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The Effect of Wetsuit Leg Coverage on Swimming Speed and Selected Physiological Measures

by

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THE EFFECT OF WETSUIT LEG COVERAGE ON SWIMMING SPEED AND SELECTED PHYSIOLOGICAL MEASURES (128 pp.)

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The effect of wetsuit leg coverage on swimming speed and body temperatures was investigated by having 10 triathletes swim 1500 meters 4 times in two different water temperatures (20C & 27.8C) in short-sleeved wetsuits. Subjects swam twice in a full wetsuit which covered the leg to the ankle and twice in a half suit which ended at mid-thigh. Four skin temperatures, forehead, chest, right thigh and right calf as well as esophageal temperature (T_{es}) were measured during each swim. Swimming speed was recorded as the total time it took a subject to complete 1500 meters. Skin temperatures and esophageal temperature were measured prior to, and at 5 minute intervals during each swim. In several subjects T_{es} was invalid due to the swallowing of water and shifting of the

esophageal probe. A 2x2 analysis of variance (water temperature x suit length) factorial design was performed on each dependant variable (heartrate, swimming speed and weight change). Water temperature, suit length and the interaction between water temperature and suit length were not significant for any of the variables (heartrate, swimming speed, weight change). In addition a 2x2 MANOVA was done to test for differences in the means of all skin temperatures. Subsequent univariate F tests showed that suit length had a significant effect on calf skin temperature but not thigh temperature. Water temperature had a significant effect on head, chest and calf skin temperatures. There was no significant effect of suit length on swimming speed.

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CHAPTER ONE

INTRODUCTION

In recent years, there has been a growth in interest in ultra endurance sports and multi sport events, and the triathlon is the most popular form. The best known of these is the Hawaii Ironman Triathlon. Developed on the island of Oahu in 1978, it challenges participants to complete three endurance events in one day; the 2.4 mile Waikiki rough water swim, the 112 mile bicycle race, and the 26.2 mile marathon. Gordon Haller, one of the original 15 contestants, won the race in 11 hours and 46 minutes (Perry, 1983). Although it was not the first triathlon, it was, and is still considered the most grueling. It set the precedent for future triathlons that all three events would be performed in one day.

The triathlon as conceived by the United States Triathlon Association is any competition that combines swimming, bicycling and running. Order and length may vary but the competition is to be continuous (Montgomery, 1983). Usually the first leg of a triathlon takes place in the water and, depending on the competitors' skill and experience, it can aid toward victory or end in defeat. Therefore

swimming with the accompanying ambient water temperatures, distance and conditions becomes an integral part of each triathlon competition. From the cold waters (55 F) and swift currents of San Francisco's "Escape From Alcatraz" triathlon to the mild waters of the Waikiki competition the triathlete must be able to adjust to various environments in the pursuit of victory.

The development of lighter, thinner and tailored wetsuits has increased the triathletes' ability to participate in races in which he or she might otherwise be unable to compete due to the risk of hypothermia. Recent research suggests that wetsuit use may favorably effect swimming speed (Loudon, 1987, Parsons, 1986) as well as benefiting cycling by decreasing the warm up time needed by the triathlete (Loudon, 1987). The risk of hypothermia has caused triathlon governing bodies to set water temperature limits on the use of wetsuits in competition. The Triathlon Federation/USA (1987 Triathlon Guidebook), recommends an "upper temperature limit of 72 F, +2 degrees at the discretion of the race director". According to Tri Fed/USA any triathlete wearing a wetsuit above the temperature limit will be ineligible to receive any awards or prizes.

Two recent studies investigating the effect of wetsuit use on

swimming speed (Parsons, 1986, Loudon, 1987), have shown conclusively that regardless of the temperature the use of a wetsuit increases swimming speed. Loudons' subjects were able to increase their swimming speed 2-3 minutes over a 1.5k swim; and Parsons reported a 7% increase in swimming speed with a wetsuit.

This research has raised other issues concerning the use of wetsuits in competition. Pro-wetsuit users as well as the medical community contend that the wetsuit is necessary for the safety and health of the triathlete (Loudon, 1987, Parsons, 1986, Dukes, 1986) and that any advantage gained during the swim would be countered by a slower transition time needed to remove the suit. Those against the use of wetsuits in competition feel that the goal of a triathlete is to overcome and adjust to various environments including cold water. Their belief is that the advantage gained by using a wetsuit extends into the cycling event since the triathlete would need less time to recover from the cold. (Parsons, 1986)

Except for water temperature there are no regulations regarding the type of wetsuits used in competition. The United States Triathlon Federation (Tri Fed/USA) swimming rules state that "fins, gloves, paddles etc. or floating devices or buoyancy suits

of any kind are prohibited". Yet wetsuits are being considered floatation devices by some. Dukes (Dukes, 1986) has used wetsuits as a floatation device in teaching water safety education to youngsters. Harper (1985) and Parsons (1986) have both reported that triathletes feel it is the "buoyancy factor" in the wetsuit that aids their swimming.

STATEMENT OF PROBLEM

The purpose of this study was to determine the difference in swim time between using a wetsuit with full-leg coverage and one with half-leg coverage. If the full-leg coverage yields faster performances, can this increase in speed be due to better thermoregulation? The effect of leg coverage on swimming speed was studied by having subjects swim with full-leg coverage and half-leg coverage in cool (20C) and warm (27.8C) water temperatures. Swimming speed was recorded as the total time it took a swimmer to complete 1500 meters and was then compared to percent leg coverage. The effect of the water temperature was studied by measuring the skin temperatures (mean of 4 sites), heart

rate and core

temperature of the subjects and comparing them to the amount of leg coverage.

LIMITATIONS AND ASSUMPTIONS

Certain limitations and assumptions were made concerning this study.

1) Only 10 subjects were used, therefore, the inferences that can be made for the whole population of triathletes is limited.

2) Demographic data collected from these triathletes from the southwest region of the U.S. may be different from those in other geographic locations.

3) Volunteers consisted of men and women aged 23-43 years who, because they trained daily and competed regularly, were assumed to be fit.

4) New wetsuits were donated from Aleeda in sizes small, medium and large. Although they were not specifically tailored to the individual, the best possible fit was made.

5) All subjects, except one male, had experienced at least one triathlon, and most subjects had used a wetsuit (diving,

surfing, triathloning) before, therefore, no "practice time" with the wetsuit was given.

6) It was assumed that each individual would attempt to achieve the best swim time possible.

7) It was assumed that all subjects completed the questionnaire honestly.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

INTRODUCTION

Although there is a substantial amount of research on athletes in individual and team events there is only limited research on the triathlete. Most information available is in manual form, dealing with the "How To's" of triathlon training and usually written by former triathletes (Perry, 1983, Montgomery, 1983, Town, 1985) who wish to share their training tips, theories and triathlon experience with others. There are also national and regional publications (Triathlete Magazine, Triathlon Magazine) that contain articles ranging from nutritional recommendations for triathletes to the latest racing equipment. There is, however, extensive research on physiological parameters in swimmers, water immersion, hypothermia, and the heat exchange that occurs in a wetsuit.

STUDIES IN HYPOTHERMIA

Hypothermia, which is an abnormally low body temperature, is a major concern of the triathlon medical advisors and governing

bodies. However, studies on the use of wetsuits for protection against the cold in triathlon competitions are limited. Loudon and Parsons, (1987, 1986) have both studied triathlete performance in a wetsuit and strongly advise the use of a wetsuit in cold water especially for lean triathletes. Studies on the diving women of Korea who have been using wetsuits since 1977 show that work time under water is greatly increased as compared to women without wetsuits (Kang et al, 1983, Park et al, 1983). The increase in work time underwater was attributed to the insulation that prevented a significant drop in core temperature protecting the diver from cold stress.

Normal body temperature has a range from 36-40 C (Yousef, 1987). A drop in body temperature below 36 C has a detrimental affect on both the health and physical performance of an individual. Other detrimental effects are diminished judgment, hallucinations, muscular weakness and rigidity that can all contribute to decreased physical performance and, in the case of the triathlete, reduced swimming speed. This reduction in swimming speed leads to increased exposure to the cold water and further body cooling (Pugh & Edholm, 1955, Nadel et al, 1974).

Nadel (1974) has shown that the decrease in performance due to hypothermia is caused by a reduction in maximal aerobic power and also an increase in the energy cost of submaximal exercise. Swimming against a water velocity designed to produce 40% of their maximum aerobic power (previously determined during swims in 26 C water); Nadels' subjects used 61% of their VO2 max in 18 C water and 47% of their VO2 max in 26 C water. This increase in submaximum VO2 in lower water temperatures was attributed to supporting the shivering mechanism and is consistent with similar findings by Homer and McArdle (Homer & Bergh, 1974, McArdle et al, 1986, McArdle et al, 1976). These studies have also reported an increase in oxygen cost at rest and during submaximal exercise in lower water temperatures.

Two normal responses to cold exposure in man are peripheral vasoconstriction and shivering. Shivering is an involuntary response of the skeletal muscles in an effort to increase metabolic rate (i.e., heat production), and may cause a rate increase from 3 to 7 times greater than resting metabolism (Hemingway, A, 1963). Vasoconstriction, on the other hand, aids in maintaining core temperature by decreasing blood flow to the skin and, therefore, the

heat flux to the muscle tissue in the extremities. Vasoconstriction creates an overall insulative layer of non-fatty tissue that, together with subcutaneous fat aids in preventing excessive heat loss.

Shivering in response to cold water immersion tends to negate the insulatory effect of vasoconstriction by increasing the blood flow to the extremities causing greater body cooling. This accelerated cooling rate is seen most often in lean subjects in water temperatures between 18-20 C and is reflected by their higher submaximum VO2s' (McArdle et al, 1976, Nadel et al, 1974, Holmer & Bergh, 1974). During maximum effort swims, however, the maximum VO2 attainable by lean swimmers is reduced due to their lower insulation against the cold. Since body fat aids in controlling the rate of heat loss, lean swimmers can only achieve a percentage of the maximum aerobic capacity when performing in cold water (18 C), however, fatter swimmers can still achieve their max VO2 (Holmer, I, 1979, Nadel et al, 1974).

In studies on heat storage and heat loss, body composition plays a major role in helping an individual maintain a constant internal body temperature. Internal body temperature is maintained by a balance between heat produced and heat loss. In the water, heat

loss is approximately twenty-five times greater than in the air (Nadel et al 1974, Neilsen, B. 1978, Yousef, 1987, McArdle et al, 1986). The amount of heat loss varies with water temperature, duration of exposure, and swimming speed (Neilsen, B. 1978, Holmer 1979, McArdel et al 1986).

Physiological mechanisms controlling heat loss are peripheral vasoconstriction, shivering thermogenesis, subcutaneous fat layers, increased metabolic rate, and larger muscle mass. Of these mechanisms it appears that the insulative layer of subcutaneous fat is the most important since it decreases the heat flow from the core to the skin (Nadel et al 1974, Neilsen, B. 1978, Park et al, 1983, McCafferty et al, 1978).

When long distance swimming events (e.g., channel races, triathlons) take place in water temperatures below 20 C rapid body cooling occurs especially in lean individuals (Bergh, 1978, Holmer et al 1979, Nadel et al, 1974, Pugh & Edholm, 1955). Fatter individuals are less susceptible to cold and are able to maintain and even increase core temperature during cold water swims. It has been suggested that for fatter individuals 18 C may be a more favorable water temperature during heavy exercise (McArdle et al, 1986), due

to their lesser core to skin heat flux. On the other hand, this temperature has been found to be debilitating for leaner individuals both at rest and during exercise (McArdle et al, 1984, McArdle et al, 1984).

Several studies have documented the relationship between internal body temperature during cold water immersion and percent body fat. Nadel (1974) observed that the decreases in body temperature after 20 minutes of swimming in cold water (18 C & 26 C), were inversely related to the amount of body fat of the individual, with the greatest reduction of core temperature occurring in the leaner swimmers. Swimming in moderately cold water (19 C) has been shown to produce hypothermia within 1-2 hours in 15 out of 49 swimmers (Bergh, 1978). Lean subjects who had mean skinfolds less than 10mm had faster cooling rates than the fatter subjects with mean skinfolds greater than 20mm (Bergh, 1978, Holmer, 1979). During rest, skin and subcutaneous fat account for only 10-15% of the tissue insulation, with the muscle through vasoconstriction acting as a more important insulator (Veicsteinas et al, 1982, Toner, 1984). However, during exercise, muscle insulation is decreased due to increased blood flow and it is

the unperfused skin and subcutaneous fat that defends against heat loss. This advantage is lacking in leaner individuals who will have a greater transfer of heat from the core to the skin due to less subcutaneous fat on the exercising arms and legs.

This advantage of a higher percent of fat has been documented in other studies (Bergh, 1978, Hayward et al, 1981, Holmer, 1979, Neilsen, 1978, Pugh & Edholm, 19555). In a distance swim averaging 72 minutes, it was the individuals with a higher mean fat skinfold who were able to maintain their body temperature (Bergh, 1978). Pugh (1955) showed that a thin subject had a decrease in core temperature while swimming in 16 C water whereas a fatter subject was able to maintain his body temperature.

Other factors such as increased metabolic rate and cutaneous vasoconstrictor responses along with subcutaneous fat play an important role in determining an individuals ability to maintain internal body temperature (Hayward et al, 1981). Increased metabolic rate as a mechanism for increasing heat production has been well documented in studies on the breath-hold diving women of Korea and Japan (Hong et al, 1967, Rennie et al 1962, Park et al, 1983). These women were able to rest in water temperatures of

30C without visible shivering when compared to men or non-diving women. This ability to maintain internal body temperatures during cold water immersion was attributed to higher basal metabolic rates, a larger non-fatty insulative shell from vasoconstriction and a greater percent body fat in the Korean diving women. This metabolic rate was 25% higher in diving than non-diving women of the same percent body fat. Surprisingly this was found to occur only during the winter months when the women were diving in cold waters and did not exist during their summer dives and was, therefore, considered a cold adaptation mechanism (Hong et al, 1967).

Since 1977 this cold adaptation mechanism has disappeared in the diving women due to the regular use of wetsuits (Park et al, 1983). A higher basal metabolic rate is also found in Eskimos, though it is considered a result of their high protein diet and not due to cold stress since they get adequate protection from their clothing (Hong et al, 1967, Yousef,1987). The greater insulation found in the Koreans compared to Americans of equal body fat was attributed to the larger shell of nonfatty tissue created by a decreased blood flow to the extremities. This shell was found to be 180% as thick in the

Korean diving women as in the Americans (Rennie et al 1962), and allowed the diving women to tolerate lower water temperatures without shivering. However, in a later study by Kollias (1974) comparing lean and obese American women immersed in 20 C water, observed similar tissue insulation as had been found in the diving and non-diving women of Korea in 30 C. Kollias suggests that the similarity is due to the fact that vasoconstriction may not have been complete for the American women at 30 C.

Vasoconstriction decreases the circulation to the extremities which lessens the skin to water temperature gradient. A lower gradient means less heat loss and maintenance of core temperature. When internal body temperature is maintained there is no need to increase heat production through shivering. Since shivering decreases tissue insulation and increases convective heat loss this mechanism becomes advantageous during cold exposure (Kang et al, 1963). Vasoconstriction is also seen in the Australian Aborigines who sleep naked without shivering due to their ability to increase tissue insulation during cold exposure twice as well as individuals with the same percentage of body fat (Yousef,1987,1988).

Percentage of body fat still plays an important role in internal

temperature maintenance. It has been pointed out that both the shivering threshold and maximum body insulation attainable (vasoconstriction + subcutaneous fat) are directly related to an individuals subcutaneous fat thickness (Hanna et al, 1972, Rennie et al 1962, Kollias, 1974). The insulation given by a non-perfused muscle layer increases as subcutaneous fat thickness increases. The Korean women were better adapted to endure cold exposure than men due to their higher percent body fat and only the more obese American subjects in both Rennie and Kollias' studies tolerated lower water temperatures as well as the Korean divers (Rennie et al, 1962, Kollias et al, 1974). In a study of a world class female distance swimmer (McCafferty et al, 1978), her greater percent body fat (36%) as subcutaneous fat over working muscles allowed her to gain heat (0.2 C) during swimming. The minimal heat loss from vasoconstriction, the subcutaneous fat layers and heat gained during exercise provided a temperature balance that was ideal for long distance swimming in cold water.

Due to the high convective heat transfer in water, within a few minutes of immersion, skin temperature will differ by less than one degree from water temperature (Nadel et al, 1974, Shiraki et al,

1986, Shiraki, 1988). Most individuals feel comfortable at rest in water temperatures from 33-35 C (Holmer, 1978, Lange et al, 1974, Arborelius et al, 1972). In water temperatures of 30 C or less some individuals run the risk of progressive hypothermia occurring after immersion (Holmer, 1979). This is especially true for lean swimmers, however with sustained hard work such as swim training, enough heat is produced to balance heat loss at temperatures as low as 24-25 C (Robinson & Somers, 1971, Holmer I, 1979).

The ability of trained swimmers to maintain body temperatures in colder water has been linked to swimming efficiency (Pendergast, Kohrt et al,, 1987, Bergh, 1978). The more efficient an individual the greater the speed due to the greater propulsive force. Non-trained lean swimmers had the lowest body temperatures in a long distance swim (Bergh et al, 1978), whereas the lean competitive swimmers had less body cooling. The lesser body cooling of the competitive swimmers was attributed to their high energy output resulting in a faster swimming speed that also lead to less cold exposure time.

In comparing men to women with the same percent fat at rest

and immersed in cold water (18 C & 26 C) McArdle (1984), found that women were not able to maintain core temperature as effectively as men. The decrease in body temperature was attributed to their smaller lean body mass and larger surface area-to-mass ratio (SA/mass). Another study immersed obese (29-41% fat) and lean (21-24% fat) women in 20 C and concluded that the SA/mass ratio as well as body fatness and size must be considered in the overall metabolic and thermal responses of an individual. The SA/Mass ratio has been described by Kollias (1974) as body surface area (3 wt(kg)/ht(cm)) divided by weight in kg multiplied by 100. In studies on heat dissipation on land (Epstein et al, 1983, Shapiro et al, 1980), the SA/mass ratio is considered a major factor in the evaporative cooling process. The more surface area that is available per unit of body weight, the more efficient the thermoregulatory mechanism.

The only significant physiological difference found in these heat exposure studies between men and women was the higher (10%) SA/mass ratio in the women. This greater surface area allows for greater cooling power in comparison to individuals with a greater body mass and smaller SA/mass ratio. Several studies (Toner et al,

1986, Kollias et al, 1974, McArdle et al, 1984) have theorized that the SA/Mass ratio may account for differences in thermal responses of individuals in water. A low surface area to mass ratio such as that found in obese individuals (Pugh & Edholm, 1955, Kollias et al, 1974) is considered advantageous in cool water exposure since it decreases the absolute heat flux to the cool water. However, recent research (Toner et al, 1986, McArdle et al, 1984) on the affect of SA/mass ratio in thermal regulation in cold water concluded that the SA/mass ratio did not account for the thermal differences found in individuals. Toner (1984) manipulated the SA/mass ratio of two groups while holding body fat constant and therefore demonstrating SA/mass ratio did not relate to core temperature. Rather it was a larger body mass that aided in the maintenance of body heat. Similar thermal responses between exercising men and women despite differences in SA/mass ratios were found in another study (McArdle et al, 1984).

According to Toner (1984,1986) the SA/mass ratio theory has been abandoned as an important factor in thermal responses. Instead it is the vasoconstriction to the skin and muscle mass, as well as the amount of subcutaneous fat and its distribution that are the

important physiological factors affecting heat loss. In McArdles' study (1984), when his female subjects exercised in cold water, they were able to retard internal heat loss compared to the men. This was attributed to their greater limb fat that provided greater protection from heat loss. Fatter individuals have a lower SA/mass ratio than lean individuals and above 30 percent body fat both men and women have similar low levels of metabolism (heat production) when exposed to cold water. A lower level of heat production means less heat loss to the cool water. Kollias (1974) observed that before an increase in heat production could be detected in an individuals' body fatness had to be below 27%. Therefore, both women and fatter individuals have an advantage during cold water swims since a greater body fatness with a larger distribution of fat over the exercising limbs will decrease the amount of heat lost in the water.

Since women of all ages possess, on the average, a greater amount of body fat than men, they may have the physiological edge during endurance swimming events. Their higher percent body fat provides both hydrostatic, as well as insulatory benefits during swimming (McCafferty et al, 1978, McArdle et al, 1986). Since fat

is less dense than muscle and bone, women tend to be more buoyant allowing a more horizontal position for swimming and reducing drag.

During cold water immersion a larger muscle mass at rest acts as a more important insulator than fat (Veisctenias et al, 1982). A larger muscle mass at rest, according to Veisctenias, accounts for 80-85% of the total tissue insulation due to the decreased blood flow to the non-exercising limbs (Kang et al, 1983, Park et al, 1983, Veicsteinas et al, 1982, Hayward et al, 1981, Rennie et al, 1962, Toner et al 1986). Decreased blood flow to the extremities creates an insulative layer that, along with the subcutaneous fat layer, provides an effective barrier against heat loss. This insulation effect is reduced during exercise when a major portion of the muscle mass is engaged in exercise and blood flow to the muscle is increased. Then the subcutaneous fat and skin layers, that remain unaltered during exercise, become the main defense against heat loss (Toner et al, 1984, Veicsteinas et al 1982, Toner et al 1986).

Shivering, as well as exercise, can increase heat loss more than heat production (Rennie et al, 1962, Park et al, 1983, Kang et al, 1963, McCafferty et al, 1978). Since shivering is caused by rhythmic contractions and is a function of both the water

temperature and the thermal insulation of body fat (McArdle et al, 1984, Hayward et al, 1981), its metabolic effects are similar to those of light exercise. Shivering is widely distributed among the muscles of the trunk and extremities and can increase an individual's oxygen consumption rate 2-5 times over that of resting (Hemingway, A., 1963).

In lean subjects, shivering and moderate exercise in cold water, causes an increase in heat loss and a greater drop in core temperature than at rest (McArdle et al, 1984, McArdle et al, 1984, Hayward et al, 1981). This is due to their smaller insulative subcutaneous fat layer over the exercising muscles. Therefore, it is the individuals with a greater percent body fat and a correspondingly lower level of heat production who will have the advantage in cold water swims.

In trying to establish an "optimal" water temperature for the best swimming performance, ranges of 28-30 C for sprinting events have been suggested (Holmer, I, 1979). For swimming distances requiring up to 20 minutes, temperature ranges between 21-33 C were found to work best (Neilson, B. 1974, Robinson & Somers, 1971). Robinson (1971) has suggested that the "optimal"

temperature for distance swimming may be near 29 C since at that temperature subjects' core to skin temperature gradients where adequate for heat conductance. However, when a wetsuit was used for swimming a given distance it was the cooler water temperatures (18 C & 26 C) that elicited the faster swim times. Two studies regarding swimming speed in a wetsuit (Loudon, 1987, Parsons et al, 1986) have reported faster times in cooler water.

CARDIAC RESPONSE TO WATER IMMERSION

Several investigators have found a lower heart rate for equal workloads when comparing exercise in the water to exercise on land (Kohrt et al, 1987, McArdle et al, 1976, McArdle et al, 1971, McArdle et al, 1978, Park et al, 1983, Kollias et al 1974, Magel et al 1969). Heart rate measurement during swimming is usually done using one of three methods; hard wire to EKG on deck, telemetering the heartrate (Magel et al, 1969), or taking post-exercise heart rates (Magel et al, 1971). This lower heart rate with swimming has been attributed to several factors; the water environment, the prone body position, the muscle mass involved and the immersed face.

A) The medium in which swimming is performed.

Due to the high convective heat transfer in water, pool temperatures from 27-33 C have been found to be best for dissipating heat (Dixon et al, 1971, Magel et al, 1971) In a good water environment a decrease in the thermoregulatory demand leads to an increase in the central blood volume and stroke volume (Kohrt et al, 1987, Magel et al 1969, Magel et al, 1971), that follows a greater transport of O2 to the exercising muscles. This greater transport of O2 is due to being weightless (Holmer, I., 1978). The buoyancy and hydrostatic pressure reduce the pooling of blood in the lower extremities.

B) The prone position in the water.

Exercise on land in a supine position elicits a lower heart rate and greater cardiac output than an upright position (Magel et al, 1971). When comparing treadmill running to swimming, lower maximum heart rates have been reported during swimming (McArdle et al, 1971, Holmer et al, 1974). Several researchers have reported heart rate to be lowered 10-15 bpm (Dixon et al, 1971, Holmer I, 1974, Kohrt et al, 1987, Holly et al, 1986, O'Toole et al, 1987). This lowered heart rate has been found in both elite and recreational swimmers. The lower heart rate in swimming, as compared to running, has been attributed to differences in the training, muscle

mass at work and the hydrostatic and gravitational effects of water immersion on cardiovascular responses. (Holmer, I, 1978, Holmer, I., 1979). Some studies (Magel et al, 1969,1971) suggest that the lowered heart rate found during both submaximal and maximal swimming is due to a greater venous return and cardiac filling. Dixon (1971) compared the heart rate and stroke volume of trained and recreational swimmers during swimming and running. In the trained swimmers a lower maximum heart rate and a higher stroke volume was observed during the swim. Whereas the untrained swimmers had both a lower maximum heart rate and stroke volume swimming. Dixon suggests that the greater stroke volume in the trained swimmers is due to an effective muscle-pump-action by the musculature used, as well as the advantageous prone body position. Recreational swimmers were assumed to have an ineffective muscle pump due to lack of training.

C) The amount of muscle mass utilized during swimming.

The smaller muscle mass, mostly arms and upper body used in swimming also accounts for the lowered heart rates (Holmer, I., 1978,1979, Kohrt et al, 1987). Studies (Kohrt et al, 1987, McArdle et al, 1976, Magel et al, 1971, Holmer et al, 1974) have shown that

swim training increases the body's ability to load and transport oxygen. A general result of endurance training. However, even elite swimmers attain lower maximum heart rates and VO2's in the water as compared to exercise on land (Kohrt et al, 1987, McArdle et al 1976, Magel et al, 1971, Holmer, I., 1979). The lower heartrate in water verses air exercise has been attributed to the smaller muscle mass needed during swimming and the lack of gravitational stress associated with carrying body weight as on land.

D) The affect of swimming on breathing rate.

The prone position in swimming does not permit as free a breathing as in the air (Magel et al, 1969, Magel et al, 1971). Breathing during swimming is dependent on arm movement and speed and occurs when the head is coordinated with the arm stroke. In most swimming strokes the face remains immersed while breath holding and controlled expulsion of air underwater occurs (McArdle et al, 1971, Counsilman, 1977, Maglischo, 1982). Therefore, swimming meets the criteria for evoking a lowered heart rate, mainly face immersion and breath holding. (Magel et al, 1969)

BODY TEMPERATURE EXCHANGES IN A WETSUIT

Studies on changes in body temperature of individuals in wetsuits in cold water show that there is still a decrease in core temperature. Even with a wet suit, lean individuals do not have an advantage over individuals who have the added insulation of a higher percent body fat (Wolff et al, 1985, Yeon et al, 1987, Shiraki et al, 1986).

Yeon (1987) found when studying Korean wet-suit divers at rest in cold water (14-19 C), that the skin temperatures of the trunk were higher than in the limbs. This was attributed to two factors: a) the higher insulation given the body by the double layer from the pants and jacket on the trunk (5-6mm) and, b) the decrease in heat flow to the limbs due to peripheral vasoconstriction. During exercise, however, the insulative value of the wetsuit was decreased even though the subject was wearing the same wetsuit as at rest. This was due to the lower insulation on the limbs (single layer) and the increased blood flow to the exercising muscles.

Shirakik (1986) did a study on the energetics of wetsuit diving in male Japanese breath-hold divers. Results show that although there was a decrease in core and skin temperatures with a wetsuit on it was slower in divers wearing wetsuits than those without.

There was an initial rapid drop in body temperatures of both protected (w/wetsuit) and unprotected divers within the first 10-15 minutes. Thereafter, the temperature decreased linearly with working time. This decrease, however, was slower in the protected divers and their skin temperature was five degrees higher at the end of work than the unprotected divers.

Another study (Kang et al, 1983) evaluated the effect of wetsuit use on daily thermal balance and duration of work in the water in female Korean divers. Since the most important factor in the duration of work for the divers is thermal stress, wetsuit use allowed protected women to stay in the water 3 times longer (2hrs) than unprotected women (30min). The decrease in core temperature that occurred in the protected divers was nonsignificant in both the summer (22 C) and winter waters (10 C). Whereas in the unprotected women, the core temperature dropped to 35 C after one hour of work in the summer water and within 30 minutes in the winter. In comparing male wetsuit divers to female wetsuit divers, the women had a higher percent body fat (25%) than the men (14%), but the duration of work underwater (2 hrs) was the same for both. This could be due to the fact that the men were diving in warmer

water (27 C and 14 C) in the summer and winter respectively as compared to the women. When the core temperatures before and after the winter dives are compared the women have higher core temperatures both before and after the dive. The women started with a core temperature of 37.6 and ended with a temperature of 37.0 after two hours work. The men on the other hand started with a slightly lower core temperature 37.5 and ended the dive with a temperature of 36.9. Though this decrease in body temperature is not very large it shows the added advantage that women have even in a wetsuit, an advantage attributed to a higher percent body fat.

Wolff, (1985) compared the insulative value of three kinds of wetsuits in cold (6.8 C & 35.5 C) water. A 4mm and 7mm wetsuit covering the whole body and head and a 4 mm wetsuit covering the trunk, head and proximal halves of upper arms and thighs. He found that exercise in the 4 mm (full) wetsuit doubled the heat loss halving the insulative value that the suit could provide. This heat loss was due to a flow of water under the wetsuit. Water flow through the neck seal and zipper lead Wolff to advise a tighter wetsuit that would improve insulation without hampering flexibility. Wetsuits that left the limbs exposed in less than 12 C,

did not protect against rapid heat loss from the increased blood flow to the exercising limbs.

PHYSICAL AND PHYSIOLOGICAL CHARACTERISTICS OF TRIATHLETES

Measurements of the physical and physiological characteristics of triathletes are limited. Recently several studies involving triathletes (Farley, 1987, Kohrt et al, 1987, Loudon et al, 1987, Parsons et al, 1986, O'Toole et al, 1987) have described some of their physical characteristics. Triathletes tend to be older than most single sport athletes ranging well into their 30's, 40's and 50's.

It is known that subcutaneous fat plays a major role in temperature regulation during exercise especially in water (Neilsen, 1978, Bergh et al, 1978, Nadel et al, 1974, McCafferty et al, 1978, Hayward et al, 1975, Kollias et al, 1974). The triathlete does three sports each with its own desirable percent body fat for optimal performance. Distance swimmers have body fat ranging from 17.1 to 30% plus (Wilmore, 1983, McCafferty et al, 1978, Pugh & Edholm, 1955). This higher percent body fat gives the swimmer added hydrostatic and insulatory benefits as compared to

leaner individuals. Elite cyclists have been reported to have low percent body fat, 8.8 and 15.4 for males and females respectively (O'Toole et al, 1987). Marathon runners also have low body fats ranging from 7.5 to 13.2 percent for males and 15.5 to 16.6 percent for females (Wilmore, 1983, Costill et al, 1970). This low percent fat for marathon runners becomes advantageous during racing due to the lesser weight carried and the greater dissipation of body heat. Table I below compares these findings on swimmers, cyclists and runners with the average found in the general population for both men and women.

In studies measuring the percent body fat of triathletes, ranges of 7.1-10.2 for the men and ranges of 12.6-14.8 for the women have been reported (O'Toole et al, 1987, Holly et al, 1986). From this information triathletes of both sexes fall within the ranges of fat for very lean athletes. These results should be viewed with caution however, since the number of triathletes measured has been small (n=9-14). Farley (1987), on the other hand, measured 61

TABLE I

COMPARISONS OF MEAN BODY FAT PERCENTAGES BETWEEN SWIMMERS, CYCLISTS, RUNNERS AND THE AVERAGE POPULATION IN THE UNITED STATES

	SWIM	BIKE	RUN	AVERAGE
FEMALES	16.2-17.1%	15.4%	15.2-16.6%	22-28.1%
MALES	9-12%	8.8%	7.5-10%	16.5%

triathletes (45 men, 16 women) at the 1987 Hawaii Ironman Triathlon and reported ranges for the men of 7.9-17.7% and the women as 12-21% body fat. These body fats are slightly higher than what has been previously reported, and possibly reflects the high carbohydrate loading done prior to the race and the various athletic backgrounds (swimming, cycling, running) and body types of the triathletes.

Lohman (1982) recommends that for most sports (though not all) extra fat will inhibit optimal performance. He estimates from

previous observations of successful athletes a range of 4-10% body fat for males and 13-18% for females would be associated with a desirable athletic performance. Most triathletes studied so far fall within this suggested optimal body fat range. Unfortunately, due to the nature of the sports involved in a triathlon a problem in terms of percentage of body fat arises for the triathlete . A high percent body fat inhibits performance in running and cycling events since the excess body mass and lessened heat dissipation would lessen physical ability. On the other hand, a high percent body fat becomes advantageous during swimming especially in cold water where leaner individuals will be more susceptible to increased body cooling.

SUMMARY

The nature of the triathlete is to overcome and adjust to various environmental conditions. Therefore, swimming, with its varying water temperatures, conditions and distances becomes a challenging part of each triathlon. Studies in hypothermia, (a major concern of triathlete medical advisors) have shown a detrimental effect on both the health and physical performance of an individual

in response to body cooling. Rapid body cooling has been shown to occur more in lean swimmers than in fatter swimmers and has also been linked to swimming proficiency. Women are considered to have the advantage over men during cold water swims. Their higher percent body fat and smaller surface area-to-mass ratio helps prevent rapid heat loss during exercise in water. Also a woman's higher percent body fat will tend to make her more buoyant allowing for a more horizontal position for swimming.

In studies concerning heat exchanges in a wetsuit, fatter subjects still had the advantage in maintaining body temperature over leaner subjects. In both cases (men and women) wearing wetsuits seemed to increase the work time under water up to 3 times longer than without a wetsuit. Women still had an advantage over the men due to their higher (25%) percent body fat as compared to the men (14%). This was reflected in the higher post-work core temperatures of the women.

Literature regarding the physical and physiological characteristics of trained triathletes is limited. The major problem for the triathlete concerns body fat. A high percentage of body fat (17-30%) is considered advantageous for distance swimming,

especially in cold water, however, a high percentage of body fat during running and biking can be detrimental to the health and performance of the triathlete.

The development of lighter and more flexible wetsuits for triathlon competition has created some controversy. Pro- wetsuit users feel that for the health of the triathlete wetsuit use should be advocated. Anti-wetsuit users feel that the increased speed reported in a wetsuit gives its wearers an unfair advantage that could possibly extend into the cycling leg due to a lesser warmup times needed on the bike.

CHAPTER THREE

METHODOLOGY

INTRODUCTION

This study was to determine the effect of wetsuit leg coverage on swimming speed and body temperatures in different water temperatures in a group of competitive swimmers and triathletes.

SUBJECTS

Ten apparently healthy, trained triathletes and swimmers were recruited from the University and the community. Volunteers were obtained from informative flyers (appendix A) posted in several university buildings and personal invitations at the local tri-club meetings. Six males and four females between the ages of 25 and 41 volunteered. Table II presents descriptive data on the 10 subjects.

TABLE II

DESCRIPTIVE DATA COLLECTED ON 10 TRIATHLETE SUBJECTS (6 MALE & 4 FEMALE) USED IN WETSUIT STUDY.

ID	SEX	AGE	HT(cm)	WT(kg)	%FAT
LM	M	34	179	69.93	8.2
SW	M	25	181.5	67.06	5.2
SP	M	37	192.2	80.20	8.6
JF	M	30	189	83.35	8.9
JS	M	41	174.5	68.41	10.9
BC	M	39	173.9	75.47	13.8
TS	F	29	165.6	68.12	20.2
ST	F	28	167.6	65.62	20.3
AF	F	41	169.5	61.32	14.4
IF	F	27	168.2	58.18	18.2

	AGE	HT(cm)	WT(kg)	%FAT
WOMEN (n=4)				
MEAN	31.3	167.7	63.31	18.3
STD	6.5	1.6	4.4	2.8
RANGE	14	3.9	9.9	5.9
MEN (n=6)				
MEAN	34.3	181.6	74.07	9.3
STD	5.9	7.5	6.7	2.8
RANGE	16	18.3	16.3	8.6
OVERALL (n=10)				
MEAN	33.4	176.5	70.37	12.58
STD	5.8	8.86	7.27	5.13
RANGE	16	24.6	25.2	15.1

EXPERIMENTAL PROCEDURES

The subjects were required to meet for a total of five sessions. The first session was an orientation meeting that was held at the exercise physiology laboratory. At this session the subject was familiarized with the nature of the study and demographic data was collected. The following four sessions occurred at the pool where test data was collected on the subject.

ORIENTATION SESSION

1) The study was explained to the subjects, testing procedures and the use of a wetsuit was demonstrated and questions were answered.
2) Informed consent forms were read and signed (appendix B).
3) A questionnaire was completed concerning the subjects triathlon experience and experience using a wetsuit (appendix C).
4) The following resting data was recorded on the score sheet (appendix D).

A- Name, age, sex

B- Resting heart rate and blood pressure (after 5 min sitting).

C- Height (in & cm)

D- Weight (kg & lbs)

E- Skinfold measurements (mm) were taken using the Harpenden skinfold calipers according to the procedure in the Y's Way to Physical Fitness (Golding et al. 1982)[1] (appendix J)

For the men 6 skinfolds were taken;

a) pectoral

b) thigh

c) ilium

d) umbilicus

e) tricep

f) scapula

For the women 5 skinfolds were taken;

a) thigh

[1] Subjects wore swim suits (two-piece for women) to facilitate the taking of skinfold measurements.

b) ilium

c) tricep

d) umbilicus

e) scapula

Percentage of fat was determined by summing the above values and using the prediction equations developed by Jackson/Pollock for the National YMCA (appendix E).

5) Schedules for testing were organized based on pool and subject availability. Choice of wetsuit leg length was randomized by a coin toss.

6) Subjects were scheduled for testing (appendix E) with the following restrictions:

a) no food was to be ingested 3 hours prior to testing

b) no exercise was to be engaged in 12 hours prior to testing

c) at least one day was allowed in between swim periods for optimal performance and to minimize possible training effects

d) subjects were asked to mentally "psych" themselves up for an optimal swim time.

FOUR TESTING SESSIONS

1) Subjects reported to the pool.

2) A 24-hour recall questionnaire regarding food intake, injuries, sleep and exercise was completed. (appendix F)

3) Testing procedures were again explained.

4) A competitive-type lycra swim suit was used and thermocouples were attached to the mid-sternal chest area, middle of forehead, right mid-thigh and right calf (on middle of belly).

5) The esophageal temperature probe (appendix G) was then swallowed.

6) ECG electrodes from a portable, battery operated ECG (microcore) were attached (appendix H).

7) The pre-exercise weight was taken after showering and with all attached equipment except the wetsuit.

8) A wetsuit (long or short leg) was chosen by a coin toss and used.

9) Baseline measurements were recorded, and proper functioning of all measurements was confirmed. (appendix I)

10) One of the following conditions was then completed depending on the schedule: (appendix E)

1) at 20C with full leg coverage

2) at 20C with half leg coverage

3) at 27.8C with full leg coverage

4) at 27.8C with half leg coverage.

During the swim all measurements including swimming speed were taken at 5 minute intervals (appendix I) and recorded on a tape recorder. At the end of the swim the subject remained in the water while he/she removed the wetsuit and then was weighed using the pre-exercise weighing procedure.

ADDITIONAL MEASUREMENTS AND PROCEDURES

1) While the subject followed the steps 1-7, listed above or sat quietly; water temperature was measured at a depth of 2 feet in the middle of the swim course and recorded.

2) Environmental conditions; air temperature, wind velocity and sky conditions were recorded. (appendix I)

3) Steps 8-11 listed above were then followed.

4) The procedure for recording the measurements during the swim was:

I. The individual keeping time notified test administrators of the 5 minute time intervals.

II. The time and all measurements were recorded by reading them aloud into an audio tape recorder in the following order:

a) Minutes swimming

b) Core Temperature (Tes)

c) Forehead Temperature (Thd)

d) Chest Temperature (Tch)

e) Thigh Temperature (Tth)

f) Calf Temperature (Tcf)

g) Heart rate (HR).

3) At the end of the swim the swimmer was signaled with a red flag.

4) The subject remained in the water while he removed only the wetsuit and immediately weighed as previously described.

5) All thermocouples and ECG electrodes were removed and the subject was allowed to dress.

TEST RECORDING PROCEDURE

To facilitate the recording of the various measurements during swimming, an aluminum laboratory cart with the equipment was wheeled along the pool deck next to the subject. The equipment and connecting wires were attached to the subject as follows:

1) All the wires (thermocouple, esophageal and ECG) were taped together and exited the wetsuit at the back of the neck closure, the wires were taped together at approximately 1ft intervals. The umbilicus to the equipment was approximately 15ft long.

2) Thermocouple cables were connected to the appropriate channel of a junction box. The junction box was attached to an electronic digital readout. All equipment was secured to the cart.

3) The ECG cables were connected to the microcore ECG from which a digital heartrate could be read.

4) A timer, the tape recorder and a pool lap counter were also secured to the cart.

Two test administrators were needed, one would suspend the umbilicus of connecting wires above the subject and monitored the

wires as well as counting the number of laps. Another helper pushed the cart, keeping abreast with the swimmer and next to the pool edge. To eliminate the need for score sheets, this person read off the measurements into the tape recorder. Subjects were instructed to swim close to the pools' edge and to do open turns.

STATISTICAL DESIGN

Analyses of variance (ANOVA) using a 2x2 (water temperature x suit length) factorial design were performed on each dependent variable (heartrate, swimming speed, weight change). Comparisons on a dependent variable (HR) were made simultaneously for each independent variable (water temperature & suit length). In addition, 2x2 factorial multivariate analysis of variance (MANOVA) was done to test for differences in the means on all the skin temperatures (head, chest, thigh, calf, core). Finally mean age, height, weight and percentage of body fat were calculated and arranged in tabular form.

CHAPTER FOUR

RESULTS AND DISCUSSION

INTRODUCTION

When swimming in cold water triathletes may wear wetsuits. Some wetsuits cover half the leg to mid-thigh, whereas others cover the whole leg to the ankle. In order to determine the effect of exposed or covered legs on swim performance and other selected physiological measures; ten subjects swam 1500 meters four times. Subjects swam twice in a wetsuit with the leg fully covered and twice in one that went to mid-thigh. Each suit was used in cool and warm water. A 24 hour recall questionnaire was completed prior to each swim to ensure that pre-test pre-requisites had been met. In addition, information on subject's triathlon experience and wetsuit use was recorded and is presented in Table III. Subjects were 21-44 year old asymptomatic, apparently healthy individuals who were training for triathlon competition.

TABLE III

PERSONAL RESPONSES TO TRIATHLETE QUESTIONNAIRE; EXPERIENCE AND WETSUIT USE

ID	SX	TRI'S COMPLETED	# OF YRS A TRIATH*	EVER USE A WETSUIT	STRONGEST EVENT
LM	M	15	C	NO	SWIM
SW	M	3	A	NO	SWIM
SP	M	1	A	YES	SWIM
JF	M	6	B	NO	RUN
JS	M	0	A	NO	BIKE
BC	M	?	C	YES	RUN
TS	F	11	B	NO	SWIM
ST	F	4	A	YES	SWIM
AF	F	7	A	YES	RUN
IF	F	20	B	YES	RUN

* Number of years a triathlete

A= 1-2 YRS

B= 2-4 YRS

C= 4-6 YRS

PHYSICAL CHARACTERISTICS

Descriptive data and physical characteristics are presented in Table II. The age range of 25-41 years is similar to other studies on triathletes (Loudon, B., 1987, O'Toole et al., 1987, Parsons et al., 1986), but mean of 33, was slightly older than most studies using single-sport athletes (O'Toole et al., 1987, Kohrt et al, 1987).

There was a wide range in height and weight, and the percent body fat was below the average adult male and female. The average for the male and female subjects was 25 and 30 percent fat respectively; while 18 percent for men and 23 percent for women is considered desirable (Golding et al., 1982). The range of 5-13% fat in the male subjects and 14-20% in the female subjects is slightly higher than the ranges of 7.1-10% for men and 12.6-14% for women reported in other studies (O'Toole et al., 1987, Holly et al., 1986, Kohrt et al, 1987). This higher fat could be accounted for by the fact that half of the subjects reported swimming as their strongest triathlon event and distance swimmers tend to have higher fat percentages than runners or cyclists. Higher percentage of body fat

helps in maintaining body temperatures during long swims in cold water.

TABLE II

DESCRIPTIVE DATA COLLECTED ON 10 TRIATHLETE SUBJECTS (6 MALE & 4 FEMALE) USED IN WETSUIT STUDY.

ID	SEX	AGE	HT(cm)	WT(kg)	%FAT
LM	M	34	179.0	69.93	8.2
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SP	M	37	192.2	80.20	8.6
JF	M	30	189.0	83.35	8.9
JS	M	41	174.5	68.41	10.9
BC	M	39	173.9	75.47	13.8
TS	F	29	165.6	68.12	20.2
ST	F	28	167.6	65.62	20.3
AF	F	41	169.5	61.32	14.4
IF	F	27	168.2	58.18	18.2

WOMEN (n=4)				
MEAN	31.3	167.7	63.31	18.3
STD	6.5	1.6	4.4	2.8
RANGE	14	3.9	9.9	5.9
MEN (n=6)				
MEAN	34.3	181.6	74.07	9.3
STD	5.9	7.5	6.7	2.8
RANGE	1 6	18.3	16.3	8.6
OVERALL (n=10)				
MEAN	33.4	176.51	70.37	12.58
STD	5.8	8.86	7.27	5.13
RANGE	16	24.6	25.2	15.1

24-HOUR RECALL QUESTIONNAIRE

All subjects were asked to abstain from eating 3 hours prior to testing and not to exercise 12 hours before tested. They were also asked to maintain their current training regime during the four testing sessions. The pre-testing requirements were met by all subjects (appendices E&F). Most subjects reported feeling hungry since they had not eaten for at least 4 to 12 hours prior to the experimental swim. Several reported skin abrasions and muscle fatigue from current training activities. Two subjects reported taking allergy medication, and half the subjects took vitamin supplements.

ANALYSES OF DATA

Separate ANOVAS, using a 2x2 (water temperature by suit length) factorial design were performed on each dependant variable [heart rate (HR), swimming speed (SS), weight changes (WCH)]. Water temperature, suit length nor the interaction between the two were not significant for heart rate, swimming speed or weight change. The F values for HR, SS and WCH are presented in Table IV.

TABLE IV

F STATISTICS for HEARTRATE (HR), SWIMMING SPEED (SS) & WEIGHT CHANGES (WCH) IN WATER TEMPERATURE (T_{H2O}), SUIT LENGTH (SL) and the INTERACTION OF WATER TEMPERATURE and SUIT LENGTH.

	HR(bpm)	SS(min)	WCH(lbs)
TH2O	2.812	1.166	.014
SUITLENGTH	.725	3.155	.181
T_{H2O} X SL	.091	3.776	1.132

[critical F value 5.32 {df= 1,8 at the .05 level}].

HEART RATE (HR), SWIMMING SPEED (SS) and WEIGHT CHANGES (WCH)

There was no statistical significance observed between the heart rates in cool or warm water swimming. However, other researchers studying the heart rates of swimmers in different water temperatures have observed significantly lower heart rates during swimming in cool water (Craig & Dvorak, 1969, Nadel et al., 1974, McArdle et al., 1976, Holmer & Berg, 1974). McArdle (McArdle et al, 1976) found that submaximal heart rates averaged 5 beats lower in 18C than in 25C water. Nadel (Nadel et al., 1974) reported heart rates ranging from 15-35bpm lower in 18C water than at the same workload in 33 C water. The lower heart rate found in cooler water is considered a response to temperature (McArdle et al 1976). In cool water increased peripheral vasoconstriction to maintain core temperature leads to an increase in central blood volume. The hydrostatic effect of immersion and the supine swimming position increases venous return and stroke volume. The result of these responses is a lower heart rate. Holmer, (Holmer & Berg, 1974) reported lower maximum heart rates (174bpm) in cool water swimming compared to running (186bpm) in cool air temperatures.

The heart rate difference was attributed to the smaller active muscle mass, supine body position and the thermoregulatory demands involved in swimming. Although both the arms and legs are used in swimming, minimal muscular work is needed to support the body in the water (McArdle et al., 1976, Craig & Dvorak, 1969, Nadel et al., 1974, Holmer and Berg, 1974).

No significant difference was observed in swim time in the full wetsuit in either water temperature as compared to the half wetsuit. Previous studies (Loudon, B., 1987, Parsons, 1986) comparing wetsuits to lycra or nylon swim suits have reported significantly faster swim times in a wetsuit. Loudon (Loudon, B., 1987) observed that every subject swam faster in the wetsuit with the fastest time being in the cooler (17C) water. This greater speed in a wetsuit was attributed to the wetsuits' heat maintenance advantage over lycra and nylon suits.

Comparisons between this study and that of other researchers was made difficult due to the fact that most research has compared materials and not coverage. Several subjects reported that subjectively they felt they swam faster in both warm and cool water with the full suit.

Weight change (weight before the swim minus weight after the swim) was minimal and was not statistically significant. The lack of statistical significance in all data could be due to a combination of factors, e.g. the small sample size, variability in swimming speeds, the combining of male and female data, and milder water temperatures (20C & 27.8C) than that previously studied (18C to 33C).

SKIN TEMPERATURES (Tsk)

Heat loss in water, as it is in air, is dependent on the temperature difference between the body surface and the surrounding environment. Previous research (McArdle et al, 1976, Toner et al, 1985) has shown that due to the elevated conductive and convective heat transfer in water, individual thermal and physiological responses will vary. These responses are dependent upon duration of exposure, water temperature, percentage of body fat, exercise intensity and the type of clothing worn. To negate the possible effects of exposure time all statistical analyses were done on the first four readings recorded from each swim, excluding the

base readings taken before swimming began.

A 2x2 (water temperature x suit length) multivariate test was used. Suit length, water temperature and the interaction of suit length and water temperature were compared to all skin temperatures. An observed F of 24.6 ($p < .05$, df 1,8) was significant for water temperature and an F of 14.8 ($p < .05$, df 1, 8) was significant for suit length. No significant difference was found in the multivariate test for the interaction of water temperature and suit length. Showing that although there was a significant effect for water temperature and a significant effect for suit length on skin temperature, there was no significant interaction effect of water temperature and suit length on skin temperature. Subsequent univariate F tests showed that suit length had a significant effect on calf skin temperature. Water temperature had a significant effect on head, chest and calf skin temperatures, and the interaction of suit length and water temperature had a significant affect on calf temperature. Thigh skin temperature was not significantly affected by either suit length, water temperature or the interaction of the

two. Table V presents the F values for the analyses of the 4 skin temperatures (head, chest, thigh and calf).

TABLE V

F STATISTICS for T_{sk} and T_{es} in WATER TEMPERATURE (T_{H2O}), SUITLENGTH (SL) and the WATER TEMPERATURE by SUIT LENGTH INTERACTION

Tsk	HEAD	CHEST	RTHIGH	RCALF
T_{H2O}	190.125*	70.939*	3.279	132.612*
SL	.01343	1.031	2.641	117.237*
T_{H2O} X SL	2.208	.12701	2.4115	7.09735*

[critical F value 5.32 {df = 1,8 at the .05 level]
*Significant at =.05

ESOPHAGEAL TEMPERATURE (Tes)

The esophageal temperature data collected on several subjects are not realistic. The swallowing of water and the shifting of the esophageal probe voids the data collected (appendix F). However, on five subjects good data was collected and this data is indicative of similar findings in the literature.

Internal temperature changes during submaximal swimming are related to water temperature, swimming intensity, and body insulation (Nadel et al, 1974, Neilson, 1978, Loudon, 1987). After 20 minutes of submaximal swimming Nadels' subjects had lower core temperatures in cold water with the amount of decrease inversely related to the degree of insulation. Other water immersion studies (McArdle et al, 1984, McMurray & Horvath, 1979, Toner et al, 1986) have observed the significant relationship between core and water temperature and between core temperature and percentage of body fat. Core temperature has been shown to change in response to water temperature even during exercise. Body fat composition is considered the major determinant in the resistance of the core to skin heat flow. Core cooling in

temperature of 26C and below has been shown to occur with greater severity in lean individuals. The decrease in the core temperature is greater in lean, slow swimmers than in lean, fast swimmers (Pugh and Edholm, 1955, Loudon, 1987, Costil et al., 1967).

The insulation afforded by wearing a wetsuit is the sum of the wetsuit and physiological insulation (subcutaneous fat & peripheral vasoconstriction). The wetsuit traps a thin layer of water between the suit and the body which is warmed to body temperature providing an insulative layer and maintains higher skin and core temperatures in cold water. Several studies have observed a decrease in the insulation given by a wetsuit with an increase in exercise (Yeon et al, 1987, Wolff et al., 1985, Loudon, 1987, Shiraki et al., 1986). The decrease in the insulation of the wetsuit was attributed to an increase in water flow under the suit. This combined with the increased blood flow to the exercising limbs lead to decreases observed in skin and core temperatures. The lack of uniform thickness observed in some suits (Yeon et al., 1987, Wolff et al., 1985) has also contributed to body heat loss.

Although the wetsuits used in this study were designed for men, a very good fit was also achieved by the women. However,

water did have a significant effect on chest skin temperature. Water entering the suit at the neck, zipper and armpit significantly decreased the insulative value of the wetsuit. Wolff et al, (1985) after observing similar decreases in core temperatures in exercising subjects in wetsuits, recommended a tighter fitting wetsuit. Especially around the zipper and the neck.

T_{sk} Calf & Head

The significantly warmer calf temperature (30.3) found in the long suit reflects the thermal benefit of the long wetsuit. Figure 1 shows the calf skin temperatures for 9 triathletes swimming in 20C water wearing the half wetsuit which left the calf exposed to the water. In Figure 1 therefore, calf skin temperature is close to water temperature and tends to decrease slightly as the triathletes swim. In Figure 2, the triathletes swam in the full wetsuit in the same water temperature with the calf covered. In the swim with the full wetsuit, calf skin temperature stayed higher than in the half suit and although there was still a slight decrease in T_{sk} calf for most of the subjects throughout the swim, calf skin temperature at the end of the swim was higher in the full than in the half wetsuit.

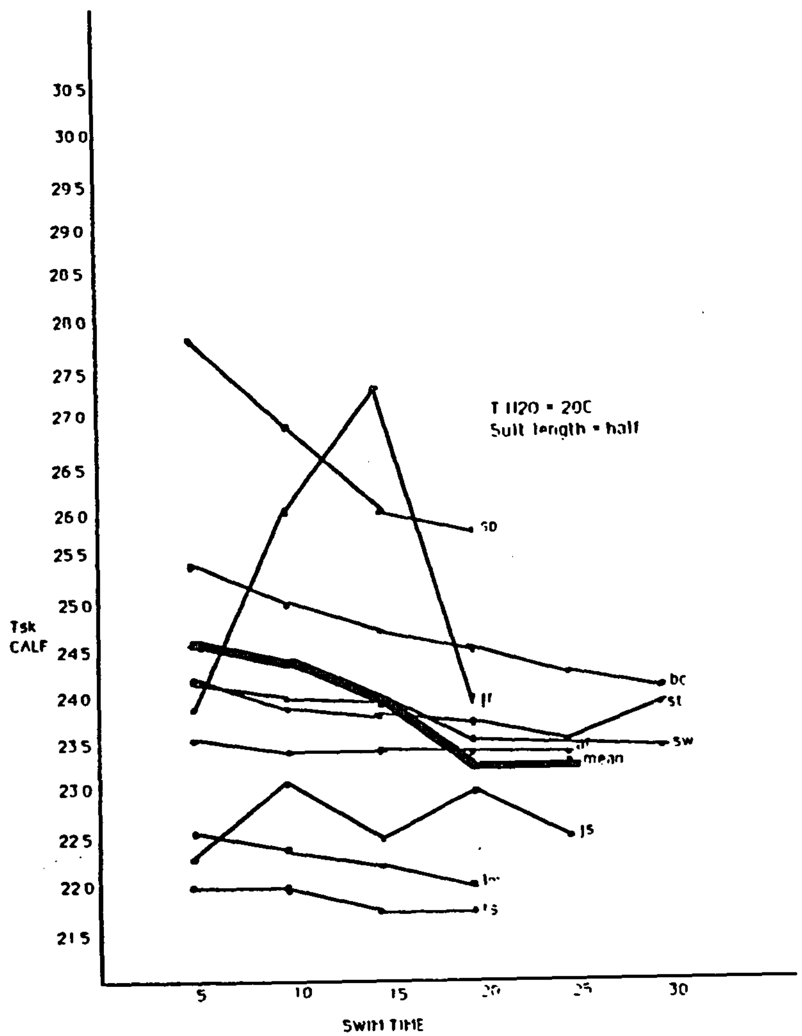

FIG 1: CALF Tsk FOR 9 TRIATHLETES IN 20C WATER WITH THE CALF EXPOSED

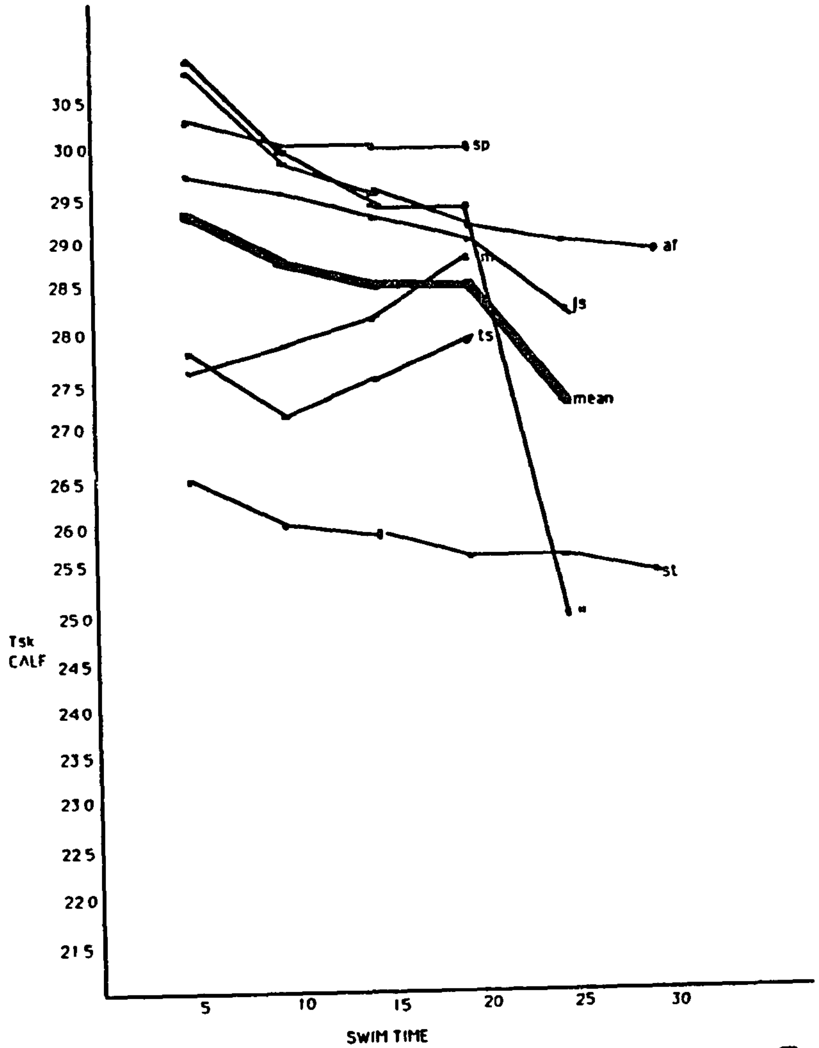

FIG 2 CALF Tsk FOR 8 TRIATHLETES IN 20C WATER WITH THE CALF COVERED

*sudden temperature drop due to loose wire

Other studies, (Shiraki et al., 1986, Yeon et al., 1987, Loudon, 1987) observing the effect of wetsuits on skin temperature noted that, although skin temperatures drop in divers wearing wetsuits, it drops at a much slower rate and is higher at the end of cold water exposure than in unsuited divers. The speed at which heat is transferred from the core to the skin and subsequently to the water is dependent upon water temperature, peripheral circulation and subcutaneous fat layers. During exercise peripheral circulation increases leading to increased skin temperatures and greater heat loss in cooler water. The effects of water temperature, and insulation on skin temperature can be observed in Figures 1, 2 , 3 and 4. With a few exceptions the T_{sk} calf in the exposed swim is within a few degrees of the water temperature and decreases during the swim. However with the full wetsuit (Figure 2) T_{sk} calf is maintained at a much higher temperature than that of the water. Figures 3 and 4 show T_{sk} in 27.8C water for both the full and half suit. In the half suit (Fig 3), calf skin temperature was close to water temperature throughout the swim. However, in the full wetsuit (Fig 4) with the calf covered, skin temperature was several degrees higher than water temperature and tended to increase during

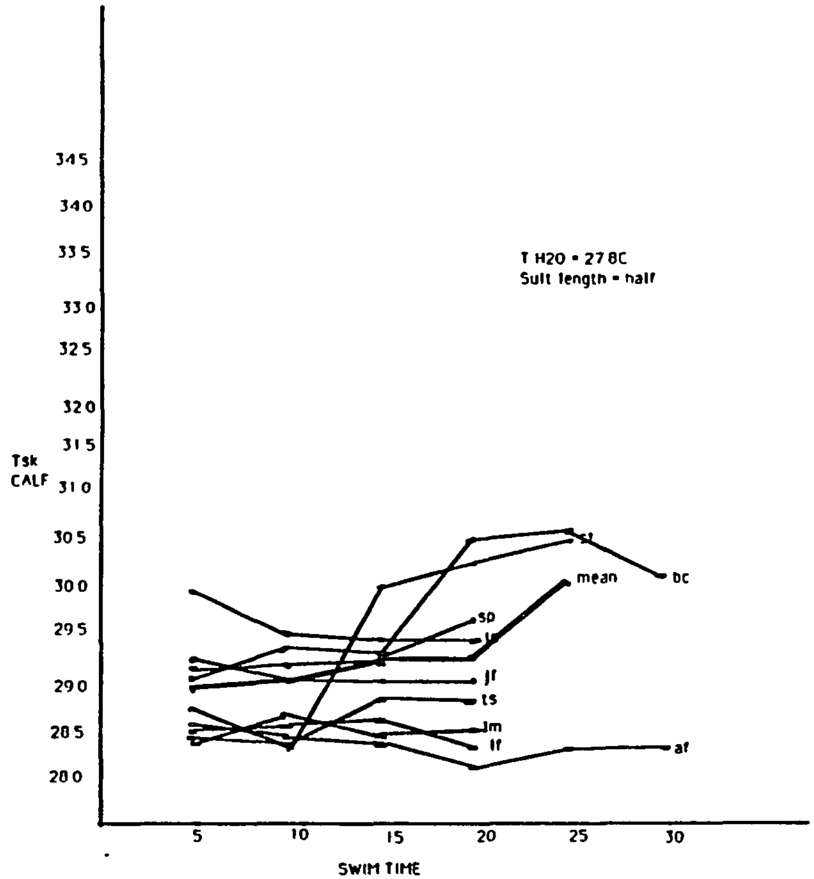

FIG 3. CALF Tsk FOR 9 TRIATHLETES IN 27.8C WATER WITH THE CALF EXPOSED

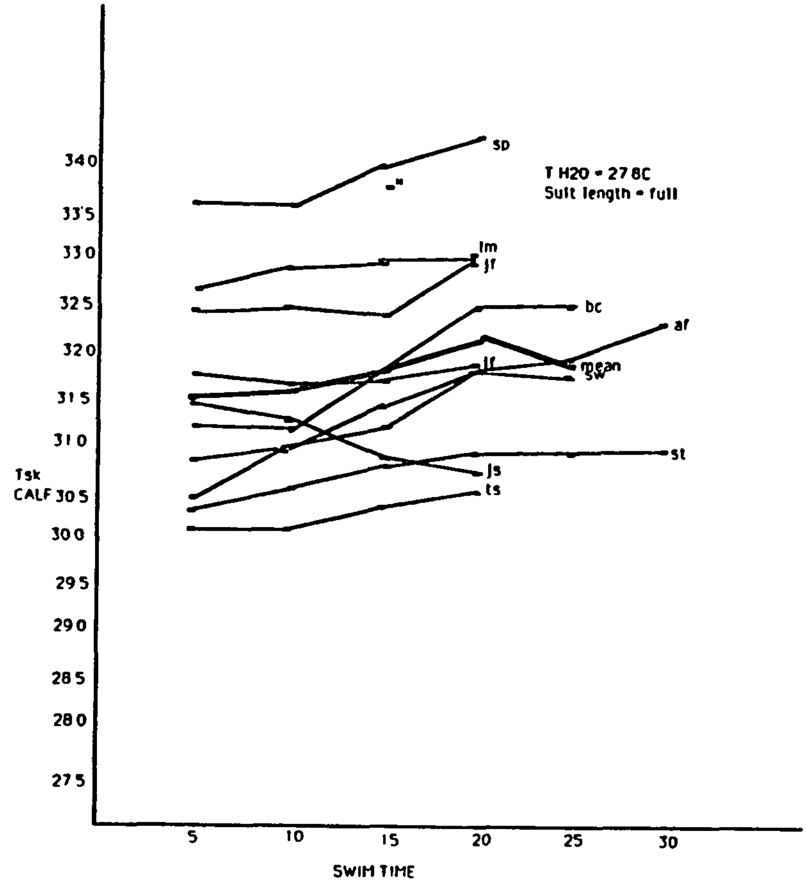

FIG 4 CALF Tsk FOR 10 TRIATHLETES IN 27.8C WATER WITH THE CALF COVERED

*Calf temperature reading unrealistic and therefore not plotted for subject bc

the swim. Figure 5 shows the mean calf skin temperatures from all testing sessions. The insulation afforded by wearing the full wetsuit is obvious in the higher mean calf skin temperatures in the full suit in both cool (20C) and warm (27.8C) water.

Water temperature had a significant effect on T_{sk} of the forehead. Decreasing in the cooler water and increasing in the warmer water. Suit length or the interaction of suit length and water temperature did not have a significant effect on T_{sk} head as they did on the T_{sk} calf. The head was covered with a thin latex cap which was pulled forward to cover the forehead thermocouple. Since latex does not offer any insulation, water flow and temperature would be expected to have a significant affect upon T_{sk} head. Therefore, since the insulation afforded by the cap was minimal the head was considered to be exposed in each testing situation.

T_{sk} Chest & Thigh

Water temperature significantly lowered T_{sk} chest but not T_{sk} thigh. This has been attributed to the water flow under the suit at the armpit and neck. On the other hand, suit length or the

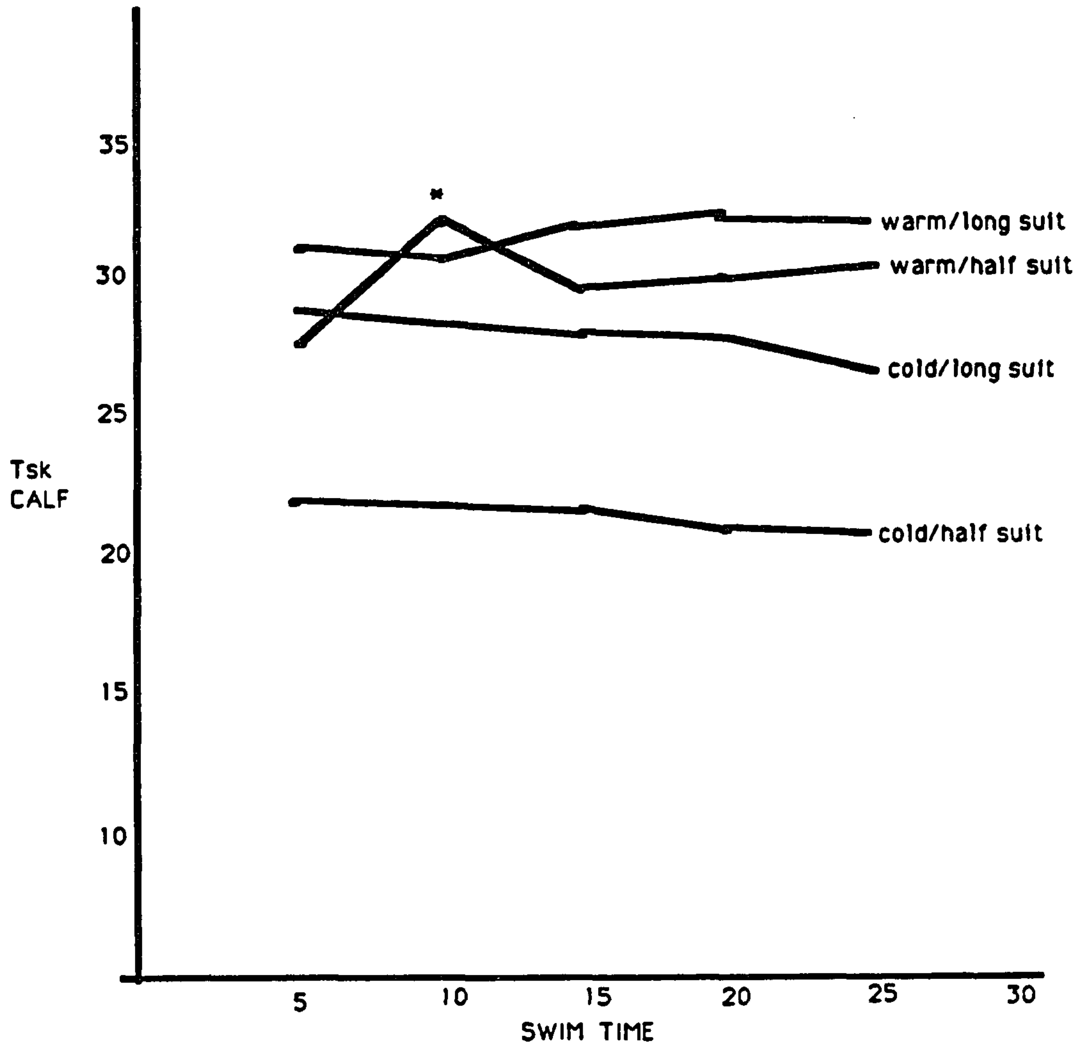

FIG 5: MEAN CALF SKIN TEMPERATURES FOR TRIATHLETE SUBJECTS IN TWO WATER TEMPERATURES 20C AND 27.8C IN FULL AND HALF WETSUITS.

* mean skewed due to skin thermocouple loosening during swim

interaction of suit length and water temperature did not have a significant effect on either chest or thigh skin temperatures.

Studies, (Hayward & Keatinge, 1981, Yeon et al., 1987) have observed that most of the heat exchange between the body core and the water occurs in the trunk area. Insulation of the trunk is mainly subcutaneous fat, whereas limb insulation is higher because it is a combination of subcutaneous fat and peripheral vasoconstriction. When exposed to cold water the body will attempt to maintain core temperature through peripheral vasoconstriction which occurs mostly in the extremities and not in the trunk. In all testing sessions (half and full suit) the chest and thigh regions were covered by the 3mm wetsuit. The effect of water on T_{sk} chest during exercise could be attributed to water flow through the armpit and neck. This decrease in the insulative value of a wetsuit with an increase in exercise is similar to the findings of other researchers (Wolff et al., 1985, Loudon, 1987, Yeon et al., 1987) who observed that exercise increased the flow of water under the wetsuit thereby decreasing skin and core temperature.

SUMMARY

Ten triathlete subjects swam 1500 meters in a wetsuit four times. Twice with full leg coverage and twice with half leg coverage in warm (27.8C) and cool (20C) water. The percentage of body fat of both the male and female subjects was slightly higher than the ranges reported in other studies.

Heart rate, swimming speed and weight change were not significantly affected by water temperature, suit length of the interaction of water temperature and suit length. However, other researchers have observed significantly lower heart rates during swimming in cool water. In other studies, comparing materials, swimming with a wetsuit yielded faster swim times than swimming in a lycra suit regardless of the water temperature.

Skin temperatures (head, chest, right thigh, right calf) showed fluctuations similar to that found by other researchers. Skin temperatures remained higher than water temperature when covered and was close to water temperature throughout the swims when covered. However, water temperature did significantly lower Tsk chest, a site that was covered throughout all the swims. The lower temperature has been attributed to water flow under the suit at the

neck and armpit. This decrease in the insulative value of a wetsuit with and increase in exercise is similar to the observations of other researchers.

Esophageal temperature data on half the subjects was not realistic due to the swallowing of water and shifting of the probe. However, some good data was collected and it is indicative of similar findings in the liturature.

CHAPTER FIVE

SUMMARY, CONCLUSIONS & RECOMMENDATIONS

SUMMARY

Wetsuits are often used by triathletes during competition, especially for cold water swims. Some of the wetsuits cover half the leg, ending at mid-thigh whereas others cover the whole leg to the ankle. Controversey exists as to whether or not wetsuits should be allowed in competition since they are considered by some to enhance performance, as well as aid in maintaining body temperatures. This study measured the effect of full and half wetsuit leg coverage on performance and selected physiological measures in two water temperatures.

Ten competitive triathletes (mean age = 34yrs) swam 1500 meters four times, twice with full leg coverage and twice with half leg coverage in warm (27.8C) and cool (20C) water. Heartrate (HR), esophageal temperature (Tes) and four skin temperatures were measured prior to and at 5 minute intervals during the swims. Swimming speed (SS) was recorded as the total time a subject took

to swim 1500 meters. Weight change (WCH) was subject weight loss during the swim. One subject was unable to complete the cold water swims.

Data was statistically analyzed with separate univariate ANOVAS using a 2x2 (water temperature by suit length) factoral design. This was performed on HR, SS and WCH. A similar 2x2 factoral MANOVA was used to test for differences in the means on Tes and all Tsk. Water temperature, suit length and the interaction of suit length and water temperature had a significant effect on Tsk calf. Univariate F tests indicated that water temperature had a significant effect on head, chest and esophageal temperatures. No statistical significance was demonstrated in either analyses on thigh temperature. Swimming speed was not significantly affected by suit length, water temperature or the interaction of suit length and water temperature.

CONCLUSIONS

The insulation afforded the swimmer is the sum of the wetsuit plus physiological insulation. Studies comparing neoprene wetsuits to lycra swim suits have found that wetsuits increase swimming

speed due to their giving increased bouyancy and thermal advantage. Because no comparisons between suit types were made, conclusions regarding speed in a wetsuit cannot be supported. This study supports the following conclusions:

1- The amount of leg coverage does not significantly affect swimming speed in cool or warm water.

2- Exposed skin temperature (calf) will display greater fluctuations in response to enviornmental temperatures than protected skin temperature (thigh).

3-Wetsuit fit is an important factor in protection against environmental temperatures since water flow under the suit at the neck and armpit had a significant affect on chest skin temperature.

RECOMMENDATIONS

Based on the results and observations, the following recommendations further research are suggested:

1. A larger sample size which will allow more inferences about the triathlete population.
2. Adding two more swims per subject in lycra suits in warm

and cold water to validate previous research concerning greater speed in a wetsuit.

3. Decreasing swimming variability by studying only elite or very experienced triathletes.

4. Studying the effect of wetsuit use on swimming speed and body temperatures of men and women triathletes in separate studies.

5. Studying the effect of different wetsuit lengths, density and fit on lean slow swimmers to develop better protection against hypothermia.

APPENDIX A

RECRUITING FLYER AND LETTERS

SUBJECTS NEEDED

FOR A

TRIATHLETES STUDY

THE EFFECT OF A WET SUIT ON SWIMMING PERFORMANCE

REQUIREMENTS

1. MALE OR FEMALE TRIATHLETE.
2. APPROXIMATELY 5 SESSIONS (ONE HOUR EACH)

YOUR BENEFITS:

1. LEARN YOUR %BODY FAT & IDEAL WEIGHT
2. BE TESTED FOR YOUR FITNESS LEVEL
3. IMPROVE THE SWIMMING PORTION OF YOUR TRIATHLON

CALL: EXERCISE PHYSIOLOGY LAB.

UNLV:739-3766

SCHOOL OF HEALTH, PHYSICAL EDUCATION, RECREATION AND DANCE

EXERCISE PHYSIOLOGY LABORATORY

November 5, 1987

Mr. Wayne Brown
President
ALEEDA
208 Main Street
P. O. Box 644
Huntington Beach, CA. 92648

Dear Mr. Brown:

The Exercise Physiology laboratory at UNLV is undertaking a study on the use of a wet suit during the swimming portion of the triathlon. The study will be primarily concerned with the amount of skin coverage and how it effects core temperature, skin temperature, heart rate and performance. The swim will be in two temperatures of water with the athlete swimming with a suit with full legs and with half legs. Thirty athletes will be swimming four times while being measured.

Is it possible for ALEEDA to supply 6 sleeveless suits, 3 with full legs and 3 with half legs (1 in each size) for the duration of the study? This is not a study to prove that one suit is better than another or that no suit is better than a suit. Instead it is studying the effect of two amounts of skin coverage.

Any publication of the study will acknowledge your participation in the study. Would you, at your earliest convenience, let us know your decision.

Very cordially,

Lawrence A. Golding, PhD.
Director, Exercise Physiology Laboratory

Peggy L. Dursthoff
Research Associate

LAG/jm

SCHOOL OF HEALTH, PHYSICAL EDUCATION, RECREATION AND DANCE

EXERCISE PHYSIOLOGY LABORATORY

November 5, 1987

Mr. Jack O'Neil
President
O'Neil Wetsuits
1071 41st Avenue
Santa Cruz, CA. 95062

Dear Mr. O'Neil:

The Exercise Physiology laboratory at UNLV is undertaking a study on the use of a wet suit during the swimming portion of the triathlon. The study will be primarily concerned with the amount of skin coverage and how it effects core temperature, skin temperature, heart rate and performance. The swim will be in two temperatures of water with the athlete swimming with a suit with full legs and with half legs. Thirty athletes will be swimming four times while being measured.

Is it possible for O'Neil Wetsuits to supply 6 sleeveless suits, 3 with full legs and 3 with half legs (1 in each size) for the duration of the study? This is not a study to prove that one suit is better than another or that no suit is better than a suit. Instead it is studying the effect of two amounts of skin coverage.

Any publication of the study will acknowledge your participation in the study. Would you, at your earliest convenience, let us know your decision.

Very cordially,

Lawrence A. Golding, PhD.
Director, Exercise Physiology Laboratory

Peggy L. Dursthoff
Research Associate

LAG/jm

UNIVERSITY OF NEVADA, LAS VEGAS/4505 MARYLAND PARKWAY/LAS VEGAS, NEVADA 89154/(702) 739-3766

SCHOOL OF HEALTH, PHYSICAL EDUCATION,
RECREATION AND DANCE

EXERCISE PHYSIOLOGY LABORATORY

November 5, 1987

Mr. Dana Love
President
PROMOTION
416 Cascade Street
Hood River, Oregon 97031

Dear Mr. Love:

The Exercise Physiology laboratory at UNLV is undertaking a study on the use of a wet suit during the swimming portion of the triathlon. The study will be primarily concerned with the amount of skin coverage and how it effects core temperature, skin temperature, heart rate and performance. The swim will be in two temperatures of water with the athlete swimming with a suit with full legs and with half legs. Thirty athletes will be swimming four times while being measured.

Is it possible for PROMOTION to supply 6 sleeveless suits, 3 with full legs and 3 with half legs (1 in each size) for the duration of the study? This is not a study to prove that one suit is better than another or that no suit is better than a suit. Instead it is studying the effect of two amounts of skin coverage.

Any publication of the study will acknowledge your participation in the study. Would you, at your earliest convenience, let us know your decision.

Very Cordially,

Lawrence A. Golding, PhD.
Director, Exercise Physiology Laboratory

Peggy L. Dursthoff
Research Associate

LAG/jm

UNIVERSITY OF NEVADA, LAS VEGAS/4505 MARYLAND PARKWAY/LAS VEGAS, NEVADA 89154/(702) 739-3766

APPENDIX B

FORMS

EXERCISE PHYSIOLOGY LAB
UNIVERSITY OF NEVADA AT LAS VEGAS

THE EFFECT OF WETSUIT LEG COVERAGE ON SWIM SPEED AND BODY TEMPERATURE

SUBJECT PREREQUISITE REMINDER

The schedule for your swim testing is listed below. This schedule has been arranged with your availability in mind. Should you be unable to make one of the testing sessions please notify the lab (739-3766) as soon as possible so that an alternate time may be chosen;

TEST # 1
DAY__________________ DATE____________ TIME_____________
TEST # 2
DAY__________________ DATE____________ TIME_____________
TEST # 3
DAY__________________ DATE____________ TIME_____________
TEST # 4
DAY__________________ DATE____________ TIME_____________

YOU ARE REMINDED OF THE FOLLOWING;
1) Please allow at least 1 hour for preparation and testing.
2) Please bring bathing suit and towel for swim test.
3) Please DO NOT EAT anything 3 hours prior to testing.
4) Please DO NOT EXERCISE 12 HOURS PRIOR to testing.
5) Please DO NOT CHANGE your current training regime for the duration of the testing period.

Thank you for your cooperation and get "psyched" for a really great swim.

EXERCISE PHYSIOLOGY LAB
UNIVERSITY OF NEVADA AT LAS VEGAS

THE EFFECT OF WETSUIT LEG COVERAGE ON SWIM SPEED AND BODY TEMPERATURE

INFORMED CONSENT

This research project is to determine the effect of wetsuit leg coverage (full leg to ankle, or 1/2 led to mid-thigh) on swimming speed and body temperatures.

Only competitive triathletes or swimmers who are currently competing and training will be used. You are asked not to change your current training regime for the duration of the study (4 sessions). And not to exercise 12 hours prior to testing.

You will swim 1500 meters four times in a wetsuit, with at least one days rest inbetween swims. Two swims will be with full leg coverage and two with half leg coverage in 20 C and 27.8 C water. Heartrate, skin temperatures (forehead, chest, right thigh and right calf) and esophageal temperature will be measured during the swim. Swimming speed will be recorded every 100 meters. The whole test period should take approximately 1 hour.

Risks are few since most triathletes are trained to swim in competition. Risk of injury while climbing into and out of the pool are possible but rare. Sore muscles may occur.

In signing this consent form, you state that you have read and understood the description of the study. Any questions which occur to you have been answered to your satisfaction. Every effort will be made to insure your health and safety. You enter into the test willingly and may withdraw at any time.

PRINT NAME	SIGNATURE	DATE
WITNESS-PRINT NAME	SIGNATURE	DATE

APPENDIX C

QUESTIONNAIRES

EXERCISE PHYSIOLOGY LAB
UNIVERSITY OF NEVADA AT LAS VEGAS

THE EFFECT OF WETSUIT LEG COVERAGE ON SWIM SPEED AND BODY TEMPERATURE

24 HOUR RECALL QUESTIONAIRE

NAME________________________ SWIM #___________

SUIT WORN full____ half_____

WATER TEMP______________. DATE_______________

Please fill out the questionaire below for the last 24 hours as accurately as possible.

1) How many hours sleep did you get last night? ___________

2) If you smoke, how many cigarettes did you smoke per in the last 24 hours?________ day?

3) Are you currently taking any medication?

1) yes 2) no

IF yes, list medication and its purpose______________________

____

____

Regarding food intake

4) How long since you last ate?________________

5) What did you eat? (list foods and amounts)______________

____

____

____

6) Are you currrently taking any dietary supplements (vitamins, protien etc).?

1) yes 2) no

7) If yes, what are you taking, how much and how often?

____

____

____

8) How long since you've had something to drink? (other than water).________________________________

9) What did you have to drink?__________________________

10) Appetite wise, how do you feel now? (circle one)

hungry

full

comfortable

__Regarding injuries

11) Are you currently recovering from any injuries?

1)YES 2)NO

12) What is the nature of your injury?____________________

____

____

13) Has the above injury caused you to lose any training time?

1)YES 2)NO

14) If yes, how much time?______________________

15) How long since your last exercise ? (give time and type of activity)____

16) How long did you engage in the above activity?_________

QUESTIONS 19, 20 & 21 ARE FOR SWIM TRIALS 2, 3 & 4 ONLY;

17) Do you have any muscle soreness?

1) yes 2) no

18) If yes, what area of the body?

____

____

____

19) Do you feel rested and "ready" for this swim or fatigued from previous trials?

rested ______ fatigued_______

The next question is to be answered by female subjects only.

---

20) What are the approximate dates of your last menses?

start____________

finish____________

EXERCISE PHYSIOLOGY LAB

UNIVERSITY OF NEVADA, LAS VEGAS

THE EFFECT OF WETSUIT LEG COVERAGE ON SWIM SPEED AND BODY TEMPERATURE.

TRIATHLETE QUESTIONAIRE

---

note : You must be under age 45 to be considered for this study

---

NAME (LAST)____________________(FIRST)______________.

AGE___________.

OCCUPATION____

PHONE # (DAY)______________(EVE)________________

ADDRESS:____

____

1) HOW LONG HAVE YOU BEEN A TRIATHLETE? (circle response)

A) 1-2 YR B) 2-4 YRS C) 4-6 YRS D) MORE THAN 6

2) HOW MANY TRIATHLONS HAVE YOU COMPLETED?___________

3) WHAT IS YOUR PERSONAL BEST TIME FOR THE FOLLOWING:

1 MILE SWIM ______________

25 MILE BIKE ______________

HALF MARATHON RUN__________

4) WHICH OF THE THREE SPORTS (BIKING, SWIMMING, RUNNING) DO YOU CONSIDER YOUR STRONGEST EVENT?

A) BIKING B) SWIMMING C) RUNNING

5) HAVE YOU EVER COMPETED IN THIS EVENT AS A SINGLE SPORT ATHLETE?

1) YES 2) NO

6) FOR HOW LONG DID YOU COMPETE? ______________.

7) WHAT DO YOU CONSIDER YOU WEAKEST EVENT IN THE TRIATHLON?

A) BIKING B) SWIMMING C) RUNNING D) NONE

8) DO YOU USE A WETSUIT IN COMPETITION DURING THE SEASON?

1) YES 2) NO

9) HOW MUCH OF YOUR BODY DO YOU COVER WITH A WETSUIT?

A) ALL (HEAD, ARMS, LEGS, BODY)

B) TRUNK, LEGS, BUT NOT ARMS OR HEAD

C) TRUNK AND PART OF THE LEGS BUT NOT ARMS OR HEAD

D) JUST COVER THE TRUNK BUT NOT HEAD, ARMS OR LEGS

10) DO YOU OWN A WETSUIT?

A) YES B) NO

11) WHAT KIND OF WETSUIT DO YOU OWN?

A) WINDSURFING WETSUIT

B) SURFING WETSUIT

C) TRIATHLON WETSUIT

D) REGULAR DIVING WETSUIT

12) MANUFACTRURES' NAME ________________________.

13) IF YOU DO NOT OWN A WETSUIT WHAT DO YOU DO FOR COMPETITION?

A) RENT A SUIT

B) BORROW A SUIT

C) SWIM WITHOUT A WET SUIT

D) REFRAIN FROM ENTERING THAT RACE

14) WHAT DO YOU LIKE BEST ABOUT USING A WETSUIT?

A) FEEL FASTER

B) FEEL WARMER

C) FEEL MORE CONFIDENT ABOUT SWIMMING

D) DON'T FEEL AS TIRED AFTER THE SWIM

15) WHAT DO YOU DISLIKE ABOUT USING A WETSUIT?

A) FEEL SLOWER

B) FEEL IT DOESN'T WARM ME

C) NOT ABLE TO SWIM AS WELL

D) OTHER_______________________.

16) DO YOU FEEL THAT YOU SWIM FASTER BECAUSE OF A BOUYANCY EFFECT OR BECAUSE YOU ARE LESS AFFECTED BY THE COLD WATER TEMPERATURE?

A) BOUYANCY______

B) LESS AFFECTED BY COLD________.

C) BOTH________.

D) NEITHER_______.

BELOW IS A SCHEDULE OF TIMES DURING THE DAY FOR THE SWIM. MARK AN (X) IN THE TIME SLOTS THAT YOU CAN BE THERE.

DAY / 8:00 /9:00/10:00/11:00/12:00/1:00/2:00/3:00/4:00/

MON____

TUES____

WEDS____

THURS____

FRI____

SAT____

SUN____

THANK YOU

PARTICIPANT IDENTIFICATION

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)*

A Self-administered Questionnaire for Adults

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check the ☑ YES or NO opposite the question if it applies to you.

YES NO

☐ ☐ 1. Has your doctor ever said you have heart trouble?

☐ ☐ 2. Do you frequently have pains in your heart and chest?

☐ ☐ 3. Do you often feel faint or have spells of severe dizziness?

☐ ☐ 4. Has a doctor ever said your blood pressure was too high?

☐ ☐ 5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?

☐ ☐ 6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?

☐ ☐ 7. Are you over age 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

* Developed by the British Columbia Ministry of Health. Conceptualized and critiqued by the Multidisciplinary Advisory Board on Exercise (MABE).

Reference: PAR-Q Validation Report, British Columbia Ministry of Health, May, 1978.

* Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare. M29-120

APPENDIX D

DATA COLLECTION SHEETS

EXERCISE PHYSIOLOGY LAB
UNIVERSITY OF NEVADA AT LAS VEGAS

THE EFFECT OF WETSUIT LEG COVERAGE ON SWIM SPEED AND BODY TEMPERATURE.

% FAT SCORE SHEET

SUBJECT NAME______________________________ AGE_______

SEX___

DATE________ SWIM TEST #__________

HEIGHT______________ins ____________cm

WEIGHT______________lbs ____________kg (dry)

SKINFOLD MEASUREMENTS

tricep	__________mm	_____________mm	____________mm
pectoral	__________mm	_____________mm	____________mm
midaxilla	__________mm	_____________mm	____________mm
umbilicus	__________mm	_____________mm	____________mm
Illium	__________mm	_____________mm	____________mm

Mean of skinfolds __________

Sum of skinfolds (4 for men______ 3 for women______)

RESTING HEARTRATE (taken for 1 full min) after 5 min sitting______________

RESTING BLOOD PRESSURE (after 5 min sitting)_________

EXERCISE PHYSIOLOGY LAB
UNIVERSITY OF NEVADA, LAS VEGAS

THE EFFECT OF WETSUIT LEG COVERAGE ON SWIM SPEED AND BODY TEMPERATURE.

SWIMMING SCORE SHEET

NAME__________________ SWIM #__________ H2O

TEMP_____

SUBJECT WEIGHT (prepared and wet - suit)______________

ENVIRONMENTAL CONDITIONS;

air temp_________ wind velosity_____________

sky conditions_________________ Wetsuit coverage __________

Wetsuit size __________

MIN SWIMMING / Core / Thd / Tch / Tth / Tcf / HR / sw sp

0____

5____

____

10____

____

15____

____

def: Tch-chest, Thd-head, Tth-thigh, Tcf-calf, sw sp-swimming speed

APPENDIX E

PROCEDURES

ESTIMATING PERCENT BODY FAT

The following is the procedures followed and the prediction equations used (Jackson/Pollock National YMCA) as a means of obtaining percent body fat. The following guidelines were observed throughout the testing;

1) All measurements were taken on the right hand side of the body.

2) All measurements except standing height were taken in the natural position (poor posture included).

3) Skinfold measurements were taken with a Harpenden skinfold caliper containing a constant spring that applies 10 g/mm2, which was applied using the following technique;

A- With the subject standing relaxed, both hands were used to firmly lift the skinfold between the thumb and four fingers, making sure that no muscle had been included.

B- Once secured, the right hand was released and the calipers placed just below the exact site to be measured.

C- When the movement of the needle stopped, the reading was taken to the nearest half millimeter.

D- The calipers were then removed and the skinfold released.

E- The procedure was repeated three times and the mean of the three measurements was taken to be sure of an accurate measurement.

4) Before body weight was taken the subject was asked to void the bladder; weight was then recorded in kg with the subject as close to nude as possible (shorts and shirt or swim suit).

The anatomical landmarks used in taking the various skinfold measurements are described below.

a) Tricep- a vertical fold on the back of the upper arm, halfway between the shoulder and the elbow joint.

b) Pectoral- a diagonal fold on the pectoral line halfway between the axillary fold and the nipple.

c) Mid-Axilla - a vertical fold on the mid-axillary line at nipple level- mid-sternum.

d) Umbilicus- a vertical fold approximately one inch to the right of the umbilicus.

e)Ilium - a diagonal fold just above the crest of the ilium, i.e., the highest peak on the side of the pelvic girdle, on the mid-axillary line.

The anthropometric estimation of percent fat through the use of the Jackson/Pollock prediction equations, requires skinfold measurements from the following locations;

For men - sum of 4 skinfolds

1. Pectoral
2. Ilium
3. Umbilicus
4. Mid-Axilla

For women - sum of 3 skinfolds

1. Tricep
2. Abdomen
3. Ilium

Once the skinfold measurements were taken the following prediction equations were used to estimate percent body fat.

Equation for the men using the sum of 4 skinfolds:

$$\% \text{ fat} = .27784(X_1) - .00053(X_1)^2 + .12437(X_2) - 3.28791$$

Where: X_1 = sum of 4 skinfolds

X_2 = age of subject

Equation for the women using the sum of 3 skinfolds:

$$\% \text{ fat} = .41563(X_1) - .00112(X_1)^2 + .03661(X_2) + 4.03653$$

Where: X_1 = sum of 3 skinfolds

X_2 = age of subject

EKG ELECTRODE ATTACHMENT

Subject electrode preparation was as follows;

1) Skin was abraded by rubbing the site with a rough towel and acetone.

2) Electrodes were placed at the following sites;

Right Shoulder

Left Shoulder

Left Ribcage

3) EKG cables (white, black & red) were attached to the appropriate electrodes;

White to R Shoulder

Black to L Shoulder

Red to L Ribcage

APPENDIX F

ESOPHAGEAL TEMPERATURE PROBE INSTRUCTIONS

EXERCISE PHYSIOLOGY LAB
UNIVERSITY OF NEVADA, LAS VEGAS

ESOPHAGEAL TEMPERATURE PROBE INSTRUCTIONS

The use of the esophageal temperature probe in this study is important. The esophageal probe has been thoroughly sterilized. To use the esophageal probe:

1. Place the clear plastic end of the probe in your mouth with the tip at the back of your throat.

2. Gently push the probe down your throat while continually swallowing until the red mark on the probe is reached. Water is available to aid in swallowing the probe.

3. Once the probe is swallowed it will rest in the esophagus approximately level with the heart. The end of the probe will be taped to the side of the face to hold it in place.

4. At first you may be aware of the probe as it tickles the back of your throat but you will adapt to it quickly and it will not interfere with your breathing.

5. When testing is complete, remove the probe slowly and hand it to the laboratory personnel.

If you feel unduly uncomfortable please talk to the laboratory personnel, your comfort is important.

APPENDIX G

DATA USED IN STATISTICAL COMPUTATIONS

DATA COLLECTED DURING SUBJECT TESTING FOR USE IN
STATISTICAL COMPUTATIONS

ID	SEX	AGE	HT	WT	%FAT	RHR	TH2O*	SUIT*
LM	M	34	179	69.93	8.2	60	2	1
LM	M	34	179	69.93	8.2	60	2	2
LM	M	34	179	69.93	8.2	60	1	1
LM	M	34	179	69.93	8.2	60	1	2
SW	M	25	181.5	67.06	5.2	70	2	1
SW	M	25	181.5	67.06	5.2	70	2	2
SW	M	25	181.5	67.06	5.2	70	1	1
SW	M	25	181.5	67.06	5.2	70	1	2
SP	M	37	192.2	80.20	8.6	67	2	1
SP	M	37	192.2	80.20	8.6	67	2	2
SP	M	37	192.2	80.20	8.6	67	1	1
SP	M	37	192.2	80.20	8.6	67	1	2
JF	M	30	189	83.35	8.9	60	2	1
JF	M	30	189	83.35	8.9	60	2	2
JF	M	30	189	83.35	8.9	60	1	1
JF	M	30	189	83.35	8.9	60	1	2
JS	M	41	174.5	68.41	10.9	60	2	1
JS	M	41	174.5	68.41	10.9	60	2	2
JS	M	41	174.5	68.41	10.9	60	1	1
JS	M	41	174.5	68.41	10.9	60	1	2
BC	M	39	173.9	75.47	13.8	49	2	1
BC	M	39	173.9	75.47	13.8	49	2	2
BC	M	39	173.9	75.47	13.8	49	1	1
BC	M	39	173.9	75.47	13.8	49	1	2

TS	F	29	165.6	68.12	20.2	72	2	1
TS	F	29	165.6	68.12	20.2	72	2	2
TS	F	29	165.6	68.12	20.2	72	1	1
TS	F	29	165.6	68.12	20.2	72	1	2
ST	F	28	167.6	65.62	20.3	79	2	1
ST	F	28	167.6	65.62	20.3	79	2	2
ST	F	28	167.6	65.62	20.3	79	1	2
ST	F	28	167.6	65.62	20.3	79	1	1
AF	F	41	169.5	61.32	14.4	54	2	2
AF	F	41	169.5	61.32	14.4	54	2	1
AF	F	41	169.5	61.32	14.4	54	1	1
AF	F	41	169.5	61.32	14.4	54	1	2

*water temp: 1= cold 2= warm
*suit (length): 1= short 2= long

SWTM	HR	CORE	CH	HD	TH	CA	PREWT	PSWT
21.62	164.2	35.4	29.7	30.6	25.3	28.4	156.25	155
22.52	159	35.9	29.5	30.1	33.4	32.8	155.75	155
21.21	144.5	33.9	25.8	25.1	30.3	22.3	156	156
21.86	147.3	33.2	25.8	22.6	29.6	28.0	155	155
31.22	150	33.7	31.7	30.3	33.9	28.5	148	147.25
26.69	144	36.0	33.2	30.7	34.1	31.3	150.75	150.5
30.95	145	35.6	24.8	24.8	30.6	23.9	156	154
25.91	152.3	35.5	23.9	24.3	31.3	29.4	151	151
19.68	156.2	32.0	32.3	30.9	34.5	29.3	-	-
19.39	163.2	38.1	32.4	30.4	34.6	33.7	177	176
18.76	157.5	35.9	28.9	28.0	33.1	28.5	175	174
19.04	159	35.2	27.4	25.0	31.9	30.1	176	175
21.75	155	33.5	30.7	33.1	34.9	32.6	184.5	184.25
23.66	162	36.1	32.5	31.8	33.8	30.1	184.5	184.5
23.64	157.5	31.4	25.2	26.9	30.2	25.3	185	183
22.05	149	36.5	26.9	29.8	32.4	30.4	184	184
22.22	141	36.4	31.7	31.4	17.4*	29.6	148.5	148.25
20.98	134	36.6	32.4	32.0	34.4	31.1	147.5	146.5
25.89	135	32.0	26.9	25.6	31.4	22.8	146	145
25.06	139	36.4	27.9	26.7	31.6	29.4	148	147.5
34.24	177.8	38.1	28.9	31.8	34.6	29.2	168	166
34.57	148.3	37.0	31.1	31.9	34.3	32.2	168.75	167.5
29.49	146.5	36.7	25.7	25.5	30.5	24.9	167	167
25.47	142.3	34.1	26.3	24.1	30.2	29.2	164	163
20.49	152	35.9	34.1	32.9	31.1	28.5	151.25	150.75
21.28	167.7	36.6	29.3	32.0	32.4	30.3	153	152
21.24	172.3	34.6	24.3	24.8	27.2	21.9	154	153.5
20.95	166.5	36.5	24.7	26.0	27.8	27.6	150	150

31.76	153	37.7	31.2	31.4	32.5	29.5	147.25	146.5
34.02	154	37.7	29.8	33.5	33.3	30.7	140.25	139.5
32.14	140	36.9	25.0	23.6	27.9	25.9	146	143
31.94	153.3	37.2	27.6	26.5	29.6	23.9	140.25	140
29.34	154	37.8	29.9	31.8	32.7	31.8	136.75	135
30.76	148	37.8	31.3	29.8	32.7	28.3	134	134
28.22	142.7	35.9	28.6	26.2	29.5	23.3	134	133.5
22.37	147	37.5	27.5	25.9	30.1	29.9	131	131

APPENDIX H

RAW DATA

RAW DATA COLLECTED DURING COLD WATER SWIMS IN FULL AND HALF 3MM WETSUITS

SUB: JS **SEX:** M **SUIT:** HALF **WATER TEMP:** 20C **PREWT:**146
POST WT: 145 **TOTAL SWIMTIME:** 25:53:59

MINUTE	HR	CORE*	HEAD	CHEST*	THIGH	CALF
0	70	34.5	33.0	34.4	32.9	33.9
5	135	32.0	26.4	27.2	31.3	22.3
10	134	31.1	25.6	27.0	31.5	23.1
15	134	30.9	25.5	26.9	31.4	22.6
20	137	31.5	25.5	26.8	31.4	23.0
25	141	32.0	25.8	26.7	31.5	22.5

SUB: JS **SUIT:** FULL **WATER TEMP:** 20C **PREWT:**148 **POST WT:** 147.5 **TOTAL SWIMTIME:** 25:05:71

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	47	36.3	32.0	32.4	30.6	30.4
5	147	36.1	27.0	28.3	31.0	29.8
10	139	36.3	26.6	27.9	31.5	29.5
15	135	36.5	26.6	27.7	31.8	29.2
20	137	36.5	26.5	27.5	32.0	29.0
25	138	36.4	26.0	27.6	32.2	28.2

*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: LM **SEX:** M **SUIT:** HALF **WATER TEMP:** 20C **PREWT:**156
POST WT: 156 **TOTAL SWIMTIME:** 21:12:32

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	56	35.7	29.3	30.6	30.4	23.0
5	144	33.1	25.1	26.2	30.2	22.6
10	143	33.3	25.1	25.9	30.4	22.4
15	146	34.8	25.0	25.5	30.3	22.2
20	145	34.5	25.0	25.6	30.3	22.0

SUB: LM **SUIT:** LONG **WATER TEMP:** 20C **PREWT**:155 **POST WT:** 155 **TOTAL SWIMTIME**: 21:51:37

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	58	36.5	24.9	31.2	29.3	28.5
5	143	33.0	22.7	26.3	29.4	27.6
10	148	34.0	22.7	26.0	29.6	27.8
15	148	33.5	--	25.5	29.6	28.1
20	150	32.4	--	25.6	29.6	28.6

==

SUB: BC **SEX:** M **SUIT:** HALF **WATER TEMP:** 20C **PREWT**:167
POST WT: 167 **TOTAL SWIMTIME**:29:29:46

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	56	37.5	31.3	33.2	32.1	28.4
5	153	36.6	26.4	26.2	30.9	25.3
10	150	36.8	25.2	25.9	30.6	25.0
15	145	36.3	25.2	25.5	30.3	24.6
20	138	37.0	24.9	25.3	30.2	24.5
25	147	35.5	24.8	25.0	30.0	24.3
29	148	37.3	23.9	25.2	29.9	24.1

----

*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: BC **SUIT:** LONG **WATER TEMP:** 68F **PREWT**:164 **POST WT:** 163 **TOTAL SWIMTIME:** 25:28:43

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	57	37.3	33.0	34.2	32.1	34.2
5	141	34.5	24.9	26.8	30.7	30.9
10	142	34.8	23.9	26.1	30.2	29.9
15	144	33.2	23.8	26.3	29.9	29.4
20	142	33.8	23.7	26.1	29.8	29.4
25	145	34.3	23.6	25.8	29.5	25.4

==

SUB: SP **SEX:** M **SUIT:** HALF **WATER TEMP:** 20C **PREWT**:175 **POST WT:** 174 **TOTAL SWIMTIME:** 18:45:46

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	58	36.3	32.1	33.9	33.0	32.1
5	153	35.9	32.1	28.7	32.6	32.2
10	156	35.5	26.1	28.9	32.3	29.9
15	160	35.8	26.7	28.9	33.6	26.1
18	161	36.4	27.1	29.0	33.8	25.7

- -

- -

SUB: SP **SUIT:** LONG **WATER TEMP**: 20C **PREWT:**176 **POST WT:** 175 **TOTAL SWIMTIME:** 19:02:63

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	61	36.5	30.6	32.7	31.2	31.4
5	169	34.8	25.5	27.7	31.5	30.3
10	153	34.8	25.1	27.5	31.8	30.0
15	157	34.8	25.1	27.3	32.0	30.0
19	157	35.3	25.0	27.2	32.1	30.0

==

*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: JF **SEX:** M **SUIT:** HALF **WATER TEMP:** 20C **PREWT:**185
POST WT: 183 **TOTAL SWIMTIME:** 23:38:36

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	58	33.8	29.6	32.4	30.5	28.7
5	162	31.5	26.0	25.2	30.7	23.9
10	156	31.4	27.6	24.8	27.2	26.1
15	155	30.1	28.2	26.6	31.1	27.2
20	157	32.7	26.0	24.1	31.6	24.1

SUB: JF **SUIT:** LONG **WATER TEMP:** 20C **PREWT:** 184 **POST WT:** 184 **TOTAL SWIMTIME:** 22:02:70

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	60	36.8	33.3	33.7	33.5	33.6
5	148	36.1	28.4	27.7	32.0	30.6
10	147	36.6	29.0	27.2	32.1	30.2
15	149	36.8	30.8	26.5	32.4	--
20	155	36.6	31.0	26.3	32.9	--

SUB: AF **SEX:** F **SUIT:** HALF **WATER TEMP:** 20C **PREWT:**134
POST WT: 133.5 **TOTAL SWIMTIME:** 28:12:96

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	59	35.7	34.3	34.2	32.1	31.0
5	150	35.8	26.6	28.9	30.6	23.5
10	138	35.9	26.2	28.6	29.7	23.3
15	138	36.2	26.1	28.5	29.1	23.3
20	145	35.8	26.0	28.4	28.5	23.2
25	148	36.1	26.0	28.4	28.5	23.2

---

*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: AF **SUIT:** LONG **WATER TEMP:** 20C **PREWT:** 131 **POST WT:** 131 **TOTAL SWIMTIME:** 30:22:19:

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	67	38.2	32.0	34.3	31.8	34.6
5	146	37.4	26.2	28.3	31.1	31.1
10	149	37.8	25.8	27.4	30.0	29.7
15	146	37.3	25.7	27.3	29.7	29.5
20	147	37.3	25.7	27.0	29.5	29.3
25	145	37.1	25.5	26.8	29.2	29.0
30	151	37.1	25.4	26.6	29.2	28.9

==

SUB: TS **SEX:** F **SUIT:** HALF **WATER TEMP:** 68F **PREWT**:154 **POST WT:** 153.5 **TOTAL SWIMTIME**: 21:14:20

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	66	37.3	27.3	33.5	27.1	24.1
5	177	35.5	24.4	24.2	26.7	22.0
10	171	34.9	24.6	24.4	26.7	22.0
15	170	33.5	24.8	24.5	27.3	21.7
20	170	34.5	25.2	24.1	28.1	21.7

SUB: TS **SUIT**: LONG **WATER TEMP:** 20C **PREWT:** 150 **POST WT:** 150 **TOTAL SWIMTIME**: 20:56:80

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	58	36.9	27.9	33.3	27.3	26.7
5	164	36.3	25.4	24.5	27.4	27.7
10	165	35.8	25.6	24.6	27.3	27.2
15	162	36.6	26.0	24.8	27.7	27.5
20	175	37.2	27.0	24.7	28.8	27.9

==

*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: ST **SEX:** F **SUIT:** HALF **WATER TEMP:** 20C **PREWT:**140.25
POST WT: 140 **TOTAL SWIMTIME:** 31:56:33

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	75	37.1	30.2	33.2	32.1	31.2
5	150	36.5	27.0	27.5	30.3	24.2
10	152	37.3	26.6	27.4	29.8	23.9
15	154	37.6	26.2	27.6	29.4	23.8
20	157	37.4	26.2	27.7	29.2	23.6
25	145	36.8	26.1	28.3	29.2	23.6
30	155	37.5	26.3	28.5	29.3	23.8

SUB: ST **SUIT:** LONG **WATER TEMP:** 20C **PREWT**: 146 **POST WT:** 143 **TOTAL SWIMTIME**: 32:08:40

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	60	36.8	25.7	30.6	27.7	27.7
5	146	36.8	23.9	25.1	28.1	26.5
10	142	37.0	23.5	25.0	28.1	26.0
15	135	36.9	23.4	25.0	27.9	25.7
20	137	36.9	23.5	25.0	27.8	25.4
25	137	36.8	23.5	24.9	27.6	25.4
30	131	36.7	23.3	25.0	27.5	25.3

===

SUB: SW **SEX:** M **SUIT:** HALF **WATER TEMP:** 20C **PREWT:** 156
POST WT: 154 **TOTAL SWIMTIME:** 30:56:82

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	66	37.6	28.1	34.0	32.5	32.3
5	145	35.8	25.2	25.0	30.6	24.1
10	147	36.2	24.9	25.0	30.6	24.0
15	145	35.4	24.7	25.0	30.7	23.8
20	144	35.0	24.6	24.5	30.3	23.7
25	140	35.0	24.5	24.4	30.2	23.3
30	144	35.0	24.5	24.4	30.3	23.2

SUB: SW **SUIT:** LONG **WATER TEMP**: 20C **PREWT**: 151 **POST WT:** 151 **TOTAL SWIMTIME**: 25:54:67

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	89	37.2	33.2	34.5	33.8	35.7
5	150	34.7	25.2	24.2	31.7	30.7
10	154	36.0	24.2	24.1	31.4	29.4
15	152	35.7	32.9	24.0	31.1	28.8
20	153	35.5	23.9	23.6	31.1	28.6
25	164	35.4	23.9	23.6	31.0	28.1

*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

RAW DATA COLLECTED DURING WARM WATER SWIMS IN FULL AND HALF 3MM WETSUITS

SUB: AF **SEX:** F **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:**136.75
POST WT: 135 **TOTAL SWIMTIME:** 29:20:50

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	72	37.2	34.5	34.2	31.8	30.1
5	143	37.6	31.5	30.3	32.0	30.5
10	154	37.8	31.5	30.4	32.3	31.0
15	156	38.0	31.7	29.4	32.9	31.6
20	162	37.9	32.4	29.8	33.9	31.8
25	162	38.0	32.7	30.0	34.9	32.0
29	173	38.1	32.5	29.4	35.3	32.4

SUB: AF **SUIT:** HALF **H2OTEMP:** 27.8C **PREWT:**134 **POSTWT:** 134
TOTAL SWIMTIME: 30:45:44

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	66	37.5	35.3	35.1	32.9	27.9
5	147	37.9	30.0	31.5	32.5	28.5
10	150	37.8	29.8	31.1	32.7	28.4
15	146	37.8	29.7	31.2	32.7	28.2
20	154	37.8	29.8	31.3	33.0	28.2
25	157	37.7	29.7	31.4	33.3	28.3
30	163	37.1	29.9	31.7	33.5	28.2

==

SUB: TS **SEX:** F **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:**153
POST WT: 152 **TOTAL SWIMTIME:** 21:16:76

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	70	36.8	33.9	33.5	30.7	31.3
5	149	35.1	29.7	28.5	30.8	30.2
10	153	37.6	32.5	29.5	31.8	30.1
15	173	37.9	32.9	29.9	33.3	30.4
20	184	36.0	33.2	29.9	34.0	30.5

SUB: TS **SUIT:** HALF **H2OTEMP:** 27.8C **PREWT:**151.25 **POSTWT:** 150.75 **TOTAL SWIMTIME:** 20:29:14

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	70	36.8	33.1	34.8	30.8	28.9
5	127	36.0	30.7	31.6	29.7	28.3
10	133	35.0	33.6	34.8	30.3	28.5
15	179	-	33.8	35.0	31.6	28.7
20	169	-	33.5	34.8	32.6	28.5

SUB: JF **SEX:** M **SUIT**: Long **WATER TEMP:** 27.8C **PREWT:**184.5
POST WT: 184.25 **TOTAL SWIMTIME:** 21:45:18

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	80	35.0	30.6	33.8	33.0	33.2
5	145	33.3	33.6	30.1	33.6	32.4
10	147	34.7	33.5	30.6	34.7	32.4
15	162	33.6	33.1	30.9	35.8	32.4
20	166	32.5	31.2	31.2	35.8	33.1

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*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: JF **SUIT:** HALF **H2OTEMP:** 27.8C **PREWT:** -- **POSTWT:** --
TOTAL SWIMTIME: 23:39:87

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	74	36.1	35.9	35.4	34.9	34.3
5	158	27.4	31.2	30.7	30.9	29.1
10	165	-	30.9	31.8	31.8	29.0
15	158	-	30.7	32.2	35.6	29.0
20	166	-	30.5	32.4	35.9	29.0

==

SUB: SP **SEX:** M **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:** 177
POST WT: -- **TOTAL SWIMTIME:** 19:23:83

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	77	37.2	31.0	33.3	32.2	33.3
5	156	37.2	29.5	31.5	33.5	33.6
10	161	37.9	30.1	31.9	34.3	33.6
15	166	38.2	31.1	32.5	34.9	34.0
19	170	38.7	30.9	32.7	35.5	34.3

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SUB: SP **SUIT:** HALF **H2OTEMP:** 27.8C **PREWT:** 182 **POSTWT:** 181
TOTAL SWIMTIME: 19:40:96

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	58	34.8	31.0	34.1	32.0	32.0
5	138	32.0	29.9	32.0	33.7	29.2
10	157	-	30.1	32.0	34.4	29.2
15	160	-	31.5	32.2	34.4	29.2
19	170	-	32.2	33.2	35.2	29.6

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*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: LM **SEX:** M **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:** 155.75
POST WT:155 **TOTAL SWIMTIME:** 22:31:09

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	60	36.1	31.8	33.5	32.4	31.5
5	130	35.9	30.0	29.4	33.1	32.5
10	171	35.3	30.0	29.4	33.4	32.7
15	169	36.1	30.1	29.5	33.4	32.8
20	166	36.6	30.4	29.6	33.6	33.0

SUB: LM **SUIT:** HALF **H2OTEMP:** 27.8C **PREWT:** 156.25 **POSTWT:** 156.25 **TOTAL SWIMTIME:** 21:37:28

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	69	36.0	30.0	30.1	30.3	28.9
5	130	35.5	30.2	29.8	29.9	28.4
10	171	35.2	30.3	29.4	24.5	28.3
15	178	-	30.7	29.4	23.9	28.4
20	178	-	31.0	30.0	22.7	28.4

SUB: SW **SEX:** M **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:** 150.75
POST WT:150.5 **TOTAL SWIMTIME:** 26:41:48

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	63	36.2	31.4	34.9	32.5	31.8
5	152	35.6	30.2	33.7	33.5	30.9
10	142	36.0	30.0	33.1	34.0	31.0
15	140	36.1	30.5	32.6	34.3	31.4
20	143	36.3	32.0	33.3	34.7	31.8
25	155	36.4	33.1	33.9	35.5	31.7

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*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: SW **SUIT:** HALF **H2OTEMP**: 27.8C **PREWT:** 148 **POSTWT:** 147.25 **TOTAL SWIMTIME:** 31:13:07

MINUTE	HR	CORE*	HEAD	CHEST	THIGH	CALF
0	65	35.8	31.7	31.9	32.4	28.6
5	-	33.7	30.2	31.9	33.1	28.6
10	-	--	30.3	31.9	33.7	28.5
15	-	--	30.3	31.5	34.2	28.5
20	-	--	30.4	31.4	34.6	- -
25	-	--	30.9	31.6	34.8	- -
30	-	--	30.9	31.6	34.8	- -

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SUB: JS **SEX:** M **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:** 147.5 **POST WT:**146.5 **TOTAL SWIMTIME**: 2O:59:35

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	65	36.6	32.7	34.5	33.0	32.5
5	126	36.1	31.0	31.5	33.2	31.6
10	132	36.6	31.4	32.5	33.8	31.3
15	138	36.8	32.6	32.8	34.8	30.9
20	142	36.9	33.0	32.7	35.6	30.8

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SUB: JS **SUIT:** HALF **H2OTEMP**: 27.8C **PREWT:** 148.5 **POSTWT:** 148.25 **TOTAL SWIMTIME**: 22:13:43

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	61	36.7	33.2	34.4	17.5	31.2
5	133	35.8	30.4	31.4	18.2	29.9
10	141	36.3	30.6	32.0	17.3	29.6
15	145	36.8	31.5	31.7	17.3	29.5
20	145	36.6	33.1	31.7	16.8	29.4

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*Tes is made invalid due to the swallowing of water and shifting of the esophageal probe.

SUB: IF **SEX:** F **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:** 129.75
POST WT: 129.25 **TOTAL SWIMTIME:** 22:44.05

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	54	36.9	33.1	33.6	31.7	32.0
5	120	37.0	29.5	30.7	31.9	31.8
10	129	37.3	29.3	30.7	32.0	31.7
15	133	37.1	29.2	20.8	32.1	31.7
20	137	37.3	29.2	30.7	32.3	31.9

SUB: IF **SUIT:** HALF **H2OTEMP**: 27.8C **PREWT:** 127.75 **POSTWT:**
125 **TOTAL SWIMTIME**: 23.08.00

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	64	36.2	32.8	33.3	25.8	29.4
5	123	36.0	28.5	30.2	30.9	28.5
10	--	36.5	29.0	29.6	31.2	28.5
15	--	36.6	29.4	29.4	31.6	28.5
20	179	36.6	29.8	29.2	31.9	28.3

SUB: ST **SEX:** F **SUIT**: Long **WATER TEMP:** 27.8C **PREWT:** 140.25
POST WT: 139.5 **TOTAL SWIMTIME:** 34:01.49

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	64	37.2	35.5	33.0	31.1	30.0
5	-	37.2	--	29.6	31.5	30.3
10	-	38.0	--	30.2	32.6	30.5
15	156	38.0	33.0	29.5	34.0	30.9
20	152	38.0	33.9	30.0	34.9	31.0
25	151	--	33.9	28.0	35.5	31.0
30	150	--	34.7	28.0	35.7	31.1

SUB: ST **SUIT:** HALF **H2OTEMP**: 27.8C **PREWT:** 147.25
POSTWT:146.5 **TOTAL SWIMTIME:** 31:45:34

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	75	37.5	31.5	35.5	31.4	28.8
5	156	37.5	30.3	--	31.3	29.1
10	154	37.7	31.3	--	32.0	29.3
15	156	37.8	31.8	--	33.0	29.2
20	146	37.8	32.0	31.1	33.0	30.6
25	144	37.7	32.0	29.9	34.2	30.6
30	155	37.7	31.7	30.5	34.3	30.6

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SUB: BC **SEX:** M **SUIT:** Long **WATER TEMP:** 27.8C **PREWT:** 168.75
POST WT: 167.5 **TOTAL SWIMTIME:** 34:34:00

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	67	37.1	34.4	34.7	32.3	32.1
5	143	36.8	31.0	31.1	32.5	31.2
10	150	37.0	30.7	31.1	32.9	31.2
15	--	36.9	31.6	31.8	33.8	33.8
20	150	37.3	34.2	30.4	39.9	32.6
25	142	37.2	34.3	30.4	35.6	32.6

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SUB: BC **SUIT:** HALF **H2OTEMP**: 27.8C **PREWT:** 168 **POSTWT:**
166 **TOTAL SWIMTIME:** 31:45:34

MINUTE	HR	CORE	HEAD	CHEST	THIGH	CALF
0	60	37.4	30.8	28.6	32.6	28.4
5	183	37.9	30.9	29.1	33.0	28.4
10	179	38.0	32.0	29.8	34.2	28.3
15	173	38.4	32.1	28.2	35.1	30.0
20	176	38.0	32.3	28.4	36.0	30.2
25	--	37.6	32.4	28.3	36.5	30.6
30	155	37.8	32.4	28.3	36.5	30.1

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