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A Validation of Target Heartrate Formulas Used in Swimming

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A VALIDATION OF TARGET HEARTRATE FORMULAS USED IN SWIMMING

by

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A VALIDATION OF TARGET HEART RATE
FORMULAS USED IN SWIMMING

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The purpose of this study was to explore whether procedures used to establish target heart rates (THRs) for running are applicable to front crawl swimming. Eight male and 22 female fitness swimmers from Western Michigan University participated in this study. Their exercise durations under three experimental conditions were compared. The conditions were: (a) Condition 1, a treadmill run at an intensity equal to a THR of 85% of heart rate reserve (HRR); (b) Condition 2, a front crawl swim at an intensity equal to 85% of HRR; and (c) Condition 3, a front crawl swim at an intensity equal to 85% of HRR minus 12 beats per minute (bpm). The ANOVA indicated that significant differences in exercise duration existed. Results of a Tukey HSD test indicated that there was a significant difference ($p < .05$) in the mean durations between Condition 1 and Condition 2. An ANCOVA was calculated on the two swim conditions using stroke rate (bpm) as the covariate. Results of this analysis indicated a significant difference existed between the two swimming conditions. It was concluded that subtracting 12 bpm from a THR based on the HRR method is a valid procedure when fitness swimmers perform the front crawl.

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Tasha Kay Litwinski

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CHAPTER I

INTRODUCTION

The use of target heart rates (THRs) is a widely accepted technique for controlling work intensity during exercise. Many individuals are unsure about how hard to push themselves when they are working out, and a THR can help them control exercise intensity. The American College of Sports Medicine (ACSM) recommends that an individual exercise between 60% and 90% of his or her maximum heart rate (MHR) or at 50% to 85% of maximal oxygen uptake (max VO_2; ACSM, 1995). THR can be measured directly from data obtained during a submaximal graded exercise test on a treadmill. A subject's max VO_2 has a relatively linear relationship with heart rate. THR can also be estimated using established regression equations. The most widely used THR formula is the one established by Karvonen (Karvonen, Kentala, & Mustala, 1957).

According to McArdle, Katch, and Katch (1991) participants in activities that involve a high degree of arm movements (such as swimming) should subtract 10 to 13 beats per minute (bpm) from their calculated THR. In swimming the differences are possibly the result of a variety of things, smaller muscle mass of the upper body, horizontal position while swimming, and the cooling effect of the water (McArdle et al., 1991). The differences in training that might occur from this lower THR has prompted this investigation.

Statement of the Problem

The problem of this study was to compare subjects' exercise duration under three experimental conditions. The conditions were: (1) a treadmill run at an intensity equal to a THR of 85% of heart rate reserve (HRR), (2) a front crawl swim at an intensity equal to a THR of 85% of HRR, and (3) a front crawl swim at an intensity equal to a THR 85% of HRR minus 12 bpm.

Purpose of the Study

The purpose of this study was to explore whether procedures used to establish THRs for running are applicable to front crawl swimming. It is a common practice to set THRs for swimmers 10 to 13 bpm lower than for runners. In this study subjects' durations when swimming front crawl at an intensity equal to two different THRs 85% of HRR and 85% of HRR minus 12 bpm, were compared to their durations while running on a treadmill at an intensity equal to 85% of HRR.

Delimitations

The study was delimited to the following:

1. Subjects were 30 college-aged males and females.

2. Subjects were 18 to 29 years old.

3. THR was calculated using the Karvonen HRR method. HRR was determined by the formula, MHR - resting heart rate (RHR).

4. MHR was determined by the formula, 220 - age.

5. RHR was taken by the investigator after the subject had been sitting erect for 10 min.

6. Running was performed on a treadmill.

7. Swimmers swam the front crawl while attached to a tether.

8. All exercise sessions were under the supervision of Western Michigan University exercise science graduate students.

9. Heart rate (HR) was monitored using a Polar Heart Rate Monitor.

10. Subjects performed only one trial in each mode of exercise.

Limitations

The study was subject to the following limitations:

1. The subjects were selected opportunistically rather than by random techniques.

2. Subjects performed only a single trial for each experimental condition.

3. The mechanical efficiency of subjects' swimming and running skills was not controlled.

Assumptions

The investigator of the study assumed that:

1. The subjects were sufficiently warmed up before testing occurred.

2. The Polar Heart Rate Monitor accurately measured HRs in the water and on the treadmill.

3. Subjects performed to the best of their ability on all occasions.

4. Training between experimental conditions did not affect performance.

Hypotheses

Hypotheses tested were as follows:

1. The mean exercise duration for the treadmill run at an intensity equal to 85% of HRR was not significantly different from the mean exercise duration associated with the front crawl swim at an intensity equal to 85% of HRR minus 12 bpm.

2. The mean exercise duration on the treadmill run at an intensity equal to 85% of HRR was longer than the mean exercise duration associated with the front crawl swim at 85% of HRR.

Definition of Terms

For consistency of interpretation the following terms were defined:

1. <u>Cardiovascular Endurance</u>: "The ability to perform large muscle movements over a sustained period of time" (Bishop, 1989, p. 108).

2. <u>Heart Rate Reserve (HRR)</u>: "The maximum heart rate minus resting heart rate" (Bishop, 1989, p. 108).

3. <u>Intensity</u>: "The level of exertion during training" (Bishop, 1989, p. 108).

4. <u>Karvonen Formula</u>: "A method of calculating the intensity target range for aerobic work using percentage of the heart rate reserve" (Bishop, 1989, p. 109). For example, if 85% intensity is desired, then the formula would be THR = .85(MHR - RHR)

+ RHR.

5. Maximum Heart Rate (MHR): "The highest heart rate obtainable with exertion" (Bishop, 1989, p. 110). In this study, the formula, 220 - age, was used to estimate MHR.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The use of THR for prescribing exercise is a widely accepted practice. THR can be established by several different formulas that are based on MHR, either measured directly or estimated for age. MHR in swimming has been observed to be significantly lower than that in running on numerous occasions (Dixon & Faulkner, 1971; Holmer, 1972; Magel et al., 1974). This indicated that using a MHR developed from treadmill running may result in an overestimation of the THR. This chapter is divided into three sections: (1) specificity, (2) establishing an exercise intensity, and (3) monitoring HR during exercise.

Specificity

The training effect from exercise produces changes in the metabolic and physiological systems, depending on the type of activity engaged in. It is known that weight training produces specific strength adaptations and that endurance training produces specific cardiovascular adaptations without a substantial interchange between weight and endurance training (McArdle et al., 1991). In other words, specific training produces specific training effects, and in order to properly measure these effects the researcher needs to study a specific form of exercise.

Body Position

McArdle, Glaser, and Magel (1971) measured max VO_2, HR, and ventilatory response during free swimming and walking in a study with 5, male, trained, college swimmers. The swimming and walking tests were discontinuous. The subject exercised for 4 min at increasing work loads up to volitional exhaustion. In the walking test, work was increased by raising the elevation of the treadmill. In the swim test, work was increased by increasing stroke frequency by means of an electronic pacing device. The results showed that VO_2 was linearly related to work intensity in both the swimming and walking tests. The HR response during swimming averaged 9 to 13 bpm lower than the HR during walking, and maximum HR averaged 22 bpm lower in swimming than in walking.

In attempting to explain the significantly lower HR in swimming versus walking at similar VO_2 levels, several factors the researchers considered: (a) the medium in which each activity was performed, (b) the position of the body, and (c) the active muscle mass involved in each form of exercise (McArdle et al., 1971). In another study, HR was found to be slower in a supine position on land than in the upright position (Bevegard, Holmgren, & Jonsson, 1963). The lower HR was due to a larger stroke volume in the supine position. This suggested that the lower HR in swimming was due to a facilitated venous return and greater cardiac filling, which would result in a larger stroke volume and lower HR in submaximal and maximal work (McArdle et al., 1971).

Respiration

Due to the mechanics of the front crawl, breathing does not take place as easily as in walking. Breathing during the front crawl is dependent on the arm movement and can only occur when the head is turned to the side. During the rest of the stroke the face is submerged in the water while exhaling or breath holding.

Research conducted by Magel and Faulkner (1967) involved measuring the max VO_2 of 26 highly trained, male, college swimmers during treadmill running, tethered swimming, and free swimming. In the treadmill test, 5-min runs were made at 7 mph with increasing grades. The tethered swimming consisted of 3-min swims during which increasing weights were supported. The free swimming test involved six maximum 50-yd swims during which energy expenditure was measured. The researchers also compared the four competitive strokes, freestyle, butterfly, backstroke, and breaststroke. They found the following significant differences between treadmill running and tethered swimming: (a) a higher oxygen extraction, (b) lower pulmonary ventilation, (c) lower tidal volume, (d) lower respiratory exchange ratio, and (e) lower heart rate. When swimming strokes were compared, the reduction in max HR associated with swimming did not occur in backstroke swimming. The fact that backstroke swimmers do not encounter any restriction in their respiration, due to their supine position, this may be the reason they were able to achieve heart rates similar to those attained on the treadmill. Because the maximum HR of backstroke swimmers was the same during swimming and running, the lower max HR associated with other swimming strokes may be due to breath holding rather than water immersion (Magel & Faulkner, 1967).

Heart Rate

HRs in swimming have been recorded to be 11 to 21 bpm lower than those recorded in running (Magel, McArdle, & Glaser, 1969). Possible explanations for the lower HR in swimming include: (a) immersion in water temperatures between 27 to 32 °C, (b) the horizontal body position in swimming versus the vertical position in running, (c) the consistent use of a smaller muscle mass in swimming (arms and upper body), (d) temperature regulation changes, (e) heat dissipation in water, (e) diving bradycardia, (f) the stress of carrying one's body weight in running versus the buoyancy effects of the water, and (g) relative skill level in the exercise activity (Holmer, 1972; Dixon & Faulkner, 1971; Magel et al., 1969; Magel et al., 1974; Magel & Faulkner, 1967; McArdle et al., 1971; McArdle, Magel, Delio, Toner, & Chase, 1978).

McArdle et al., (1978) compared the effects of run training on max VO_2 and HR changes during swimming and running. They studied 20 college-aged male recreational swimmers. Eleven subjects were assigned to a run-training program, and 8 subjects served as controls. The run-training program consisted of exercising 20 min per day, 3 days per week at 85% of MHR which was predetermined during an initial treadmill max VO_2 test. Subjects were tested before and after the run training using a treadmill run and a tethered swim test. The author reported a reduction in max HR as a result of the run training in both the swimming and the running tests. This was believed to be due to an improvement in stroke volume or arterial-venous oxygen ($(a\text{-}v)O_2$) difference. The author also reported that it appeared that "run training produces a general exercise bradycardia. For both running and swimming exercise, submaximal heart rates decreased to an almost identical amount following 10 weeks of run training" (McArdle et al., 1978, p. 19).

Magel et al. (1969) studied the effects of the HR response to selected competitive swimming events of 7 male college swimmers. The swimming events studied were the front crawl over 50-, 100-, 200-, 500- and 1000-yd distances, and the breaststroke, butterfly, and back crawl over 100- and 200-yd distances. The subjects swam the event they normally swam in competition. The subjects then ran on an indoor track a distance that was comparable in time to those they had swam. They reported that there was no significant differences in the max HRs between strokes in the 100- and 200-yd events. The differences in max HRs achieved during running and swimming were all significantly different (15- to 20-bpm difference). These differences were attributed to the relatively smaller muscle mass used in swimming as compared to the larger muscle mass used in running. It was also speculated that the added stress of carrying one's body weight in running was offset by the buoyancy effects of the water.

Max VO_2

In studies comparing swimming to running, results indicated that recreational swimmers achieved 80% of the max VO_2 attained in treadmill running (Dixon & Faulkner, 1971; Holmer, 1972; Magel et al., 1974). In trained swimmers, researchers reported different results. Magel and Faulkner (1967) and Dixon and Faulkner (1971) reported no significant difference in the max VO_2 for trained swimmers during swimming and running.

Holmer (1972) reported the highest max VO_2 in swimming was 89% of that recorded during running for trained swimmers. These data suggested that the state of training or prior experience in swimming may account for the variations in aerobic power.

Specificity of training is an important factor when considering the max VO_2 attained in swimming and running. Specific training and local adaptations in skeletal muscle make significant contributions to the improvements made in max VO_2 (McArdle et al., 1978). They found that run training was an ineffective method of training to improve maximal aerobic power for swimmers as opposed to treadmill runners; swimmers improved only 2.6% but treadmill runners were observed to improved by 6.3%. This may be due to an increased use of leg muscles in tethered swimming at heavy work loads (McArdle et al., 1978).

When analyzing the max VO_2 of tethered swimmers, Magel and Faulkner (1967) found tethered swimming was a highly reliable technique for establishing max VO_2 ($r = .93$). Also, swimming max VO_2 scores were not significantly different from the max VO_2 scores obtained in treadmill running. They also found that max VO_2 was significantly greater during free swimming than during tethered swimming.

Establishing an Exercise Intensity

A cardiovascular training program is dependent on the proper frequency, duration, and intensity of the exercise sessions in order to achieve weight loss goals and reduce the risk of coronary heart disease. ACSM recommends participating in aerobic activity 20 to 60 min, 3 to 5 sessions per week at an intensity 60 to 90% of MHR or 50 to 85% of max

VO_2 (ACSM, 1995).

Borg Scale

Borg's Rating of Perceived Exertion (RPE) is a scale used in graded exercise tests (GXT) to determine the level of exercise intensity that the subject perceives. The original scale uses the rankings 6 (very, very light) to 20 (very, very hard) to approximate the HR values from rest to maximum (60 bpm to 200 bpm; Powers & Howley, 1994). The RPE scores were a good indicator of a subject's effort and allowed researchers to know when a subject was approaching exhaustion.

Max VO_2

The measurement of max VO_2 represents the standard against which other estimates of cardiorespiratory fitness are compared. VO_2 provides important information on the capacity of the endurance system and requires integration of the ventilatory, cardiovascular, and neuromuscular systems (McArdle et al., 1991). Max VO_2 increases with increasing loads on a GXT until the maximal capacity of the cardiorespiratory system is reached; attention to detail is crucial if one is to obtain accurate values (Powers & Howley, 1994).

Target Heart Rates

The HR values associated with the exercise intensity needed to produce a cardiovascular training effect is called the THR. THR can be determined by two methods, direct and indirect. The direct method involves the subject participating in a maximal GXT. The HR at each stage of the test is compared to the subject's HR achieved at that particular work load.

THR can also be estimated from some simple calculations. The relationship between HR and workload is relatively linear. The HRR or Karvonen method of calculating a THR has four simple steps: (1) subtract age from 220 to get a MHR, (2) subtract RHR from MHR to obtain HRR, (3) calculate 60% to 90% of the HRR, and (4) add each HRR value to the RHR to obtain the THR (Powers & Howley, 1994). The other indirect method of calculating the THR is the percentage of MHR. This method has two steps: (1) subtract age from 220 to determine MHR, and (2) calculate 70% to 85% of MHR to obtain the THR.

Monitoring Heart Rate During Exercise

HR during exercise can be measured in a variety of ways, including palpation of the carotid or radial artery, using a stethoscope on the chest, and using surface electrodes that transmit the signal to an oscilloscope, electrocardiograph, or a monitor that can display HR directly (Powers & Howley, 1994). HR during exercise should be measured for 15 to 30 s during steady state exercise to obtain a reliable estimate of HR. A post-exercise HR should be measured for 10 s within the first 15 s after completion of exercise; this 10-s count is then multiplied by 6 to express the HR in bpm.

Summary

THR formulas have been used for years to help individuals in their exercise training programs. These formulas are based on MHR, which can be measured directly or estimated based on age. When using these formulas in swimming, researchers have reported that the MHR achieved is lower than that achieved in running. Possible reasons for the lower MHR obtained in swimming include the horizontal body position, the breathing pattern involved in swimming (which may include breath holding), water temperature, or the use of upper body as compared to the lower body used in running.

CHAPTER III

METHODS AND PROCEDURES

The use of THRs is a widely accepted practice for controlling work intensity during exercise. When individuals are unsure about how hard to push themselves when they are working out, THRs can help them control their work intensity in relation to established standards. It is an established practice that participants in activities involving a high degree of arm movement (such as swimming) subtract 10 to 13 bpm from their THR calculated by the HRR method. This adjustment is believed to be necessary for a variety of reasons, smaller muscle mass of the upper body as opposed to lower body muscle mass, the horizontal body position in swimming, and the cooling effect of water emersion (McArdle et al., 1991).

The problem of this study was to compare subjects' exercise duration under three experimental conditions: (1) a treadmill run at an intensity equal to a THR of 85% of HRR, (2) a front crawl swim at an intensity equal to a THR of 85% of HRR, and (3) a front crawl swim at an intensity equal to a THR of 85% of HRR minus 12 bpm. The conduct of the study included the following procedural steps: (a) subjects, (b) instruments, (c) experimental procedures, and (d) analysis of data.

Subjects

The 30 subjects were volunteers who were enrolled at Western Michigan University, Kalamazoo, during the course of the investigation. The main criteria for participation included: (a) all subjects had previous swimming experience, either competitive or recreational; (b) all subjects were capable of swimming front crawl continuously and maintaining a proper breathing pattern; and (c) subjects were between the ages of 18 and 29 years.

Approval to conduct this study was required by Western Michigan University's Human Subjects Institutional Review Board (HSIRB). The appropriate forms were submitted by the principal investigator to the HSIRB. After clarification and changes, the board granted approval for this study (see Appendix A). Prior to participating in any of the exercise sessions, subjects were required to read and sign an implied consent form (see Appendix B). All subjects were screened to determine their health status (see Appendix C).

Instruments

To measure HR in the three exercise sessions the following test instruments were used:

1. <u>Polar Heart Rate Monitor,</u> model # 61210, was used to measure HR in conjunction with an Aero Sport metabolic cart, model Teem 100. To use this device the subject was required to wear a transmitter belt made of hard plastic and an elastic strap around the chest. The transmitter must be in contact with flesh to obtained an accurate

reading, thus all subjects were required to wear the device under their t-shirts and female swimmers were required to wear this under their swim suits. In order to continuously monitor HR, a receiver consisting of a long cord was used with one end plugged into the Teem 100 metabolic cart and the other end tucked under the transmitter belt during swimming sessions. A watch-like receiver was used during treadmill sessions.

2. In order to monitor the heart rate continuously, a tether was used to keep the subjects stationary while swimming. This was necessary so that HR could be monitored continuously during the exercise sessions. The tether used in this study was a StretchCordz Long belt slider, model number S11875, manufactured by NZ Manufacturing, Inc. The waist belt is 2 in. wide with a sliding attachment connected to an 18-ft latex tube.

3. The pool depth was 3.5 ft and the average water temperature was 85 °F.

4. A Cornus, single-event stopwatch was used to measure duration. Time was recorded to the nearest tenth of a second.

5. Subjects ran on a motor driven Quinton treadmill, model #18-60.

6. A Seiko metronome was used to provide the cadence during the swimming conditions.

Experimental Procedures

Each subject participated in three exercise sessions. Each session began with the subject sitting upright for 10 min to establish the RHR. THR was then calculated for each subject using the Karvonen formula based on HRR. In order to control for a possible order effect each subject was randomly assigned to the exercise conditions. Condition 1 consisted of the subject running on the treadmill at a speed that elevated the HR to the 85% of HRR, the THR. A warm-up prior to the exercise session consisted of the following: (a) the subject walked or ran for 2 min at 3.5 mph; (b) after the initial 2 min, speed was increased by 1 mph every 2 min until the THR was achieved; (c) once the THR was reached, HR at the end of 1 min was compared to HR at the end of 2 min to determine if a steady state (HR1 - HR2 < 6 bpm) had been achieved. If a steady state at the THR (± 4 bpm) did not exist, speed was increased or decreased and the comparison repeated until a steady state at the THR existed. After the warm-up the subject rested for 10 min. Then the subject ran on the treadmill at the speed associated with the THR established in the warm-up. Exercise continued until the subject signaled volitional fatigue by raising his or her hand overhead. Total run time was recorded. A 3-min cool-down at 3.5 mph concluded the session.

Conditions 2 and 3 required the use of a tether to keep the swimmer stationary while monitoring HR. In Condition 2, subjects' THRs were set at 85% of HRR and in Condition 3 they were set at 85% of HRR minus 12 bpm. The subject warmed up prior to these sessions. The warm-up consisted of the following: (a) the subject swam for 2 min at a cadence of 50 bpm; (b) after the initial 2 min, the cadence was increased by 5 bpm every minute until the THR was achieved; (c) once the THR was reached, HR at the end of 1 min was compared to the HR at the end of 2 min to determine if a steady state (HR1 - HR2 < 6 bpm) had been achieved. If a steady state at the THR (± 4 bpm) did not exist, the cadence was increased or decreased and the comparison repeated until a steady state existed at the THR. After the warm-up, the subject rested for 10 min. Then, the subject swam at the cadence associated with the THR until he or she failed to maintain the cadence (fell behind and failed to speed up within 10 s) or signaled volitional fatigue by standing up. Total swim time was recorded. A 3-min cool-down at 50 bpm concluded the exercise in these sessions.

Analysis of Data

The research hypotheses were tested using a one-way repeated measures ANOVA statistical design included in the BMDP-2V statistical package. The 5% level of confidence was chosen to determine significance. If the $\underline{F}$ statistic was significant, the Tukey HSD test for multiple comparison was used to compare mean differences. The dependent variable was exercise duration. The repeated measures were the exercise conditions, the treadmill run at 85% of HRR, the front crawl swim at 85% of HRR and the front crawl swim at 85% of HRR minus 12 bpm.

CHAPTER IV

RESULTS AND DISCUSSION

The problem was to validate the THR formulas used in swimming among a heterogeneous group of college-aged fitness swimmers. All participants in the study were students currently enrolled at Western Michigan University. This chapter includes the results and discussion.

Results

Data were gathered on 8 male and 22 female fitness swimmers. Their ages ranged from 18 to 29 years, with a mean age of 20.77 years. Each subject performed one trial for each condition. Condition 1 consisted of the subject running on a treadmill at 85% of HRR. Condition 2 consisted of the subject swimming the front crawl on a tether at 85% of HRR, and Condition 3 consisted of the subject swimming the front crawl on a tether at 85% of HRR minus 12 bpm.

Means and Standard Deviations

Table 1 presents the means and standard deviations for the three conditions. In Condition 1 the mean run duration was 504.41 s, and the standard deviation was 487.67 s. This condition was used as the reference group. In Condition 2 the mean swim duration was 212.90 s less than in Condition 1, and the standard deviation was 87.38 s less than in Condition 1. In Condition 3 the mean swim duration was 35.64 s less than in Condition 1 and 177.26 s more than in Condition 2. The standard deviation was 638.35 s, 150.66 s more than in Condition 1 and 238.06 s more than in Condition 2.

Table 1

Means and Standard Deviations for Testing Conditions

	Condition 1	Condition 2	Condition 3
M	504.41	291.51	468.77
SD	487.69	400.29	638.35

Note. All measurements are in seconds.

Analysis of Variance

A randomized block ANOVA design for repeated measures was calculated. The independent variable was the exercise condition (1, 2, and 3). The dependent variable was exercise duration. The ANOVA summary is reported in Table 2. A significant difference was found between the conditions, $F(2, 58) = 3.87$, $p < .05$. As expected, a significant difference was found among subjects, $F(29, 58) = 6.00$, $p < .05$. A Tukey HSD multiple comparison test was calculated to determine which mean comparisons were significant.

A significant difference existed between the means for Condition 1 and Condition 2. No significant differences existed in the means between Condition 1 and Condition 3 or between Condition 2 and Condition 3. The results of the Tukey HSD multiple comparison test are presented in Table 3.

Table 2

ANOVA Summary for Exercise Duration

Source	SS	df	MS	F
Condition	780,153.62	2	390,076.81	3.87*
Between Subjects	17,519,146.98	29	604,108.52	6.00*
Residual	5,842,101.27	58	100,725.88	

*Significant at the .05 level.

<u>Analysis of Covariance</u>

During the course of the data collection associated with the swimming conditions, it was observed that a substantial learning effect occurred from the first swim test to the second swim test, regardless of the random order of presentation. This resulted in a lower HR response in relation to the workload on the second swim test. Therefore, an analysis of covariance was calculated on the swim conditions using stroke rate (bpm) as the covariate. The analysis of covariance summary is presented in Table 4. Results indicated that a significant difference existed between the mean durations of the two swimming conditions, $F(1, 28) = 7.61$, $p < .05$.

Table 3

Results of Tukey HSD Multiple Comparison for the Conditions

Conditions	M	3	1
2	291.51	177.26	212.9*
3	468.77	---	35.64
1	504.41		---

Note. All entries represent differences between the means of the two conditions

*Significant at the .05 level.

Discussion

This study was prompted by the investigator's personal interest in swim training for the fitness swimmer. Previous investigations indicated that a swimming THR could be established by subtracting 11 to 13 bpm from a calculated THR determined by the Karvonen formula (DiCarlo, Sparling, Millard-Stafford & Rupp, 1991). The exact reason why such an adjustment might be necessary was not completely understood. Because many of the previous studies were conducted using highly trained swimmers as subjects, this researcher decided to conduct an investigation to determine whether reducing the calculated THR is a valid procedure for a heterogeneous group of male and female swimmers who possessed a wide range of both fitness and swimming skill levels.

As the study progressed, it was obvious that a wide variety of skill and fitness levels, as well as attitudes, existed among the subjects. Swimming skill levels varied from subjects who had previous competitive experience in either high school or clubs to others who had very basic skills with some flaws in mechanics. The range of fitness extended from a few collegiate athletes in training for various collegiate sports to some subjects who rarely worked out. Subjects expressed attitudes that ranged from "I hate swimming or I hate running" to "I love swimming or I love running".

Results of the ANOVA indicated that there was a significant difference among the three testing conditions, as well as among subjects. A Tukey HSD multiple comparison test was then calculated to determine where the differences occurred. The results indicated that there was a significant difference between Condition 1 and Condition 2. The Tukey test also indicated that there was no significant difference between Condition 1 and Condition 3 or between Condition 2 and Condition 3. These results indicated that a significant difference existed between the subject's cardiovascular response to the run THR and the swimming THR calculated without the reduction of 12 bpm. However, the analysis also indicated that the cardiovascular response of the subjects was not significantly different between the swimming THR and the swimming THR with the reduction (lowered by 12 bpm).

An ANCOVA was calculated on the swim conditions using stroke rate (bpm) as the covariate. This was done in response to the observation that there appeared to be a substantial learning effect from the first swim test to the second swim test regardless of the random order. Two factors, test anxiety and the tether, seemed to create the learning effect. This confounded the stroke rates at the THRs for the two swim conditions. Test anxiety was predictably greater during the first swim test. This was probably due to the subjects' fear of the unknown, not knowing what to expect in the test. The tether also caused difficulties for some subjects. Many of the subjects had never swum while attached to a tether. This may have caused differences in the amount of resistance they allowed the tether to apply to them. The covariance analysis was conducted to account for this learning effect. Results from the analysis of covariance indicated that a significant difference existed between the mean duration of the two swimming conditions.

There are only a few investigations in which HR during swimming was studied using groups larger than 10 subjects. Magel and Faulkner (1967) studied 26 highly trained, male, collegiate swimmers during treadmill running, tethered swimming, and free swimming. They reported an average HR during swimming of 12 bpm less than during running. However, they found only a difference of 1 bpm between the backstroke and running. The investigators speculated that these differences between swimming strokes was due to the unique breathing pattern associated with the front crawl in which the face was in the water.

Holmer, Lundin, and Eriksson (1974) studied 11 female and 12 male elite swimmers, comparing running on a treadmill and swimming in a flume. The mean HR was found to be 15 bpm lower in swimming than in running. They concluded that this may have been the result of the intensity of training, the size of the muscle mass, body position, and heat exchange factors. A definite conclusion was not stated due to a lack of specific data related to circulatory and respiratory function during swimming.

Magel et al. (1974) reported a mean difference of 13.2 bpm between tethered swimming and treadmill running in 30 college male, recreational swimmers. McArdle et al. (1978) reported a greater difference of 22.1 bpm between swimming HR and running HR. In both studies the researchers attributed the reduction in HR to improvements in stroke volume or $(a\text{-}v)O_2$ difference.

DiCarlo et al. (1991) studied 34 college-age fitness swimmers, 19 males and 15 females who performed treadmill running and tethered swimming. They found a difference of peak HR during maximal swimming and running to be 11 bpm to 13 bpm less than maximal HR predicted from age, they also found that resting HR while standing was significantly higher than when supine or when sitting. They stated that the position of the body during measurement of RHR should be similar to the position assumed during the specific mode of exercise studied. They concluded by suggesting that the HR_{max} obtained from treadmill exercise or from a prediction formula be reduced by 12 bpm.

The results of this study indicated that subtracting 12 bpm from a THR based on the HRR method is a valid procedure when fitness swimmers perform the front crawl stroke. This result is very consistent with the findings of the investigators presented in this discussion. Differences in methodology make direct comparisons between these previous studies difficult. However, it is apparent that a reduction in THR is necessary for recreational swimmers when performing the front crawl stroke.

It should be noted that measuring HR during swimming proved to be an extremely difficult task. Many difficulties were experienced by this investigator. Although the use of the tether allowed continuous HR monitoring, it may have substantially changed the swimming technique of some of the subjects.

Table 4

Analysis of Covariance for the Swimming Exercise Durations

Source	SS	df	MS	F
Condition	458,919.97	1	458919.97	7.61*
Between Subjects	14,582,578.92	28	520806.39	8.63*
Residual	1,689,339.88	28	60333.57	

*Significant at the .05 level.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was conducted to validate THR formula used in swimming. In order to determine this, three testing conditions were created. Condition 1 consisted of the subjects running on a treadmill at a speed that elicited a HR equal to 85% of HRR. In Condition 2, the subjects swam while attached to a tether to a cadence that elicited a HR equal to 85% of HRR. In Condition 3, the subjects swam while attached to a tether to a cadence that elicited a HR equal to 85% of HRR minus 12 bpm.

The subjects were currently enrolled Western Michigan University students. Each subject performed one trial of each of the three testing conditions.

An ANOVA was performed on the dependent variable, exercise duration, as was the Tukey HSD multiple comparison test. An ANCOVA was performed on the swim conditions using stroke rate (bpm) as the covariate. The research findings were compared to the results of previous studies.

Findings

An alpha level of .05 was used to determine significance in the present study. An ANOVA was calculated to determine if there was a significant difference between the conditions. A Tukey HSD multiple comparison test was calculated to determine which mean comparisons were significant, and an ANCOVA was calculated to determine if there was a difference between the swim conditions based on stroke rate. The results indicated the following:

1. There was a significant difference among the three conditions, $\underline{F}(2, 58) = 3.87$, $\underline{p} < .05$.

2. There was a significant difference between the means for Condition 1 and Condition 2, $\underline{M} = 504.41$s and $\underline{M} = 291.51$s, respectively.

3. There was no significant difference in the means between Condition 1 and Condition 3, $\underline{M} = 504.41$s and $\underline{M} = 468.77$s, respectively.

4. The Tukey HSD multiple comparisons test indicated there was no significant difference between the means of Condition 2 and Condition 3, the two swimming conditions, $\underline{M} = 291.51$s and $\underline{M} = 468.775$s, respectively.

5. The ANCOVA using stroke rate as the covariate indicated that significant differences existed between the means of Condition 2 and Condition 3, $\underline{F}(1, 28) = 7.61$, $\underline{p} < .05$.

Conclusions

The above findings led the investigator to suggest the following conclusion: Subtraction of 12 bpm from a THR calculated by the HRR method is a valid procedure for establishing a THR for fitness swimmers who perform the front crawl.

Recommendations

Based on the results of this study, the following are recommendations for further research:

1. A different form of monitoring HR is needed to obtain more accurate results.
2. A larger number of older adults could be analyzed.
3. A different way to equalize the resistance of the tether in combination with the workload would help equalize the workload for all subjects.
4. Different strokes could be analyzed.
5. RHR could be measured while the subject is in a prone position, such as that in front crawl swimming.
6. Other aquatic activities (e.g. water jogging, water walking, water aerobics, water polo) could be analyzed in relation to HR and THRs.

Appendix A

Human Subjects Institutional Review Board Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: November 28, 1995

To: Tasha Litwinski

Richard A. Wright

From: Richard Wright, Chair

Re: HSIRB Project Number 95-11-12

This letter will serve as confirmation that, upon receipt of the required revisions, your research project entitled "A validation of target heart rate formulas used in swimmimg" has been approved under the full category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: November 28, 1996

xc: Roger Zabik, HPER

Appendix B

Informed Consent Form

Western Michigan University
Department of Health, Physical Education and Recreation

Principal Investigator: Dr. Roger Zabik

Research Associate: Tasha Kay Litwinski

I have been invited to participate in a research project entitled "A validation of target heart rate formulas used in swimming". I understand that this research is intended to study the correct use of target heart rate formulas for swimming. I further understand that this project is for Tasha Litwinski's master's thesis.

My consent to participate in this project indicates that I will attend three, 1-hour exercise sessions each on a different day with Tasha Litwinski. At these sessions, I will participate in submaximal exercise tests. On one of those days, following a warmup I will run on a treadmill at a speed associated with 85% of heart rate reserve. For example, at an intensity of 85% the formula would be Target Heart Rate (THR) = .85 ((220 - age) - Resting Heart Rate (RHR)) + RHR. I will then maintain the HR until I reach volitional exhaustion. The swimming sessions will consist of swimming front crawl while attached to a tether. Each swim session will begin with a warmup. Following the warmup, I will swim at a cadence associated with 85% of heart rate reserve. I will maintain that pace until I reach volitional exhaustion. Volitional exhaustion should occur after approximately 15 to 20 min. Both exercise sessions will end with a 3-min. cool-down.

I am aware that I will be performing exercise that will gradually increase in intensity to a very high level. To my knowledge, I presently do not have any cardiovascular, pulmonary, or metabolic disease that would prevent me from participating in this study. I do not presently have any orthopedic injuries that might be aggravated by exercise, nor have I been medically treated for such an injury during the past year. I am aware that certain risks exist related to my participation in a submaximal exercise test. These risks may include muscle soreness, heart attack, or drowning. If any contraindication shows up in the physiological monitoring of the test, the test will be stopped and I will be encouraged to go to the University Health Center for evaluation. If an accident or injury occurs, appropriate emergency medical measures will be taken, however no further compensation or treatment will be made available to me. I understand that I may terminate my participation with this research for any reason at any time without prejudice or penalty. The results of this test will have no impact on my academic evaluation.

I understand that all the information collected about me is confidential. That means that my name will not appear on any papers or publications associated with this research. All forms will be coded, and Tasha Litwinski will keep a separate master list with the names of participants and the corresponding code numbers. Once the data are collected and analyzed, the master list will be destroyed. All other forms will be retained for 3 years in a locked file in the principal investigator's laboratory.

I understand that I may refuse to participate or quit at any time during the study without prejudice or penalty. If I have any questions or concerns about this study, I may contact either Tasha Litwinski at 387-5994 or Dr. Zabik at 387-2680. I may also contact the Chair of the Human Subjects Institutional Review Board at 387-8293 or Vice President for Research at 387-8298 with any concerns that I have. My signature below indicates that I understand the purpose and requirements of the study and that I agree to participate

______________________________ ______________________________

Signature Date

Appendix C

Subject Screening Form

SUBJECT SCREENING FORM

Subject No. __________

Yes/No

_____ 1. Do you smoke cigarettes?
_____ 2. Do you have diabetes?
_____ 3. Have you been told that you have high blood pressure and/or do you take blood pressure medication?
_____ 4. Has a member of your immediate family (parent or sibling) suffered from coronary or other atherosclerotic disease before age 55?
_____ 5. Have you been told that you have a high blood cholesterol level?
_____ 6. Are you taking any medication, prescribed or over the counter? What are you taking?
_____ 7 Is there any possibility that you are pregnant (women only)?
_____ 8. Are you taking any of the following drugs?
Beta Blockers, Alpha Blockers, Amphetamines, Antiadrenergic Agents, Nitrates and Nitroglycerin, Calcium Channel Blockers, Cocaine, Digitalis, Diuretics, Peripheral Vasodilators, Marijuana, Angiotensin-Converting Enzyme, Antiarrhythmic Agents, Sympathomimetic Agents, Antihyperlipidemic Agents
_____ 9. Have you experienced chest pains, shortness of breath, tightness in the chest, or fainting spells?
_____ 10. Do your ankles swell?
_____ 11. Do you have varicose veins?
_____ 12. Do you have a systemic infection?
_____ 13. Do you have mononucleosis?
_____ 14. Are you or have you been recently ill?
_____ 15. Do you have an injury that may be aggravated by exercise?
_____ 16. Do you have arthritis?
_____ 17. Do you experience extreme shortness of breath, especially with exercise?

Failure to answer any of these questions will result in elimination from the study. If a potential subject answers 'yes' to two or more of items 1-5, he or she does not qualify as 'apparently healthy'. Only 'apparently healthy' individuals will be selected for participation. An individual judgement will be made concerning participation of potential subjects answering yes to items 6-17. The judgement will be based on the potential impact of exercise on that particular. Individuals with cardiovascular disease, those with known symptoms of cardiovascular disease, and/or those possessing more than two known major risk factors or orthopedic injuries that required medical treatment during the past year or that are chronic enough to warrant exclusion will also be eliminated

Appendix D

Data Collection Sheet

DATA COLLECTION SHEET

NAME____ AGE______
GENDER____________

CONDITION 1: Treadmill

RHR________	Calculate THR	MHR (220-age)	________
		-RHR	________
		x .85	________
		+RHR	________
		THR	________

Speed subject attained steady state THR during warm-up __________

Duration (in min.) of run until volitional fatigue __________

CONDITION 2: Swim at 85% HRR

RHR__________	Calculate THR	MHR (220-age)	________
		-RHR	________
		x .85	________
		+RHR	________
		THR	________

Cadence subject attained steady state THR during warm-up __________

Duration (in min.) of swim until volitional fatigue __________

CONDITION 3: Swim at 85% of HRR minus 12 bpm

RHR__________	Calculate THR	MHR (220-age)	________
		-RHR	________
		x .85	________
		+RHR	________
		-12 bpm	________
		THR	________

Cadence subject attained steady state THR during warm-up __________

Duration (in min.) of swim until volitional fatigue __________

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