A Coaching Review

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A Coaching Review

BY JOHN LEONARD

1. A Comparison of Four Different Start Combinations.

This is one of those research papers that are interesting, but of limited immediate use to the coach. Conclusions are that: 1) a flat entry gets the swimmer into the water faster than the hole entry, 2) the swimmer should practice both hole and flat entries as well as both grab and track start techniques to determine which is individually better. Since we know there are dangers inherent in the hole entry, (and that these can be mitigated by caution, practice and deep water) and we also know that many swimmers can complete the dive/stretch/1st stroke portion of the race more advantageously with the hole entry, it is confusing to try to understand what use a coach can make of this study. It is clear that if you go directly into the water (the flat start), you will enter faster than if you go “up and out” before the hole entry. The entry, as the authors point out, is only one consideration in maximizing the “start” procedure for speed. The study measured to a standard of 8 meters from the start, for college swimmers. Since any college swimmer can dive and cover the 8 meters with just the very initial part of the glide, this can in no way judge the overall effectiveness of the various starting procedures evaluated in the study. The authors carefully acknowledge this.

2. Effects of Iron Supplementation on Iron Status of Young Female Swimmers During the Pre-Season Phase

This study says that in young female swimmers, it may be necessary to undertake an iron supplementation, in consultation with a doctor or sports scientist who is familiar with the athlete, and that iron status should be routinely monitored.


This is a very interesting study that looks at a simple but important concept: How fast or easily can a swimmer move in the warm-down pool and effectively remove lactic acid from the system? We have all seen athletes who barely float while loosening down, and at the other end of the spectrum athletes who expend more energy in the warm-down than in the race. How much is enough?

The results indicate that swimming at 65% of race velocity will significantly reduce the lactate values, and make for a better recovery rate for the athlete. Recovery will also depend on the total amount of lactate accumulated. (The higher the lactate, the longer the time needed in active swimming recovery. Further, the amount of swimming at that rate is not yet determined, but 15-20 minutes is recommended as reasonable by the researchers, and is obviously already recommended in practical terms by many coaches.

65% of race velocity provides a “window” for the coach to think of in terms of how energetic the warm-down swim should be for effective recovery. Obvious additional questions include “for how long?” and does 65% of race velocity correspond to any simple physical determinant, such as heart rate, that an athlete could use when a coach is not immediately available to calculate the 65% of velocity.
A Comparison of Four Different Start Combinations

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Abstract

The objectives of this study were to compare four different types of swimming start combinations, using two starting techniques (track and grab) and two entry methods (flat and hole), in time to an 8.0 meter mark and to entry. Twelve experienced competitive collegiate male swimmers underwent an initial training program, consisting of five 45-minute sessions, to learn and practice each start combination. Subsequent to training, swimmers were filmed and timed performing three trials of each start combination. Three 2 × 2 analyses of variance were used to measure time to 8.0 meters, time to entry and angle of entry. It was shown that subjects performing starts involving a flat entry method were significantly faster (p < 0.0001) than subjects using the hole entry to the 8.0 meter mark. There were no significant differences (p > 0.05) in time to 8.0 meters demonstrated between subjects using the grab and track start techniques. In time to entry, swimmers using the track technique were faster to entry compared to those using the grab (p < 0.001) and those using the flat entry were faster than those using the hole entry (p < 0.001). Swimmers using a hole entry also had a significantly more acute angle of entry than those employing the flat entry.

These findings warrant the following conclusions: 1) the flat entry method is a faster and safer method of entry, 2) each swimmer should learn and practice both start techniques (grab and track) before deciding which method is best for him or herself and 3) the swimmer entering the water first off the starting block is not a good indicator of which start technique is fastest, as the glide appears to be a very important phase of the start.

Introduction

A superior start in competitive swimming is a major concern of top level performers. Factors such as a quick reaction time, a fast forward motion, optimum flight time and distance, a streamlined entry and an effective glide are all ingredients contributing to the development of today's start techniques and entry methods. In the past two decades extensive research has been conducted using various types of starts (2, 3, 9, 12, 13, 14, 17, 18) in an attempt to optimize the aforementioned factors and, thus, determine the ideal start techniques and entry methods. Unfortunately, there are still diverse opinions as to which competitive swim start technique should be performed.

Prior to the 1972 Olympics, the conventional method was the predominant start technique used in swimming. At about this time, the grab technique was introduced and its overall effectiveness quickly brought about the demise of the conventional start technique. In 1974, a third technique of starting, the track start, received attention and was soon performed successfully in international competition.

Immediately following the introduction of the grab and track start, extensive research (3, 12, 18) comparing the three starts was initiated. Results from these studies indicated that each start was shown to have advantages. The conventional technique emphasized horizontal flight distance, the track start emphasized quickness to entry and the grab start successfully blended elements of both the conventional and track techniques. After several studies, the conventional technique, despite its flight advantage, was shown to be overall mechanically ineffective at getting the swimmer off the block quickly. Consequently, very few competitive swimmers actually use this technique today, other than for relay exchanges. By the 1980's, attention shifted to methods of entry (10, 17), namely the flat and hole methods. To date however, there appears to be no definitive answers as to which start technique, entry method or combination of these two aspects of starting are most effective. In fact, observation at any typical swim meet at any level of competition will show both types of start techniques and entry
methods used regularly.

The primary objective of this study was to determine which type of start technique—grab or track—and which type of entry method—flat or hole—resulted in the fastest start combination.

Methods

Subjects. Twelve male volunteer subjects recruited from the New Mexico State University mens' swim team and the Las Cruces (NM) Aquatic Team were used in this study. All subjects were between the ages of 18 to 24 years-old. To participate in the study, the subjects were required to have at least two years experience in competitive swimming with an accredited National Collegiate Athletic Association (NCAA) program or registered United States Swimming (USS) club.

Instrumentation. A 16mm intermittent pin-registered, LoCam high speed motion picture camera, filming at 50 frames per second was used to film each trial. The field of vision of the camera covered the starting block, the starter, the path the subject traveled through the air and into the water up to the 8.0 meter mark.

A Dekan automatic performance time analyzer was used to measure the total time to the 8.0 meter mark. This apparatus was activated manually (foot pedal) at the start signal (pistol) and was deactivated automatically when a string, attached to the subject's waistline, reached a distance of 8.0 meters from the top leading edge of the pool deck. In addition, a camera flash was manually activated at the start to insure accuracy of film documentation.

For film analysis, a stop-action projector projected the image onto a vertical opaque surface. Attached to the front of the screen was a cursor arm of a Numronics digitizer which was used to collect position data from the filmed performance. The digitizer was interfaced with a personal computer to attain center of gravity and entry time data.

Biomechanical Analysis. Each of the subject's twelve test trials was analyzed. Digital data were collected from six frames of each trial: the frame at which takeoff occurred, the two frames prior to and the two frames following the takeoff and the frame of initial contact with the water. From each of the preselected frames, vertical and horizontal coordinates for 16 points were collected: top of head, shoulder (near and far), elbow (near and far), wrist (near and far), hip (near and far), knee (near and far), ankle (near and far), toe (near and far) and a relative point which acted as an origin (the top leading edge of the starting platform). The position data collected were then transferred to the computer and analyzed by software written for this study indicating displacement, time, center of mass, and angular quantities (takeoff and entry angles).

Experimental Design

Training Phase. All starts for pretraining, training and testing were performed in the deep end of the pool (depth 12 1/2 feet). During pretraining, fifteen potential subjects were viewed in both start techniques, track and grab and both entry methods, flat and hole. Following pretraining, the subjects attended five, 30- to 45-minute training sessions to practice each of the individual start techniques, entry methods and start-entry combinations. All four combinations were practiced during all five training sessions. Videotape recording was used during each session for instructional feedback and coaching assistance. All combinations were performed as freestyle starts.

The major points of instruction that were emphasized for each technique or method were:

Grab start—Both feet should be placed shoulder-width apart at the front of the block. Toes are to be curled over the front of the platform. The hands should grasp the front of the block outside of the feet.

Track start—One foot is placed at the front of the block with the toes curled over the front of the platform. The opposite foot is placed at least six inches behind the heel of the forward foot. Hands grasp the front edge of the block.

Hole entry—Take the dive up above the horizontal extending from the front of the starting platform at take-off. Enter the water at an angle approaching 30 to 45 degrees. Get the hips to project upward at takeoff.

Flat entry—Take the dive out, not up, in an attempt to dive directly towards the water. Emphasize quickness to entry. Keep the hips down at take-off.

Upon completion of the training sessions, the subjects were recorded on videotape performing each of the four starting combinations in a random order. This final videotape recording of each subject was viewed by the researcher and two experienced swim coaches to determine if the basic requirements, as defined in this study, of each start combination were met. The evaluators' unanimous decisions determined which subjects would continue into the testing phase of the study. Subjects who did not meet the requirements for each of the starts were eliminated from this study.

Testing Phase. Prior to the test trials, each subject was required to engage in a warm-up procedure outlined by the researchers. The 20 minute warm-up involved stretching, swimming an easy 400 freestyle and eight practice starts. The four start combinations performed for testing were: (1) the track technique with a flat entry, (2) the track technique with a hole entry, (3) the grab technique
with a flat entry and (4) the grab technique with a hole entry. Subjects were filmed and timed performing 12 starts, three trials of each of the four start combinations. All starts were performed at the deep end (12 1/2 feet) of the pool. Instructions to swimmers prior to their first start combination include these:

1) Perform each start to the best of your ability. Imagine that you are in actual competition.
2) Avoid false starting, just as you would in a race.
3) Swim freestyle (crawlstroke) at a sprinting race pace through the halfway point of the pool.

Subjects were notified immediately prior to each start which combination they were to perform for their upcoming trial. The order in which each subject performed the start combinations was determined by a systematic selection process determined prior to testing.

Statistical Analysis. Means were calculated for each of the four start combinations and each of the individual subjects for time to 8.0 meters, time to entry and angle of entry. Three $2 \times 2$ randomized complete block analysis of variances (4) ($p < .05$) were used to compare the four start combinations with start technique and entry method as independent variables, and time to 8.0 meters, time to entry and angle of entry as the dependent variables. If a significant difference was found between start combinations, a least significant difference (LSD) test (15) was used to indicate which combinations differed. A stepwise multiple regression analysis (1) was used to determine the relative contribution that the independent variable, angle of entry, had on the dependent variable, time to 8.0 meters.

Results

In the data analysis of the start combinations, start techniques and entry methods, a randomized complete block design was used to minimize the effects of individual subject differences on the performance of the start. Subject characteristics are presented in Table 1. If a significant interaction occurred at the ‘subject x start combination’ level, further investigation of the start combinations, start techniques and entry methods using the analysis of variance designed for this study would have been impractical. A significant interaction would have indicated that the individual subjects had a differential effect on the time to 8.0 meters or the time to entry. Consequently, individual subjects would appear to show differences between start combinations for the dependent variables tested. In the case of the dependent measures tested in this study—time to 8.0 meters and time to entry—no ‘subject x start combination’ interactions were seen.

Each of the start combination, start technique and entry method mean times to the 8.0 meter mark were analyzed using a $2 \times 2$ analysis of variance. The analysis revealed a significant time difference ($p < 0.01$) between the start combinations to the 8.0 meter mark. A least significant difference (LSD) test at the $p \leq 0.05$ level of significance was applied to the start combination means to determine which of the starts differed. The track start-flat entry combination was shown to be significantly faster than both the track start-hole entry and the grab start-hole entry combinations; the grab start-flat entry combination was shown to be significantly faster than the grab start-hole entry combination. The mean times to the 8.0 meter mark for each start combination, start technique and entry method are reported in Table 2.

### Table 1

**Subject Characteristics**

<table>
<thead>
<tr>
<th>Subject#</th>
<th>Age (years)</th>
<th>Weight (pounds)</th>
<th>Height (inches)</th>
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<td>170</td>
<td>74</td>
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<td>2</td>
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<tr>
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<td>18</td>
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<td>67</td>
</tr>
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<td>4</td>
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<tr>
<td>12</td>
<td>24</td>
<td>142</td>
<td>69</td>
</tr>
</tbody>
</table>

### Table 2

**Mean Angular and Time Values of Various Start Combinations, Start Techniques and Entry Methods**

<table>
<thead>
<tr>
<th>Measurement Variables</th>
<th>$8.0m_{\text{time}}$</th>
<th>$E_{\text{time}}$</th>
<th>$E_{\text{ang}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Start</strong></td>
<td>$n$</td>
<td>$\bar{X}$</td>
<td>$n$</td>
</tr>
<tr>
<td>Start Combination</td>
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<td></td>
<td></td>
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<tr>
<td>Track/Flat</td>
<td>36</td>
<td>3.213</td>
<td>36</td>
</tr>
<tr>
<td>Track/Hole</td>
<td>35</td>
<td>3.276</td>
<td>35</td>
</tr>
<tr>
<td>Grab/Flat</td>
<td>36</td>
<td>3.228</td>
<td>35</td>
</tr>
<tr>
<td>Grab/Hole</td>
<td>36</td>
<td>3.356</td>
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<tr>
<td>Start Technique</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Track</td>
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<td>3.220</td>
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<tr>
<td>Grab</td>
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<td>70</td>
</tr>
<tr>
<td>Entry Method</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>72</td>
<td>3.221</td>
<td>71</td>
</tr>
<tr>
<td>Hole</td>
<td>71</td>
<td>3.317</td>
<td>68</td>
</tr>
</tbody>
</table>

*pNote: The unequal number of subjects was attributed to missing values.*

a*time to 8.0 meters in seconds*

b*time to entry in seconds*

c*angle of entry in degrees*

When comparing entry methods, exclusive of start techniques, a significant main effect ($p < 0.001$) indicated that swimmers using the flat entry method were faster.
to the 8.0 meter mark than those using the hole entry method. No significant main effect was found to the 8.0 meter mark between swimmers using the track and grab techniques.

Mean times for each of the start combinations, start techniques and entry methods to entry were analyzed using a $2 \times 2$ analysis of variance. A significant time difference was shown ($p < 0.001$) between the start combinations to entry. A LSD test at the $p \leq 0.05$ level of significance was applied to the start combination means to determine which of the starts differed. From this test, each start combination was shown to differ from one another by a larger margin than the LSD value of 0.031 seconds. Consequently, the order of start combinations from fastest to slowest were (a) track start-flat entry, (b) grab start-flat entry, (c) track start-hole entry, and (d) grab start-hole entry, respectively. All mean times to entry for each start combination, start technique and entry method are reported in Table 2.

When comparing start techniques, exclusive of entry method, a significant main effect ($p < 0.001$) indicated that swimmers using the track start technique were faster than those using the grab start technique in time to entry. Entry method main effects, exclusive of start technique, also were shown to be significantly different ($p < 0.001$) in time entry, indicating that the flat entry method was faster than the hole entry method.

The angle of entry for start combinations was analyzed using a $2 \times 2$ analysis of variance. This analysis indicated a significant angular difference ($p < 0.001$) between the entry method main effects. This analysis indicated the hole entry angle was higher than the angle produced by the flat entry. The mean entry angles for each start combination, start technique and entry method are reported in Table 2.

**Discussion**

In this study, the track start-flat entry was shown to be the fastest start to the 8.0 meter mark, significantly faster than both grab and track start techniques with a hole entry. The grab start-flat entry closely followed the track start-flat entry in time to the 8.0 meter mark and was demonstrated to be significantly faster than the grab start with a hole entry. This finding contradicts results of Wilson and Marino (17), which indicated that the grab start-hole entry was faster than the grab start-flat entry. However, their temporal standard was measured to the point at which the leading part of the subject's body crossed a 10.93 meter line. The distance measure of 8.0 meters used in the current study was very similar to the 10.93 meters used by Wilson and Marino (17), because in the present study the 8.0 meter criterion was measured to the subject's suit top or waistline and not to a leading arm. In addition, Wilson and Marino's (17) measure was
timed using hand held stopwatches. The timing method used in this study was believed to be a more objective measure than that used by Wilson and Marino (17) since it was not subject to human judgment error. For this reason, the data collected in the current study was considered to be more accurate.

The major differences in the start combination times to the 8.0 meter mark appeared to be due to the entry method used. Figures 1 and 2 show a comparison of the entry methods for each swimmer's time to the 8.0 meter mark and to entry. The entry method results of this study contrasted with findings presented by Hobbie (10) which indicated that there was no difference in the hole and flat entry methods for the time to the criterion measure.

![Figure 1. Comparison of Entry Method to Time to 8.0 Meters.](image1)

![Figure 2. Comparison of Entry Method to Time to Entry.](image2)
The distance criterion used in his study was 6.5 meters and his design for measuring temporal data was set up identical to that used in the current study. In contrast with Hobbie’s study and the results of the current study, Guimaraes and Hay (9) indicated that entering the water at higher angles did lead to faster start times. They indicated that by attaining a higher height of the center of mass at entry, the swimmer could decrease the amount of drag produced during the glide. Unfortunately, they were unable to support this statement since they found a nonsignificant correlation \( r = .04 \) between height of entry and average water velocity.

One possible reason for the significantly slower times associated with the hole entry in the current study may have been a function of the criteria for determining the mean angle of entry \( (X = 44.18 \text{ degrees}) \). In Hobbie’s (10) study, the mean angle of entry for subjects performing the hole entry was 29.3 degrees, however his angle of entry criteria were measured using different points. Hobbie used the angle formed by the line from hip to shoulder and the water surface, whereas, the current study used the angle formed by the line from hip to wrist and the water surface. Based on pilot testing, the researchers of the current study utilized the hip to shoulder to wrist alignment to measure the angle at which the swimmers enter the water. Consequently, this difference in measurement technique may have accounted for the marked difference in the angles noted in Hobbie’s study and the current research.

If the hole method angles of entry are the cause of slower times to the 8.0 meter mark, this may provide evidence that excessively steep angles may not be productive. In a further analysis of the dependent variables, the angle of entry was shown to be a significant \( (p < .05) \) predictor variable in the time to the 8.0 meter mark. This means that the angle of entry does have an effect on the time to the 8.0 meter mark.

The present research is the only study known to the authors to actually support the flat entry as a significantly faster method of starting. The hole entry has been considered by many researchers to be a potentially more effective method of entry (10, 17). The potentially high mean angle of entry found for the hole method in the current study may have had an effect on the significantly slower times found associated with this start. Additionally, it is indicated in the current study, that angle of entry does have an effect on the start times. For these reasons, it is important not to dismiss the hole method as an effective means of entry. It is important to note, however, when teaching or training the hole entry method, that coaches must ensure the swimmer is properly performing this technique in at least a 6 foot depth. When initially learning how to perform the hole entry method, the swimmer may over-emphasize a high trajectory prior to entry. Instruction may be necessary to “flatten out” this high trajectory to assure an effective entry. Coaches also must critically observe and train competitive swimmers to make sure that they are not overemphasizing the trajectory of the dive and the height of the angle at entry regardless of what type of entry is preferred.

Many coaches, researchers and safety officials have been concerned about the potentially dangerous water depths attained by using the hole entry. Counsilman (5) commented on the fact that the average swimming pool was constructed as an all-purpose facility, consequently the diving boards were installed in the deep end of the pool leaving no space to adequately place the starting blocks at that end. This meant that most facilities set-up their starting blocks at the shallow end of the pool. Counsilman continued by stating that, since the introduction of the hole entry, over twenty young swimmers have suffered catastrophic head and neck injuries leading to paralysis. In addition, many other authorities (8, 11, 16) have warned against performing or practicing the hole entry method in depths under 4.5 feet. Welch and Owens (16), using experienced collegiate swimmers, reported that the maximum average depth and average angle of entry involved in performing a hole method was 2.56 feet and 34 degrees, respectively. Unless all swimming facilities move their starting blocks to the deep end, swimmers can not be assured safe diving conditions when traveling to meets away from their home pool. This creates potential danger for all swimmers using a hole entry, since they are unable to control the facility conditions at which they compete.

In comparing the start techniques (Figure 3) over the criterion measure, it appeared that many individual subjects performed one technique better than the other, however, there was no significant difference as a group between track and grab start techniques. All, but one swimmer, preferred the grab technique prior to the training phase of the study. Hence, some swimmers apparently performed one or the other technique better while others performed both techniques equally as well.

The results from the current study did, however, show that the track start was faster to entry (Figure 4). This appeared to support Fitzgerald’s (7) contention that the track start is a faster technique to water entry. However, the conclusion that the track start is the fastest technique over the entire criterion distance could not be made. It has been demonstrated in this study and the study by Ayalon et al. (3) that the track start gets the subject to the water faster than the grab technique, but this advantage apparently does not continue into the glide (after entry) phase of the start. It appears that some factor is inhibiting the performance of the track start at or subsequent to entry and, consequently, the deceleration upon entry is greater for the track technique than the grab
technique. This was shown to be the case in this study since the subjects performing the track start reverted to a nonsignificant time difference with the grab technique at the 8.0 meter mark.

It is important for coaches to realize that the swimmer who first enters the surface of the water is not necessarily the most effective starter. This also points out the importance of emphasizing quality features introduced in the glide phase of the start, such as streamlined and initiating kicking immediately upon entry.

Conclusions
1. The flat entry was clearly shown to be significantly faster to the criterion measure of 8.0 meters. However, no firm conclusion can be made in support of the flat entry since the angle of entry associated with the hole method may have had a detrimental effect on the start times.

2. Coaches should thoroughly take into consideration the dangers involved when teaching, implementing or supporting certain starting techniques and entry methods. Whenever possible, coaches should have facility personnel move the starting blocks to the deep end of the pool to maintain safe starting conditions for all techniques used.

3. If a swimmer does use the hole entry, the coach must check to insure that the swimmer is not taking the trajectory upward too high, that the angle of entry is not too severe and that the maximum depth of the dives are much less than the 3 feet provided at the starting end of many facilities.

4. Which starting technique, grab and track, depends upon the individual swimmer. Each swimmer should initially practice both techniques to determine which is fastest for him/her. After a thorough testing of both techniques, the swimmer should continue to perfect the faster of the two techniques.

5. It is important for coaches not to judge a start by who enters the water first, but more by who is ahead at the end of the glide phase of the start. The glide appears to be a major factor in the overall performance of the start and the important features of this phase, such as good streamlining and kicking should be emphasized by the coach.

The main objective of this study was to determine which of the four start combinations—grab start-flat entry, track start-flat entry, grab start-hole entry or track start-flat entry—was faster to the criterion measure of 8.0 meters from the starting block. The findings show that either the track start or the grab start with a flat entry, depending on the individual performing the start, is fastest.

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A Comparison of Four Different Start Combinations

References

Effects of Iron Supplementation on Iron Status of Young Female Swimmers During the Pre-Season Phase of Competition

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Abstract
Iron deficiency has been shown to be quite prevalent in athletes. The availability of iron should be important to all athletes but especially so in swimming where oxygen is limited. The aim of this experiment was to determine whether training had an effect on iron status of young swimmers and whether iron supplementation could offset any possible deterioration in iron status. Twenty, young female swimmers served as subjects, ten each in a placebo and experimental group (150 mg Fe *day* –). A control group of ten non-athletes was used for comparison purposes. Blood was taken pre and post training (12 weeks) and was analysed for hemoglobin, serum ferritin, serum iron, total iron binding capacity and transferrin saturation.

The changes that occurred between the placebo group and experimental group were considerable. Red blood cell count increased significantly post training in the experimental group (p < 0.05) as did hemoglobin (p < 0.05). In the placebo group serum ferritin, serum iron and transferrin saturation all decreased significantly (p < 0.05). Furthermore there was a significantly greater number of athletes in the placebo group who were diagnosed as being iron deficient (p < 0.05). Both the placebo and experimental groups increased their VO₂max but the increase was greater in the experimental (>30%) than in the placebo groups (19.6%: p < 0.05 and p < 0.01 respectively).

The results of this study would suggest that young female swimmers may need to undertake a course of iron supplementation as part of their normal training regime. This should be done in consultation with a medical practitioner or sports scientist familiar with the athlete’s situation. We do feel however that iron status should be routinely monitored.

Introduction
Iron is an important part of the diet since it is an essential component of hemoglobin and myoglobin as well as intracellular cytochrome enzymes. Iron therefore is widely used in the transportation and use of oxygen (O₂) and carbon dioxide (CO₂) and low levels of iron, could have implications for aerobic performance.

Lack of iron is the most common nutritional deficiency in western society (24). Several factors need to be taken into account when discussing iron status. Blood loss, whether through normal menstruation or through abnormal blood loss, for example through gastrointestinal bleeding brought on by endurance training (45) will bring about a deficiency in iron (46) while it has been shown that amenorrheic females have a reduced menstrual blood loss and thus require a similar amount of iron as males (42). Inadequate nutrition, especially where red meat is not eaten, leads to an inadequate intake of heme-iron (42) and an inadequate dietary intake in terms of kilojoules (Kj) will also lead to inadequate dietary iron intake. The recommended daily allowance for iron for Australian non-pregnant women aged 11-55 years is 12 mg*day*⁻¹ (47). The average western diet yields 5-6 mg of iron per 4180 Kj (11), therefore an athlete who eats less than twice this daily amount will in all likelihood, receive an inadequate daily allowance of iron. Difficulties in iron absorption estimated at between 5 and 15 per cent (depending on whether the iron is heme or non-heme) in normal individuals and up to 25 per cent in iron depleted individuals, although little understood may also be a factor responsible for decreased amounts of iron being available to athletes (11, 17, 23, 31 and 34).

The prevalence of iron deficiency regardless of the state of anemia of the individuals, has been studied rather extensively in runners (2, 7, 24 and 22) but not to any great extent in individuals engaged in other athletic endeavours. There have been a number of reports into sports anemia
in women (2, 25, 26, 28 and 32) but there have been very few concerning young female swimmers (36 and 49). The term “sports anemia” (51 and 52) is used to describe the existence of sideropenic anemia in athletes undergoing intensive training. The factors leading to this sideropenia are not only intensive training (35) which brings about the need for extra iron to help synthesize extra hemoglobin, myoglobin and oxidative enzymes but also a reduced absorption (4 and 17), greater loss in urine, sweat and feces (4, 9, 20, 38 and 48) as well as loss due to traumatic microhemolysis (5, 14, 15 and 26).

Numerous studies have revealed significant decreases in one or more of serum iron levels, hemoglobin concentration and total iron binding capacity as a result of training (1, 3, 8, 9 and 14). Conversely others (35 and 50) have revealed no significant difference in these factors following physical training.

Iron is important to all individuals, especially females and this is especially true if they are exercising heavily. There have been several reports that indicate that the level of iron in subjects who practice aerobic activity is in fact quite normal and is often higher than their sedentary counterparts (14, 15 and 18). Generally however, the iron status of female athletes is often very poor and may be cause for concern in many athletic endeavours. For swimmers who perform in an aquatic environment and where their exposure to oxygen may be restricted, it would appear that the role and function of iron may be of even greater importance (21 and 49). The aim of this paper is to describe the effects of training on iron status in a group of young, well trained female swimmers, as well as to describe the effects of iron supplementation on those swimmers. Finally we describe the hematological and iron status of these swimmers when compared to a group of normal non-swimming, active females.

Methods

Subjects.

Thirty, female volunteer subjects participated in this study. All signed informed consent, in accordance with the Helsinki agreement, after having the experiment described in writing and verbally to them. Twenty of the subjects, all of whom were competitive swimmers for at least one year, were randomly and equally assigned to the experimental and control groups. The other ten students, who served as the non-exercise control group, did not regularly participate in organized physical activity apart from that prescribed during school physical education lessons.

The experimental and placebo subjects came from several clubs in the area and previous to the start of this experiment had been on a three month (approximate) off-season period. The physical characteristics of the three groups are described in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Placebo</th>
<th>Experimental</th>
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<tbody>
<tr>
<td>Age (yrs)</td>
<td>16.4 ± 3.8</td>
<td>15.1 ± 2.9</td>
<td>14.8 ± 1.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>55.8 ± 2.7</td>
<td>54.1 ± 2.2</td>
<td>54.6 ± 2.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.6 ± 3.8</td>
<td>161.1 ± 2.9</td>
<td>160.4 ± 3.2</td>
</tr>
</tbody>
</table>

All swimmers attended training for at least two hours per day and seven days per week during this phase of the training. Intensity was monitored in all swimmers by use of heart rate but the intensity was variable depending upon the aim of the session and the relationship of the training session to the phase of the season and individual improvement. Discussions with coaches suggested that the swimmers worked, at varying times in the experimental period anywhere between 65-95 per cent heart rate maximum.

Analysis of Diet. Prior to the start of the experiment subjects were given a five day dietary assessment. They were required to record all food eaten in the five days leading up to the start of the experiment. This was then analysed by a qualified dietician using a computerized procedure. Vitamin C intake was also measured as this may enhance iron absorption (10).

Analysis of menstrual blood loss and symptoms. A menstrual history/background was also obtained from each subject. This questionnaire requested information pertaining to the frequency, duration and severity of the menstrual periods as well as information about use of oral contraceptives. Information as to possible symptoms associated with iron deficiency was also gathered. Such symptoms included headaches, heartburn, fatigue, decreased appetite and menorrhagia (9).

Analysis of iron and hematological status. At the beginning of the test procedure, a 10 ml sample of blood was taken from the ante-cubital vein of each subject in the three groups. This was then analysed for the following, Hemoglobin (Hgb), Serum Ferritin (SF), Serum Iron (SFe), Total iron binding capacity (TIBC), and transferin saturations (TS-calculated by SFe ÷ TIBC). This was then repeated at the end of the twelve week period.

The iron status of the subjects was classified using the three conventional stages of iron deficiency (Cook and French, 1979): Stage 1, depletion of storage iron, stage 2, decrease in transport iron and stage 3, iron deficiency anemia. The subjects were considered to have normal iron status if SF ≥ 12 ng·ml⁻¹ and TS ≥ 16%, stage 1 iron deficiency is SF ≤ 12 ng·ml⁻¹, TS ≥ 16% and Hb ≥ 12 g·dl⁻¹, stage 2 iron deficiency if TS ≤ 16% and Hb ≥ 12 g·dl⁻¹; and stage 3 iron deficiency if SF ≤ 12 ng·ml⁻¹, TS ≤ 16% and Hb ≤ 12 g·dl⁻¹.

The placebo and experimental groups was given either a placebo (gelatin capsule) treatment or iron treatment.
(150 mg Fe • day⁻¹). Each of the treatments were identical in nature and subjects had no knowledge as to whether they were receiving either the placebo or iron treatment.

**Analysis of Aerobic Fitness.** Each of the subjects used in the experiment underwent a maximal stress test to determine their aerobic fitness (VO₂max). This was an incremental test performed on a Monark bicycle ergometer. The subjects initially pedalled at 25 watts and this was incremented every minute by 25 watts until the subject voluntarily ceased exercising. Respiratory data was collected during the exercise test by open circuit spirometry using an Applied Electrochemistry Oxygen analyser (Model S3-A) and a Heraeus Binos 1 Carbon dioxide analyser. Prior to the test session each of the gas analysers was calibrated using 100 per cent Nitrogen (N₂) which was then followed by calibrating with two known mixtures of Carbon dioxide (CO₂: 2.61 ± 0.05% and 5.05 ± 0.10%), Oxygen (O₂: 18.4 ± 0.20% and 14.4 ± 0.20%) and Nitrogen (N₂) and room air. Ventilation was measured using a flow transducer (Yellow Springs Instrument: Model # 2015). During the exercise test subjects breathed room air through a mouthpiece connected to a three way Koegel valve supported by a lightweight plastic helmet which was connected via lightweight 3.0 cm diameter low resistance plastic tubing directly to the mixing chamber. Heart rate was monitored continuously during the test and a hard copy was obtained during the last fifteen seconds of each working minute utilising a Med Apps Mk 24 ECG monitor (monitoring with Lead II).

**Statistical Analysis.** Statistical significance was determined using an analysis of variance with repeated measures (ANOVA-27). The level of significance chosen prior to the start of the experiment was p < 0.05.

**Findings**

There were no significant differences in the physical characteristics of the three groups as shown in Table 1. The results of the hematological investigation are shown in Table 2. There were no differences between the three groups on the pre-test on any of the hematological parameters measured. None of the control subjects measured in this experiment were iron deficient prior to the start of the experiment. In the athletic group (both placebo and experimental) only one of the athletes in each group was found to have stage 1 iron deficiency.

In the placebo group significant changes occurred in the SF (p < 0.05), SFe (p < 0.05) and TS (p < 0.05). There was however, a significant difference in the Hgb concentration between the pre-post experimental condition (p < 0.05). Hemoglobin levels were higher (p < 0.05) at the end of the experiment in the experimental group than were either the control or placebo groups.

There was a significant increase in the number of athletes in the placebo group who had stage 1 iron deficiency compared with either the pre-test or with the experimental group post-test (p < 0.05). The number of athletes in the placebo group who were iron deficient rose from 1 to 4 while the athlete in the experimental group who was initially iron deficient returned to normal values.

During the course of the experiment the control group did not change the VO₂max reading (41.6 ± 4.5 mls O₂•kg•min⁻¹). The placebo group and the experimental group both increased their VO₂max significantly from the pre-test value (p < 0.05 and p < 0.01 respectively). The placebo group increased their VO₂max from 42.36 ± 3.9 mls O₂•kg•min⁻¹ to 50.67 ± 2.4 mls O₂•kg•min⁻¹ while the experimental group increased their VO2 max from 43.44 ± 4.1 mls O₂•kg•min⁻¹ to 56.61 ± 3.7 mls O₂•kg•min⁻¹.

Table 3 indicates that the experimental group consumed more KJ than either the placebo or control groups but this was not significant. When iron intake was measured however, the experimental group ingested approximately 6 mg•1000 cal•day⁻¹ while the control group ingested approximately 7 mg•1000 cal•day⁻¹. An analysis of the diet of the subjects indicated that the subjects in the experimental group ingested less red meat than their control counterparts (p < 0.05) but this was not different from

### Table 2.

<table>
<thead>
<tr>
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<th>Pre</th>
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<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td>RBC(10¹²/ml)</td>
<td>4112 ± 387</td>
<td>4115 ± 332</td>
<td>4259 ± 654</td>
<td>4467 ± 691</td>
<td>4391 ± 612</td>
<td>4754 ± 596*</td>
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<tr>
<td>Hgb(g•dl⁻¹)</td>
<td>12.1 ± 0.6</td>
<td>12.2 ± 0.5</td>
<td>12.3 ± 0.5</td>
<td>12.9 ± 0.6</td>
<td>12.5 ± 0.5</td>
<td>13.6 ± 0.6*</td>
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<tr>
<td>PCV(%)</td>
<td>41.5 ± 2.1</td>
<td>41.8 ± 2.0</td>
<td>40.8 ± 2.0</td>
<td>43.2 ± 2.3</td>
<td>43.1 ± 2.1</td>
<td>45.9 ± 2.0</td>
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<tr>
<td>MCV(µm)</td>
<td>89.9 ± 4.5</td>
<td>89.6 ± 4.2</td>
<td>90.6 ± 3.9</td>
<td>92.7 ± 3.3</td>
<td>90.3 ± 3.9</td>
<td>93.1 ± 4.1</td>
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<tr>
<td>MCH(µg)</td>
<td>27.6 ± 1.5</td>
<td>27.7 ± 1.7</td>
<td>28.1 ± 1.4</td>
<td>28.8 ± 1.6</td>
<td>28.3 ± 1.6</td>
<td>28.9 ± 1.6</td>
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<tr>
<td>SF(mg•ml⁻¹)</td>
<td>27.1 ± 11.9</td>
<td>26.9 ± 11.7</td>
<td>27.6 ± 9.8</td>
<td>15.7 ± 9.9*</td>
<td>26.2 ± 12.4</td>
<td>20.8 ± 12.0</td>
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<tr>
<td>SFe(mg•dl⁻¹)</td>
<td>89.4 ± 43.1</td>
<td>93.4 ± 43.6</td>
<td>90.7 ± 41.6</td>
<td>68.3 ± 38.9*</td>
<td>91.1 ± 45.7</td>
<td>79.3 ± 56.8</td>
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<tr>
<td>TIBC(mg•dl⁻¹)</td>
<td>318 ± 45</td>
<td>326 ± 51</td>
<td>322 ± 53</td>
<td>368 ± 41</td>
<td>331 ± 46</td>
<td>345 ± 39</td>
<td></td>
<td></td>
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<tr>
<td>TS(%)</td>
<td>28.11 ± 6.7</td>
<td>28.7 ± 6.6</td>
<td>28.2 ± 5.9</td>
<td>18.6 ± 6.1*</td>
<td>27.5 ± 6.1</td>
<td>22.9 ± 7.1</td>
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</table>

*significant difference between pre and post values (p < 0.05)
the placebo group.

Discussion

Iron deficiency has been reported to occur in a large percentage of female athletes (39). Iron deficiency can occur from a decreased intestinal absorption, an increased loss of iron or both. The results of this study would suggest that young female swimmers undergoing strenuous training should routinely have iron levels measured and if found to be deficient should, in consultation with team or personal physician and coach, undertake iron supplementation in order to help maintain/achieve peak performance. Athletes in this study who undertook a course of iron supplementation were significantly higher in all important blood parameters than their counterparts who undertook a placebo supplementation program. The results of this study are in agreement with others who have used large dosages of Fe (37 and 43) in so much that they have found, as we did that iron supplementation decreases the amount of iron deficiency and anemia and helps increase performances (as measured in this study by VO₂max).

It should be noted however that published reports of iron deficiency in athletes vary in laboratory studies conducted due to methodologies involved and classification methods for iron deficiency. However, most reports would agree with this study in so much that few athletes undergo significantly heavy training such that their Hb decreases 2 g/dl below normal levels. We would agree with previous studies that the prevalence of iron deficiency in athletes lies somewhere between 20 and 65% and up to 19% have anemia (2 and 24). In our study we found 40% of our swimmers had iron deficiency and 10% had anemia (in the placebo group). In the experimental group however none of the athletes were found to have either iron deficiency or anemia.

The results of this study are in agreement with those of McDonald et al. (30) who found that maximal work performance was significantly impaired in iron depleted rats. Other studies (6 and 43) have suggested that iron deficiency anemia but not iron deficiency without anemia can severely affect maximal oxygen consumption and endurance. Our results do not agree with this as we found a significant increase in VO₂max with the placebo group and thus, one might expect, an accompanying improve-

ment in performance. Severe training has been found to deplete iron stores (14).

The experimental and placebo subjects in this study ate less red meat than their control counterparts and also ingested less iron per 1000 calories than their control counterparts. This is an agreement with other previously published work (31 and 44). Iron absorption is linked to the bioavailability of iron and meat is a highly bioavailable source. Heme iron also increases the bioavailability of non-heme iron, for example from green leaf vegetables.

There is no question that iron supplementation is beneficial in restoring hemoglobin levels to normal in iron deficient and anemic subjects (16). Recent studies have suggested that iron treatment is also beneficial in iron deficient persons with marginal levels of hemoglobin by decreasing heart rate during exercise. (33 and 43). It has also been shown that iron deficiency without anemia can lead to excess lactate production during exercise and therefore it should be feasible to decrease this and hence improve performance, with iron supplementation (12, 13 and 19).

Conclusion

In conclusion, we suggest that young female swimmers should routinely be tested for their iron status and general blood count. Probably this could be incorporated into an athletes testing program given the procedure is relatively simple, not time consuming and not too expensive. Iron supplementation should be undertaken where it is deemed necessary, but this should be a decision made by physician, coach and athlete together. The extra iron would need to be in tablet form but certainly this can be supplemented with food rich in iron. The long term benefits of such a testing program to a squad of swimmers will be enhanced performance, both in competition and in training.

Bibliography


**Acknowledgements**

We wish to acknowledge the assistance of Mr. Max Meaney for his technical help in analysing the blood samples and Australian Diagnostic Corporation who kindly provided the testing kits for serum iron and total iron binding capacity. Without their assistance this study could not have taken place.
Enhancement of Lactate Recovery By Continuous Sub-Maximal Swimming

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Abstract

Lactic acid accumulation during swimming efforts above the anaerobic threshold is well established. The clearance of blood lactate is one essential element of post exercise recovery, and any technique which will enhance it may be of benefit. Sub maximal continuous swimming has been suggested as such a technique. To test this hypothesis, six national class swimmers were studied. After an adequate warmup, they made two maximum effort 200 yard short course swims. Blood lactate determinations were made at 2 minutes and then after 20 minutes of recovery. Recovery after the first test swim was by passive rest. The time of the second effort was used to calculate a swimming velocity which represented a 100 yard repeat at 65% of the velocity achieved in the test swim. Following the second effort, the swimmers performed active recovery by continuous swimming at the target velocity. During passive recovery, blood lactate levels remained above 4 millimoles/liter at 20 minutes. By comparison, active recovery reduced blood lactate levels to about 2 millimoles/liter in the same intervals, \( p = 0.000 \). This has important implications for recovery enhancement following maximal competitive efforts especially when repeat performances are expected.

Introduction

Most swimming training and competition events are endurance predominant. At levels of muscular effort above the anaerobic threshold, blood lactic acid accumulation occurs as the intensity and duration of activity increases. The production of lactic acid, long suggested to be caused by a limited availability of oxygen to accept hydrogen ions has recently been challenged. An additional contribution by rate limited enzymatic steps in the cytochrome oxidase final common pathway of hydrogen ion transfer to oxygen is suggested. (12) The resultant excess of hydrogen ions is shunted via pyruvate to lactate mediated by lactate dehydrogenase. Thus the production of lactate provides a means for handling the excess hydrogen ions and electrons being generated. The traditional label of lactate as a "waste product" is misleading. In fact, accumulated lactate can participate as a fuel following exercise by re-entering the energy cycle as a three carbon fragment donating its stored electrons and hydrogen ions to the oxidative phosphorylation cascade.

Full recovery following a maximal sustained muscular effort includes the clearance of excess blood lactate to a resting level of approximately 1 to 1.5 millimoles/liter. The persistence of high blood levels of lactate may impact an attempt to repeat the maximal performance. For the competitive swimmer, lactate recovery may become especially important when multiple events are required. Facilitating return of blood lactate to near resting levels may be of benefit. Hermansen and Stensvord have demonstrated in runners that clearance of lactate was best when a post exercise warm-down intensity of 60% of VO2 max was maintained. (5) This would be difficult to calculate or regulate in the "field" environment. Anecdote suggests that a warm down at 65% of the maximum effort
velocity will optimize lactate recovery. Such a velocity, easily calculated from the race time would provide the coach and competitor with a target during a recovery swim. Two important questions in regards this concept are: does swimming at 65% of maximum velocity enhance clearance of lactate compared to quite resting, and does this occur in a practical time frame? The testing of these hypotheses is the basis for this paper.

Methods

Six senior national level swimmers, 3 males and 3 females, were selected and instructed in the concept of the study. These swimmers were very capable of understanding and maintaining selected paces during recovery swims. A pace clock was visible to the athletes to help them confirm targeted paces. Two 200 yard test swims were done short course. Both efforts were race pace. The first swim began after a pre-meet type of warm-up of about 1500 yards. The time of each effort and final heart rate was recorded. Recovery following the first test swim was by quiet sitting on the pool deck (passive recovery), and following the second test by paced swimming (active recovery). Arterialized whole blood was collected by finger stick using a 3mm automated lancet at 2 minutes following each test effort to estimate peak blood lactate. The appropriate recovery protocol then commenced. The recovery test sample was collected at 20 minutes after the initiation of the recovery protocol. Lactate levels were checked before the second test began to confirm that they had returned to the resting range. For the active recovery swim, a 100 yard target repeat was calculated at 65% of the test effort time assuming even 100 yard splits.

Blood samples were collected in an heparinized microhematocrit tube. A 25 microliter sample of the heparinized blood was immediately removed with an automatic pipette and transferred to a 500 microliter capped polypropylene centrifuge tube containing 50 microliters of blood diluent. The blood diluent was prepared with 10 ml of Yellow Springs Instrument, Co., Yellow Springs, Ohio, Lactate Analyzer buffer solution to which was added 25 microliters of Triton X-100, and 200 micrograms of sodium fluoride. The Triton X-100 is a detergent which will lyse red cell membranes, and the sodium fluoride inhibits glycolysis at the enolase step thus halting further production of lactate. The Yellow Springs Lactate Analyzer was used to determine the lactate levels of each sample using a 25 microliter aliquot of the diluted blood. The lactate analyzer employs a semipermeable membrane with L-lactate oxidase and reads a potential caused by the production of hydrogen peroxide which gives up electrons to a silver reference cathode. Standards are used to calibrate the response to the machine which is linear up to readings of 15 millimole/liter of lactate. The 3:1 dilution technique employed requires multiplication of the read out by 3 to gain true lactate concentration levels in the test sample.

The mean lactate levels and standard deviations were calculated for each of the blood collection time intervals in the passive and active recovery tests. The group means were treated statistically using the Paired T test. A P value of <0.05 was considered significant.

Results

The times recorded during the swimming test efforts were felt to accurately reflect the level of conditioning of the subjects at the time of the test. The low peak lactate levels produced by these subjects were consistent with the fact that they were tested during the "heavy work" phase of their training cycle. The average time for the 200 yard effort for females was 1:56 and for males 1:43. Averaged heart rates for females was 180 beats/minute and 190 for males. The averaged lactate levels are listed in Table I. During passive recovery, blood lactate levels

<table>
<thead>
<tr>
<th>Table I</th>
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<tbody>
<tr>
<td>Lactate Recovery Study</td>
</tr>
<tr>
<td>TIME (MIN)</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Passive Recovery</td>
</tr>
<tr>
<td>Active Recovery</td>
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remained above the 4 millimoles/liter level at 20 minutes. By comparison, active recovery returned blood lactate levels to about 2 millimoles/liter in the same interval. Paired T test evaluation of the data at 20 minutes demonstrated a statistically significant difference, p = 0.000.

Discussion

Physiologic recovery following an intense competitive effort in swimming may be an important factor especially in championship meets where repeat efforts are often necessary. The persistence of high blood lactate levels following a maximal effort might impact a later repeat effort. Further accumulation of lactate during the subsequent effort may accelerate the time to peak blood lactate levels because the starting level is higher. Depending on the individuals lactate tolerance, levels of lactate which impair performance may be reached sooner.

Following cessation of exercise, the blood concentration of lactate begins to fall because utilization of lactate exceeds its production. It has been demonstrated that up to 60 minutes is required for blood and muscle lactate...
to return to resting levels. (11) It has been suggested that the rate of disappearance of lactate from blood and muscle would be affected by events following the exercise bout. Hermansen and Stensvold demonstrated in running subjects that the slowest rate of lactate clearance occurred during passive rest and the fastest was noted when exercise was continued between 55 and 70% of VO2 max. (5) Others have found intensities of 45 to 70% of VO2 max as being best. (1,2) The mechanism for accelerated clearance of lactate during submaximal exercise is probably multifactorial. It includes increased blood flow through the muscle to facilitate either oxidation of the lactate within the muscle where it is formed or an increase in its efflux from the muscle, its transport to other tissue for oxidation or resynthesis to glucose, or a combination of these factors. (4)

The biochemical fate of the lactate is currently under debate. Brooks supports the concept that almost all lactate is oxidized to carbon dioxide and water. (3) A position by Hill and Meyerhoff, who were earlier investigators, support the concept that at least some of the lactate has been resynthesized into glycogen in the local tissues and these concepts have more recently been supported by Hermansen. (8,10,6) This controversy has not been resolved.

It has been observed in the diving seal that following a 45 minute dive up to 70 minutes are required before the animals will voluntarily dive again. It is during this period that a high level of blood lactate is being cleared and a prolonged rest period is required. However, when a much shorter dive of approximately 15 minutes was observed, diving was resumed after only approximately 4 minutes of surface recovery. (9) These observations have implications for human athletic performance and support an important role for lactate clearance.

This study has confirmed that lactate clearance from the blood and presumably therefore from the intracellular compartments can be facilitated by sub-maximal continuous exercise, in this case swimming. It has been demonstrated that a warmdown at 65% of maximum swimming velocity significantly enhance lactate clearance. Whether this velocity of swimming activity approximates a VO2 max of 60%, suggested to be optimal for lactate clearance by previous investigators, has not been determined. (1,2,5) The results of this study support the hypotheses that statistically significant enhancement in lactate recovery is afforded by active recovery and that the time required for this is realistic for the competitive swimmer. The clearance of lactate during active recovery is probably rate limited and approximates a half life of 12 minutes as suggested by Heusner. (7) Thus, the time to reduce blood lactate to any given level will depend on the peak level. However, even at a 20 millimoles/liter, a 20 minute recovery swim will substantially reduce the lactate level.

Conclusion

The clearance of blood lactate is one essential element of post exercise recovery. Any technique which will enhance that clearance may be of benefit to recovery. Submaximal continuous swimming has been suggested as such a method. This hypothesis was confirmed by our study. A recovery swimming velocity of 65% of the velocity of the test swim was superior to passive recovery. This has important implications for recovery enhancement following maximal competitive efforts especially when repeat performances are required. The use of the race time to calculate the recovery target velocity provides the coach and competitor with a convenient "field" technique. Although a specific formula for the optimum length of time of the recovery swim has not been established by this study, approximately 15-20 minutes is probably reasonable. Finally, that the 65% velocity is optimal for active recovery has not been determined here and will be the subject of further investigations.

References

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

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

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

3. TEXT—The text should contain separate sections for the:
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   b. Methodology. This section should include a clear description of the experimental subjects and their controls. The description of the methodology should provide enough detail for others to duplicate the study. References should be provided for established methods and statistical procedures should be supported with rationale.
   c. Findings. The findings presented in the text, tables, and figures should follow a logical and parallel sequence. The statistical significance of appropriate results should be acknowledged.
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