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Improving Swimming Economy of Novice, Adult, Female Swimmers by Training on a Väsa Swim Trainer

Loreen K. Mattson
Eastern Illinois University

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IMPROVING SWIMMING ECONOMY OF NOVICE, ADULT, FEMALE SWIMMERS BY TRAINING ON A VĂSA SWIM TRAINER

(TITLE)

BY

Loreen K. Mattson

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ABSTRACT

Improving Swimming Economy of Novice, Adult, Female Swimmers By Training on a Väsa Swim Trainer

Loreen K. Mattson

The purpose of this study was to determine if the swimming economy of novice, adult, female swimmers can be increased by training on a Väsa Swim Trainer. Economy of swimming was defined as either: 1) decreased submaximal oxygen consumption ($\dot{V}O_2$); 2) decreased oxygen consumption per given distance ($\dot{V}O_2/d$); 3) decrease ratio of arm stroke cycles per given distance to swimming velocity (ASI); and 4) decrease submaximal heart rate (HR).

Eight females between the age of 35 to 60 years, mean age 50.4, who were considered to be novice swimmers (average 45.7 meter lap time greater than 60 seconds) and had been swimming at least twice a week for three weeks prior to the study, participated in this study. All subjects trained on the Väsa Swim Trainer three days a week in an attempt to increase upper body strength. In addition the subjects continued swimming weekly, for six weeks. Prior to the training period, subjects were pre-tested by swimming ten laps (457.2 meters) and performing a maximal effort on the swim trainer. Pre-test submaximal $\dot{V}O_2$, $\dot{V}O_2/d$, ASI, submaximal HR while swimming, and the väsa trainer one repetition maximum (1-RM) were calculated. After six weeks of training submaximal $\dot{V}O_2$, $\dot{V}O_2/d$, ASI, submaximal HR, and

1-RM tests were repeated to determine a training effect.

Dependent t-tests were used to determine the significance ($p < .01$) of the change in means for pre-test and post-test submaximal $\dot{V}O_2$, $\dot{V}O_2/d$, ASI, submaximal HR, and 1-RM. After six weeks of training there was a significant increase in 1-RM and a significant decrease in submaximal $\dot{V}O_2$, $\dot{V}O_2/d$, and ASI. A non-significant decrease in submaximal heart rate was observed. It was concluded that training on the Väsa Swim Trainer will improve the swimming economy of the novice, adult, female swimmer.

DEDICATION

This paper is dedicated to the Adult Fitness Swim Program at Eastern Illinois University. May the results of this study inspire these swimmers to utilize the Väsa Swim Trainer for the improvement of their swimming stroke.

ACKNOWLEDGEMENT

The author wishes to express her sincere appreciation to the eight ladies who volunteered for this study. Without their time, patience, and commitment this study would not have been possible. The author also wishes thanks to: Jeffrey McClung, Jake Emmett, Dr. Thomas Woodall, and Snowden Eisenhour, for their time and guidance throughout this study. A special thanks to Ray Padovan, Swim Coach at Eastern Illinois, for the permission to use the Väsa Swim Trainers.

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CHAPTER I

INTRODUCTION

Swimming is an excellent alternative to the walk/jog exercise program for adults. Swimming has been shown to enhance the aerobic abilities of middle-aged people without placing excessive stress on weight bearing joints (Martin et al., 1987). There are two special qualities about swimming which makes it an excellent alternative to a walk/jog program: 1) stress on the joints is minimal because the body is supported by the water, and 2) stress on the cardiovascular system is decreased, especially on hot summer days, due to the natural cooling characteristic of water.

However, not everyone finds swimming enjoyable. There are many who fear water, especially deep water, and/or fear submerging their heads. Others may find the water to be too cool and therefore uncomfortable. Those who can swim may find it swimming to be discouraging as they perceive it to require too much energy.

The later reason may be due to the fact that, in swimming, the resistance of the water and the drag created by the body must be overcome in order to move forward. Many factors can influence the amount of resistance encountered, but the two primary considerations involved in overcoming this resistance are the kicking action of the legs, and the force that is applied through the water with the arms and hands. However for the front crawl, the majority of this propulsive force comes from the arms (Holmér, 1983). Therefore, one who has greater strength in the upper body and demonstrates good stroke technique, is more capable of overcoming the resistive force of the water and thus may find swimming less demanding than other aerobic exercises such as cycling and running. Research has shown that swimming with good technique will produce a lower heart rate and oxygen uptake due to the prone body position and the less muscle mass involved when compared to running and cycling (Stenberg et al., 1967; Holmér, 1972). On the other hand, one who demonstrates poor technique and cannot produce enough force to sufficiently overcome the resistance will be very inefficient, thus utilizing more energy (Costill et al., 1985), and tiring sooner.

Propelling efficiency is very important in swimming. Research has found that the mechanical work efficiency for the front crawl ranges from 0.5 percent in the untrained swimmers to 5.9 percent in the elite swimmers (Miller, 1975). One study (van Handel et al., 1988) showed that the unskilled swimmer will expend two to five times the amount of energy expended by a skilled swimmer. Propelling efficiency can be increased by improving stroke technique and/or increasing the amount of force produced during the stroke.

For years competitive swimmers have been performing dry land exercises, in addition to swimming, to improve power and muscular endurance. These dry land exercises include weight training, and the use of resistive devices, such as elastic cords and swim benches. However very few novice and recreational swimmers train with such equipment.

The Väsa Swim Trainer (Figure 1) is one type of swim bench. It consists of a padded seat on rollers which glides up a monorail. A person lies in the prone position on the carriage, places hands in the paddles which are attached to the straps, and pulls his/her body past the hands.

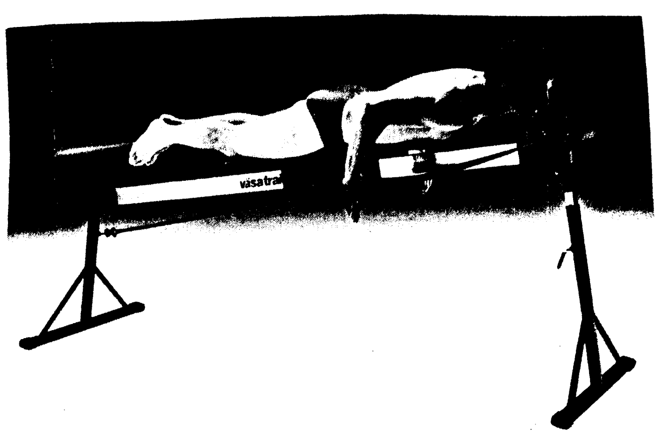

Figure 1. The Väsa Swim Trainer.

The swim trainer can be set at various degrees of incline to alter the amount of work. A rubber tubing can also be attached to the back of the seat carriage to create an added resistance.

Justification for the Study

Swimming research has been primarily focused on how the competitive swimmer can become more efficient in the water and swim faster. Research is lacking on how to improve the novice swimmer's technique and swimming performance. The Väsa Swim Trainer and similar devices have been primarily designed for the competitive swimmer. However, it has been shown that many of these devices, such as swim benches, are not very specific for elite swimmer (Schleihauf, 1983). The stroking technique of the elite swimmer follows an elliptical pattern, while the direction of the pull on a swim bench is almost straight back. The novice swimmer, however, often utilizes a stroke technique that is straight back. Furthermore, many novice swimmers, especially females, may also lack the upper body strength required to overcome the resistance of the water. It is possible that by increasing the strength of the novice swimmer and by developing a better understanding of the stroking technique the novice swimmer will become more economical in the water.

Statement of the Problem

The purpose of this study was to determine whether a group of adult, female, novice swimmers could become more economical in the water as a result of a six week training program on the Väsa Swim Trainer. Swimming economy was determined by submaximal heart rate (HR) and oxygen consumption ($\dot{V}O_2$) while swimming at a steady state, and the arm stroke index (ASI) for 10 laps (457.2 meters) of swimming.

The Research Hypothesis

Strength can be improved by training on the Väsa Swim Trainer. This improvement will significantly ($p < .01$) decrease the submaximal oxygen consumption while swimming, oxygen consumption per given distance swum, arm stroke index, and submaximal heart rate. Thus, resulting in a more economical stroke for the novice female swimmer.

Definitions

Arm Stroke Index (ASI). The ratio of the number of arm strokes (st) per distance swum to the swimming velocity (m/s) ($ASI = st/m \cdot s^{-1}$) (McMurray, DeSelm, & Johnston, 1990).

Bernouilli's Principle. A decrease in the pressure of a moving fluid as its velocity increases (Luttgens & Wells, 1982).

<u>Biokinetic Swim Bench</u>. A semi-accommodating resistance device used by swimmers, which can measure maximum arm power at a constant limb velocity.

<u>Drag</u>. A force that acts opposite to the direction in which an object is moving (Maglischo, 1982).

<u>Economy</u>. The lowest energy cost requirement to perform a given task (Cavanagh & Kram, 1985). In this study, economy is be based upon submaximal heart rate, submaximal oxygen uptake, oxygen uptake per meter swum, and the number of strokes to swim this distance.

<u>Elbows Up</u>. A term used when demonstrating the correct form on the Väsa Swim Trainer, and correct swimming technique. The elbows are above the hands at all times.

<u>Force</u>. The amount of tension that can be applied to an object (Sharp & Costill, 1982). For example, the tension created at a particular part of a pull.

<u>Lift</u>. A force that is exerted in a direction that is perpendicular to the direction of drag force (Maglischo, 1982); caused by a difference in pressure (deGroot & van Ingen Schenau, 1988).

<u>Novice Swimmer</u>. A novice swimmer in this study is defined as a person who does not compete as a swimmer and whose comfortable average speed for 50-yd (45.72-m) takes 60 seconds or longer.

<u>Power</u>. The amount of work per unit of time, or the rate at which work is done (Stamford, 1985).

Repetition Maximum (1-RM). The maximal resistance a muscle group can lift one time (Luttgens & Wells, 1982). In this study 1-RM will be the maximal amount of work calculated to be performed on the Väsa Swim Trainer one time.

Specificity. Training or developing the muscle groups in the way in which they are used during a particular exercise.

Strength. The maximum force developed during muscle contraction (Stamford, 1985).

Stroke Length. The distance that the swimmer moves forward during one complete stroke cycle of one arm (Keskinen & Komi, 1988).

Stroke Rate. One complete cycle of one arm in a given unit of time (Keskinen & Komi, 1988).

Submaximal. Exercise performed below maximal effort. In this study it is assumed that values for heart rate and oxygen consumption are based upon a steady state of submaximal swimming.

Väsa Swim Trainer. A swim bench used to help the swimmer develop upper body strength and power, while simulating a particular swim stroke. Resistance is based upon one's body weight, the slope of the carriage rail, and the tension of an optional elastic band.

Work. The force applied over a given distance, such as throughout the entire arm pull.

Assumption

It is assumed that these novice swimmers are not like the competitive swimmer: 1) they do not have the upper body strength to "pull" themselves through the water with ease, and 2) their swimming technique for the crawl stroke incorporates the straight backward motion with the arms, instead of an elliptical pull (sculling).

Delimitations

1) Subjects were females between the ages of 35 and 60 years, have a normal resting EKG, and have no medical concerns.

2) All subjects involved in this study were required to have been swimming at least twice a week for 20 minutes a session for six weeks prior to pre-testing.

3) Participants were considered novice in their swimming abilities because they have not competed in swimming events and a comfortable swimming pace per lap, 50 yards (45.72-m), was slower than 60 seconds.

4) Swimming frequency, duration, and number of laps during the training period stayed consistent throughout the training period.

Limitations

1) Swimming regularity and average swimming speed requirements for the study limited the number of subjects

participating in this study and may have had an effect on the results of the study.

2) This study was limited to females between the ages of 35 and 60 years, whose fitness level varied.

3) Determining the oxygen consumption of the swim was limited to a 30 second post-exercise value. It was assumed that the humid environment within the pool did not alter the readings of oxygen and carbon dioxide concentrations by the electronic analyzers.

CHAPTER II

REVIEW OF LITERATURE

This chapter reviews literature related to muscular strength, strength in swimming, swim benches, swimming mechanics, and swimming efficiency. This review has been structured so that the reader will be able to understand how muscular strength relates to stroke mechanics and force production in the water, and how swimming economy can be improved by increasing strength. The review of literature for this study has revealed that very few studies have been performed with the noncompetitive, especially the novice, swimmer.

Since oxygen uptake is one of the variables used to determine the economy of the swimmers in this study a review of literature on backward extrapolation to determine oxygen consumption is included in this chapter. Collecting a sample of expired air directly after a bout of steady state exercise, and then extrapolating backwards to calculate the amount of oxygen used during the swim, will allow more freedom to both the subjects and the tester.

Muscular Strength

Strength can be defined as the capacity of an individual to exert a force against a resistance in a single contraction (Sharp, 1986). To a large extent, muscular strength determines how well one performs in an activity (Montoye & Lamphiear, 1977). Increasing strength will allow one to initially move an object and/or to move an object farther with more ease, thereby increasing the amount of work accomplished (Stamford, 1985). Hickson et al. (1980) found that following a resistive training program there was a 47 percent increase in the time to exhaustion on a bicycle ergometer test, however, aerobic capacity did not significantly increase.

Muscular Strength in Women. Due to less muscle mass, the average female is weaker than the average male. Montoye and Lamphiear (1977) found that the average ratio for arm strength to body weight for the male was greater than 1.0, while the ratio for the female was 0.8. Studies have revealed the overall strength of a female to be 50 to 75 percent of a male's strength (Kroll, 1971). A female's upper body is 50 to 60 percent of the strength of the male's, while the lower body is 70 to 80 percent (Buckbee, 1981).

Training studies on untrained women have revealed gains in muscular strength and muscular endurance. After a 10 week strength training program at 70 to 80 percent of 1-RM, Drinkwater (1973) revealed a 30 percent increase in strength and an increase in muscle size in females.

Strength Training. Many studies have been performed to determine the best method to develop strength. Berger (1968) showed that performing 3 sets of 10 maximal repetitions, twice a week is just as effective for increasing strength as training 3 days a week at that same intensity. Prior to this, Berger (1962) found that performing 3 sets of 6 maximal repetitions, three times a week increased strength. Both of these studies have revealed a significant increase in one's maximal repetition (1-RM) after the first week of training. Improvements in strength were seen up until the sixth week of training. Other studies performed on weight training have differed slightly from one to the other, but the main objective is to subject the muscle to a resistance that is heavy enough so that no more than 10 repetitions can be performed at one time.

Most often strength is developed by performing three sets of four to ten repetitions, at a resistance that is 60 to 80 percent of 1-RM (Falls, Baylor, & Dishman, 1980). It is best to perform each repetition slowly; this allows more muscle fibers to be recruited and more muscle force to be produced (Wescott, 1989). Muscle tension is also continued for a longer period of time (Wescott, 1989). Any weight training exercise should therefore be performed slowly and at a consistent rate throughout the entire exercise.

Strength training for a particular exercise must be sport specific (Luttgens & Wells, 1982). In other words, the strength training exercise must simulate the range of motion and stress the same muscles that are used in the specific event (Sharp & Costill, 1982). Prior to designing a strength training program, it must be determined if the program is to increase force, power, or work (Sharp & Costill, 1982). These factors will determine the amount of resistance, the number of repetitions, and the rate in which the exercise is to be performed.

<u>Force, Work, or Power</u>. Force is the amount of tension that is applied to a object when there is not any movement, or at an instantaneous point of a movement (Sharp & Costill, 1982). Force is dependent upon the speed of the movement; as speed increases and is to be maintained, more force is required (Sharp, 1986). Strength training will help develop more muscle fibers which can then be recruited for force production (Stamford, 1985). When an object is moved from one place to another, a force will be exerted over the given distance, and work will take place (Sharp & Costill, 1982). For instance, in swimming, work is the force applied throughout the entire arm pull. Increasing strength can help increase the amount of work performed by aiding in

moving an object farther, faster, and/or with more ease (Stamford, 1985). Power is defined as work performed per unit of time. Power will only be increase by: 1) decreasing the time it takes to accomplish the same amount of work, or 2) by performing more work in the same amount of time (Stamford, 1985).

Strength in Swimming

Strength plays an important role for the swimmer. It allows the swimmer to generate more force during the pull, thus aiding in overcoming the resistance of the body. It is the strength of the swimmer's pull which determines the speed of the hand; hand speed and the angle of the hand determines the amount of force applied through the water (Schleihauf, 1979).

The purpose of swimming is to overcome body drag over a certain distance and possibly in the shortest period of time. Thus, work and power are key elements in swimming. Competitive swimming is a power limited sport. Research has shown a significant correlation (r =.81) between a competitive sprinter's performance and muscular power (Sharp & Costill, 1982). Costill (1978) found a correlation (r =.89) between power measured with a biokinetic swim bench and the speed of swimming 100 yards.

Strength training programs that have been designed to increase power have shown decrease swimming times. Sharp

(1986) strength trained ex-competitive swimmers for four weeks using five sets of ten maximal repetitions for a two arm pull. In four weeks, arm power was increased by 19 percent and the time for a 25 yard swim improved by 4 percent.

Strength has a more significant role for the untrained swimmer. Clarke and Henry (1961) determined the relationship between strength and speed of movement. Thirty-one males performed upper body weight lifting exercises three times a week, for six weeks. This training group performed three sets of ten maximal repetitions, while the control group (31 men) did not engage in any regular physical activity. After a six week training period the training group had a 17.9 percent increase in strength, while the control group had a decrease in strength. The training group also showed an increase in the speed of movement by decreasing movement time by 4.2 percent. The speed of movement for the control group decreased by 1.0 percent.

The Davis study (1955) revealed that strength training will improve swimming speeds. This study asked 17 subjects (who were involved in a swimming program) to swim once a week and weight train twice a week, for eight weeks. Times for the 25 yard and 50 yard crawl improved significantly (p =.01) when compared with the pre-weight training times.

Whether the strength training program is designed for a competitive swimmer or for a novice swimmer it is essential for the exercises to be performed at speeds similar to the speeds used when swimming (Sharp, 1986; Terry, 1984). Therefore, not only are the exercises to be similar in muscle involvement, but they are also to be speed specific. Training at a slow speed will develop the strength and force necessary for slow movement velocities, while training quickly will help develop the strength and power required for fast movement speeds (Sharp, 1986). Competitive swimming, whether it be sprinting or a 1500 meter swim, is considered to be performed at relatively fast speeds, where as for the unskilled swimmer, fast movement speeds would only apply to sprinting.

Swim Benches

Swim benches have been used to improve the swimming stroke and to increase muscular endurance, strength, and power. The Biokinetic Bench (Figure 2) is one type of swim bench. It has been used for swim training and to determine maximal force and/or power during a particular stroke. The Biokinetic Swim Bench is a semi-accommodating resistive swim bench. A constant amount of acceleration occurs based upon the proportion of the force applied by the swimmer (Costill, King, & Thomas, 1985). Speed settings range from 0 to 9; at a setting between 0 and 2, the speed is slow. This allows one to exert more force at a lower speed, thus providing an ideal way to improve basic strength. To train for power, one would set the speed setting higher, at a rate that would be similar to actual swimming speed (Terry, 1984).

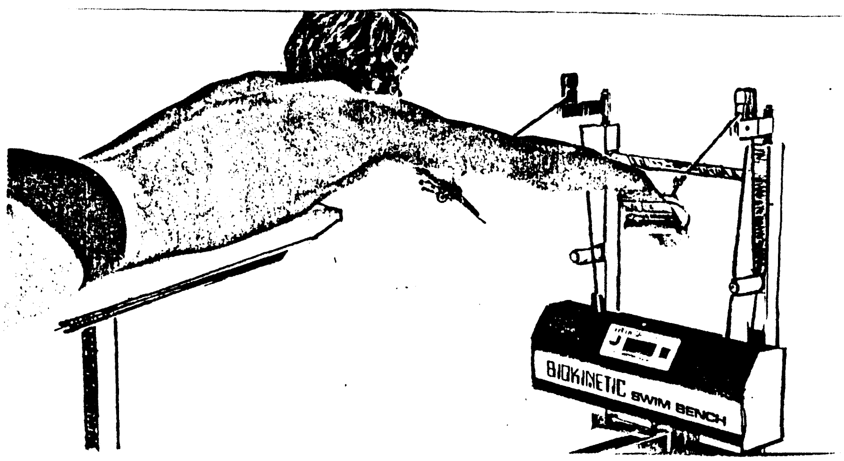

Figure 2. The Biokinetic Swim Bench.

Another type of swim bench is the swim trolley. The trolley is a bench on wheels which rolls up and down two channel irons, with two handles attached by ropes to the top of the trolley. A swimmer lies on the bench, grasps the handles of the ropes, and pulls the body forward over the hands. To make the exercise more difficult the angle of the trolley can be increased, weights can be added, or surgical tubing can be added to increase the resistance. Even though the swim trolley will not allow the swimmer to duplicate the movement exactly (compared to the stroking movements performed in the water), it has been shown to be close enough to help improve power and muscular endurance (Maglischo, 1982).

The Väsa Swim Trainer consists of a seat which is attached to a carriage that glides (coefficient of friction equals 0.008) up a monorail on ball-bearing rollers (R. Sleamaker, M.S., owner of Väsa Inc, personal communication, March 26, 1991). Pull straps with plastic hand paddles are attached at the top of the trainer. Similar to the swim trolley, a person lies on the seat, places hands in the paddles, and pulls the body forward (up the rail) over the hands. The incline of the monorail can be adjusted or surgical tubing can be attached at the base of the carriage to increase the resistance.

Mechanics of the Crawl Swimming Stroke

There are two types of swimming techniques most commonly used for the arm stroke in the front crawl: the straight back technique and the sculling technique (deGroot & van Ingen Schenau, 1988; Schleihauf, 1983). The first technique is more of a paddling action, while the later is a propeller like action (Maglischo, 1982). The first technique "pushes" the water directly backward (opposite to the direction of movement). It requires more force, is less efficient, and creates more drag than the sculling technique (Maglischo, 1982). The sculling technique consists of a series of sweeping or weaving motions which are more lateral and vertical movements than horizontal (backward) to the direction of movement. This technique is seen most often in skilled swimmers (Miller, 1975; Maglischo, 1982). This sculling motion produces a hydrodynamic lift which helps overcome drag, and aids in the forward propulsion of the swimmer (deGroot & van Ingen Schenau, 1988; Toussaint et al., 1983).

Lift and Drag. If the body were to be towed through the water, with the legs unsupported, at a velocity between 0 and 2 ft/sec, the legs would sink (Alley, 1952). This action increases the resistance during the tow. On the other hand, if this body were towed through the water at velocities between 2 and 5 ft/sec, a lift effect would occur, which would raise the legs (Alley, 1952). The elevation of the legs decreases the amount of body surface area exposed to the water, thus decreasing the amount of drag (Alley, 1952). This increase in velocity that occurs at the surface of the water causes the pressure above the body to decrease. Because there is a difference in pressure above and below the body there is a movement from a high pressure gradient to a low pressure gradient, thus an elevating action occurs. This phenomenon is called Bernouilli's Principle. However, while swimming, the body is not being towed through the water, but is being paddled or propelled (depending on the stroke) through the water.

For this reason, it is important to consider the resulting force created by the lift and drag of the hand.

A lift force cannot be created without creating a drag force, however, these two forces are not always equal in magnitude. A swimming technique that leads to a maximal lift/drag ratio is optimal (deGroot & van Ingen Schenau, 1988). It has been shown that the hand can generate propulsion forces as a result of both lift and drag forces. If the hand "attacks" the resistance of the water without an angle, there will be zero lift (Schleihauf, 1979). As this angle of attack increases, up to 40 degrees, the lift force increases (Schleihauf, 1979). The optimal angle of attack by the hand is 40 degrees. At this angle the lift/ drag ratio is 1.75; this ratio is slightly less for both the hand and arm (deGroot & van Ingen Schenau, 1988).

A technique that incorporates lift and drag will allow one to lengthen his or her stroke, while maintaining a relatively low stroke frequency (deGroot & van Ingen Schenau, 1988). The longer the stroke, the greater the distance covered per stroke. Thus, fewer strokes will be required to swim a given distance.

Stroke Length. Long strokes are usually demonstrated by elite swimmers (Toussaint et al., 1983). In the 1984 USA Olympic Swimming Trials, the longer stroke lengths were seen in the best swimmers (Keskinen & Komi, 1988). It was also noted that an increase in stroke length was the main factor for the increase in competitive swim velocities during the eight year period from 1976 to 1984 (Keskinen & Komi, 1988).

The short intensive strokes, that last half the cycle time of longer strokes, have a propelling efficiency of 0.37 (deGroot & van Ingen Schenau, 1988). Optimal propelling efficiency (0.50 or slightly higher) is seen when a swimmer uses longer strokes with a more uniform pattern of force, than when the same amount of force is produced by using shorter strokes with high peak forces (deGroot & van Ingen Schenau, 1988). Swimming at a low intensity should be compensated for by lengthening the stroke. To swim at a higher velocity the stroke rate will have to increase, but at the same time the length of the stroke must be maintained. Increasing muscular strength will improve a swimmer's level of performance in the water by allowing the swimmer to: 1) produce a high stroke rate, and 2) maintain a relatively long stroke length (Keskinen, Tilli, & Komi, 1989).

Swimming Efficiency

Holmér (1972, p.507) states that the "elite runners and cyclists are not characterized by superior efficiency in cycling or running when compared with nonathletes at submaximal work rates." However, he mentions that this does not hold true for the swimmer.

Efficiency is the ratio of work accomplished to energy expended to do that work (Cavanagh & Kram, 1985). Muscular efficiency on a cycle ergometer is determined by the pedal speed at a given power output (work) level divided by maximal oxygen uptake (Swaine & Reilly, 1983). Running efficiency can be calculated by determining the stride length and frequency for a given velocity and dividing it by oxygen consumption (Swaine & Reilly, 1983). Determining swimming efficiency, however, is rather complicated; the power output while swimming is hard to accurately determine since the swimmer does not have a fixed point from which to push. Energy is used to overcome drag, enabling the forward motion, however, some of this energy is wasted in moving the water backwards, giving the water kinetic energy (Toussaint et al., 1990). Thus, the efficiency of a swimmer will be highly determined by the stroke technique of the swimmer (Swaine & Reilly, 1983; Kemper et al., 1983; Toussaint et al., 1988; & Toussaint et al., 1990). The efficiency for the front crawl swam by a competitive swimmer may be 15 percent or slightly higher (Holmér, 1983), however, this percentage may be four times lower for the noncompetitive swimmer (Kemper et al., 1983).

Energy Cost. The energy expended during swimming is used to maintain the body on the surface of the water, and to generate enough force to overcome the inertia of the water. Because of these requirements, the energy costs of swimming are dependent upon body size, body density, and stroke efficiency (m/stroke). Chatard et al. (1985) has shown that there is no significant correlation (r =-.20) between oxygen consumption per distance ($\dot{V}O_2$/d) and hydrostatic lift created by the stroke. However, for a given body surface area, $\dot{V}O_2$/d is negatively related to hydrostatic lift created by the stroke. Therefore, if a person swam a given distance twice, however during the second time less oxygen was consumed, it could be assumed that the stroke was more effective in creating lift during the second swim than the first.

Pendergast et al. (1977) compared the competitive swimmer to the noncompetitive swimmer. This study demonstrated that the amount of oxygen used per meter swum is proportional to the ratio of resistance and efficiency of swimming. A similar study was performed comparing recreational male swimmers to competitive male and female swimmers (Costill et al., 1985). The amount of oxygen consumed during a 365.8 meter swim was very similar between the recreational swimmers and the competitive swimmers, 4.04 L/min and 4.00 L/min, respectively. The swimming velocities, however, of these two groups were significantly different, 0.89 m/s for the recreational (male) swimmers and 1.29 m/s for the competitive (male and female) swimmers. Thus, a significant difference in the swimming efficiency, in terms of oxygen cost per distance swum, was observed. The recreational male swimmers used an average of 75.6 milliliters of oxygen per meter swum during 365.8 meter swim, while the male competitive swimmers used 51.5 ml/m. The female competitive swimmers required only 41.5 milliliters of oxygen per meter during the 365.8 meter swim. Further investigation in this study suggested that the energy costs of front crawl swimming was strongly influenced by an effective application of the force during the arm stroke (Costill et al., 1985).

Arm Stroke Index. The arm stroke index (ASI) describes the swimmer's ability to move at a given velocity with the fewest number of strokes. It is a good indicator of swimming economy (Lavoie et al., 1985). The swimmer that moves the greatest distance per stroke, at a given velocity, demonstrates the most economical swimming technique (Costill et al., 1985). McMurray, DeSelm, and Johnston (1990) showed that as a swimming season progressed for competitive swimmers, ASI decreased (at a given speed), thus revealing an increase in swimming economy.

Backward Extrapolation of Oxygen

Calculating the amount of oxygen consumed while swimming has been limited to the use of the equipment to collect the expired gases (Costill et al., 1985). The snorkel type face mask worn may alter the breathing pattern of the swimmer and can create added drag. The apparatus may also restrict the movements of the swimmer. Collecting the expired air inside Douglas bags requires the bag to be suspended above the swimmer at all times, thus requiring it to move with the swimmer. If the air is expired through a closed system dead space within the inspiratory and expiratory tubes must be taken into consideration. Similar problems have been observed while measuring metabolic expenditure during cycling or running outdoors; carrying a Douglas bag around can lead to increase air resistance, thus increasing oxygen consumption (Léger, Seliger, & Brassard, 1980).

In order to alleviate these problems, studies have found that oxygen uptake measured during the recovery phase of exercise can be extrapolated backwards in order to determine oxygen uptake during the exercise (diPrampero et al., 1976; Léger, Seliger, & Brassard, 1980; Costill et al., 1985). Backward extrapolation of post exercise oxygen uptake, to determine oxygen uptake during the exercise, has been shown to be valid (r =.99) and reliable (r =.92) (Costill et al., 1985).

Costill et al. (1985) determined that backward extrapolation could be used in swimming, both at submaximal and maximal velocities. They measured the oxygen uptake of 39 collegiate swimmers during seven minutes of tethered breaststroke swimming and during 80 seconds of post exercise recovery. One minute gas samples were collected in Douglas bags during the sixth and seventh minute of the swim. Four 20 second gas samples were also collected in Douglas bags during the first 80 seconds of recovery. A regression analysis was computed between each 20 second $\dot{V}O_2$ measurement and the $\dot{V}O_2$ values determined during the exercise. From this, the equation Y = 0.916X + 0.426 was developed to predict swimming $\dot{V}O_2$ (Y is the predicted $\dot{V}O_2$ and X is $\dot{V}O_2$ based upon a 20 second recovery measurement). The value calculated by using the above equation, where X is the $\dot{V}O_2$ during the first 20 seconds of recovery, highly correlated (r =.98) to the actual swimming $\dot{V}O_2$. Replacing X with the second recovery $\dot{V}O_2$ (20-40s) revealed a similarly high correlation (r =.97), however the correlation coefficients for the other 20 second post exercise values were much lower.

Summary

There are two factors which play important roles in the speed and economy of swimming: strength and stroke mechanics. If a swimmer with long arms finds it difficult to swim at a fast velocity it may be due to a lack of muscular force and/or the lack of skill (Keskinen, Tilli, & Komi, 1989). If this swimmer increases the upper body strength, but is still incapable of reaching a high velocity, this swimmer is not effectively applying the muscular power and long levers of the body to the forward propulsion component of swimming (Keskinen, Tilli, & Komi, 1989). DeGroot and van Ingen Schenau (1988) showed that strength, or muscular power, is not the only factor important to swimming success; the efficient swimmer is one who demonstrates a technique which leads to a large lift/drag ratio.

Training on a swim bench can help improve a swimmer's muscular power and endurance, however these benches have not shown to be very specific in mimicking a technique which incorporates a high lift/drag ratio. However, from observation and reviewed articles, this ideally efficient stroke, is most often seen in only the elite, or competitive swimmers.

The economy of a swimmer's stroke can be determined by the amount of oxygen consumed for a given distance, and the number of strokes (ASI) that are taken for the given distance. Speed is not necessarily a determining factor of efficiency, or economy, however it is used to determine the arm stroke index. A swimmer who completes a given distance in the least number of strokes and uses the least amount of oxygen can be considered the most economical swimmer.

CHAPTER III

METHODS AND PROCEDURES

The following chapter describes the subjects and the equipment used in this study. The procedures for the pre and post-training tests and the training program are also described.

Subjects

Eight adult, female novice swimmers between the ages of 35 and 60 years participated in this study. The mean age was 50.4 years. Six of these volunteers were from the Adult Fitness Swimming Program at Eastern Illinois University. This program meets three times a week and participants are required to record the number of lengths, total time, and two post exercise heart rates. These six had been swimming regularly, at least twice a week for 20 minutes a session, for the previous six weeks. The other two volunteers were faculty members at EIU who claimed to have been swimming regularly, at least twice a week for 20 minutes a session, for the last six weeks.

Prior to the study, all participants were required to have a resting electrocardiogram. None of the tracings revealed any resting abnormalities. One subject was on blood pressure medication (Prinivil 5mg/day); however her blood pressure was under control. Some of the subjects admitted to having pains in the back of the neck, in the back, in the shoulders, or in the arms prior to the study. However, since these subjects were already involved in a swimming program and were not bothered by these pains when swimming, they were allowed to take part in the study. All participation was on the volunteer basis with the understanding that anyone could freely withdraw from the study at any time, especially if the training seemed to aggravate their physical condition.

All eight subjects participated in the training group. Subjects swam at least twice a week and trained on the Väsa Swim Trainer three times a week, for six weeks. The number of times per week each subject swam, the number of laps swam, and the total time swam were recorded weekly for each subject during the six weeks of training. This was done in order to assure that the amount of swimming had been controlled and had not varied from the amount of swimming performed prior to the study.

Equipment

Carbon dioxide, oxygen, and the amount of air expired during 30 seconds of recovery were measured by an on-line, open circuit system which included the following: Beckman LB1 carbon dioxide gas analyzer, Beckman E2 oxygen gas analyzer, Rayfield gas meter, mixing chamber, two three foot long rubber hoses, Hans Rudolph two way valve, rubber mouthpiece, and nose clips. Prior to testing, and periodically throughout the testing, the gas analyzers were calibrated with gas sampled of predetermined CO_2 and O_2 concentrations. Thermometers were used to measure the air and water temperatures, while a barometer was used to measure the barometric pressure.

Heart rates were measured and recorded in memory every five seconds during the swim by a waterproof Polar Heart Rate Monitor and Watch. A transmitter was placed on the subjects' chests with electrode tabs. Prior to placement the area was abraded with an abrasive felt pen and then wiped with rubbing alcohol and dried.

A stopwatch was used to time 10 laps of swimming at a comfortable pace set by each subject. A metal rod was used in the post-training testing to set the pace (based upon the average time per lap calculated from the pre-training test) for the each swimmer. This rod was struck on the side of the pool to emit a sound through the water to inform the subjects when they were to be in the middle of the pool or at the end of the pool.

A Väsa Swim Trainer was used for the pre and post-training testing and for the training. A video camera was used to record the proper and improper training technique on the swim trainer. This tape allowed the subject to see what was meant by "elbows up".

A scale was used both at the pre and post-training testing to weigh each subject prior to being maximally tested on the swim trainer. The average length traveled during each pull when tested on the swim trainer was measured by a tape measure. The weight of the subject, while wet, and the average distance traveled were used to determine the maximal amount of work (ft-lb) performed on the Väsa Swim Trainer.

Procedures

All subjects were informed on the testing protocol: 1) swim ten laps at a steady pace, 2) listen for the signal which indicated one lap to go, 3) retain the last breath, and 4) breathe into the mouthpiece. The subjects were allowed to practice breath holding, putting in the mouthpiece, lowering themselves to neck level in the water, and breathing naturally into mouthpiece. Prior to the pre-training swim test the subjects swam one or two laps in order to warm up the muscles and to recognize a comfortable pace. These initial laps were also performed prior to the post-training swim test to warm up and to also get an idea of the pace in which they were to swim. It was also important that the subjects could hear the sound of the rod hitting the wall, so that the post-training swim pace would be steady and consistent with the pre-training swim time.

Prior to being maximally tested on the Väsa Swim Trainer all subjects were instructed on the correct technique. They were told to perform as many pulls as possible, and informed that the test would be terminated upon their failure to maintain good technique, as determined by the tester. Subjects were allowed to perform a few easy pulls in order to get a feel for the technique.

Pre and Post-Training Swim Tests. Polar Heart Rate electrode transmitters were placed on the chests of the subjects and recording monitor watches were placed on the subjects' wrists. Subjects swam ten laps, 457.2 meters, at normal comfortable paces, during the pre-training swim test. During the post-training swim test the subjects were paced by a sound that was emitted through the water (caused by a metal rod being hit against the wall of the pool) every time the subjects were to be at the ends and in the middle of the pool. The heart rates were monitored and recorded every 5 seconds throughout the swim. The entire swim was timed, however, the third, sixth, and ninth laps were timed separately. Also, during these three lap segments, the number of stroke cycles were counted. Based upon the number of stroke cycles and the time at lap three, six, and nine, the arm stroke index was calculated (strokes/$m \cdot s^{-1}$). On the final lap, the subjects retained their last breath of air when they were approximately six feet away from the edge of the pool. While holding their breath the subjects placed the mouthpiece into the mouth, while the nose clips were placed on the nose. The subjects lowered themselves until the water level reached the neck. They then exhaled and began to breathe naturally into the mouthpiece. Thirty seconds of recovery breathing, starting from the first expiration, was analyzed by the gas analyzers and measured by the gas meter. After 30 seconds of recovery breathing the O_2 and CO_2 percentages and the volume of expired were recorded.

The following formula was used to determine the amount of oxygen consumed during 30 seconds of recovery breathing:

$$\dot{V}O_2 = \dot{V}_E * [0.265 * (1.000 - F_{EO2} - F_{ECO2}) - F_{EO2}],$$

where $\dot{V}_E$ is the amount of air expired in one minute (30s *2) and corrected to STPD, F_{EO2} is the fraction of expired oxygen, and F_{ECO2} is the fraction of expired carbon dioxide (Blair et al., 1988). The amount of oxygen consumed 30 seconds post-exercise is then extrapolated backwards by the following equation in order to determine $\dot{V}O_2$ during the swim:

$$Y = 0.373 + 0.9295X$$

The predicted $\dot{V}O_2$ during the swim is Y and X is the $\dot{V}O_2$ during the 30 seconds of recovery (pilot study: Appendix A).

<u>Pre and Post-Training Swim Trainer Test</u>. After a five to ten minutes rest the subjects performed a maximal test on the Väsa Swim Trainer. While wet, the subjects were weighed so that the maximal force required at various angles could be calculated. Prior to this test the subjects performed a few pulls at a lower workload (lesser angle) in order to get a feel for keeping the elbows up and so that the distance traveled with each pull could be measured. The swim trainer was then placed at an angle in which the tester felt that each individual subject would be able to do at least one good pull, with proper technique, but not more than 15 continuous pulls with proper form. The total number of pulls were recorded, along with the weight (pounds) of the subject and the average distance traveled (inches) during each pull. The subjects followed the same test on the Väsa Swim Trainer before and after the training period.

The one repetition maximum was calculated by determining the total work performed and dividing this number by a predetermined number set by Berger (1982). This predetermined number is based upon the number of repetitions completed (i.e. 4 repetitions = 0.94 and 8 repetitions = 0.84). Since work is the total force applied over a given distance, force must be calculated first. The force equals the total weight of subject and carriage multiplied by the sine of the angle (σ) of the pull:

$$F = wt(lb) * \text{sine } \sigma$$

(Luttgens & Wells, 1982; pp. 265-276).

Since work was to be expressed in ft-lb, the following equation was used to calculate work:

$$W = (d / 12) * (wt * \text{sine } \sigma) ,$$

therefore the equation for determining a subject's 1-RM on the Väsa Swim Trainer was:

$$1\text{-RM} = [(d / 12) * (wt * \text{sine } \sigma)] / X ,$$

where X is the predetermined number set by Berger (1982) based upon the number of repetitions performed.

<u>Training</u>. All subjects were instructed as to how to adjust the swim trainer and the proper technique required for the swim trainer. The muscles that were involved and how the pulling action on the Väsa Swim Trainer related to swimming were mentioned prior and during training.

Two weeks prior to the actual six weeks of training the subjects trained on the swim trainer in order to become accustomed to it. This practice was performed prior to the testing of oxygen consumption. Week one included 2-3 sessions of two sets of 6-10 repetitions, at 60-70 percent of 1-RM. Week two included 2-3 sessions of three sets of 6-10 repetitions, at 60-70 percent of 1-RM.

All subjects trained on the Väsa Swim Trainer for an additional six weeks, three times a week, allowing a day between sessions. A training session consisted of three sets of 8-12 repetitions. Subjects were to rest for one minute between sets. Each repetition was to be performed slowly, during both the pull and the recovery phase. The subjects started out training on the Väsa Swim Trainer at 65-70 percent of the 1-RM that was predicted from the maximal effort performed during the pre-training test. The work load was progressively increased by either increasing the angle of the swim trainer or by adding a rubber tubing to the back of the carriage. The work load was increased when 12 repetitions could be easily performed. If any of the subjects were bothered by previously known pains, or any other problems became present, the progression was modified to a work level which would not initiate pain and yet required some effort. The key to training for this study was to train at a work level in which 8-12 repetitions could be performed with good technique before failure.

Analysis of Data

Dependent t-tests were performed to determine if training on the Väsa Swim Trainer for six weeks significantly:

1) increased the one repetition maximum on the Väsa Swim Trainer.

2) decrease submaximal oxygen consumption, submaximal heart rate, and the arm stroke index during a ten lap, 457.2 meter, swim.

The level of confidence was set at .01 to denote statistical significance in this study.

CHAPTER IV

ANALYSIS OF DATA

The purpose of this study was to see if novice, female swimmers could improve their swimming economy by training on a Väsa Swim Trainer. Increasing swimming economy can be determined in four ways: 1) decreasing submaximal exercise oxygen consumption, 2) decreasing oxygen consumption per given distance at a fixed velocity, 3) decreasing the number of arm stroke cycles per given distance, and 4) decreasing submaximal exercise heart rate.

Table 1

Differences in Pre and Post-Training Means for Maximal Repetition (1-RM), Submaximal Oxygen Consumption ($\dot{V}O_2$,, Oxygen Consumed Per Distance Swum ($\dot{V}O_2$/d), Arm Stroke Index (ASI), and Submaximal Heart Rate (HR).

	Pre Mean	Post Mean	% Change	p
1-RM (ft-lb)	108.17	147.63	+36.5	.0012 *
$\dot{V}O_2$ (L/min)	1.72	1.43	−16.9	.0085 *
$\dot{V}O_2$/d (ml/m)	49.8	41.1	−17.5	.0094 *
ASI ($st/m \cdot s^{-1}$)	523.4	489.6	− 6.5	.0014 *
HR (bpm)	147.7	137.6	− 6.8	.0296

* $p < .01$

The significance between pre-training and post-training were determined by one-tailed, dependent t-tests. The level of confidence was set at .01. A summary of the results from this study are presented in Table 1.

Väsa Swim Trainer

The amount of work performed on the swim trainer was determined by the subject's one repetition maximum (1-RM). To calculate 1-RM the total weight of the subject and the carriage, the angle of the monorail, the average distance traveled with each pull, and the total number of pulls performed were determined. Total work (force times distance) was calculated and then divided by a percentage based upon the number of repetitions (see p. 34).

Table 2

Pre and Post-Training Values For Repetition Maximum (1-RM) Performed On The Väsa Swim Trainer

Subject	Pre 1-RM (ft-lb)	Post 1-RM (ft-lb)	Change 1-RM
1	132.48	158.61	+26.13
2	119.30	174.71	+55.41
3	101.44	153.74	+52.30
4	92.90	84.83	- 8.07
5	144.69	211.48	+66.79
6	96.96	133.49	+36.53
7	99.94	159.31	+59.37
8	77.62	104.91	+27.29
Mean	108.17	147.63	+39.47
Std Dev	22.21	39.77	±24.37

The mean 1-RM determined prior to training was 108.17 ft-lb, while the mean post training 1-RM was 147.63 ft-lb. A 36.5 percent increase in 1-RM occurred over the six weeks (18 sessions) of training on the swim trainer. This increase was calculated to be significant at a .01 level of confidence (Table 1). Refer to Table 2 for individual changes of 1-RM.

Energy Cost

In this study the energy cost to swim the ten laps, 457.2 meters, at a steady state was determined by two methods: 1) the amount of oxygen consumed per minute of submaximal swimming (L/min), and 2) the amount of oxygen consumed per meter swum (ml/m). Oxygen uptake for the first 30s of recovery breathing was determined and then extrapolated backwards, using the equation Y = 0.373 + 0.9295X. (Y is the $\dot{V}O_2$ during submaximal swimming.)

Prior to training, the group mean oxygen consumption during submaximal swimming was 1.72 L/min. Post-training measurements revealed a 16.9 percent decrease in submaximal oxygen consumption while swimming at the pre-training pace. The post training mean $\dot{V}O_2$ was 1.43 L/min. This decrease in $\dot{V}O_2$ was statistically significantly beyond the .01 level of confidence (Table 1). Individual data for $\dot{V}O_2$ (L/min) is presented in Table 3.

Table 3

Pre and Post-Training Values For Predicted Oxygen Consumption ($\dot{V}O_2$) While Swimming Ten Laps

Subject	Pre $\dot{V}O_2$ (L/min)	Post $\dot{V}O_2$ (L/min)	Change $\dot{V}O_2$
1	2.18	1.87	-0.31
2	1.57	0.95	-0.62
3	1.79	1.70	-0.09
4	1.49	1.42	-0.07
5	1.94	1.36	-0.58
6	1.61	1.29	-0.32
7	1.46	1.40	-0.06
8	****	****	****
Mean	1.72	1.43	-0.29
Std Dev	6.00	6.00	±0.24

**** Lack data on oxygen consumption due to problems with the O_2 gas analyzer on date of testing.

The economy of swimming can also be determined by the amount of oxygen consumed for a given distance, ml/m (Pendergast et al., 1977). To calculate $\dot{V}O_2$/d, the $\dot{V}O_2$ (L/min) during the submaximal swim is converted to ml/s (multiply by 16.67), and swimming velocity (distance/time) is determined in m/s. The mean oxygen consumed per meter swum prior to training was 49.8 ml/m. This value decreased by 17.5 percent over six weeks of training on the swim trainer to a mean of 41.1 ml/m. This was a statistically significant change ($p < .01$) (Table 1). Individual results for $\dot{V}O_2$/d are presented in Table 4.

Table 4

Pre and Post-Training Values For Predicted Oxygen Consumption ($\dot{V}O_2$) Per Distance Swum

Subject	Pre $\dot{V}O_2$/d (ml/m)	Post $\dot{V}O_2$/d (ml/m)	Change $\dot{V}O_2$/d
1	68.6	58.8	9.8
2	49.4	29.9	19.5
3	53.4	50.5	2.9
4	44.4	42.2	2.2
5	56.6	39.8	16.8
6	42.6	34.1	8.5
7	33.7	32.4	1.3
8	****	****	****
Mean	49.8	41.1	4.5
Std Dev	11.2	10.4	6.6

**** Lack data on oxygen consumption due to problems with the gas analyzer.

Arm Stroke Index (ASI)

The arm stroke index is the total number of arm stroke cycles required to swim a given distance at a given swimming velocity ($st/m \cdot s^{-1}$). Stroke cycles were counted during laps three, six, and nine, averaged, and then multiplied by ten (10 laps). This was done in order to estimate the total number of stroke cycles required to swim 457.2 meters. Swimming velocity was determined by dividing the total distance, 457.2 meters, by the total time (s) it took to swim the distance. The arm stroke index was then calculated by the following equation:

$$ASI = \text{total number stroke cycles} / \text{velocity}$$

A 6.5 percent decrease in mean ASI was calculated after six weeks of training on the swim trainer. The pre-training mean ASI was 523.4 st/m·s^{-1} while the post-training mean ASI decreased to 489.6 st/m·s^{-1}. This decrease was statically significant at the .01 level of confidence (Table 1). Individual results for ASI are presented in Table 5. The data for the total number of strokes and swimming velocities of each individual are located in Appendix B.

Table 5

Pre and Post-Training Values For The Arm Stroke Index (ASI)

Subject	Pre ASI (st/m·s^{-1})	Post ASI (st/m·s^{-1})	Change ASI
1	742.1	683.5	58.6
2	562.8	535.5	27.1
3	529.8	514.7	15.1
4	714.3	645.7	68.6
5	532.1	488.1	44.0
6	444.4	426.3	18.1
7	388.9	378.0	10.9
8	272.7	245.4	27.3
Mean	523.4	489.6	33.7
Std Dev	6.00	6.00	21.2

Heart Rate

The heart rate was monitored during the swim and was recorded every 5 seconds into the memory of the Polar Heart Rate Monitor watch. These recorded values were averaged after the swim. The mean heart rate recorded during the pre-training swim was 147.7 bpm. The average heart rate for swimming 457.2 meters after six weeks of training on the swim trainer was 137.6 bpm. These values denote a 6.8 percent decrease between the pre and post-training mean heart rates. This decrease in the heart rate was not found to be significant at a .01 level of confidence (Table 1). The pre and post-training heart rates for each subject are presented in Table 6.

Table 6

Pre and Post-Training Values For Submaximal Heart Rate (HR)

Subject	Pre HR (bpm)	Post HR (bpm)	Change HR
1	165.9	149.6	-16.3
2	144.0	114.5	-29.5
3	146.0	140.2	- 5.8
4	152.1	151.2	- 0.9
5	145.0	118.2	-26.8
6	147.1	142.0	- 5.1
7	139.6	145.5	+ 5.9
8	142.0	139.5	- 2.5
x	147.7	137.6	-10.1
SD	6.00	6.00	±12.7

Discussion

The review of literature for this study revealed that there is little research on strength and power for the recreational swimmer, especially the novice, adult female swimmer. The research that has been performed on strength and the novice swimmer (Clarke & Henry, 1961; Davis, 1955) has been directed towards the speed of swimming, not the economy of swimming. Montoye and Lamphiear (1977) stated that muscular strength will determine how well an activity is performed; this could be taken to mean more than just improvement in speed.

Swim benches have been use primarily by competitive swimmers to improve their swimming performance by increasing muscular endurance, strength, and power. In this study a Väsa Swim Trainer was used by non-competitive, novice, adult female swimmers, to determine if they too can benefit from a swim bench training program.

<u>One Repetition Maximum</u>. All but one of the subjects increased in 1-RM, Subject 4 decreased slightly from 92.90 ft-lb to 84.83 ft-lb. Subject 4 was hindered by pain in her elbow joints throughout the study, therefore, even though she started training at 64 percent of 1-RM, she had to actually regress in work production (by decreasing angle) over the six weeks. Despite the lack of increase in 1-RM for this subject a significant ($p < .01$) improvement for mean 1-RM was observed. This suggests that a training program similar in repetitions, sets, and days, to past strength training program (Berger, 1968; Falls, Baylor, & Dishman,

1980; Wescott, 1989) can be followed in order to increase work performance on the swim trainer.

<u>Oxygen Consumption</u>. The rate of oxygen consumption during the 457.2 meter swim in this study, 1.72 L/min, was much lower than the rate of oxygen consumption during a 365.8 meter swim by recreational and competitive swimmers in a study performed by Costill et al. (1985), 4.04 L/min, and 4.00 L/min, respectively. The results in this present study do not agree with Kemper et al. (1983), who stated that non-competitive swimmers may be up to four times less efficient in swimming the front crawl than competitive swimmers. This is probably due to two factors: 1) Costill et al. were testing male swimmers, while this study tested female swimmers, and 2) the swimmers in Costill et al. study swam at a higher velocity, 0.89 to 1.29 m/s, than the mean velocity in the present study, 0.53 to 0.88 m/s. Because of these differences, it is hard to compare the oxygen consumption in this present study, by novice, female swimmers, to Costill's study and to similar studies that focus on competitive swimmers and male recreational swimmers.

The current investigation revealed a significant decrease of 16.9 percent in submaximal oxygen consumption after the six week training program. The greatest decrease in $\dot{V}O_2$ after six weeks of training on the swim trainer was

0.62 L/min. This was present in the slowest subject, 0.53 m/s. The smallest decrease in $\dot{V}O_2$ during submaximal swimming, 0.06 L/min, was present in one of the fastest subjects, 0.72 m/s. Both of these subjects, however, improved significantly on the swim trainer. Similar results were observed when oxygen consumption was described as oxygen required to swim a given distance ($\dot{V}O_2/d$) at a constant velocity. The slowest swimmer, who improved significantly on the swim trainer, decreased $\dot{V}O_2/d$ the most, 19.5 ml/m, while the fastest swimmer did not decrease $\dot{V}O_2/d$ as much, only 1.3 ml/m, even though she improved significantly on the swim trainer.

There was not a direct relationship between the decrease in oxygen consumption while swimming and the increase of 1-RM ($r = -.44$). It was observed, however, that the swimmers who increased strength and whose swimming velocity was 0.63 m/s or slower, decreased the amount of oxygen required to swim the 457.2 meters at a given velocity. According to Alley (1952), a body towed through the water at a velocity slower than 2 ft/s (0.61 m/s), could cause unsupported legs to sink. A sinking of the legs was not noticed in these slow swimmers, however, the kicking action of the legs was very minimal. Because of the lack of or limited kick, the legs were being basically "towed" behind the body as one swam, thus increasing body drag. As previously stated, the best swimmer does not pull or tow the body through the water, but propels the body through the water. This is accomplished by increasing the force applied to the water by increasing hand speed and optimizing the angle of the hand (Schleihauf, 1979). The results of this study suggest that by increasing the strength of a slow novice swimmer (less than .63 m/s), by means of a Väsa Swim Trainer, more force can be applied to the water, thus decreasing the resistance of the body in the water. Therefore, increasing strength has an indirect relationship to the energy cost of swimming at slow swimming velocities. Body resistance is decreased by increasing the force applied to the water, force is determined by hand speed, and hand speed is determined by strength.

Arm Stroke Index. The fastest swimmers in this study took fewer strokes than the slowest swimmers, thus demonstrating a longer stroke length. These results agree with the findings by Keskinen and Komi (1988), that the fastest competitive swimmers take the longest strokes. After six weeks of training on the Väsa Swim Trainer the fastest swimmers still demonstrated fewer strokes, but all subjects decreased in the total number of stroke cycles.

Swimming velocity between the pre and post-testing remained the same, relative to the subject. The arm stroke index was determined by the total number of strokes for 457.2 meters at a given velocity. After six weeks of training the mean ASI significantly ($p < .01$) decreased by 6.5 percent. All subjects improved ASI but the swimmers that demonstrated the highest ASI prior to training improved the most.

There was no significant correlation between the increase of 1-RM and the decrease in ASI. The subject who improved in ASI the most, 68.6 $st/m \cdot s^{-1}$, was Subject 4 who actually decreased in 1-RM by 8.07 ft-lb. Subject 6 increased her 1-RM by 59.37 ft-lb but only increased the ASI by 10.9 $st/m \cdot s^{-1}$. Increasing strength on a swim trainer may not be the determining factor in decreasing the number of strokes taken when swimming a given distance. These results suggest that not only does training on the Väsa Swim Trainer increase strength, but it may also allow the novice swimmer to develop a better stroke technique.

<u>Heart Rate</u>. The average heart rate during the swim did decrease by 6.8 percent, however this change was not significant at the .01 level of confidence. This change in the heart rate did not show a statistically significant correlation with the changes in 1-RM on the swim trainer, but it did correlate ($r = .96$) with the changes in $\dot{V}O_2/d$. This suggests that the less oxygen required to swim a given distance the lower the heart rate will be.

Summary of Findings

Three out of the four independent variables significantly ($p < .01$) improved, however, a significant correlation between the change in 1-RM and the change in the other variables cannot be made. All but one subject improved in strength drastically, but the improvements in swimming economy seemed to be more effected by the pre-training state. The lower the swimming economy prior to the study, the more effect the training on the swim trainer had on the swimmer. The slowest swimmers who increased in strength also revealed the greatest decrease in $\dot{V}O_2$, $\dot{V}O_2/d$, and ASI. Those subjects who did not improve very much in swimming economy were probably already economical at the velocity chosen.

Swimming velocity was the same for both the pre and post-testing, therefore if a subject showed a decrease in $\dot{V}O_2$, ASI, and HR during the post-testing it could be concluded that the swimmer had become more economical. Those swimmers who increased in strength and required less oxygen to swim the post-test were probably more capable of producing a force strong enough to overcome the resistance caused by body form in the water. Those who ended up taking fewer strokes during the ten lap post-testing swim were also demonstrating swimming economy. This decrease in ASI can be the results of an increase in strength and/or an improvement in swimming technique. Increasing strength will create more force to be applied through the water; improving technique will aid in the application of force to the water for a longer period of time.

The greatest change in the ASI after six weeks of training was present in a subject who did not increase in strength, nor did she decrease $\dot{V}O_2$ or heart rate. The subject decrease ASI by 68.6 $st/m \cdot s^{-1}$; this calculated to be 38 fewer strokes taken during the ten lap post-test. This data suggests that training on the swim trainer can improve swimming economy even if strength is not increased. The swim trainer most likely improves swimming technique.

CHAPTER V

SUMMARY

The purpose of this study was to determine if training on the Väsa Swim Trainer would improve the overall swimming economy of novice, adult female swimmers. Eight females volunteered for this study. The study involved six weeks of training on the swim trainer in addition to weekly swimming.

Training on the Väsa Swim Trainer involved six weeks of performing 8-12 repetitions, three times (sets) a session. This program was followed three times a week. The subjects started training at 65-70 percent of their predetermined 1-RM, then progressively increased the resistance so that performing three sets of 8-12 repetitions would always require effort. The resistance was increased by either increasing the slope of the monorail or by adding a rubber surgical tubing to the back of the carriage. Two weeks prior to the actual training period the subjects "trained" on the swim trainer, only performing two sets, 2-3 times a week. This was done to familiarize the subjects with the swim trainer and the proper technique to training on the swim trainer.

Prior to the six weeks of training, and directly after these six weeks, swimming economy for all subjects was determined by a ten lap, 457.2 meter swim. Swimming economy for this study was determined by $\dot{V}O_2$, $\dot{V}O_2/d$, ASI, and HR. The subjects were also tested on the swim trainer in order to determine the one repetition maximum. The difference in 1-RM and the four dependent variables used to determine swimming economy was calculated after all pre-test and post-test data had been compiled. Dependent t-tests were used to determine if the changes between the pre-test and post-test data was significant. The differences for one repetition maximum, submaximal oxygen consumption, oxygen consumption per given distance, arm stroke index, and heart rate were calculated. The level of significance was set at .01.

There was a significant ($p < .01$) improvement in performance on the Väsa Swim Trainer after six weeks of training. The six week training protocol, which was designed for strength training, significantly increased the one repetition maximum. This improvement on the swim trainer seemed to have some effect on swimming performance, or swimming economy. After six weeks of training there was a significant ($p < .01$) decrease in oxygen consumption during steady state submaximal swimming, and a significant ($p < .01$) decrease in the arm stroke index. The heart rate during swimming did not significantly ($p < .01$) decrease, although it did correlate to the decrease in $\dot{V}O_2$/d.

Conclusion

In conclusion, this study reveals that after training on the Väsa Swim Trainer there was a significantly improvement in the swimming economy of the novice, adult female swimmer. These improvements in swimming economy were shown by a decrease in oxygen consumption during submaximal swimming, and by decreasing the ratio of arm strokes per distance swum to the swimming velocity. Therefore, swimming economy can be increased by decreasing $\dot{V}O_2$ and/or ASI. This study also demonstrated that the novice, adult female swimmer can increase swimming economy by training on the Väsa Swim Trainer without increasing strength, by improvement in the swimming stroke technique.

The overall determining factor for improvement in swimming economy by training on a swim trainer, is, however, dependent on the initial swimming economy of the swimmer. The lower the economy of the swimmer, the more training on the Väsa Swim Trainer will improve swimming economy.

Recommendations for Further Study

As the review of literature for this study reveals, there is a limited amount of studies performed on novice swimmers, especially female, novice swimmers. Therefore, this population warrants further investigation. The following recommendations are made based on the results and experiences gained from this study.

1) A similar study should be conducted with a larger sample which will allow the subjects to be placed into groups based upon submaximal swimming velocity.

2) A similar study should be conducted which has some subjects train at a low resistance or work level, while others train between 60-80 percent of 1-RM, in order to develop strength.

3) A study should be performed to see if the Väsa Swim Trainer would be of aid in teaching one how to swim.

4) A study should to be performed to determine training programs for swimmers based upon stroke technique, the lift/drag, propelling method, and the straight backward, pushing method.

5) A study should be performed to determine if there is a difference between the resistance that is created by non-kicking legs which sink and non-kicking legs that are spread apart, yet are afloat.

The first two recommendations would allow comparisons to be made between increased strength and improved swimming technique to swimming economy, at a particular swimming velocity. Recommendation number three is to see whether or not the Väsa Swim Trainer could be used as a teaching tool. The last two recommendations would allow one to compare the differences between swimming economy for the competitive and novice, male and female swimmer. The last recommendations are also geared toward improving swimming economy for all swimmers, whether male or female, novice or competitive.

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APPENDIX A

ABSTRACT

PILOT STUDY: EVALUATING THE USE OF BACKWARD EXTRAPOLATION OF RECOVERY $\dot{V}O_2$ MEASURED BY ON-LINE, OPEN CIRCUIT CALORIMETRY, TO DETERMINE $\dot{V}O_2$ DURING STEADY STATE EXERCISE.

BY LOREEN K. MATTSON

Seven females between the ages of 35 and 60 years, mean age 50.4, were tested on a treadmill to determine if exercise oxygen uptake ($\dot{V}O_2$) could be predicted from expired gas samples taken with an on-line, open system, 20 and 30 seconds after exercise. A subject walked on a treadmill at 3.0 mph (0.0 percent grade); when a steady state was reached two 30s expired gas samples were taken (while walking). After two 30s exercise gas samples were taken, the treadmill was stopped and the gas expired during the next 30 seconds of recovery were measured and analyzed. Percentages of O_2 and CO_2, measured by E2 and LB1 Beckman gas analyzers, and the amount of air inspired, measured by a Rayfield gas meter, were recorded after 20s of post exercise and 10s later (30s into recovery).

Oxygen consumption was determined for the 30s exercise samples measured and the 20 and 30 second samples measured directly after exercise. Regression analysis were performed on the 20s recovery VO_2 and the 30s recovery $\dot{V}O_2$ to determine the best equation for predicting exercise $\dot{V}O_2$. The equation, $Y = 0.373 + 0.9295X$, where Y is the predicted $\dot{V}O_2$ during exercise, and X is the $\dot{V}O_2$ during 30 seconds of recovery, revealed a higher correlation coefficient ($r = .89$) to the actual $\dot{V}O_2$ during exercise than the 20 second sample ($r = .80$).

This study demonstrates that it is possible to predict $\dot{V}O_2$ during submaximal exercise by using post exercise $\dot{V}O_2$. However, this study demonstrates that exercise $\dot{V}O_2$ can be more accurately predicted by using a 30s expired gas sample, instead of a 20s gas sample, taken directly after exercise.

APPENDIX B

INDIVIDUAL SWIMMING VELOCITIES AND TOTAL NUMBER OF ARM STROKES DURING PRE AND POST-TRAINING SWIM TESTING

	PRE-TRAINING			POST-TRAINING		
SUBJECT	#STROKES	TIME (10 laps)	AVE TIME (m/s)	#STROKES	TIME (10 laps)	AVE TIME (m/s)
1	393.3	14:22	0.53	360.0	14:22	0.53
2	298.3	14:16	0.53	286.0	14:16	0.53
3	296.7	13:38	0.56	287.0	13.38	0.56
4	400.0	13:34	0.56	360.0	13:34	0.56
5	303.3	13:27	0.57	280.0	13:27	0.57
6	280.0	12:10	0.63	267.0	12:10	0.63
7	280.0	10:33	0.72	273.0	10:33	0.72
8	240.0	8:40	0.88	220.0	8:40	0.88