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Editor’s Message

Although I have been a member of the Associate Editorial Board for the JOURNAL OF SWIMMING RESEARCH since its beginning, this issue marks the start of my tenure as Editor-In-Chief. As one of the Associate Editors put it, “this is both an honor and a responsibility”. Webster’s defines an “honor” as an exalted title or rank and “responsibility” as something for which one is responsible or accountable. (Do I sound like an editor yet?) The position of Editor-In-Chief is therefore one in which the individual has the honor of working for the good of the journal and its readers.

When I started coaching swimming in the early 70’s, I undertook that honor and responsibility with the single-minded goal of helping swimmers to achieve some measure of success in their sport. I also hoped that in striving for this success, the swimmers would have fun and learn more about themselves and others. When I started my career as an Exercise Physiologist, I set the goal of learning as much as I could about physiological factors that govern a person’s performance ability and to share this with other scientists, students, coaches, and athletes. It was my hope (and still is) that this sharing might help coaches and athletes push the limits of human performance a little higher. So, the career changed but the final goal remained the same.

As I start in my role as Editor-In-Chief I find myself setting goals again. Not surprisingly, the goals I have set for my appointment are not much different than the ones I set when I started coaching or when I started in Exercise Physiology. I hope that through my position as Editor-In-Chief and with the able assistance of the Associate Editors and the American Swimming Coaches Association, we can help provide a direct link between researchers and coaches for sharing of scientific ideas and developments that have potential applications to improving performance. To these ends there will be several changes in the Journal that will be implemented at various times over the next year or so.

Recognizing that the researchers must be aware of the specific needs of coaches, we will begin to establish a more open and bidirectional path of communication between these groups. A discussion forum will be added to the Journal in which a researcher can write to pose a question to coaches regarding training, nutrition, preparation for competition, or any other aspect of athlete management. A response from the coaching community will be solicited and the subsequent discussions will be published. This forum will also be set up in the other direction where a coach may pose a problem to be discussed by researchers.

The papers that are published in the Journal will also begin to change. The author guidelines have been revised and the Editorial Board will require authors to write a section on practical applications suggested by their findings. We must recognize, however, that not all research will generate immediately applicable information. Some research may simply help to lay the foundations for later research that will lend itself well to application. Other research may help to catalyze creative thought processes in coaches who will then find new and better ways of preparing swimmers. The authors will, however, be expected to discuss how their findings may contribute the development of practical solutions and improved understanding of the demands of swimming.

Other plans for future issues include establishing a “Letters to the Editor” column, establishing an annual award for best paper, increased representation of coaches on the Editorial Board, publication of round table discussions that may be held at the World Clinic, and annual indexing of the contents of each year’s issues.

To bring about these and other changes in order to make the journal more responsive and relevant is the task that will be shared by me, the Editorial Board, the researchers, and coaches. The fact that I have been given the opportunity to help coordinate these efforts is not only an honor and a responsibility, but also a privilege I gratefully accept.

Rick L. Sharp
Editor-In-Chief
Predicted and Actual Pre-Competition Anxiety In High School Girl Swimmers

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Abstract

This investigation examined the ability of female high school swimmers to predict pre-competition anxiety according to Hanin's Zone of Optimal Function (ZOF) theory. Seventeen swimmers completed the state version of the State-Trait Anxiety Inventory for Children (STAIC) 24-hr prior to an easy and difficult competition with instructions to respond as to "how you think you will feel 1-hr prior to the meet". The STAIC was then completed 1-hr prior to each meet utilizing the standard ("right now") instructional set. On an earlier occasion Ss completed the STAIC under baseline conditions as well as with instructions to try to recall their anxiety prior to their individual best, usual, and worst performances. Pre-competition anxiety was significantly elevated (P<.05) above baseline prior to the difficult, but not the easy meet. The correlations between predicted and actual pre-competition anxiety were .77 (P<.01) for the difficult meet and .39 (P>.05) for the easy meet. Anxiety was significantly elevated above baseline for the recall of best and worst performances (P<.001), but not in the case of the usual performance (P>.05). It is concluded that younger athletes are able to accurately predict anxiety prior to a difficult competition in accordance with Hanin's ZOF theory.

A host of psychological factors have been regarded to influence sport performance, and anxiety is foremost among them. Various theories have been proposed in attempts to predict and explain the effect of anxiety on sport performance, and most theoretical approaches assert that anxiety exerts a uniform effect on performance in athletes performing the same sport or related sport tasks (i.e., long distance runners and swimmers) (1). Hence, any attempt to improve performance will involve manipulating anxiety (i.e., either increase or decrease) to the same degree among all members of a given team prior to athletic competition (2).

The inverted U-theory is the most well known theory of anxiety and sport performance, and this theory implies that a moderate level of anxiety is best for performance (1,3,6). When anxiety is either higher or lower than this moderate level performance worsens, and the inverted-U function is described. In addition, the optimal moderate level of anxiety is regarded to be dependent on the type of sport task being performed. In explosive, gross motor tasks a higher level of anxiety is considered desirable whereas in tasks requiring less effort a relatively lower level of anxiety is desirable (1).

However, convincing evidence in support of theories based on groups effects is lacking (6), and findings in support of group based theories such as inverted-U have come under recent criticism (10). In contrast to theories based on group effects, Hanin (4) has advanced the Zone of Optimal Function (ZOF) theory which is based on the concept that there are individual differences in the anxiety-performance relationship among athletes. On the basis of assessments of pre-competition anxiety and performance of Soviet athletes Hanin has found that each athlete performs best when her/his pre-competition anxiety is within a narrow range. Furthermore, this range, or zone of optimal function, may be low, moderate, or high depending on the particular athlete. When pre-competition anxiety falls outside this zone performance deteriorates.

ZOF theory is different from inverted-U because Hanin (4) has found that some athletes—regardless of sport—perform best at either a low or high level of
anxiety, and a moderate pre-competition anxiety would worsen the performance of these individuals. In contrast, inverted-U theory would predict that all athletes in a given sport would perform best at the same level of anxiety.

Hanin (4) has found that athletes can accurately recall pre-competition anxiety of past competitions, and has used this as a method of determining an athlete’s ZOF. With this strategy, an athlete would complete the anxiety inventory with instructions to recall how he/she felt prior to her/his very best performance. Hanin’s (4) research has also demonstrated that athletes can make accurate predictions of their own pre-competition anxiety up to several days prior to the actual meet, and the correlations between predicted and actual pre-competition anxiety have been found to be higher for difficult competitions in comparison to easy meets.

To date, only limited research utilizing ZOF theory has been performed with athletes in North America, and this work has been conducted only with adult athletes. For example, Raglin and Morgan (11) found that male college swimmers could accurately predict pre-competition anxiety 24- and 48-hr prior to difficult and easy competitions. In accordance with Hanin’s findings, predictions of anxiety tended to be more accurate in the case of a difficult competition, and swimmers judged as performing successfully were found to be more accurate in predicting their pre-competition anxiety than were unsuccessful swimmers.

It is not known, however, if the previous findings generalize to younger athletes. Hanin (4) has stated that past experience influences the ability to predict anxiety in upcoming performances, consequently younger athletes may lack the experience necessary to make accurate predictions. Also, some researchers regard high levels of anxiety as exerting a uniformly negative influence on sport performance in children (3,6), and ZOF theory would not apply to younger athletes if this were the case. Hence, the present study was performed in an attempt to replicate and extend previous research on ZOF theory in a sample of female high school swimmers.

Method

Subjects

The subjects in this investigation were 17 members (Mean age = 15.5, Range = 14-17) of a girl’s high school swim team who had an average of six years of experience in the sport. Written permission was received by each of the swimmer’s parents prior to participation, and the procedures were approved by the superintendent of the school district as well as the school board before the investigation was initiated. Prior to completing an informed consent document the swimmers were assured that the results would be treated in a confidential manner and they would be free to drop out of the investigation at any time.

Materials

Actual and recalled pre-competition anxiety was assessed with the state version children’s version of the Spielberger State-Trait Anxiety Inventory (STAIC) (14). The state version of the STAIC is a likert format questionnaire that contains 20 statements pertaining to aspects of anxiety (e.g., “I feel calm”). All testing took place in a quiet classroom located near the pool and each session lasted approximately 15-min.

Design and Procedure

During the initial assessment session each athlete first completed the state version of the STAIC utilizing the standard instructional set (i.e., “how do you feel right now at this moment”), and this served as a baseline measure. The athletes then performed retrospective recalls of past competitions modeled after a protocol described by Hanin (4). This was achieved by having the swimmers fill out the state version of the STAIC three separate times on the basis of how they recalled feeling immediately before the: 1) usual, 2) best, and 3) worst performances of their swimming careers.

Additional assessment sessions were subsequently held prior to both an “essay” and a “difficult” meet, and these meets were chosen by the coach on the basis of past performances against the opposing teams. Twenty-four hours prior to each meet, the swimmers completed the state version of the STAIC on the basis of “how you think you will feel one hour before tomorrow’s meet.” Finally, the swimmers again completed the STAIC approximately 1-hr prior to the meet using the standard instructional set.

Results

The baseline and retrospective recollection data were analyzed via a one-way ANOVA (15), and are displayed in Figure 1. A significant main effect was observed
(P < 0.01), and Newman-Keuls post-hoc analyses revealed that state anxiety in the best and worst conditions was significantly (P < 0.05) elevated above baseline, whereas the usual condition was not greater than baseline (P > 0.05). The anxiety means in the best and worst conditions did not differ (P > 0.05) from each other, but each of these values was significantly (P < 0.05) greater than the usual condition.

Baseline, predicted and actual pre-competition anxiety data were analyzed via repeated measures ANOVA (15), and these findings are summarized in Figure 2. It was observed that actual pre-competition state anxiety was significantly (P < 0.05) elevated above baseline in the case of the difficult meet. Actual pre-competition anxiety was also significantly (P < 0.05) higher in the difficult meet in comparison to the easy competition.

Predicted pre-competition anxiety was found to be higher (P < 0.05) than the actual value in the case of the easy meet, but for the difficult meet the predicted and actual pre-competition anxiety values were not significantly different (P > 0.05). The correlation between predicted and actual pre-competition anxiety of .77 was significant (P < 0.05) in the case of the difficult meet, in the easy meet the correlation did not achieve significance (r = .39, P > 0.05).

Discussion
The findings from the present study are in general agreement with previous work involving ZOF theory. In the present sample the magnitude of the anxiety elevations observed in the retrospective recalls of best and worst performances were found to be similar to values observed with female (9) male (8) and long-distance runners. In both the present sample, as well as in the case of the runners, significant differences in recalled pre-competition anxiety were not found between best and worst performances. The observation that recalled pre-competition anxiety in the best condition is not lower than the worst value indirectly refutes the contention that high anxiety uniformly exerts a negative effect on physical performance in young athletes (3,6). That is, if high levels of anxiety consistently exerted a negative influence on performance, then the anxiety value in the worst condition would be greater than the value for the best condition. Furthermore, in the present sample 23.5% (4 of 17) of the athletes reported that they experienced an anxiety level at least two standard deviations above the published age group mean (14) in the best condition.

The observation that retrospective recall of pre-competition anxiety under the usual condition was not greater than baseline is in disagreement with previous work where recalled pre-competition anxiety under usual conditions was found to be elevated to the same degree as recollections of best or worst (8,9) performances. However, in independent but related research involving recollections of past performances in young female swimmers by means of the STAI, pre-competition anxiety was significantly elevated in the case of usual performances (12). It remains unclear whether this discrepancy is unique to the present sample, or if this finding can be generalized to other age-group athletes. Previous work with young athletes has found that mean pre-competition anxiety for an entire team may not be elevated above baseline, whereas anxiety may be significantly elevated in some individual cases (13). Hence, for many young athletes, an “easy” or “average” competition may not be anxiety provoking. However, the T-score values of pre-competition anxiety for the easy meet ranged from 42 to 68, indicating the competition was anxiety provoking for some individuals. This finding also supports Hanin’s contention that there is considerable variability in the pre-competition anxiety of athletes participating in the same activity.

In this investigation the swimmers were more accurate in predicting pre-competition anxiety for the difficult meet in comparison to the easy meet, and the correlation between predicted and actual pre-competition anxiety (r = .77) achieved in the difficult meet is in close agreement with previous work involving North American (11) and Soviet athletes (4). The nonsignificant correlation observed in the easy meet (r = .39) is lower than that observed by Raglin and Morgan (11) but values of this magnitude have been reported by Hanin (4).

A significant (P < 0.05) difference between predicted and actual pre-competition anxiety occurred in the easy meet, and this finding implies that the swimmers anticipated the easy meet to be more anxiety provoking than it actually was. It is possible that this finding reflects uncontrolled factors particular to the easy meet, the swimmers, or the coach. Alternatively, this observation could also reflect a general tendency for younger athletes to overestimate pre-competition anxiety in easy
meets, but it is not known if this tendency occurs in young male athletes as well. Furthermore, the effect of overestimation of precompetition anxiety on performance has not been determined, and further research is needed to address these issues.

The findings of the present investigation indicate that young athletes can accurately predict pre-competition anxiety prior to difficult competitions to a degree of accuracy comparable to adult athletes. Hanin (4) has reported that Soviet coaches have used predicted pre-competition anxiety values to identify, in advance of the actual competition, those athletes who will be in need of some form of intervention (i.e., either increasing or decreasing anxiety). The present findings suggest that this approach may be practical for age group athletes in instances where the competition is challenging or difficult, but not for easier meets.

However, it is suggested that further research is needed before ZOF theory be utilized on an applied basis. In some cases elevated pre-competition anxiety may reflect an underlying psychological illness (e.g., generalized anxiety disorder) rather than a response to the competition per se. In addition, some individuals display paradoxical increases in anxiety in response to relaxation procedures (5), hence any psychological assessment or intervention should be carried out under the supervision of a qualified psychologist.

Conclusions
Based on the present sample the following conclusions can be made.
1. Retrospective recalls for pre-competition anxiety for best and worst conditions reveal increases in anxiety for female high school swimmers, and these changes are similar to those found in other athletic groups.
2. Female high school swimmers can accurately predict their level of pre-competition anxiety 24-hr prior to a difficult meet, and the degree of accuracy achieved is comparable to that observed in other athlete groups.
3. In comparison to a difficult meet, female high school swimmers overestimate pre-competition anxiety 24-hr prior to an easy meet.

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The Use of Arm Stroke Index To Indicate Improvement In Swimming Training During a Competitive Season

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Abstract

Thirty-six men and women competitive swimmers had their heart rate, blood lactate, and arm stroke index (total number of strokes/(m/sec)) measured while performing slow, moderate, and all-out swimming during early, middle, and late training season workouts to determine the responsiveness of the arm stroke index (ASI) to stroke proficiency and training. The results indicated that the heart rate, lactate and ASI responses during the submaximal butterfly swims were significantly greater (p<0.05) than the other strokes. MANOVA statistics indicated a trend toward lower ASIs during the moderate pace trials than either the slow or all-out trials for all strokes (p<0.06). The overall MANOVA indicated that compared to early season ASIs were significantly (p<0.05) reduced by late season. However, the backstroke did not follow this trend. Correlational analysis indicated that the fastest backstroke, butterfly and front crawl swimmers had the lowest ASIs (r = 0.847, 0.98, 0.838, respectively). However, this relationship was not as precise for the breaststroke (r = 0.705). The results of this investigation indicate that ASI may be a sensitive indicator of training and stroke proficiency that can be easily introduced by coaches and swimmers into their training programs.

Introduction

The evaluation of swimming performance for training purposes is a major concern for swimming coaches. For years the major tool used by swim coaches to assess the physiology of the swimmer was heart rate. However, in recent years coaches have come to rely on measurements of blood lactate to predict performance times. Three main approaches to this testing have been documented. Mader et al. (6) developed a two speed test, based on the lactate/velocity curves during 100 and 400 m swims. Gullstrand and Holmer (2) suggested a progressive series of ten 100 m swims. Olbrecht et al. (7) and Simon et al. (9) took another approach and used a set of 400 or 300 m swims, respectively. These techniques have enabled swim coaches to examine the physiological effects of their training and predict performance; however the techniques do little to evaluate stroke mechanics and efficiency. Also, the longer swims are cumbersome to administer due to the time involvement and the fact that many younger swimmers cannot adequately sustain the butterfly stroke for repeated 400 m swims. Thus, Sharp et al. (8) have suggested two, 200 yard/meter swims at 90 & 100% of maximum separated by 20 minutes. The problem with this approach is that lactate normally responds exponentially with increases in exercise intensity, yet the response curve of Sharp et al., based on only two points, suggests a linear relationship. However, the data of Heppes et al. (3), supports the use of the 200 yd/m distance. They compared lactate responses during swims of 30 min at 90%, 20 min at 100%, 10 min at 105%, 5 min at 112% and 2 min at 118% VO2max, and found the highest lactate values two minutes post exercise occurred during the 2 min swims (approximately 200 yds) at 118%.

Considerable physiological evidence exists concerning the development and use of lactate/velocity curves for swimming training. The curves have been used for predicting a theoretical performance time. The curve has also been used to demonstrate a training effect (5); since training reduces lactate levels at a given speed. Keskimer et al. (4) have suggested that the lactate/velocity curves may differ with each stroke. However, there is a considerable lack of evidence on the backstroke, breaststroke and butterfly to support this hypothesis.

Lavoie et al. (5) have suggested that stroke economy can be evaluated by measuring arm stroke index (ASI);
the ratio of the number of arm strokes per distance swim to the swimming velocity. They have shown the ASI to be strongly correlated to oxygen uptake \( r = 0.938 \) and highly reliable \( r = 0.935 \). Their results noted that the ASI decreases as speed increases. Thus, ASI may be a valuable non-invasive tool for swim coaches lacking the facilities to measure lactate. Furthermore, Lavoie suggests that the ASI is predictive of maximal aerobic power during swimming. However, the speeds they evaluated were below present competitive rates. Also, their investigation only examined front crawl (freestyle) swimming.

The results of these studies suggest the need for a more simplified means of analyzing the conditioning response that would include both biomechanical and physiological measures that would be adaptable to all four competitive strokes. Therefore, this project was undertaken to produce a more accessible method of analysis that, 1) omits the expense of lactate analysis, 2) gives a better overall assessment than heart rate, and 3) responds to adaptations of training.

Methods

Initially, 31 men and 27 women from the University of North Carolina’s swim teams signed an informed consent to participate in the project. The testing occurred early, mid season and during the final week of their training season. Of the initial 58 subjects complete data was obtained on 36; 18 men and 18 women. Their specialties were as follows; 7 backstroke, 11 breaststroke, 4 butterfly and 14 freestyle.

During each testing session the swimmers completed three, 200 yd swims with 8 min rest between; the first at a slow pace, the second at a moderate pace and the third all-out. All trials were at a self selected pace, initiated from a push off (no dive), and timed to the nearest 1/10 of a second. Two-hundred yard swim distances were chosen based on the data of Heppes et al. (3) which suggested the distance was a viable alternative to the longer distances. Also, that distance is swum competitively in all four strokes.

Each swimmer was instructed to count the number of arm cycles for the entire distance, including any underwater strokes. Within five seconds of completing the swims the subjects measured their heart rates by carotid palpation for ten seconds. It was realized that palpation may not be the method of choice because of the inherent inaccuracies. However, we chose this method because four swimmers were simultaneously completing the trial and we did not have sufficient equipment to measure all at once. We had trained the swimmers to measure their own heart rates and had previously verified their accuracy. Also, most swimming coaches rely on palpation to obtain their swimmers heart rates. Once heart rate was measured they exited the water, reported their counts, dried their hand and arm, and had a finger prick blood sample taken for immediate lactate analysis. Thus, lactate samples were obtained within two minutes of the completion of the swim.

The lactate analysis was completed using an automated Yellow Springs Instruments Lactate Analyzer which was calibrated after every tenth sample. ASI was calculated by converting the swim times into speed (m/sec), then dividing the number of arm strokes for the 200 yds by the speed:

\[
\text{ASI} = \frac{\text{Number of strokes}}{\text{Speed (m/sec)}}
\]

The data were analyzed three ways. First, individual regression lines for speed vs lactate, heart rate and ASI were computed for each stroke. Comparative regression analysis was then completed comparing the responses to the four strokes. A second level of analysis was completed using MANOVA techniques comparing strokes, speed, heart rate, lactate and ASI. When significance was found \( p < 0.05 \) appropriate step-down ANOVA and post hoc (Newman Keuls) testing was completed. Third, simple rank order correlations were made within each gender comparing the peak swim ASI with the rank order of their competitive speed.

Results

Regression analysis within each stroke indicated no significant differences in the slope of the responses be-
Table 1.
Relationship of gender to heart rate, lactate, swim speed and ASI during slow, moderate and fast pace swimming. The data represent the overall mean ± SD of the combined early, mid and late season trials. (See text for statistical analysis.)

<table>
<thead>
<tr>
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<th>Breaststroke</th>
<th>Butterfly</th>
<th>Front Crawl</th>
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Between men and women for the heart rate and lactate results (Table 1). Thus, the results were combined for the MANOVA. The MANOVA testing also indicated no significant differences between gender for heart rate. However, significant differences between strokes were noted (Fig 1), with the slow butterfly trials having higher heart rates than the slow trials for the other strokes (p < 0.05). Significant differences were noted between gender for maximal lactate concentrations, with the men having higher lactates than the women (p < 0.05; see Table 1). When comparing the lactate levels between strokes (Fig 2), the slow trials for the butterfly stroke resulted in higher concentrations than the other three strokes (p < 0.05). No other significant differences were noted.

The regression lines for speed of the swims were found to have a similar slope for the men and women. However, the intercepts were noted to be significantly different, with the men having a greater speed at the intercept for all strokes. Follow-up MANOVA (Fig 3) indicated that the men were consistently swimming at a higher speed than the women for all strokes for all three trials (p < 0.05; see Table 1). MANOVA comparisons of the four strokes also indicated significant differences with the crawl stroke being significantly faster than the other three (p < 0.05). The backstroke and butterfly were found to be similar in speed, but greater (p < 0.05) than the breaststroke.

ASI regression results were inconclusive as the results were not linear (Fig 4). However, follow-up MANOVA did indicate a trend (p < 0.06) toward a lower ASI during the moderate pace trials than either the slow or all-out trials for all four strokes. It was also noted that the women had significantly higher ASI than the men for all four strokes (p < 0.05). Comparisons between strokes indicated different patterns for the men and women (Table 1). The women had significantly higher ASIs when comparing the breaststroke to all other strokes. The butterfly stroke was also found to be significantly greater (p < 0.05) than either the back or front crawl. For the men, the butterfly had the highest ASIs (p < 0.05) with the back and front crawl having the lowest (p < 0.05). When comparing the early, mid and late trials, for all four strokes, the ASIs were found.
to be significantly reduced comparing late and early season. However, the early and mid season, as well as the mid and late season were not significantly different.

Rank order correlations indicated that the fastest swimmers in the butterfly, back and front crawl also had the lowest ASIs ($r = 0.98, 0.847, 0.838$, respectively). However, the correlation for the breaststroke was considerably lower ($r = 0.705$).

**Discussion**

The most significant finding of this study is that ASI can be a sensitive indicator of swimming economy and performance. The fact that the ASI is lowest in the fastest swimmers is indicative of their improved swimming economy. The ASI results also indicate that as the training program progresses, the swimmer’s strokes become more economical. Thus, as the swimming proficiency increases, the ASI at a given speed will decrease. Plotting each swimmers ASI during slow, moderate and all-out swimming throughout the season may be a good indicator of improved performance. The obvious advantage of the use of ASI is that there is minimal expense, requiring only a stroke count. Our results would suggest a 5-10% improvement could be noted during a training season.

Lavoie et al. (5) suggested that ASI should reach an optimum which will probably occur at speeds greater than 1.0 m/sec. Furthermore, Lavoie suggested that if the speed continued to increase above the optimum, a
rise in ASI would be expected. Our results for the
women swimmers support this contention, with the ASI
for the butterfly and front crawl tending to be lower
for the moderate speed than either the slow or all-out
trials. Also, this optimum occurred at speeds of
approximately 1.46 and 1.51 m/sec, respectively, well
above the speeds investigated by Lavoie. Contrary to
the suggestion of Lavoie, the men had a continuous
decline in ASI even at the highest speeds. It would have
been interesting to measure ASIs in these men during
a swim meet when they are going their fastest and com-
pare them to our results. It is possible that different
results would have occurred.

When the individual data, rather than group means,
are examined a slightly different picture is presented.
The fastest and most proficient swimmers show little
or no change in ASI as their speed increases up to max-
imum, while the slower, less efficient swimmers have
a higher ASI at the fastest speed. The breaststroke seems
unique among the competitive strokes (Table 1) in that
increases in speed are accomplished with increases in
stroke rate, even by the most proficient swimmers.

Sharp et al. (8) have indicated that during a four
month training program the greatest changes in velocity
occurs within the first two months. Thereafter, im-
provements in speed still occur but at a much slower
rate. In fact, the front crawl swimmers they studied had
little change in speed during the last two months of their
training program. We found the pattern to be quite
variable, with some swimmers responding as Sharp
suggested while others improved equally, or more so during
the second part of the season. This, once again, sug-
gests the importance of the individual, rather than the
group. We did note one illogical finding within our sub-
jects. When comparing the early, mid and late trials,
improvements in speed were found for the backstroke,
breaststroke and butterfly. However, no improvements
were noted for the front crawl, yet their meet perfor-
ance times were improving. This response, although
quite perplexing, may be in agreement with Sharp et
al. (8).

Our data indicate that at the speeds chosen by the
subjects, the submaximal exercise heart rates were similar
for the breaststroke, breaststroke and front crawl. Only
the butterfly trials had higher submaximal rates. The
higher rates were related to the fact that the butterfly
swimmers were swimming at a speed that was closer to maximal
than the other strokes. If the speeds are adjusted so that
they are of equal proportion of maximal speed, then
the heart rates are similar for all four strokes. Thus,
for a coach, heart rates are still an extremely valuable
tool for the assessment of the training program.

Maximal post-swim lactate concentrations did not
change from the early to the mid trials; however the
maximal values during the late season trials
demonstrated a trend toward an increase, particularly
for the breaststroke, butterfly and freestyle. This would
suggest that the training was improving their anaerobic
capacities; in agreement with the velocity data for the
butterfly and breaststroke, but in opposition to the
freestyle data. We cannot explain these differences. The
lactate data for the slow and moderate paced trials did
not significantly change, yet the speed increased. This
would be expected from the training program (8). Thus,
when using the lactate/velocity curve to indicate a train-
ing effect, the curve should either shift to the right or
the slope should become steeper (more vertical).

Our maximal lactate results were somewhat lower than
previously reported (3,4,5,8). We believe the differences
are related to the timing of our samples, the duration
of our swims, and most important individual differences.
We took immediate post exercise samples while most
other reports examined five minute post samples.
Previous research has indicated that blood lactate con-
centrations peaks between the fifth and tenth minute
post exercise (1,4). Most other studies have also com-
pleted multiple tests or longer swims which could result
in higher lactate concentrations compared to those
achieved during our relatively short swims. However,
Heppes et al. (3) did find that of all the swim intensi-
ties and times at that intensity, two minute swims at
118% of VO2max resulted in the highest lactate values
two minutes after exercise. The time for our swims
ranged from 1.75 to 2.7 minutes, similar in length to
Heppes et al., suggesting that our results should have
been similar for the fast trials. Actually, because of the
large variations between swimmers, the absolute levels
are not as significant as the comparisons within a swim-
mer on a test/retest basis.

Submaximal lactate concentrations were similar for
back and front crawl, as well as the breaststroke; how-
ever, the butterfly had higher levels. The higher lac-
tates during the submaximal butterfly swims are prob-
ably related to the slow and moderate pace trials being
completed closer to maximal velocity than for the other
three strokes. This response, in conjunction with the
higher submaximal heart rates and ASIs, suggests that
it was more difficult to swim the butterfly slowly than
the other strokes.

In summary, our data suggest that the arm stroke in-
dx may be a viable indicator of stroke proficiency that
can be used by coaches to monitor seasonal progress
in all four competitive swim strokes. The ASI can also
be used to predict success, as the fastest swimmers tend
to have the lowest ASIs. Our data further suggests that
the combination of heart rate, arm stroke index, and
speed can sense changes in training equally as well as
blood lactate analysis. However, we cannot comment
on the prediction of swim performance (time). We sug-
gest that graphs for each swimmer be developed using
heart rate versus velocity and ASI versus velocity. Thus the coach and the swimmer can easily monitor progress.

References

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