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Can Critical Power Predict and Monitor Swimming Performance?

Michelle L. Stoppenhagen-Noll

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Can Critical Power Predict and

Monitor Swimming Performance?

(TITLE)

BY

Michelle L. Stoppenhagen-Noll

THESIS

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Can Critical Power Predict and Monitor Swimming Performance?

Michelle L. Stoppenhagen-Noll
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ABSTRACT

Can Critical Power Predict and Monitor
Swimming Performance?

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McClung, & Dr. Jake Emmett

The purpose of this study was to determine if critical power (CP) can be used to predict and monitor swimming performance. Fifteen female collegiate swimmers from Eastern Illinois University volunteered as subjects for this study. CP was measured on an arm ergometer. Freestyle performances in the 50 and 100 yard distances were also measured. All three tests were measured both pre- and post-season. Results indicated that CP can predict performance in the 50 and 100 yard freestyle swims. Those with higher CP will swim faster. CP can monitor improvement in 50 yard times. CP is not a good indicator of improvement in the 100 yard times. This may be because the 100 yard swim uses more energy from the lactic acid system while CP may be a better indicator of potential energy from the ATP-PC system.

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I acknowledge Dr. Jeffery McClung for direction and guidance throughout this study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Identification of the Problem

Swimming is a sport which relies heavily on technique for optimal performance. For this reason, and the fact that it is performed in the water, monitoring swim performance is difficult. Monitoring, or keeping a record of progression or regression is important to coaches because it allows them to determine either successful or unsuccessful training techniques. It is also a good motivational tool for the swimmer. Currently, most monitoring techniques are done in the water simply through competition and recording times of performances. This procedure does not necessarily predict performance. A good performance can not determine whether another performance in several weeks or months will be an improvement or not. However, recording times does monitor a swimmer's progress or regress. A test that involves sustaining a maximum power which can be accomplished out of the pool and has the ability to both monitor and predict a swimmer's performance throughout the season would be valuable to the coach and athlete in assessing potential and improvements in swimmers.

Critical power is a value that could be measured out of the water and at any time in the course of training. The

measurement of critical power through the use of the arm ergometer could be a sufficient way to predict and monitor swimming performance.

Statement of the Problem

The purpose of this study will be to determine if critical power when measured on an arm ergometer can be used to predict and monitor swimming performance.

Limitations

1. Individual body fat percentage was not measured.
2. The entire team was not tested due to pre-existing shoulder injuries.
3. A longer distance, such as the 400 yard freestyle was not measured.

Delimitations

1. The study will only be using 15 females from the Eastern Illinois University Swim Team.
2. The study will only focus on freestyle performances.

Definitions of Terms

Critical Power--the maximum power a muscle group can indefinitely continue to perform work without fatigue (Monod & Scherrer, 1965).

Work Limit--the total work achieved during the time of exercise (Housh, Housh & Bauge, 1990).

Time Limit--the time it takes until fatigue causes exhaustion (Housh, et al., 1990).

Freestyle--one of the four competitive strokes. It involves alternating arm pulls and breathing laterally while on the front. It is also known as the front crawl.

Hypothesis

Critical power can be used to predict and monitor freestyle swimming performance among competitive collegiate female swimmers at Eastern Illinois University.

Significance of the Study

The study will identify a simple way to predict and monitor swimming performance apart from technique. If successful, these results will provide coaches with a way to predict the capabilities of the swimmers before the season begins along with a way to measure the success of their programs.

CHAPTER II

REVIEW OF LITERATURE

Theoretically, during exercise there is an intense level at which a muscle group can indefinitely continue to perform work without fatigue. This point has been termed critical power (CP)(Monod & Scherrer, 1965) and is related to other terms such as "anaerobic threshold" and "onset of blood lactate," or OBLA. Anaerobic threshold is difficult to measure because it requires gas analyzers and other costly equipment that is difficult for an untrained investigator to use. OBLA requires a blood sample of the subject which in turn requires experienced technicians to be involved in any testing. CP, on the other hand, is simple to measure, easily determined, and is an effective way to estimate anaerobic threshold without the use of gas analyzers and measuring blood lactate levels. In fact, recent studies have shown CP to be significantly coorelated to the anaerobic threshold (deVries, Moritani, Nagata, & Magnussen, 1982; Moritani, Nagata, deVries, & Muro, 1981).

Investigations concerning the relationship between the work limit (WL) and the duration of this WL, or time limit (TL), was first explained by Monod and Scherrer in 1965. They studied dynamic work capacity and determined that during a dynamic work task to exhaustion, the muscle group will achieve a WL in a given TL. As less power is applied,

there is a longer time limit (Figure 1).

The CP test involves two exhaustive workouts at different power levels from which the WL and the TL are determined. WL is calculated as the product of the power and the TL for a given trial (Monod & Scherrer, 1965). A relationship is seen by plotting the WL against the TL of several exercise trials. This relationship has been shown to be highly linear at $r > .98$ (deVries et al., 1982) (Figure 2). The relationship between WL and TL is described by the equation:

$$WL = a + b(TL) \quad \text{(Equation 1)}$$

The slope (b) of this equation is considered to be equal to the CP while the y-intercept (a) represents the anaerobic work capacity, or the energy stores solely within the muscle (glycogen, phosphogens, and the oxygen bound to the myoglobin) (Moritani et al., 1981). Therefore, a and b represent the body's total power from aerobic sources (b) and anaerobic sources (a), or the total power (P). The above equation can then be rewritten:

$$WL = P(TL) \quad \text{(Equation 2)}$$

Combining equations 1 and 2 results in the following equation:

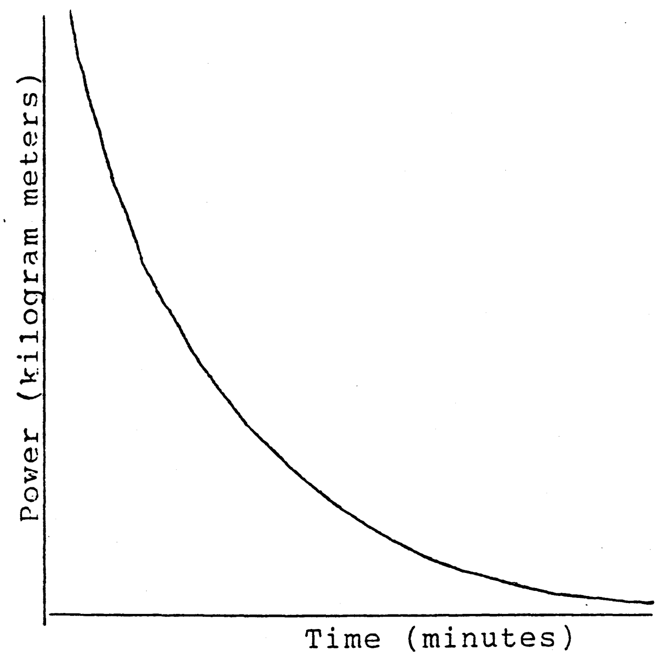

Figure 1. The relationship between applied power and duration of exercise.

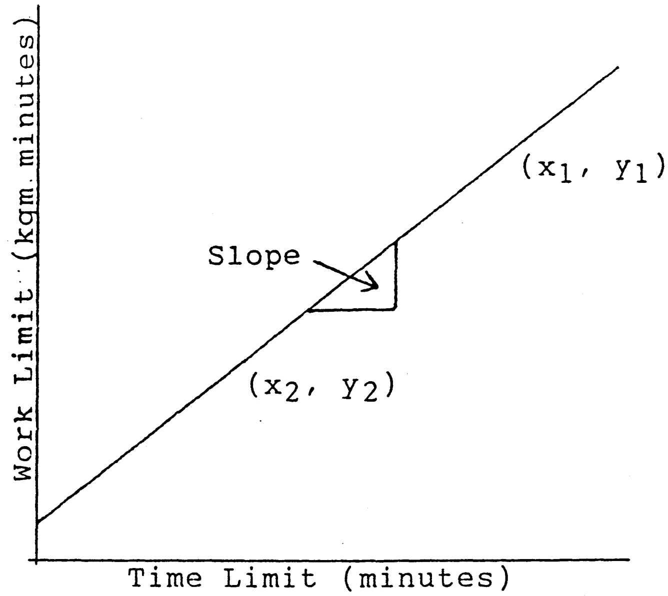

Figure 2. The relationship between work limit and time limit. The slope is the critical power.

TL = a/(P - b) (Equation 3)

Equation 3 allows for the calculation of the time to fatigue when the imposed power output exceeds the CP of the subject. At this point the muscles must utilize their energy reserves, and muscular fatigue may take place when these reserves of energy are depleted. When the required power output approaches very close to CP (or b) and (P - b) approaches zero, the work may, in theory, be continued almost indefinitely. Therfore, if the power output was set at a level which one can perform indefinitely, a/TL will approach zero and P will approach b (Moritani et al., 1981). In other words, when the power output is less than b or the CP, the time to exhaustion would in theory be indefinite. However, depletion of fuel sources, increases in body temperature, boredom, electrolyte imbalances and other factors will eventually cause the subject to stop. But, by determining CP, one can guarantee maximal aerobic endurance.

It is easy to calculate CP following two or more trials of exhaustive workouts. For example, in this study subject MH worked 800 kpm for 2:10 (or 2.16) minutes. Her WL would be 800 times 2.16 or 1728 kgm min. Her TL is 2.16 minutes. The next day she did 700 kpm for 6:49 (or 6.81) minutes. Her WL would be 700 times 6.81 or 4767 kgm min. Her TL is 6.81 minutes. A linear relationship is shown by plotting these values on a graph. The slope of this line is the critical power. The CP of MH is determined by the equation:

$$\text{Slope} = \frac{4767 - 1728}{6.81 - 2.16} = \frac{3039}{4.65} = 653.5 \text{ kgm}$$

In this example, her CP is 653.5 kgm. She should be able to maintain this power output for an indefinite period of time.

It was once thought that three or more tests must be performed in order to accurately determine CP, or the slope of this linear relationship (Monod & Scherrer, 1965). However, following further studies, it was concluded that two carefully administered tests would be sufficient. This can be by carefully selecting two powerloadings according to body weight and fitness level, such that the times to exhaustion (TL) of the two range from one to ten minutes and differ by approximately five minutes (Housh et al., 1990). These researchers concluded that using a high and low power is most accurate in determining CP. They added that by using two powerloadings that had close TL's at either the high or low powerloadings may cause an error because of a possibility of a change in the slope of the linear relationship between TL and WL. An error in either the high or low applied powerloading when the powerloadings are further apart will not produce an error that is as great as when the powerloadings are closer together (Figure 3).

By using CP tests during preseason training, coaches and swimmers are able to make a near accurate prediction of performances at the end of the season. CP testing throughout the season gives coaches and swimmers an

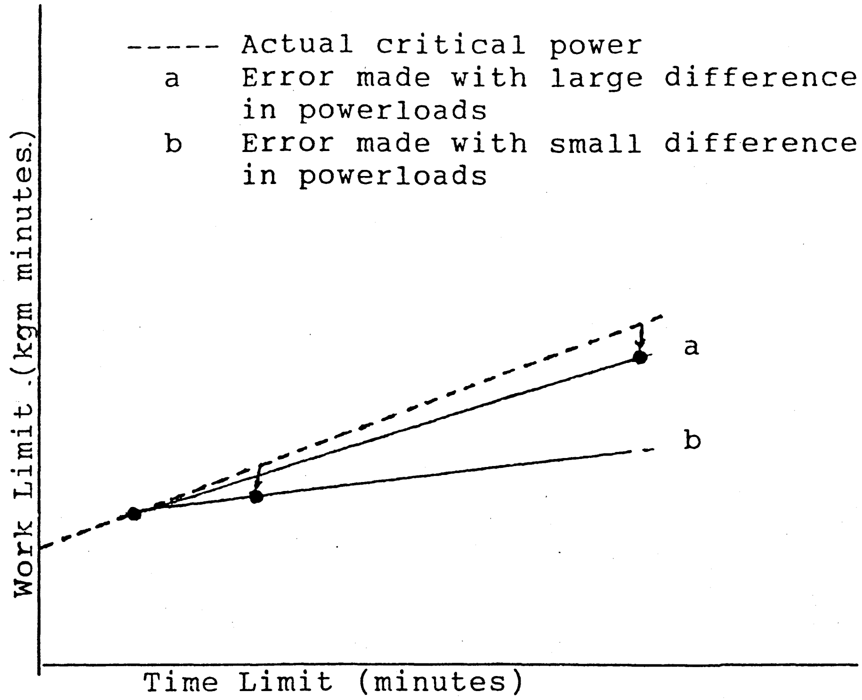

Figure 3. The difference between errors made with powerloads close together and with powerloads far apart.

additional way to monitor performances. These tests may also be a beneficial dryland training technique if used on a regular basis. Unfortunately, there is a need for further research in the area of using CP testing as a predictor of performance. There is not enough information available to convince coaches and swimmers to use CP as a reliable measurement.

CHAPTER III

PROCEDURES

Setting

Testing was performed in the Eastern Illinois University natatorium. The environment was controlled to a temperature of 30 degrees centigrade and a humidity of 80 percent. Both the preseason trials and postseason trials were done in this environment prior to afternoon team practice.

Instruments

The following instruments were used in this study:
Arm ergometer--All trials were conducted on a Cybex Upper Body Ergometer. The seat was adjustable for both height and proximity to the machine. The seat height was adjusted so that the arm crank was at shoulder level. The seat was and the length of the crank handles were set to allow for near full extension of the arm at the end of the forward cranking motion with as little upper body motion as possible.
Stopwatch--A stopwatch was used to record the duration of the exercise and the 50 and 100 yard freestyle performances.

Subjects

The subjects for this study consisted of 15 females who were all members of the Eastern Illinois University swim team. All were between the ages of 18-22 years and were free of injury.

Treatment

Instructions to Subjects

Subjects were allowed to wear cloths of their choice; however, because the trials were conducted before practice, most wore their swimsuits. No specific eating instructions were given.

After adjusting the arm ergometer appropriately, the subjects were told to crank at 60 rpm's at a specific workload for as long as possible. The machine was set at a crank speed of 60 rpm's. The workload was determined by the investigators based on observation and knowledge of swimming ability and general strength. In other words, the more powerful swimmer would start with a higher workload.

The first trial consisted of a workload that allowed the subjects to crank for six to eight minutes. The subjects cranked without knowledge of elapsed time. On the following day a second trial was completed in the same manner except the workload was increased so that the

duration of the exercise was limited to two to three minutes. A third trial was sometimes needed due to an error in the estimation of the workload. The subjects were told to crank until exhaustion on both trials. Exaustion was established by excessive sweating and shortness of breath. These trials were done after one month of training and prior to any competition. They were again repeated four months later before their taper, or rest, prior to their championship meet.

Additional Tests

Time trials were taken during practice. Times were recorded in distances of 50 yards and 100 yards. All subjects swam freestyle. These trials were conducted during practice, and subjects were asked to give a maximal effort as if in a competition situation. Competition times were not used because of limited opportunity for 15 swimmers to compete in the 50 and 100 yard freestyles in a dual meet. A team is limited to three entries per event.

Between the pre- and post-competition testing, training consisted of 5000-6500 yards per day five to six days per week. Some swimmers were on a weight program as an opptional supplement two to three times per week.

Statistical Analysis

Collection of Data

Both the power (kgm) and the length of time that the subject sustained this load were recorded. The time trials were taken using a hand-held stopwatch and recorded in seconds.

The work limit was determined by multiplying the time limit by the workload. The WL and TL were then graphed against each other placing the TL on the abscissa and the WL on the ordinate. Both high power and low power trials were graphed and a straight line was drawn between them. The slope of this line is the CP and is determined by the following equation (Figure 4):

$$\text{Slope} = \frac{y1 - y2}{x1 - x2}$$

This procedure was done for both the preseason and postseason data.

Analysis of Data

A coorelation analysis was applied to the data to determine whether CP can predict swimming performance. A Student's T-test was used to determine the effect of training on CP and performance times. A confidence level of $p < .05$ was used to determine significance.

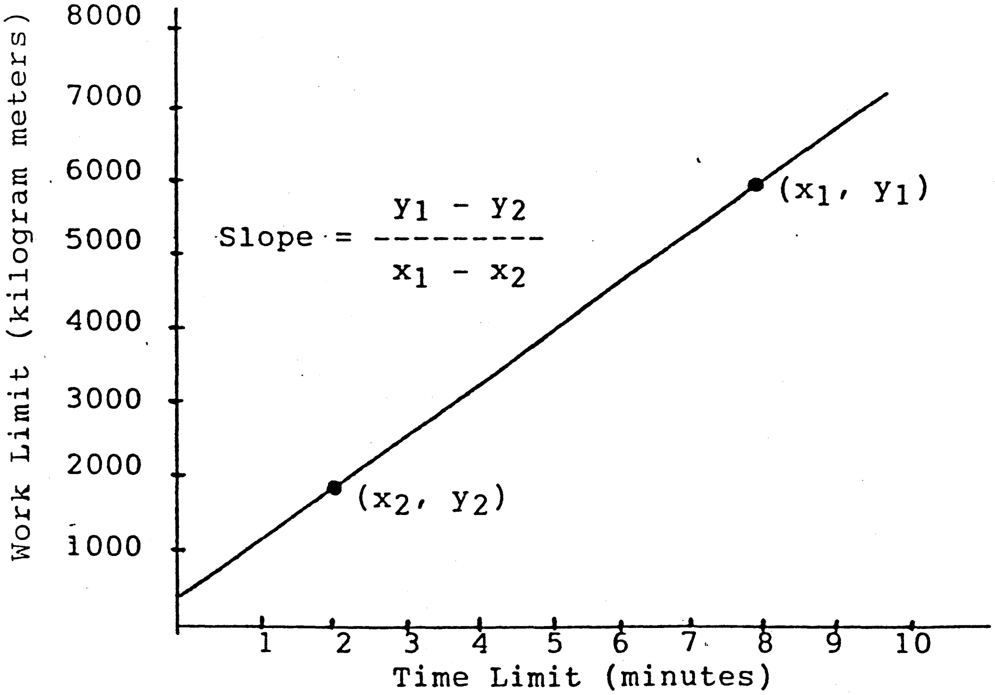

Figure 4. The high and low power trials are graphed and the slope of this line is the critical power.

CHAPTER IV

RESULTS

All subjects were able to complete both CP tests. Prior to testing, most were quite eager to be a part of the study. However, due to the high physical demand, they were not as anxious to participate after the first trial. Almost all experienced excessive muscle soreness and extreme physical exhaustion. No subjects dropped out due to simple unwillingness to continue.

The mean CP of the 15 female swimmers for the pre-competition trials was 512.6 $\pm$ 78.3 kgm with a range of 456-762 kgm. The mean CP for the post-competition was 603 $\pm$ 78.3 kgm.

The 50 yard freestyle times had a pre-competition mean of 29.3 $\pm$ 1.7 seconds and a post-competition mean of 28.4 $\pm$ 1.4 seconds. The 100 yard freestyle times had a pre-competition mean of 62.4 $\pm$ 3.5 seconds and a post-competition mean of 61.3 $\pm$ 3.1 seconds.

The values show an 18.3 $\pm$ 3.2% change in CP from pre- to post-competition. The 50 yard times decreased 0.7 $\pm$ 0.9 seconds while the 100 yard times decreased 1.1 $\pm$ 0.9 seconds (Table 1).

A significant increase of 18.3 $\pm$ 3.2% in CP was seen from pre- to post-competition. Despite a decrease of 0.7 $\pm$ 0.9 seconds in the 50 yard swim times and 1.1 $\pm$ 0.9 seconds

in 100 yard swim times, there was no significant difference in the pre- to post-competition swim times (Table 1).

The increase in CP correlated to the decrease in both 50 yard times ($p < .01$) and the 100 yard times ($p < .01$) (Figures 5 & 6).

	PRE TRIALS	POST TRIALS	CHANGE	
CP	512.6 ± 78.3	603 ± 90.9	91	*
50 yards	29.3 ± 1.7	28.4 ± 1.4	-0.7 ± 0.9	-
100 yards	62.4 ± 3.5	61.3 ± 3.1	-1.1 ± 0.9	-

Table 1. The results of pre- and post-trials of critical power (CP), 50 yard times, and 100 yard times.
* $p < .01$; - not significant

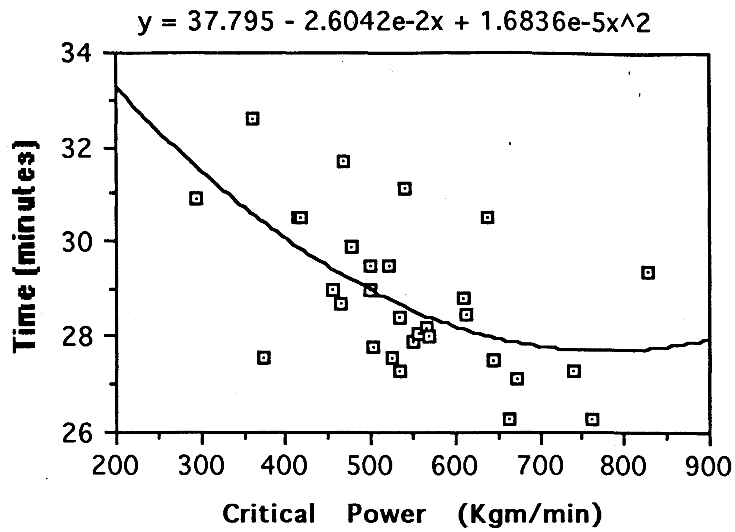

Figure 5. The correlation between critical power and 50 yard times for both pre- and post-competitions.

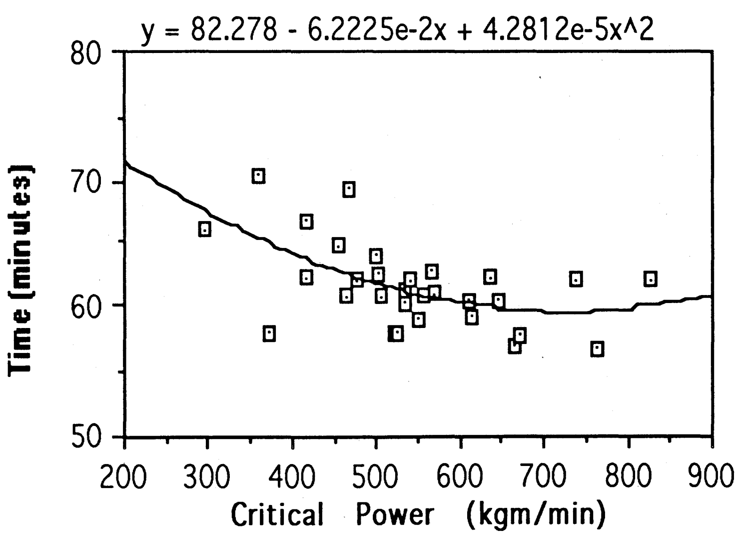

Figure 6. The correlation between critical power and 100 yard times for both pre- and post-competitions.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to determine whether critical power can be used to predict and monitor swimming performance. Arm crank ergometry was used to measure CP.

Subjects recruited for the study were 15 female competitive swimmers on the swim team at Eastern Illinois University. Subjects were put through two exhaustive arm ergometer tests at the beginning of pre-season training. WL and TL were calculated following a high power test and a low power test. These values were graphed and the slope of this line determined the CP. CP tests were repeated after the season and before their taper in preparation for the championship meet.

Using a coorelation analysis ($p < .05$), CP showed a significant increase from pre- to post-competition. The 50 and 100 yard times, although faster, showed insignificant improvements. CP at any given time was shown to predict both the performances in the 50 and 100 yard freestyles ($r^2 = .34$ and $r^2 = .322$, respectively). The change in CP coorelated with the improvements in the 50 yard times but not significantly with the 100 yard times.

Conclusions

By using a CP test, performance in both the 50 yard and the 100 yard freestyle can be predicted but not with great accuracy. An increase in CP will result in improvement in the 50 yard times. The lower the CP is initially, the more improvement there will be in the 50 yard time from pre- to post-competition (Figure 5). For example, a swimmer with a low CP and a slow time may improve the time by several seconds if the CP is increased. This could be done by weight training and swim bench training. On the other hand, a swimmer with high CP and a fast 50 yard time may not improve the time as drastically even if the improvement in CP is high. This may indicate that technical or mechanical work is needed to see more improvement in the 50 yard performance.

Since an elite swimmer, who swims at a faster pace, encounters more resistance than a novice swimmer swimming at a slow pace, greater improvements in CP would be required to increase swimming speed. On the other hand, the novice swimmer would have less water resistance swimming at a slower pace so a given improvement in CP would result in a greater increase in speed. An elite swimmer is highly successful when less than 0.5 seconds is dropped from the 50 yard time whereas an equal achievement in a slower sprinter may be 2.0 seconds or more.

An increase in CP is not a good indicator of improvement in the 100 yard time. This may be because it takes nearly one minute to complete, which means the dominate energy source may be from different systems which CP is not an indicator of. Most likely, the 50 yard swim requires energy predominately from the ATP-PC system. The 100 yard swim, although still relying mostly on the ATP-PC system would require a greater share of the energy to come from the lactic acid system (Fox, Bowers, & Foss, 1988). Therefore, CP may be a better indicator of the energy potential from the ATP-PC system rather than the "anaerobic threshold" for swimming. If so, this may be due to the high skill and strength requirements of the 100 yard and, even more so, 50 yard swims.

Recommendations

The results of this study indicate that CP may be a simple way to determine sprinting performance and monitor improvement. Because of the ease in administering and determining CP, coaches may find it advantageous to use CP tests during preseason to aid in the decision to stress the use of weight training of simple stroke technicalities to improve performance. A swimmer with low CP should be advised to increase strength by adhering to a strength training program. However, a swimmer with high CP needs to

maintain stroke technique to improve the 50 yard time.

Swimmers can use CP tests as a motivational tool as well. As CP increases, there is a high probability that 50 yard times will improve as well. Periodical CP tests will allow swimmers to see strength improvements that will relate to their 50 yard free times.

Suggestions For Further Research

1. Conduct a similar study using swimmers that are all considered freestyle swimmers.

2. Conduct a similar study but convert nonfreestylers' times to equivalent freestyle times rather than using strictly freestyle times. For example, a very successful breaststroker may be a relatively poor freestyler. In this study, only freestyle times were used, which possibly puts a disadvantage on the breaststroker.

3. Conduct a similar study using male swimmers to compare the CP difference in gender along with the possible differences in predicting and monitoring CP.

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