data has yet to be presented. However, the most obvious hypothesis explaining the contrasting data may be that, as a group, elite women swimmers comprise a different, developmentally distinct, population now as compared to women competing in swimming a decade or two ago. The present study was undertaken in order to evaluate the ages of elite women swimmers during the time interval in which the AOM for swimmers has apparently changed (early 1970's to present). It is hypothesized that a simple increase in the age of elite competitive women swimmers may explain the apparent difference in AOM in this cohort. If so, this would serve as further evidence demonstrating the later menarche associated with athletic participation is due to selective factors which favor later-maturers in sports rather than factors which actively delay the maturation process. The data might also allow evaluation of when women swimmers "peak" answering the question: "Do women swimmers reach their competitive zenith at age 15 or 16 as has generally been assumed or much later as is frequently observed in other sports?"

Methods

The ages of all women participants at the U.S. National Championships were derived from the official meet results obtained at the Amateur Athletic Union's, the U.S. Swimming's Long Course Swimming Championships (LCSC), and/or the U.S. Olympic trials for the years 1972 through 1996. During this time, approximately 7,221 women participated in these meets. The ages of these women were obtained from the official meet transcripts. The age reported is that at last birthday. Unfortunately, records of ages for participants in these meets prior to 1972 were not preserved and are no longer available. Also for two years, 1985 and 1987, complete data were unobtainable thus placing some uncertainty on values for nonfinalists during these two meets.

Eligibility for participation in these meets is based upon individual attainment of a predetermined qualifying standard which has been set for each event. These qualifying times are determined from the average of the 32nd time achieved in the preliminary events in the two previous championships (26). Participation is not limited to a certain age range nor does a participant need to be a member of a recognized swim team. These meets are held in July or August on an annual basis. The exception to this is the Olympic trials which has varied over time. The location of the meet varies annually throughout the country insuring equal competitive opportunities are available for all participants and travel costs do not present a continued disadvantage to individuals from any geographical region.

The age of each participant was recorded (in years) as of the first day of the meet (26). Although participation in most of these meets is open to individuals from other countries, only the ages of the American swimmers were considered for this analysis. Although swimmers are eligible to swim in all events for which they have met the qualifying standard, each woman's age was incorporated into the data only once. Participants were divided into two groups; ALL ENTRANTS and a subset of this group, FINALISTS. Women who placed in the top eight places were included once in the analysis of the age of the FINALISTS and once in the calculation of the age of ALL ENTRANTS. Women not placing in the top eight were included once in the calculation of the age of ALL ENTRANTS. In addition, participants competing in the freestyle events from 1984 to 1996 were evaluated for age trends and classified as sprint (50 and 100 m), middle (200 and 400 m) and distance (800 and 1500 m) swimmers.

The data analysis included computation of descriptive statistics, student's t-tests for independent groups and a one-way ANOVA with Scheffé post hoc analysis. Other post hoc analyses included regression and trend analysis. Differences were considered significant when the level of probability for rejecting the null hypothesis was less than 0.05.

Results

The change in the age of ALL ENTRANTS from 1972 through 1996 was 2.7 yrs while the mean age ranged from a low of 15.7 yrs in 1973 to a high of 19.2 yrs in 1992 (Table 1). A time-series trend analysis revealed that a significant trend did exist with linear, quadratic and cubic components for the increase in age from 1972-1996 (Figure 1). From this, it can be seen that age appears to be increasing in a cyclical
### TABLE 1. All entrants and finalists, 1972 to 1996.
The results are printed as Age, S.D., (n).

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ALL ENTRANTS X AGE (yr)</th>
<th>n</th>
<th>FINALISTS X AGE (yr)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>16.1 ± 2.0</td>
<td>(330)</td>
<td>16.8* ± 2.2</td>
<td>(49)</td>
</tr>
<tr>
<td>1973</td>
<td>15.7 ± 1.7</td>
<td>(250)</td>
<td>16.3* ± 1.5</td>
<td>(57)</td>
</tr>
<tr>
<td>1974</td>
<td>15.7 ± 1.8</td>
<td>(544)</td>
<td>16.6* ± 1.9</td>
<td>(56)</td>
</tr>
<tr>
<td>1975</td>
<td>16.2 ± 1.8</td>
<td>(292)</td>
<td>16.8 ± 1.9</td>
<td>(59)</td>
</tr>
<tr>
<td>1976</td>
<td>16.4 ± 1.9</td>
<td>(228)</td>
<td>16.5 ± 2.2</td>
<td>(59)</td>
</tr>
<tr>
<td>1977</td>
<td>16.3 ± 1.8</td>
<td>(323)</td>
<td>16.2 ± 2</td>
<td>(53)</td>
</tr>
<tr>
<td>1978</td>
<td>16.6 ± 1.7</td>
<td>(288)</td>
<td>16.6 ± 1.5</td>
<td>(49)</td>
</tr>
<tr>
<td>1979</td>
<td>16.8 ± 1.9</td>
<td>(245)</td>
<td>17.1 ± 1.9</td>
<td>(57)</td>
</tr>
<tr>
<td>1980</td>
<td>16.1 ± 1.9</td>
<td>(308)</td>
<td>17.2 ± 1.9</td>
<td>(52)</td>
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<tr>
<td>1981</td>
<td>17.2 ± 1.7</td>
<td>(286)</td>
<td>17.4 ± 1.8</td>
<td>(58)</td>
</tr>
<tr>
<td>1982</td>
<td>17.4 ± 2.0</td>
<td>(178)</td>
<td>17.8 ± 1.9</td>
<td>(49)</td>
</tr>
<tr>
<td>1983</td>
<td>17.6 ± 1.9</td>
<td>(421)</td>
<td>18.3* ± 2.5</td>
<td>(60)</td>
</tr>
<tr>
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<td>18.3 ± 2.4</td>
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<td>1985</td>
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<td>16.9 ± 2.2</td>
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</tr>
<tr>
<td>1986</td>
<td>17.9 ± 2.4</td>
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<td>17.8 ± 2.3</td>
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<td>1987</td>
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<td>**</td>
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<td>(63)</td>
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<tr>
<td>1988</td>
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<td>(397)</td>
<td>19.5* ± 3.3</td>
<td>(60)</td>
</tr>
<tr>
<td>1989</td>
<td>18.1 ± 2.2</td>
<td>(288)</td>
<td>18.7 ± 2.4</td>
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</tr>
<tr>
<td>1990</td>
<td>18.2 ± 2.4</td>
<td>(294)</td>
<td>18.6 ± 2.2</td>
<td>(64)</td>
</tr>
<tr>
<td>1991</td>
<td>18.0 ± 2.6</td>
<td>(309)</td>
<td>18.8* ± 2.8</td>
<td>(72)</td>
</tr>
<tr>
<td>1992</td>
<td>19.2 ± 2.8</td>
<td>(241)</td>
<td>19.5 ± 2.6</td>
<td>(64)</td>
</tr>
<tr>
<td>1993</td>
<td>18.0 ± 2.6</td>
<td>(262)</td>
<td>18.9* ± 2.4</td>
<td>(62)</td>
</tr>
<tr>
<td>1994</td>
<td>17.7 ± 2.5</td>
<td>(404)</td>
<td>19.0* ± 3.2</td>
<td>(63)</td>
</tr>
<tr>
<td>1995</td>
<td>18.3 ± 2.9</td>
<td>(479)</td>
<td>19.1* ± 3.6</td>
<td>(61)</td>
</tr>
<tr>
<td>1996</td>
<td>18.8 ± 3.1</td>
<td>(236)</td>
<td>19.2 ± 3.7</td>
<td>(59)</td>
</tr>
</tbody>
</table>

* Statistically different from all entrants
** Unavailable

Manner which corresponds with Olympic years in which the United States was an active participant (1972, 1976, 1984, 1988, 1992 and 1996).
The age of the FINALISTS, i.e., the women who finished with the top eight performances in each event, also increased from a low of 16.2 to a high of 19.5 over this period of time (Table 1, Figure 2). The range of ages during this time span are illustrated on Figure 3 for all entrants and finalists. The
age of ALL ENTRANTS was determined to be $17.92 \pm 1.1$ years while the age of the FINALISTS was $17.37 \pm .98$ years. Year-by-year comparisons identified eight years in which the FINALISTS were significantly older than ALL ENTRANTS (Figure 2).

During this time the number of participants per year averaged 306 women and varied widely from a low of 178 swimmers in 1978 to a high of 544 in 1974. The number participating in the finals in any given year varied little through time ($58 \pm 6$). The number of women qualifying for the consolation finals, i.e., placing 9th through 16th, was $66 \pm 5$ and again varied little through time.

The age of women participating in the Olympic trials was found to be increasing as well. The age of ALL ENTRANTS in the Olympic years was significantly greater than those in non-Olympic years ($17.77 \pm 2.35$ versus $17.22 \pm 2.15$ yrs, respectively).

To identify whether or not age was a factor in terms of success within events of different distances, participants in the freestyle events from 1984 through the present were coded to reflect sprint (50 and 100 m), middle-distance, (200 and 400 m) and distance (800 and 1500 m) swimmers. Sprinters ($19.1 \pm 3.1$ yrs) were found to be significantly older than middle-distance ($18.5 \pm 2.6$ yrs) and the sprinters and middle-distance swimmers were significantly older than the distance swimmers ($17.7 \pm 2.3$ yrs).

**Discussion**

Although the parameters which have contributed to the observed increase in age of women participants in the sport of swimming are relatively easy to identify, the implications of this increase in age and its relationships to traits coincident with success in the sport are more difficult to elucidate. Clearly, the social and economic environments associated
Figure 2

Mean Age of Women Swimmers

1972 - 1996

* Finalists older than all entrants, p<.05

with athletic participation by women in the U.S. are different today when compared to a decade or two ago. Across sports, the number of women competing is vastly different, at least partially due to the increased number of competitive opportunities available to women (4). Title IX, which was enacted in 1972, has had a dramatic impact upon increasing and prolonging athletic participation as the number of universities providing financial support to athletic programs and financial assistance to women athletes has increased by more than ten times during these years (4). Media promotion and social acceptance of the athletic woman have played a large role in the increase in participation at all levels of competition. Finally, increased awareness of the physiological benefits of sports and athletic training and reduced concern over possible long-term negative effects has undoubtedly contributed to encouraging and prolonging active participation of women in competitive sports (16,17,22,24).

The observed increase in participant age in swimming over a relatively short time interval is dramatic. Whether this increase in participant age accounts for the similar increase in the AOM in swimmers can be only be surmised. Reports published in the early 1960's on the AOM for swimmers suggest that swimmers were younger at menarche than controls (2). Later estimates from the early 1970's for the AOM for competitive swimmers suggest that they were similar to sedentary controls (swimmers, 13.1 yrs versus controls, 12.8 yrs) (11). However, the most recent data suggest that, similar to other athletes, swimmers are much older at menarche (14.4 yrs) than are sedentary women (12.8 yrs) (20,23). The results of these studies need to be evaluated within the context of the findings of the present data.

We suggest that the AOM for the competitive swim population may have been influenced by selection or population dynamics rather than by factors which have
operated to alter the rate of development of the individual members of the swim population or in fact the general population per se. If this is true, then the widely publicized association between early athletic participation and later menarche should be considered suspect (9). This would be consistent with the view that menarche is by and large under genetic control (28).

In general, later-maturers have been shown to be more athletically adept than early maturers. In relation to physical size, late maturers tend to have longer limbs, a more linear physique, a more ectomorphic somatotype than early maturers (13,19). This appears to be due to inherited traits and secondary to a prolonged adolescent growth spurt (27, 25). In addition, late maturers have been shown to perform better on tasks requiring motor skills (3) and athletic events in which the body must overcome the force of gravity (12). However, when all of the competitors within a sport are young, those who mature at an early age may, in fact, have a temporary competitive advantage when compared to later, slower maturers (10). Early maturing individuals tend to be taller, stronger and more agile than late maturers during the adolescent age (or until both groups reach a similar state of biological development). (See 13 for review.)

In 1983, Malina (13) postulated that maturation rate may influence success in swimming. He suggested that, based upon indices of maturity status for swimmers competing at this time (menarche was significantly earlier than other athletes and similar to nonathletes), the “typical physique of a late-maturing girl is probably not appropriate for swimming”. Nevertheless, factors which have subsequently been shown to be determinants of swim performance such as strength, power output and greater lean body mass (6,18,21)
have all been shown to favor the older, later-maturer. Our results, that the finalists are older than all entrants appear to indirectly support and confirm this contention.

Furthermore, using similar criteria, children and adolescents can be shown to be athletically inferior to young adults. Their ability to generate power at supra maximal aerobic workloads is lower than adults (7). It has been shown that, in general, muscular strength is greater in adult women in absolute terms than in children (1). This strength difference does not appear to be due to changes in the cytoarchitecture or anatomical structure but to the increase in cross-sectional area of the muscle and the increased lean body mass which occurs with age (7). We therefore hypothesize that the change in the age of the competitive population from 1972 until the present has brought about a change in the developmental attributes appropriate for success in swimming. As the duration of competitive participation and the participant age have increased, the temporary advantage of the early-maturer has been superseded by the superior athletic attributes of the later-maturer.

In support of this theory, Malina and Merrett report that there has been a significant increase in androgyny indices of women athletes between 1969 and 1990 (14). They suggest this is related to enhanced talent identification and selection as the level of competition has increased in women's sport. They also speculate that due to Title IX, the differences between women athletes in the 1960's and now reflect prolonged participation, increased selectivity, and athletic recruitment.

The only other existing data available upon age trends in competitive women swimmers are intriguing. An analysis of the age of nationally competitive Swedish swimmers from 1946 to 1962 concluded that women competing in swimming were decreasing in age over this time (2). The average age of the female finalists decreased from approximately 20 yrs of age to 15.7 yrs of age over this 16-year period. Although the authors could not explain this finding, they speculated it was most likely due to changes in the sport per se rather than changing maturation patterns in the entire Swedish population. Unfortunately, similar data prior to 1972 are unavailable for U.S. swimmers and thus direct comparisons with the present data may not be appropriate.

The time-series trend analysis performed on the data identified a statistically significant trend with linear, quadratic and cubic components. Once again, the determinants of these components are unknown. However, we speculate that one element complicating the relationship between participant age and time is the occurrence of the Olympic games every fourth year. Prior to 1972, competitive swimmers received few tangible rewards beyond the personal satisfaction associated with success. The major exception to this being promotion and coverage of the Olympic games. The United States has traditionally been successful in Olympic swimming competition to the extent that participation represents perhaps the single most important motivating factor in the sport. Success in the Olympic games today represents substantial financial benefits from sources within the sport as well as those external to it. Present results clearly illustrate an increased participant age in Olympic years (1972, 1976, 1984, 1988, 1992, 1996) than in other years, indicating the importance of the Olympics in terms of continued athletic participation.

Whether or not this age trend will continue in the future seems unlikely, yet it is difficult to predict. A number of successful competitors in recent national caliber meets are approaching their thirties and yet remain competitive if not elite. The most recent U.S. Women's Olympic Swim team (ave.=19.3 yrs) was second oldest in age with the 1992 team being the oldest (ave.=21.08 yrs). (USS press release 3/12/96.)

Finally, our data suggest that, at least in the freestyle events, sprinters are older than middle-distance and distance athletes. There may be several explanations for this. One could be that training at the collegiate level favors the development of sprint swimmers. A second possibility is that because power is such an important input to sprinting success, the strength advantage of the more mature swimmers becomes evident. Or, it may be that older sprinters are able to maintain a greater percentage of their personal best performances for a longer period of time. More research is needed before this observation can be explained.

In conclusion, the age of elite competitive women swimmers in the United States has increased by nearly three years during the last two decades. A shift in age has taken place and competitive swimming is no longer a sport dominated by high-school athletes, rather one largely dominated by swimmers of college age or older. We hypothesize that as women swimmers have become older, a prolonged developmental rate may now represent a competitive advantage in swimming. Thus, the increase in the age of the swimmers may be responsible for the literature which reports an increase in the AOM of the swimming population over the last 30 years. To what extent this age trend will continue is difficult to predict. Little is currently known about the athletic capability of the post-collegiate woman. However, recognition of the fact that the participant characteristics (in this case, age) can change the sport (competitiveness) and thus change subtle criteria necessary for success within it (developmental rate as evidenced by menarche) is novel. The acceptance of this hypothesis casts further doubt upon the proposed causal association between early athletic training and the later mean AOM observed in athletic populations. Because of the obvious success of the older competitors, it seems clear that women can continue to compete at a high level beyond their middle teens into their twenties and perhaps beyond. Finally, it would appear that the successful peri-adolescent athlete is more of an anomaly in competitive swimming today than is the elite woman at or
beyond her collegiate years. Future research should focus on the performance attributes of women who have maintained their intensive training program beyond the collegiate years in an attempt to determine the potential for continued athletic success of women into their third and fourth decades of life.

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In Print: Swimming 1991-1992

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Abstract

The idea of a scientific journal specifically dedicated to enhance communication between scholars interested in competitive swimming and the professional practitioners in the sport, i.e., coaches, originated from the late Keith Sutton. His vision was that JSR would serve the American and indeed the international swimming community by acting as an educational forum without a compromise in scientific rigor. In this way, JSR would serve researchers seeking an attentive, appreciative audience as well as serve those who wish to apply recent results obtained from the frontiers of science. One of Keith's original concepts is actualized by that which follows, a bibliography of publications relevant to the swim community. It is hoped that this bibliography continues to present a useful guide to information relevant to coaches, swimmers and researchers.

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"Swimming performance following different recovery protocols"
1. A ______-min recovery protocol was used in the comparison between subsequent swim performances.
2. Rowing was chosen as an alternative recovery protocol since ________________________________.
3. No significant difference was reported for mean lactate levels and mean time differences between swimming recovery at _________ % of the lifetime best velocity for each subject on the 200-yard freestyle and rowing recovery at _________ % of the age-predicted maximum heart rate.

"Effects of a workshop intervention on competitive performances of age-group swimmers"
4. If provided with appropriate resources, parents (can/cannot) assist age-group swimmers to develop pre-race and race strategies. (Strike out the incorrect alternative.)
5. Which of the following are appropriate coaching decisions for developing pre-race and race strategies in age-group swimmers? (Check those which are correct.)
   a.__________ Only present information that the coach knows will work for all swimmers.
   b.__________ Practice elements of strategies at training sessions.
   c.__________ Present a lot of information and allow swimmers to select that which is relevant for them.
   d.__________ Be prepared to answer questions from and assist swimmers/parents in the development of race strategies.
   e.__________ Tell swimmers how they should swim their races.
6. The major content of a swimming-race strategy should be the (skills/effort) to be involved in the race. (Strike out the incorrect alternative.)

"The effect of swim training, reduced training, and retraining on velocity-blood lactate relationships"
7. Swimming velocity corresponding to the ___________ lactate concentration was the only velocity to improve during the initial four weeks of training.
8. A period of reduced training significantly decreased the swimming velocity corresponding to the ________ and ________ lactate concentrations.
9. If a period of reduced training is inevitable, the more ________________ swimming should be included to maintain mechanical efficiency.

"A kinematic and kinetic analysis of the freestyle and butterfly turns"
10. In the present study, which turn (butterfly or freestyle) recorded the highest peak push-off forces?
11. In previous studies, the presence of ___________ has prevented a precise indication of when the foot/hand contact on the wall first occurs.
12. A high push-off speed, but low glide speed, may indicate problems in the swimmer’s ___________.

"...on the ages of U.S. women swimmers"
13. How much older were women athletes during Olympic years than in the subsequent years?
14. Sprinters tend to be older or young than endurance participants?
15. When the participants are all mature, as is suggested by the current data, does swimming favor early- or late-maturers?
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