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PHYSIOLOGICAL RESPONSE OF FEMALE SPORT DIVERS TO EXERCISE DURING TREADMILL AND UNDERWATER WORKBOUTS

The University of North Carolina at Greensboro ED.D. 1983

University Microfilms International 300 N. Zeeb Road, Ann Arbor, MI 48106

PHYSIOLOGICAL RESPONSE OF FEMALE SPORT DIVERS

TO EXERCISE DURING TREADMILL AND

UNDERWATER WORKBOUTS

by

Barbara Sue Graves

A Dissertation submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

Greensboro
1983

Approved by

Rosemary McGee

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APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro.

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March 24, 1983
Date of Acceptance by Committee

February 2, 1983
Date of Final Oral Examination

GRAVES, BARBARA SUE. Physiological Response of Female Sport Divers to Exercise During Treadmill and Underwater Workbouts. (1983) Directed by: Dr. Rosemary McGee. Pp. 105

The purpose of this study was to evaluate certified female sport divers on selected physiological variables obtained during underwater and treadmill workbouts. The primary research question sought to determine the oxygen uptake ($\dot{V}O_2$) and heart rate measures of the subjects during an exercise bout while submerged on self-contained water breathing apparatus (scuba). An additional question asked whether the heart rate values obtained during the underwater exercise bout significantly differed from heart rate values obtained during a comparable workbout on the treadmill.

Seventeen open water certified female sport divers volunteered to participate in the study. The maximal aerobic capacity for the group was 2.018 $l \cdot min^{-1}$ and 33.35 $ml \cdot kg^{-1} \cdot min^{-1}$ with a mean percent fat of 25.13. The averaged values for $\dot{V}O_2$ ($l \cdot min^{-1}$), $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate ($b \cdot min^{-1}$) of the underwater exercise were 1.24 $l \cdot min^{-1}$, 21.24 $ml \cdot kg^{-1} \cdot min^{-1}$, and 137.3 $b \cdot min^{-1}$, and for submaximal treadmill were 1.55 $l \cdot min^{-1}$, 26.36 $ml \cdot kg^{-1} \cdot min^{-1}$, and 161.6 $b \cdot min^{-1}$. A paired t test was used to compare heart rate values of the underwater and submaximal treadmill workbouts.

Heart rate was found to be significantly lower in the underwater workbouts with a mean of 140.1 versus a mean of 159.6 for the submaximal treadmill. An additional paired t test compared the underwater and treadmill $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$). Significant differences were found in

the $\dot{V}O_2$ $l \cdot min^{-1}$ with a mean of 1.29 for the underwater workbout. Similarly, a significant difference was found between the $\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$ for the underwater workbout (mean of 22.15) and the submaximal treadmill workbout (mean of 25.95). With the data collected in this experiment, it was not possible to statistically differentiate whether the heart rate differences were due to noncomparable $\dot{V}O_2$ levels and thus noncomparable work intensity or were due to cardiorespiratory differences between water and land work.

Since the $\dot{V}O_2$'s were significantly different and could not be considered comparable in terms of energy expenditure in this study, the observed heart rate differences must be cautiously interpreted. The differences could be attributed to researcher error and/or difficulty in comparing treadmill and underwater energy expenditure or to environmental temperature, position, external pressure, and other cardiorespiratory differences.

ACKNOWLEDGMENTS

The completion of my dissertation has depended on many people. First of all, I want to express my appreciation to Dr. Rosemary McGee, who has provided much support and critical advice through the study. The other members of my committee, Dr. Jerry Wilkerson, Dr. William Powers, and Dr. Blanche Evans, have also been very helpful.

The underwater scuba workbout would not have been possible without the assistance of the following people: Dr. Arthur Dicks of Duke University, Dr. Yancey Mebane, Joe Nelson of the Physics Department of the University of North Carolina at Greensboro, Bill McDonald and Dick Reilly of the Professional Association of Diving Instructors (PADI), Dan Herema and Ed Scott of U. S. Divers, Jon Hardy, Susan Bangasser, Jeanne Bearsleeper, Steven Linton of Scuba Schools International, and John Carter, Proprietor of Scuba Shack in Greensboro.

My data collection was easier because of these helpers: Debbie Trogden, Ken Drake, Rolayne Wilson, Jan Claiborne, Ned Gulbranson, and Charles Cicciarella. I also want to thank my typist, Margaret Thompson, for her time and endurance. Marje Martin, Statistical Consulting Center of the University of North Carolina at Greensboro, assisted me greatly in the data analysis and supported me as a friend. Grover and Denise Moberley of South Ocean Beach Hotel, Nassau, Bahamas, provided me with the escape when I needed it and also the solitude to write.

Finally, special appreciation is extended to Dr. James E. Drake for his positive support and assistance including his Canon copier and typewriter throughout almost all of this endeavor.

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CHAPTER I

INTRODUCTION

Diving with self-contained underwater breathing apparatus (scuba), called scuba diving, is a relatively new sport which actually began during World War II. In France, Captain Jacques-Yves Cousteau and Emile Gagnan developed the first efficient and safe open-circuit scuba during the early 1940's. They did this by combining high pressure air tanks, and an improved demand regulator for military use (U.S. Navy, 1975). Since that time, equipment improvement and proper training techniques have made diving accessible, not only to military personnel, but to the general public.

The sport diver of today realizes during training that scuba, under normal conditions, places few physical demands upon the body, but even with advancements in equipment and instruction, certain limitations exist for the sport diver, whether male or female. Some of these limitations involve the basic gas laws, the need for underwater life-support equipment, and the behavior of dangerous marine life (Kizer, 1981). In addition, anatomical and physiological differences exist between the sexes which require some special considerations. These differences occur because of body size, percentage of body fat, lung capacity, menstrual cycle, and other physiological factors which can affect such scuba performance factors as air consumption and bottom time.

Most information vital to the sport diver has been obtained on the male diver who was either in the military forces or performed for commercial concerns. The majority of this research has been conducted at Duke University's F. G. Hall Laboratory. The most recent was the four-part Atlantis series, in which three participants were involved in extensive physiological and psychological testing. This entire project examined divers working at extreme depth. The impact of compression rates and gas mixtures was also taken into consideration. The third dive of this project set a world's record at 2250 feet, a depth which had seemed unattainable at one time. The divers did not suffer the previously experienced High Pressure Nervous Syndrome (HPNS), which is tremors and delirium, nor other ill-effects of previous deep divers. The fourth Atlantis dive was not as successful as the third because one subject did suffer from HPNS. This type of diving research, however, will continue ("Duke Dive Called Hell," 1982).

Statement of the Problem

The purpose of this study was to evaluate certified female sport divers on selected physiological variables obtained during treadmill and underwater workbouts.

The primary research question of this study was: What were the aerobic capacity ($\dot{V}O_2$ $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate (HR) measures of these females while submerged on scuba?

Another question was also addressed: Were the HR values obtained during the underwater exercise bout significantly different from HR values obtained during a comparable $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) workload on the treadmill?

Definition of Terms

For the purposes of this study, the following physiological terms were defined:

Fat-free weight: a measure of active tissue in the body, equal to the total body weight minus the fat weight, and is generally expressed in kilograms.

Fat weight: composed of two types of fat, essential and nonessential. Essential fat is that which is required for normal physiological functions, and is stored in areas such as bone marrow, heart, lungs, liver, spleen, kidneys, and central nervous system. Nonessential fat accumulates in adipose tissue. Fat weight may be calculated by multiplying the percentage of fat by the body weight (Mathews & Fox, 1981).

Maximal oxygen consumption: $\dot{V}O_{2max}$ or aerobic work capacity; $\dot{V}O_{2max}$ is the maximal rate at which one can supply oxygen to the tissues and indicates how efficiently the tissues utilize this oxygen.

Percentage of body fat: the proportion of the body weight estimated to be fat as determined by hydrostatic weighing. The terms is used as a measure of body composition (Sparling, 1979).

Tare weight: the weight of all equipment suspended in the water or worn by a subject during an underwater weighing session.

Also, for the purposes of this study, the following scuba terms were defined:

Air consumption: the amount of air used during a scuba dive.

Bottom time: the time spent underwater on a scuba dive. The time is calculated from the beginning of the descent underwater to the beginning of the ascent.

Nationally recognized scuba agency: nationally recognized agency which offers scuba certification courses. Five major agencies are located in the United States: National Association of Skin Diving Schools (NASDS), National Association of Underwater Instructors (NAUI), Professional Association of Diving Instructors (PADI), Scuba Schools International (SSI), and Young Men's Christian Association (YMCA).

Neutral bouyancy: a position obtained underwater by the diver in which there is a tendency to neither float nor sink. During a normal breathing cycle, the diver will rise slightly during inhalation and sink slightly during exhalation.

Open circuit scuba: a scuba system designed to expel the exhausted air of a diver directly into the environment.

Open water diver's certification: a certification ("c") card issued by a nationally recognized scuba agency, service as proof that a diver has successfully passed a written test and completed several open water dives. The "c" card also allows the diver access to the use of scuba tanks filled with air.

Scuba: acronym for self-contained underwater breathing apparatus. In this study scuba was further defined as an open circuit system.

Sport diver: a scuba diver who dives primarily for recreational enjoyment.

Assumptions

This study proceeded under certain assumptions:

1. Since all the subjects had at least an Open Water Diver's Certification, they were considered proficient with basic scuba skills and comfortable in the pool environment.

2. The laboratory instruments used to analyze the expired gases were appropriately and accurately calibrated.

3. The subjects performed as requested during the testing session.

Limitations of the Study

The research design and practical considerations of the study created certain limitations:

1. Due to the nature of the study, random sampling was not feasible for obtaining subjects.

2. Since the pool environment was controlled, results were not generalized to an open water environment.

3. The diver's depth during the underwater workbout in the pool was more shallow than that of an open water dive.

4. The independent variables in this study did not represent all the possible factors that influence female diving.

performance, such as level of motivation, anxiety levels, and other psychological parameters.

5. The subject's air consumption during the scuba workbout was not a variable in this study. The pressure gauge was in increments of 100 psi (pounds per square inch) which was not an exact enough measure.

Scope of the Study

Subjects

The subjects for this study were 17 certified female sport divers ranging in age from 18 to 40 years. Each diver had an open water certification from a nationally recognized scuba agency. They were volunteers whose levels of fitness and diving expertise were varied.

Tests

Each subject participated in five testing sessions during which physiological measures were obtained. First, each subject was introduced to the laboratory and underwater procedures prior to the actual data collection. This introduction helped to minimize anxiety levels and maximized data reliability. Second, following the acquaintance session, body composition measures were evaluated using an underwater weighing technique. Third, a test of maximal aerobic capacity was conducted on the treadmill which assessed fitness level. Fourth, a submaximal underwater workbout on scuba was conducted. Heart rate and $\dot{V}O_2$ measures were determined. The final testing session was a submaximal treadmill test. This test assessed heart rate response to a workload determined from the underwater $\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$. All of these tests were conducted in May 1982.

Significance

Scuba is in essence a high-risk activity involving any number of potentially life-threatening situations which can evolve from the physical condition of the subject. Any information, therefore, that will help prepare the participant or the scuba instructor to deal with these hazards is of obvious merit. The utilization of less formal measures, such as heart rate and air consumption, may be pertinent. Monitoring air consumption is an established procedure. Heart rate, therefore, may be used in conjunction with air consumption to alleviate potential problems such as anxiety and running out of air. After much more research has been conducted, the air consumption might be used as a possible estimate of $\dot{V}O_2$ ($l \cdot min^{-1}$) for underwater work.

This study can add to the general body of knowledge for the sport diver since the bulk of research has been conducted on the military or commercial diver. Specifically, results of this study will contribute to the knowledge of the female sport diver relative to body composition, $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$), and heart rate.

CHAPTER II

REVIEW OF LITERATURE

> Scuba diving is causing a revolution in underwater exploration, salvage, science, and treasure hunting as well as in underwater sports. But one must learn the limitations before thrills and excitement can be enjoyed. (Bridges, 1960, p. 44)

Since 1960, diving as a sport has increased greatly and the equipment has improved remarkably. Yet, research in the sport diving area has been limited. This chapter reviews the physiological limitations of scuba diving and also scuba diving research in general.

Physiological Limitations of Scuba Diving

Certain physiological limitations exist for the sport diver even with improvements in scuba gear and instructional techniques. These limitations are discussed in relationship to underwater pressure, which causes major limitations in two general dimensions of diving: (a) descent and ascent, and (b) depth and bottom time.

Descent and Ascent

The sport diver descends below the surface of the water and must immediately adapt to the changes in surrounding pressure. At sea level, this surrounding pressure is 14.7 pounds per square inch (psi). Upon descent, the pressure increases. At a depth of 33 feet, the pressure is doubled (29.4 psi), at 66 feet it is tripled (54.1 psi), and so forth in increments of 33 feet. Each of these increments is considered an atmosphere (atm) (U.S. Navy, 1975).

Pressure changes normally do not affect muscles and bones of the human body since these components are virtually incompressible. What is affected is the respiratory system (Lanphier, 1975). According to Boyle's Law, the volume of a gas is inversely proportional to the pressure at a constant temperature (Sport Diver Manual, 1979). For example, as the body descends underwater, the lungs are compressed in proportion to the pressure exerted by the surrounding water. Since the diver continues to breathe compressed air from a scuba tank, the lungs receive an adequate amount of air and the pressure change is generally not felt. Dead air spaces, such as in the ears, must remain at normal pressure by the Valsalva Maneuver or the tympanic membrane will puncture.

A lung expansion problem arises if the diver holds a breath of air on ascent. The air in the lungs will expand as the pressure decreases and will take the least line of resistance. Since the breath is not being exhaled normally, an alveoli may rupture in the lungs, causing an air embolism. If the air bubble reaches the brain through the bloodstream, a fatality results. Pneumothorax, subcutaneous smphysema, and mediastinal emphysema are other air expansion problems which can occur on ascent if the breath is held. All of these air expansion problems can result by ascending from a depth as shallow as six feet on scuba if the breath is held. Craig (1980) stated that during a six-foot ascent, a pressure difference of 140 millimeters of mercury (mmHG) exists between the lungs and the rest of the body. This pressure was well above the 80 mmHG which caused air expansion problems in experimental animals. Since an air-breathing creature naturally tends to hold its breath underwater, this tendency must be avoided at all costs by the sports diver. If one breathes naturally or exhales continuously on ascent, air expansion problems will be avoided (Sport Diver Manual, 1979).

The diver's ascent rate is very important too. This rate should be one foot per second which renders the nitrogen in the blood stream virtually harmless. If the rate is faster, the nitrogen may go from a liquid to a gas form. These bubbles settle in the joints of the body or spinal cord, resulting in the bends (U.S. Navy, 1975). The bends are discussed in the following section.

Depth and Bottom Time

Another limitation to a diver underwater is the depth and bottom time of a dive. Depth must be taken into account because of Dalton's Law. This law states that the pressure of a gas in a mixture of gases is directly proportional to the percentage of that gas in the mixture. In other words, the partial pressure of oxygen from a scuba tank increases in the diver's lungs on descent. This means that the dissociation curve, known as the Bohr effect, moves to the left since more oxygen is available to the alevoli. The Bohr effect aids the diver to an extent, but becomes detrimental at five atm (132 feet). The diver at this depth will be breathing almost pure oxygen, resulting in oxygen poisoning (Mathews & Fox, 1981). Much research has been conducted at Duke University's F. G. Hall Laboratory with different gas mixtures using helium, nitrogen, and oxygen to prevent the oxygen poisoning. Their results have determined that with less oxygen in the breathing mixture, oxygen poisoning can be prevented and a person can function almost normally at depths greater than 60 atms (2000 feet). This research has been directed toward the commerical diver and is not practical at this time for open circuit scuba divers.

Nitrogen must also be discussed in relation to bottom time and depth of a dive because of the possibility of a narcotic effect and the occurrence of the bends. Jacques Cousteau (1966) referred to this narcotic effect as rapture of the deep, while others (Duffner & Lanphier, 1960; Mount, 1975) have referred to it as nitrogen narcosis since, under pressure, the nitrogen starts to behave like an anesthetic gas. These effects are similar to those of alcohol, resulting in "Martini's Law." This law states that for every 50 feet one descends, a sensation similar to drinking a martini on an empty stomach occurs (Mathews & Fox, 1981). Sport divers are affected differently at various depths with nitrogen narcosis (Cousteau, 1960; Mathews & Fox, 1981; Sport Diver Manual, 1979). The first effect is the slowing of mental activity. Other symptoms can be a feeling of excitement and euphoria, slow responses to visual and auditory stimuli, limitations of association, and concentration difficulty (Behnke, Thomson, & Motley, 1935).

Several studies have measured the effects of nitrogen on humans. One experiment (Kiessling & Maag, 1962) utilized the Purdue pegboard to measure Choice Reaction Time and to test conceptual reasoning. At four atm (100 feet), reaction time decreased by 20.85%, manual dexterity decreased 7.90%, and conceptual reasoning by 33.46%. They concluded that mental function was the most severely affected and narcosis was not affected by length of time at four atm. Bennett and Towse (1971) conducted similar experiments in which the results were not affected by the length of bottom time or at depth. Another study (Poulton, Catton, & Carpenter, 1964) indicated that slower mental processes occurred at less than four atm and possibly as low as two to three atm (33 to 66 feet).

The cure for nitrogen narcosis is very simple. All that a diver must do is to ascend to a shallower depth. The prevention of narcosis altogether is to avoid deep diving. Nitrogen narcosis has no aftereffects. The danger is in what might go wrong while the diver is under the effects at depth because of the slowing of mental processes and reflexes (Kiessling & Maag, 1963).

The bends, also known as decompression sickness, is caused by nitrogen. Henry's Law states that gases will enter into a liquid in proportion to the partial pressure of the gas at a given temperature (Sport Diver Manual, 1978). If the partial pressure of nitrogen is doubled, then the amount of nitrogen dissolved in the bloodstream and tissues also doubles. This nitrogen is harmless to the diver as long as it remains dissolved in the bloodstream. If the ambient pressure is reduced too quickly, such as by too fast an ascent from a depth, the dissolved nitrogen can come out of solution and form tiny bubbles in the blood and tissues of the body (Sport Diver Manual, 1979).

The most common symptom for decompression sickness is local pain in the arms and legs. This pain causes the joint to appear bent, hence the name, bends. More serious cases of the bends involve the central nervous system, which include other symptoms such as unconsciousness, shock, vision, and hearing (Sport Diver Manual, 1979). Any diver suspected of having decompression sickness should be taken to a recompression chamber immediately. If the trip is made in an airplane with an unpressurized cabin, the flight should be at the lowest altitude possible. Higher altitudes will increase the size of the bubbles.

Previously, a theory, which concerned the creation of bubbles by the nitrogen coming out of solution in the bloodstream at depth, contended and supported that, by correct decompression, the formation of bubbles was avoided completely. Currently, investigators have indicated that these nitrogen bubbles always exist during a dive and that safe decompression merely limits the size and the number of the bubbles (Phoel, 1977).

Because the absorption of nitrogen depends on the bottom time and depth of the dive, diving tables are used to help divers know when they must consider decompression and the stops to make diving ascents for the transport of nitrogen safely out of the body (Craig, 1980). The ascent rate of 60 feet per minute was built into tables to help prevent the bends. The diving tables were designed and tested specifically for male Navy divers, 20 to 30 years old. Since sport divers are a cross section of the general public, the tables should be used with a safety margin. Some divers are more susceptible to the bends than others. Alcohol, drugs, excessive fat, and age (over 30) have been known to increase any diver's susceptibility to the bends (Walder, 1975).

Scuba Diving Research

The previously discussed physiological limitations of scuba diving are evident for both males and females. Much research has been conducted in these physiological areas, but mainly with male commercial or Navy divers as subjects. However, some research has been conducted with sport divers in several areas. The following areas are discussed with respect to sport divers: bradycardia, pulmonary ventilation, aerobic capacity, temperature, and circulatory responses.

Bradycardia

Bradycardia, a slowing of heart rate, is attributed to breath holding and water submergence (Hong, 1963; Irving, 1939) and was first observed in diving vertebrates such as ducks and geese, then demonstrated in man (Kawakami, Natelson, &

Dubois, 1967). In the realm of diving physiology, bradycardia has been an overworked topic (Dueker, 1981). Many sport divers, however, are not aware of this reflect-initiated response.

Hempleman (1978) demonstrated that water immersion without breath-holding results in bradycardia. Another study (Scholander, Hammel, Lemessurie, Hemmingsen, & Garey, 1962) was conducted on Australian skin divers. These divers' heart rates decreased to one-half of their surface heart rate while their blood pressures remained normal during a skindive (Dueker, 1981; Scholander et al., 1962). Ingjer (1978) reported the same decrease in heart rate as Scholander et al. (1962). Ingjer also found no relationship between the degree of bradycardia in the various test maneuvers and level of physical fitness. Swimmers and nonswimmers alike experienced a similar cardiac response (Craig, 1980; Irving, 1939).

Water temperature also plays a major role in the bradycardia response. In cold water, results of arm immersion tests indicated a decrease in the flow of blood in the forearm in male subjects (Hempleman & Lockwood, 1978; Wells, 1932). When the water temperature approximated body temperature, the heart rate increased and also the body temperature. Since most pools are 63° to 85° F, the normal response of a submerged individual would be a decrease in the heart rate (Wells, 1932). Tuttle and Templin (1942) substantiated this decrease by submerging 100 men in pool temperature water. The decrease in heart rate varied directly with the resting pulse rate. Seven men had abnormal responses which were attributed to fright.

Current research (Gandevia, McCloskey, & Potter, 1978; Dueker, 1975) reinforced the previously discussed bradycardia reflex. Craig (1980) indicated that younger subjects tended to have a greater bradycardia response than adults. He also found no difference in the reflex under the surface or submerged 15 or 23 meters.

Bradycardia can be important to the sport diver, both in training and open water dives. Since most training is in a pool environment, the novice diver should experience the decrease in heart rate. If not, the diver may need extra attention and assurance from the instructor to reduce the fright level or other problems such as chilling which can arise during training. Open water is generally 88° F at most, so the diver, again, should experience the reflex.

<u>Pulmonary Ventilation</u>

Pulmonary ventilation seldom results in limitations of maximum performance of land activities at sea level (Faulkner, 1968). However, ventilation often becomes inadequate while swimming and scuba diving even at moderate workloads because the vital capacity of the diver is reduced. This reduction is caused by hydrostatis pressure which impedes the respiratory muscles and displaces blood into the thorax. With increased depth while breathing surface air, the vital capacity decreases and becomes nonexistent below a depth of 50 cm (Faulkner, 1968). In other words, the subject is unable to breathe. Thus, snorkels for the skin diver are designed to be shorter than 50 cm.

Agnostini, Gurtner, Torri, & Rahn (1965) had subjects sit in water with head exposed and reported a reduction of 11% in vital capacity. The same decrease was reported when the subjects submerged to -20.5 cm. Song, Kang, Kang, & Hong (1963) also studied vital capacity, but with "ama" divers. Ama are women in Japan or Korea who free-dive for pearls. These women have been diving for centuries, and were found to have a greater vital capacity than a control group. The greater capacity was due to their higher inspiratory capacity. The ama also had a lower residual volume to total lung capacity ratio. The invesitgators suggested that the differences were attributed to long-term adaptions due to daily diving. This tendency no doubt is explained partially by increased work of breathing higher density gases at depth. Also, many divers seek to have an adaptive phenomenon which decreases their respiratory response to CO_2.

A scuba diver, breathing compressed air, has the most common disorder of the pulmonary system--simple insufficiency of alveolar ventilation. This disorder results in alveolar and arterial carbon dioxide pressure elevations (Duffner & Lanphier, 1960; Lanphier, 1975; Schaeffer, 1975). Thus, coordination and extra work required in inspiration caused by the increased water pressure make the untrained swimmer or diver more aware of breathing. Untrained swimmers and divers also experience a sensation of working close to maximum capacity (Faulkner, 1968).

At a given level of oxygen consumption and carbon dioxide production in underwater work, pulmonary ventilation is generally lower than in other forms of exertion (Duffner & Lanphier, 1960). Greenbaum (1960) compared underwater swimmers' and laboratory personnel's respiratory responses to oxygen. He found that the underwater swimmers had lower ventilation equivalents which suggested they breathed more efficiently than the lab personnel.

The respiratory exchange ratio (R) is also dependent on pulmonary ventilation. The lower R which is obtained during swimming indicates hypoventilation while an elevated R indicates hyperventilation (Schaeffer, 1979). The performer in air generally overbreathes during maximum work whereas a swimmer's ventilation is minimized during exercise. The swimmer's hypoventilation and lower R may be of significance because of carbon dioxide retention.

Aerobic Capacity

Since every individual has an upper limit to oxygen uptake, maximal aerobic capacity has been a good index to use in assessing an individual's cardiovascular and respiratory fitness level. The male diver of average size and reasonable fitness has a $\dot{V}O_{2max}$ of at least 3.0 liters per minute (Lanphier, 1975). Values as high as 6 liters per minute have been reported in cross-country skiers, but this value is rare (Hanson, 1973; Wilmore & Haskell, 1972).

Metabolic and respiratory studies have been conducted on the runner as well as the swimmer. Caution must be taken when there is a transfer of data between the two (Duffner & Lanphier, 1960; Egstrom, 1982). Duffner and Lanphier (1960) also stated that energy expenditure may be equal but what else will be equal? Holmer, Ludin, and Eriksson (1974) and Astrand and Rodahl (1977) believed that cardiorespiratory responses in swimming may be different due to ventilation restriction, temperature, and external pressure increases which have been discussed. They believed that a reduced muscle mass and horizontal position could contribute to these differences. Nygaard and Nielsen (1978) also attributed the $\dot{V}O_2$ differences to the oxidative capacities of the muscles used during running and swimming.

$\dot{V}O_{2max}$ was higher in running than swimming (Astrand & Rodahl, 1977; Bonen, Wilson, Yarkony, & Belcastro, 1980; Carroll, 1970; McArdle, Magel, Lesmes & Pechar, 1976). However, $\dot{V}O_2$ at a submaximal swimming speed has been found to depend on the subject's degree of training, body dimensions, technique, and style (Holmer, 1974). Astrand and Rodahl (1977) reported that trained swimmers had a 6 to 7% lower $\dot{V}O_{2max}$ while untrained swimmers were 20% lower than their $\dot{V}O_{2max}$.

Female sport divers, as a group, have not had maximal aerobic capacity assessed. However, women between the ages of 20 and 29 have been reported to have a mean $\dot{V}O_{2max}$ ($l \cdot min^{-1}$) value of 1.95 $\pm$ 0.37, $\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) of 35.7 $\pm$ 1.2 and heart rate ($b \cdot min^{-1}$) of 195 $\pm$ 8 (Shephard, 1982). Another study (Saltin & Astrand, 1967) of women found that the less active group had a $\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) lower than 40 while highly trained swimmers, runners, and cross-country skiers had $\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) greater than 55.

Oxygen consumption has been measured during scuba diving by using either closed-circuit or open-circuit scuba units. The closed-circuit rebreathing system has a device known as a counterlung. This counterlung is a carbon dioxide absorbent and a source of oxygen. The oxygen is usually stored in a cylinder at high pressure. The $\dot{V}O_2$ of the diver may be determined by measuring the drop in pressure in the cylinder over a specified amount of time. The majority of metabolic research has been done by using this method on naval personnel (Donald & Davidson, 1954; Goff & Bartlett, 1957; Goff, Brubach, & Specht, 1957; Goff, Frassetto & Specht, 1956; Miller, Wangensteen, & Lanphier, 1971; Specht, Goff, Brubach, & Bartlett, 1957).

Donald and Davidson (1954) conducted oxygen consumption studies by the pressure drop method. The subjects walked slowly underwater and walked at a maximum rate on a muddy bottom. The average $\dot{V}O_2$ ($l \cdot min^{-1}$) values ranged from 0.6 to 1.77, respectively. Their results of swimming on scuba, although using a limited number of subjects, reported an average $\dot{V}O_2$ ($l \cdot min^{-1}$) of 2.17 at speeds from 0.8 to 1.0 knots and 3.35 at 1.0 to 1.4 knots. The range of individual variations in the subjects was large.

Open-circuit scuba systems have been utilized most extensively by the sport diving population. Only a few metabolic studies have been conducted with this particular system. Foley, Billings, and Huie (1967) were the first to directly measure $\dot{V}O_2$ underwater from an open-circuit scuba system. The subjects swam for 20 minutes during which time air was collected. Only individual data were reported. The equipment was designed to draw a sample of each expired breath into a low pressure storage tank for later analysis. Analysis was conducted through a tube in which a valve collapsed during inhalation, sealing off the tube. The $\dot{V}O_2$ ($l \cdot min^{-1}$) values obtained ranged from 1.14 to 2.07 for swimming speeds varying from 1.73 km/hr (1.08 mphy) to 2.45 km/hr (1.52 mph).

Another study, (Russell, 1971) conducted on male sport divers in open water, utilized an adaptation of the Foley et al. (1967) technique. Physiological data were collected at three different atmospheres at rest and during moderate exercise. $\dot{V}O_2$ ($l \cdot min^{-1}$) increased significantly in both situations as pressure was increased.

Carroll (1970) adapted a flow control valve similar to the one previously described. He did this in order to collect expired gases directly underwater on open circuit scuba. The gases were collected in bags instead of into a low pressure tank. He obtained mean $\dot{V}O_{2max}$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) values for scuba diving of 2.98 and 37.9, respectively and free swimming, underwater of 3.19 and 40.8, respectively for male sport divers. He also suggested that an estimation of the limit of a sustained working capacity for the average underwater swimmer would require a $\dot{V}O_2$ of 2.23 $l \cdot min^{-1}$ (70% of 3.19 $l \cdot min^{-1}$).

Wittlieff (1976) devised another method of collecting expired air from an open circuit system by positioning the mouthpiece of a two-hose regulator lower than the regulator hosing with the exhaust hose lower than the mouthpiece. This positioning prevented any free flow of air from the tank. Wittlieff determined the mean volumetric gas usage of divers in three different water temperatures in order to validate current air consumption tables.

Temperature

$\dot{V}O_2$ can be affected by environmental temperature whether in water or air. In fact, temperature has been found to be important in standardizing experimental conditions. Taylor, Buskirk, and Herschel (1955) and Buskirk and Taylor (1957) have suggested a room temperature of 78 ± 4° F (25.5°C). No ideal temperature has been cited for testing conducted in swimming pools or open water. Several studies, however, have studied the effects of different water temperatures upon $\dot{V}O_2$.

Costill (1965) studied the effects of three different water temperatures (64°, 77°, and 90°F) on three minutes of maximal exercise. He reported a uniform energy expenditure was required to perform the maximal exercise. The subjects performed a flutter kick against a swimming ergometer. McArdle et al. (1981) stated that significant increases in energy cost would not result within a 28-30°C (82-86°F) range. Craig and Dvorak (1968) in addition, found that the $\dot{V}O_2$ was higher at 24°C than if the same work was performed in warmer water. This difference was attributed to hemodynamic changes.

Sport divers must concern themselves with the temperature of the water which can vary from near 30°C to 0°C. Exposure suits and body composition can play a very important part in the diver's comfort. Although the diver's regular and voluntary exposure to the water seldom produces hypothermia, one can get uncomfortably cold and sometimes dangererously so (Webb, 1975). Since the heat conductance of water is 25% greater than that of air (Holmer, Stein, Saltin, Ekblom, & Astrand, 1963), a sport diver can suffer severe heat loss without noticing the change in body temperature. The diver also might not be aware of this heat loss which can, indeed, be dangerous (Dueker, 1981).

A diver has to maintain a rectal temperature of 35°C as a low limit or serious problems from hypothermia will begin (Wells, 1975). Several studies have substantiated this limit. Kang et al. (1965) discovered that the Korean ama leave the water when they feel that they must. This departure occurs when their rectal temperature is 35°C. Another study (Pugh & Edholm, 1955) had a subject who was incapacitated when his rectal temperature had fallen to 34°C. Beckman and Reeves (1966) exposed 24 nude men to a water temperature of 24°C. More than half of the men had to stop their exposure because of cramps and spasms in large muscle groups. Two had stopped when their rectal temperatures reached 35°C. All the reasons for the subjects ceasing the study were related to excessive body heat loss.

Craig and Dvorak (1968) conducted two similar experiments in 24°C water, one in which the subjects were nude and another in which a neoprene wet suit was worn. One particular subject had a higher heat loss with the wet suit, but was very comfortable and did not shiver at all after an hour's exposure. The subjects, during the 60 minutes' nude exposure, had an average skin temperature fall of 7.9°C and a heat loss of 183 kcal.

A mild adaptation to cold water can be developed by a human as seen in the studies of the Koreans (Kang et al., 1965) and by Hong (1965). In comparing the diving women to nondiving Korean women, the diving women had a lower thermal conductance in a certain water temperature than the nondiving women. This lower conductance occurred even though the subcutaneous fat thickness in both groups was not different. In 1972, Hanna and Hong also observed scuba divers who had lower critical water temperatures when compared to control subjects, even with the same skinfold thickness.

Body fat may be expressed as fat weight, essential and nonessential, and may be assessed indirectly by methods such as underwater weighing and skinfold measures. Generally, women average more body fat than men (McArdle et al., 1981). Wilmore and Behnke (1970) reported an average of 25.7% fat for healthy normal college women, while 29.7% was reported by Pollock, Laguridge, Coleman, Linnerud, and Jackson (1975) for an older group, aged 33-50 years.

A layer of subcutaneous fat can be of benefit to the diver since the thermal conductivity of fat is about one-half that of muscle (Wells, 1975). Pugh and Edholm (1955) studied a professional channel swimmer who was in 16°C water about 6 hours in a 10-mile race. A nonprofessional swimmer who was tall and thin swam in the same water and was in trouble after an hour. He had a drop in rectal temperature and had to be helped from the water. The subcutaneous fat layer was the obvious difference. In addition, the professional swimmer was trained to maintain a high level of metabolic heat production for hours. To emphasize these results, both of these men were studied again in a water bath of 16°C. The thin man lost heat faster than the fatter man again.

Hanna and Hong (1972) also found that the thicker the subcutaneous fat, the lower the critical water temperature. This critical water temperature is the lowest water temperature one can tolerate without shivering after an exposure of three hours. Keatinge (1969), in a rectal temperature study of 10 men, found that men with thicker skinfolds had a lesser fall in the rectal temperature. Also, Sloan and Keatinge (1973) studied boys and girls in training for competitive swimming. They found that the greater the skinfold thickness, the less the fall in body temperature.

Sport divers must be aware of the temperature of the water in which they are diving and must use adequate protection. Many divers, such as the ama and commercial divers know when to stop. They pay attention to symptoms, such as shivering and a decrease in performance, which help them avoid developing hypothermia.

<u>Circulatory Responses</u>

Water immersion tends to affect the human body since the body becomes weightless (Epstein, Pins, Arrington, DeNunzio, & Engstrom, 1975). Redistribution of blood volume, cardiac output ($\dot{Q}$), stroke volume (SV), central venous pressure, and peripheral vasconstriction are all effected when one is submerged. In a standing position the heart rate is usually increased with a reduced SV because of gravitational resistance. A steady state of exercise will cause an increase in SV. This increase is directly proportional to oxygen consumption and work rate.

Blood volume is redistributed to the heart and intrathoracic vessels during water immersion (Epstein et al., 1979). This redistribution causes an increase in central venous pressure, peripheral vasconstriction, SV, and $\dot{Q}$ (Arborelius, Balldin, Lija, & Lundgren, 1972; Echt, Lange, & Gauer, 1974; Craig & Dvorak, 1968; Lange, Lange, Echt, & Gauer, 1974).

During a head-out immersion study Arborelius et al. (1972), a $\dot{Q}$ increase of 32% was produced with little change in heart rate. Central blood volume increased 0.7 liters. Studies in which the subjects were in a horizontal position show that $\dot{Q}$ was maintained at similar levels of energy expenditure (McArdle et al., 1976; Craig & Dvorak, 1968). The decrease in heart rate was compensated by the increase in the SV of the heart. The SV was also higher because of the increased central blood volume and venous return.

A sport diver has fins for propulsion through the water and rarely uses the arms; moreover, a minimal muscle mass is needed to support the body in water as opposed to the runner on land. Since fewer muscle groups are at work and therefore thermoregulatory demands for skin circulation are lower, the increase in peripheral resistance could be the effect of a reduced vascular bed. Some investigations have shown that a modified circulatory response was a result of thermoregulatory demands (Nadel, Holmer, Bergh, Astrand, & Stolwijk, 1974; Saltin, 1973). If the air and water temperature were the same, the circulatory responses were within the same range (Craig & Dvorak, 1968), except in 35°C when the subjects suffered heat exhaustion.

Summary

The two general dimensions discussed, (a) descent and ascent and (b) depth and bottom time, are very important to the sport diver. If the diver ascends too quickly, dives too deeply, or remains at depth too long, then problems can result. The diver must be aware of the water temperature in the diving environment and of personal body composition to alleviate exposure problems. The awareness of these conditions enables the diver to gain greater proficiency and to minimize potential problems.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to evaluate certified female sport divers on selected physiological variables obtained during treadmill and underwater workbouts. This chapter describes methods and procedures which were utilized in the collection and analysis of the data. Measures of body composition, maximal aerobic capacity, submaximal scuba and treadmill performance were obtained on 17 certified female sport divers between the ages of 18 and 40 during the spring of 1982. This chapter will recount information about the subjects, specific data collection procedures for the various tests, and data analyses.

Selection of Subjects

The study was designed to include female scuba divers who had at least an open water certification from a nationally recognized scuba agency. The divers were all volunteers recruited by personal phone calls, letters, referrals by diving instructors, Piedmont Diving and Recreation meetings, and a mailing by the Professional Association of Diving Instructors (see Appendix A). Seventeen subjects volunteered to participate in the testing.

Each subject attended and completed five separate sessions which were necessary for obtaining the data. The laboratory and underwater procedures were explained to each subject prior to the actual data collection. This explanation helped to minimize anxiety levels and maximize data reliability. During this session, each subject read and completed an informed consent form, self-medical-history form, and an information sheet (see Appendix B).

The 17 subjects ranged in age from 18 to 40 with a mean age of 30. Their mean height was 65.9 inches (167.39 cm) and mean weight was 127.8 pounds (58.1 kg). Twelve were involved in some type of exercise program varying from running to weight lifting. Ten of the subjects worked in a sedentary or inactive occupation such as a secretary. The others held active positions, such as a swimming teacher. None of the subjects had serious medical problems. Fourteen subjects were non-cigarette smokers at the time of the testing.

The data for this study were obtained within a four-week period. The testing of 10 subjects was completed during a one-week period at the beginning of May 1982. The remainder of the testing was conducted two weeks later during another one-week period. The general testing schedule for the subjects is displayed in Table 1.

Several subjects had more than one type and level of certification, which is not unusual among a diving population. One subject had been certified since 1976, four had been certified in 1980, another four in 1981 while eight had been certified within the last year.

Table 1

General Testing Schedule for Female Divers

Day	Test	Test Condition
1	Informed consent Information sheet Self-medical history	
2	Underwater weighing	4-hour fast
3	Maximal aerobic capacity	No strenuous activ-vity 4-hour fast
4	Underwater scuba	2-hour fast
5	Submaximal treadmill	No strenuous activ-ity 2-hour fast

The type of certification agency, as shown in Table 2, indicated that the majority of the divers (82%) were certified by PADI, which is the largest agency. The remainder were certified by the other agencies. The diver's highest level of certification is also shown in Table 2. These levels were only in open water, advanced open water, and instructor. No divers were tested whose highest level was divemaster or assistant instructor (Table 2).

The total number of open water dives for each subject, displayed in Table 3, indicated an immense difference in the instructors and the other divers. The three instructors had logged over 300 dives each, while the others ranged between

Table 2

Type of Scuba Certification

Agency	Number	Certification	Number
PADI	14	Open Water	8
NASDS	1	Advanced Open Water	6
MAUI	1	Dive Master	0
SSI	4	Assistant Instructor	0
YMCA	2	Instructor	3
	22*		17

* Five of the subjects had dual certifications

0 and 75. The median, 35 dives, is more representative of the data than the mean for the total number of dives because of the degree of skewness of the data. Within the past year, five of the subjects had not done any open water diving. In fact, two of the five had not dived since certification. To the other extreme, 2 of the 3 subjects who were instructors had made 50 dives and the other instructor had made 140. Again, the median, 15 dives, must be stated instead of the mean because of the degree of skewness of the data.

Specific Data Collection Procedures

Pilot Testing

Prior to any actual data collection, an extensive pilot study was conducted. This pilot was directed toward the underwater scuba workbout. Since expired air was to be collected from the diver, a system had to be designed to

Table 3

Subject Dive Experience

Total Dives Since Certification		Dives in Last Year	
Number of Dives	Subjects	Number of Dives	Subjects
0	2	0	5
5	1	5	1
7	2	6	1
10	1	7	1
20	1	15	1
25	1	22	1
30	1	24	1
35	2	32	1
38	1	35	1
50	1	38	1
75	1	50	2*
300	1*	140	1*
400	1*		17
	17		

* Instructors

stop the air from flowing directly from the scuba tank to the collection air bag through the regulator. This air flow is called free-flow.

The investigator first attempted to design a system in which the air would be collected underwater. The diver was stationary and the exhaled air flowed from the regulator through a hose into the bag. Two problems resulted, free-flow and lift of the collection bag as it filled.

Carroll's study (1970) had a flow control device designed to cease the free-flow of a scuba diver. This design was taken to Duke University's F. G. Hall's Laboratory and shown to Dr. Arthur Dicks, who adapted this design. The investigator had this design built; it worked efficiently for two to three minutes underwater, and then the rubber tubular valve burst. The parts were remachined, filed, and the same problem existed. Another valve was developed (see Figure 1). The detailed description is included in method of gas collection discussed later in this chapter. Still, the rubber tubular valve would not endure the entire workbout. A thin gummed rubber tubing was also tried, but would not completely close, so the free-flow problem still existed. After considerable experimenting, a fiberglass screening was placed on the exhalation end of the valve and all problems were solved for the gas collection.

Introduction Session

The investigator met with the subjects on the UNC-G campus to acquaint each with the purpose and procedures of the

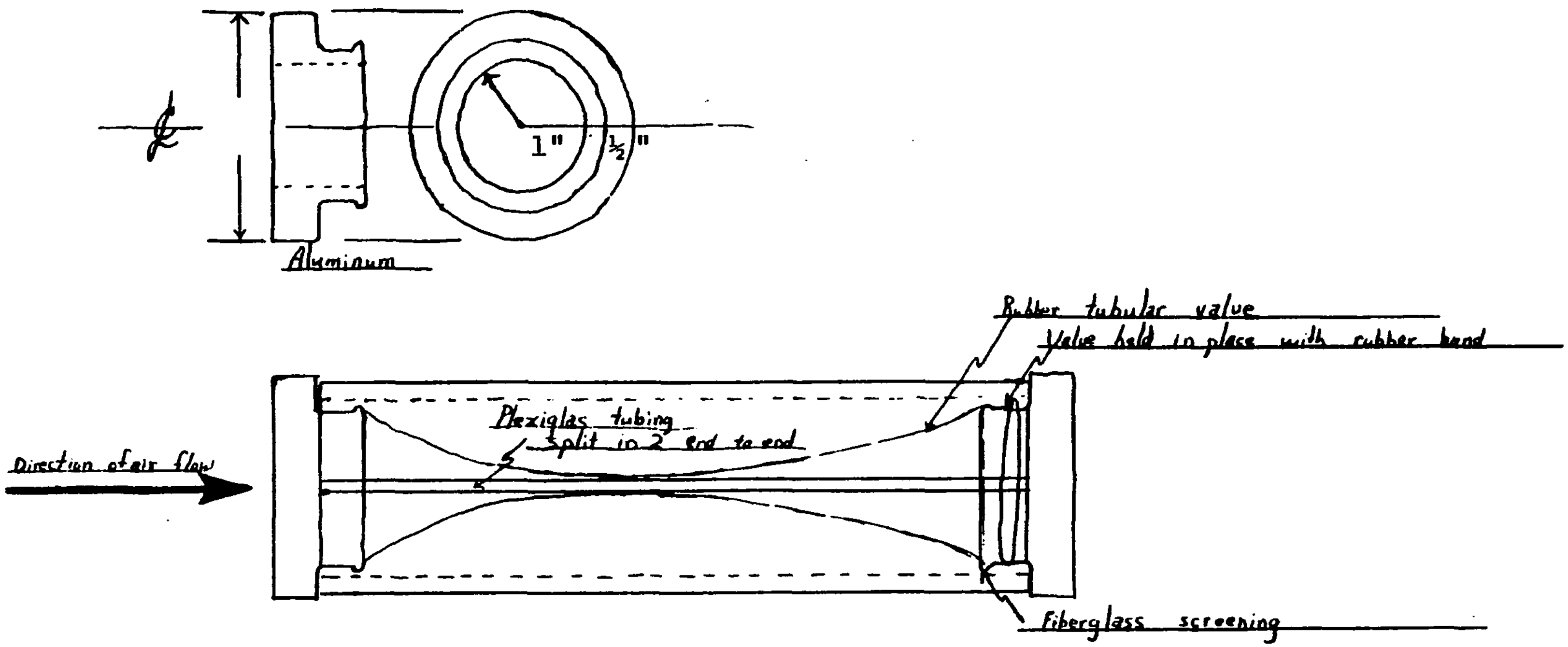


Figure 1. Scale drawing of redesigned flow control valve.

study. Consent, information, and self-medical history forms were completed and a testing schedule established (see Appendix B). A five-page testing information packet, which included a description of each testing session, was also distributed (see Appendix B). During this session, the subjects took a tour of the Rosenthal Human Performance Laboratory and swimming pool. All the testing equipment was demonstrated and questions were answered by the investigator.

Underwater Weighing Session

Body composition (% fat) was determined by underwater weighing in the laboratory tank at the Home Economics Laboratory. The procedure used was similar to that described by Wilmore and Behnke (1970). The subjects refrained from eating for four hours and smoking for one hour prior to testing. Upon reporting to the laboratory, the subject was sent to the bathroom to urinate and expel, as much as possible, any gas or fecal material from the bowels. Each subject was instructed to put on a two-piece swimsuit to minimize air trapped in the suit.

Wearing only the bathing suit, the subject was weighed using Detector Scales to the nearest one-fourth pound. The room temperature was recorded in degrees Centigrade. The subject, with a noseclip attached, then sat on a stool beside a spirometer. A couple of breaths were taken prior to a maximal inhalation. After the maximal inhalation, the subject inserted the mouthpiece in the mouth and then exhaled maximally into the spirometer. While exhaling, the subject bent forward to force as much air as possible out of the lower parts of the lungs. This position simulated the underwater weighing position. The measurement was recorded in liters by the investigator. The procedure was repeated two more times. The estimated residual volume was computed from the highest vital capacity, corrected to BTPS. The nose clip was removed and the subject prepared to enter the underwater weighing tank. The investigator measured the water temperature in the tank in degrees Centigrade and recorded it.

After the subject climbed into the underwater weighing tank, she sat on a swing. A 1.36 kg weight on a weight belt, worn on the waist, was used by some subjects to enable them to remain submerged more easily. The subject was instructed to place the weight belt, if used, on the swing and to submerge up to the neck without touching the swing. The tare weight was determined at this time by reading the Chatillon. The weight belt was worn then, if necessary, by the subject who sat on the swing. To minimize the possibilities of having air trapped in the suit, the subject ran her hands over the suit and pulled it out from the body to replace any air with water. She then submerged completely.

The underwater weighing procedure was practiced. The subject was instructed to bend forward at the waist until the head became completely submerged and the feet did not touch the bottom. The subject forcefully exhaled as much air from the lungs as possible and held the air out for as long as possible. Most subjects were able to count slowly to seven before coming up for air. The scale reading had considerable fluctuation, but tended to stabilize within a relatively narrow range the longer the subject remained submerged.

Feedback was given to the subject by the investigator concerning stillness underwater and the length of time the breath was held. The underwater weighing procedure was practiced four or five times until the subject performed sufficiently well to obtain a valid underwater weight. Then, the subject was weighted four or five more times to insure an accurate reading. The highest, consistent reading was recorded.

Maximal Aerobic Capacity Session

Each subject wore shorts, t-shirt, and tennis shoes for the treadmill test, which was administered in the Rosenthal Human Performance Laboratory. After height and weight were indicated on Detecto scales and recorded, two electrodes were attached for the determination of heart rate by a Narco-Biosystems radiotelemetry unit (see Appendix C). The electrodes were placed on the sternum and just under the left breast at the midclavicular line. The head gear, Daniel's one-way breathing valve, and nose clip were adjusted for comfort.

Generally, two assistants were in the lab to assist the investigator. They had previous experience in their duties and also went through a review of the procedures before the actual testing session began. One assistant operated the treadmill and the other the heart rate recorder while the investigator collected the expired air.

The Bruce protocol was used for the maximal treadmill test (see Appendix C). The protocol was continuous, multistage, speed-, and grade-incremented. After a 5-minute warm-up period walking 3 miles per hour at a 5% grade, the subject rested for 2 minutes, then proceeded with the test.

The subject walked/ran as many stages as possible until maximal volitional fatigue. A plateau of $\dot{V}O_2$ ($l \cdot min^{-1}$), a heart rate within the estimated maximal for age, or increase in $\dot{V}O_2$ ($l \cdot min^{-1}$) of less than 150 ml, were the criteria for accepting the value as maximal. Measures of heart rate, ventilation, temperature of expired gas, and percentages of O_2 and CO_2 in the expired gas were obtained the last two minutes of the test except where mechanical dysfunctions occurred (see Appendix C).

The gas samples were measured for percentage of O_2 and CO_2 using Beckman OM-11 and LB-2 electronic gas analyzers, respectively. The analyzers were calibrated with gases of known concentrations. Volume of expired air was measured by a Parkinson-Cowan CD-4 gas meter. The gas meter had been previously calibrated using a 120-liter Tissot. Temperature of the expired air was determined by a thermistor inserted in the inlet port of the dry gas meter. Computations of O_2 uptake and CO_2 production were made according to the method described by Consolazio, Johnson, and Pecora (1963). The highest rate of O_2 consumption obtained during the treadmill test was accepted as the maximal oxygen uptake provided other stated criteria were met.

Underwater Scuba Workbout Session

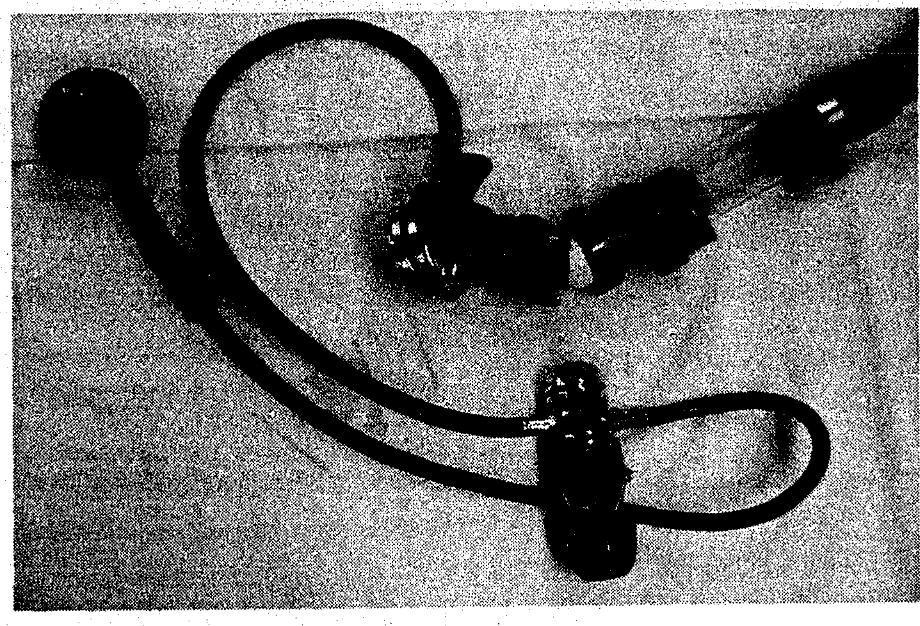
Method of gas collection. The major purpose of the underwater scuba workbout was to collect expired gases of the subjects while submerged. This gas collection, when analyzed, determined energy expenditure of this submaximal workbout.

To cease the free-flow problem, which occurred when corrugated tubing was connected from the regulator to the surface, a flow control valve was adapted from an earlier study of scuba divers (Carroll, 1970). The flow control valve opened when the subject exhaled because the expired gas pressure was greater than the surrounding water pressure. The operation of this valve is shown graphically in Figure 1.

The second-stage exhaust port of a U.S. Divers Conshelf XIV single-hose regulator was removed and replaced with a plastic hose connector. A 450 plastic elbow was inserted to allow the flow control valve to be mounted adjacent to and below the diaphragm of the demand valve in the second stage. The location was critical because a differential in water pressure would again cause free-flow. Another plastic hose connector was placed on the elbow. Next, the flow control valve was attached.

The flow control valve had six components: two metal hose connectors, one rubber tubular valve, two parts of plexiglass tube covering, and fiberglass screening (see Figure 2). The valve was assembled in the following manner. One metal hose connector was attached to the hose connector next to the 45 elbow on the regulator. The other metal hose connector was placed at the beginning of the eight foot section of corrugated tubing which led to the surface. Fiberglass screening was taped over the opening of this hose connector to prevent the rubber tubular valve (a Trojan condom) from bursting. The valve was placed between the two metal hose connectors and sealed with Shoe Goo (a commercially available sealant product). A rubber band also held each end of the valve on the hose connectors. A plexiglass covering protected the valve. To make the covering, a 1½-inch plexiglass tubing was split in two equal pieces. The rough edges were filed and two ½-inch inner diameter holes were drilled into each fiberglass side to allow an even distribution of water flow. The fiberglass covering was held together around the valve by metal hose clamps. The clamps allowed for stability of the valve and a quick way to change the valve if necessary.

All hose connections were coated with the rubber sealant to prevent water seepage into the valve and hose. Hose clamps secured each connection for extra protection. Black electrical



A. Regulator Parts
   1. First stage
   2. Second-stage mouthpiece
   3. Pressure guage

B. Flow Control Valve
   4. 45° elbow
   5. Hose connectors (not visible)
   6. Rubber tubular valve
   7. Plexiglass tube covering
   8. Fiberglass screening (not visible)

C. Hose leading to collection bags

Figure 2. Flow control valve and regulator system.

tape kept the excess of the clamps from protruding and scratching the diver and equipment during the bout.

Scuba workbout. The underwater scuba workbout was conducted in the Rosenthal Swimming Pool. Each subject wore a swimsuit. Her weight was taken on the same Detector scales was used in the previous session. Electrodes were attached to the subject similarly to the previous treadmill session except the leadline was 8 feet. This length allowed the elemetry unit to be held above the water when the subject submerged. The unit was enclosed in a plastic pill bottle.

Time was allowed for the subject to choose proper fitting fins. There was a selection of three sizes: small, medium, and large. The U.S. Diver's company in Santa Ana, California, provided full-foot Passport fins for the study. The same type of fins was used across subjects to help control for consistency in the subject's kick.

The regulator, bouyancy compensator, and flow control valve system had been assembled by the investigator previous to the actual testing session. The regulator was a Conshelf XIV single hose, two-stage regulator with a Farallon pressure guage attached. John Cater, proprietor of Scuba Shack in Greensboro, North Carolina, supplied the pressure guage and also the scuba tanks. Each subject used her own personal mask and the same U.S. Diver's scuba gear throughout the underwater testing.

The bouyancy compensator jacket, a Sea Otter II, and backpack, were also supplied by the U.S. Diver's Company.

The aluminum tanks were 80 cubic feet and filled to 3000 pounds per square inch prior to the testing session. The valve designed to prevent free-flow within the 8-foot air hose to the surface was attached so the subject did not have to worry about it interfering with the workbout.

The subject, after donning her fins and scuba equipment, placed on a nose clip, then her mask. Prior to swimming, the subject submerged and breathed through the regulator. By doing this, she acquainted herself with the noises of the flow control valve and the sensation of the exhaled air being released into a hose leading to the surface instead of into the water. If no problem arose, a swimming practice session of 2 minutes was made on the scuba equipment. The subject submerged to a depth of 2½ to 3 feet and checked herself to see if she were neutrally bouyant. If the subject was neutral, she proceeded; if not, she emerged, donned a weight belt, and added weights until she felt neutral.

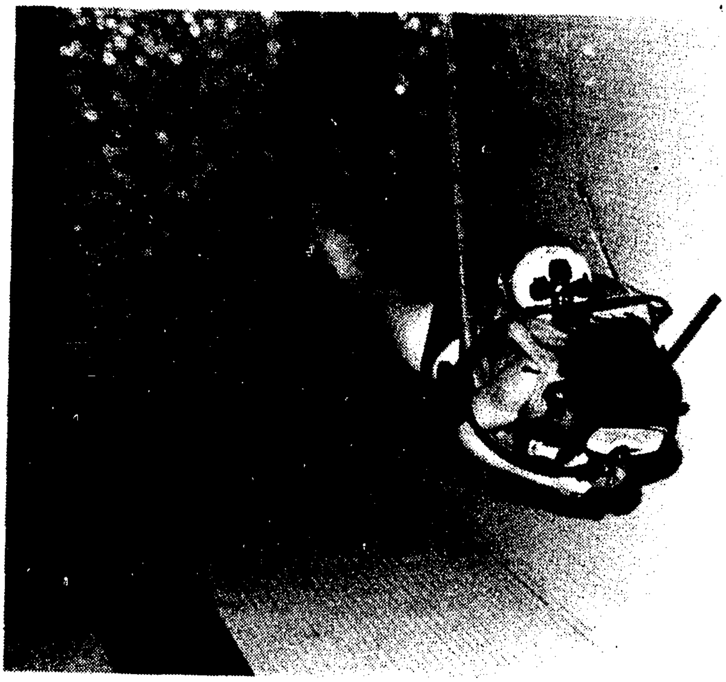
The swimming practice session was performed by the subject following a path indicated underwater in the pool. This path was made with bricks marked with arrows. The depth of the diver was checked by squares on the side of the pool. In addition, the investigator could tell by the depth of the exhalation hose in the water. The kick rate was projected by a metronome through an underwater speaker. This kick rate was 86 kicks (beats) per minute or 43 kicks per leg, approximately 1.363 miles per hour (2.1935 km/hour). As the subject swam, using only her kick as propulsion (no arm-stroke movement), the investigator walked along the side of the pool, checking depth and kick-cycle cadence.

After the practice session, feedback was given to the subject about depth and kick cycle. The actual testing then began. The subject swam for 6 minutes, at a depth of 2½ to 3 feet (see Figure 3). Air was collected in a metero-logical balloon the last 2 minutes of each workbout by the investigator and the heart rate was recorded the last 10 seconds of each minute on a Beckman Type R411 recorder from an EKG transmitted by radiotelemetry. A previously trained assistant operated the recorder and also monitored the time of the workbout.

At the end of 6 minutes, to signify the end of the bout, either the underwater speaker was turned off or a weight was tapped in the water on the side of the pool. While the investigator analyzed the expired gases in the Human Performance Laboratory, the subject had help removing the scuba gear and was instructed to sit out of the water to prevent chilling.

Approximately 10 minutes later, another bout was begun under the same conditions as the first to assure consistency. After completion of the second workbout, the subject had the electrodes removed, changed clothes, and was free to leave.

The values from the analysis of two gas samples were averaged and values utilized in the actual data analysis.



Flow control valve

Regulator

Telemetry wire

Gas collection hose

Figure 3. Scuba subject during data collection.

The two heart rate values from both workbouts were also averaged for use in the analysis.

Treadmill Test (Submaximal) Session

Submaximal testing was conducted in the Rosenthal Human Performance Laboratory at least 24 hours after the underwater workbout. The subject dressed similarly to the previous treadmill session.

The two underwater workbouts were averaged to determine the $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), except in three cases when only one value was available because of mechanical failure. The treadmill speed and grade were determined from the underwater workbout $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) using a graph of the energy cost of walking and running from Margaria, Cerretelli, Aghemo, and Sassi (1963) (see Appendix C). The treadmill speed was determined to elicit an energy expenditure comparable to that of the underwater workbout.

Initially, the subject's weight was recorded and electrodes attached. A brief warm-up period of 2 minutes, 0% grade, and 2½ mph on the treadmill was completed. The head gear, mouthpiece, and nose clip were then adjusted for comfort. The subjects walked on the treadmill for 6 minutes at the previously determined speed. Expired gases were collected in a meterological balloon the last 2 minutes of the bout and analyzed for O_2 and CO_2 as in the underwater workbout. The heart rate was recorded the last 10 seconds of each minute. The heart rate as determined during minute 5-6 was averaged and used in the analysis.

While the gases were being analyzed, the subject rested. Approximately 10 minutes later, the test was repeated. Upon completion, the subject rested while the gases were analyzed. The electrodes were then removed and she was allowed to leave. The results of both trials were averaged, except where mechanical difficulties prevented completion. In a couple of cases, the gas collection hose became disconnected during the gas collection time causing the loss of sample air.

Data Analysis

The Statistical Package for the Social Sciences (SPSS) was the computer program used to analyze the data. The data were analyzed as follows:

1. A condescriptive program was run to obtain the means, standard deviation, minimum, and maximum values for the variables.

2. A paired *t* test was performed to determine whether there were significant differences in heart rate, $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) and $\dot{V}O_2$ ($l \cdot min^{-1}$) for the two sessions of the underwater workbouts. If no significant differences were found between the two workbouts, the heart rate and $\dot{V}O_2$ measures on scuba were defined as the average of the two sessions. These averaged measures answered the primary question of the study which was: What were the aerobic capacity ($\dot{V}O_2$ $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate measures of the subjects while submerged on scuba?

3. A paired *t* test was performed to determine whether there were significant differences in heart rate, $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)

and $\dot{V}O_2$ ($l \cdot min^{-1}$) for the two submaximal treadmill workbouts. If no significant differences were found between the two workbouts, the heart rate and $\dot{V}O_2$ measures were defined as the average of the two sessions.

4. Using the average of the two underwater workbouts and the average of the two treadmill workbouts, a paired _t_ test was used to compare heart rate values for the underwater vs. treadmill workbouts. Similarly, underwater and treadmill $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) were compared with a paired _t_ test. These two paired _t_ tests addressed the question: were the HR values obtained during the underwater exercise bout significantly different from the HR values obtained during a comparable $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) workload on the treadmill?

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to evaluate certified female sport divers on selected physiological variables obtained during treadmill and underwater workbouts. The primary research question was : What were the $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate ($b \cdot min^{-1}$) values of the subjects while submerged on scuba?

Another question was also addressed: Were the heart rate values obtained during the underwater exercise significantly different from heart rate values obtained during a comparable workload on the treadmill? This chapter has been divided into sections: (a) Description of Sample, and (b) Underwater and Treadmill Workbouts.

Description of Sample

Measures of fat percentage and maximal aerobic capacity were evaluated prior to the underwater and submaximal treadmill workbouts for the 17 subjects. Descriptive data, including type and level of scuba certification, number of open water dives, exercise programs, type of job, age, height, and weight were included previously in Chapter III.

The physiological limitations of scuba diving, as previously discussed in Chapter II, did not affect the 17 subjects during the scuba workbout except for ascent. The subjects were submerged at a depth of 2½ to 3 feet. To avoid lung expansion problems, even at a shallow depth (Craig, 1981), they exhaled during the short ascent. This exhalation had been an important part of their certification classes. Since the depth was shallow and bottom time was only 12 minutes for the 2 bouts, nitrogen narcosis and the bends were nonexistent.

Fat percentage was assessed by underwater weighing. A mean of 25.13% with a standard deviation of 5.93 placed this group within the average group of adult women as cited by Wilmore and Behnke (1970). Yet, the subjects were lower in percentage of fat than the 29.7% reported by Pollock et al. (1975). These female subjects had a greater percentage of fat than their male counterparts (McArdle et al., 1981).

$\dot{V}O_{2max}$ was assessed by using the Bruce protocol. The values obtained were $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate ($b \cdot min^{-1}$), $\dot{V}CO_2$, and R (see Table 4). As expected for females, both of these $\dot{V}O_{2max}$ mean values were less than those reported for males (Lanphier, 1960). Yet, $\dot{V}O_{2max}$ ($l \cdot min^{-1}$) was within the range reported by Shepard (1982) for a younger group of women. The mean $\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) was also much lower in this study than other previous studies on divers (Carroll, 1970; Donald & Davidson, 1954). However, both of the studies were conducted with trained males. The $\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) of 33.35 would categorize the women as a sedentary group if compared to highly trained swimmers, runners, and cross country skiers (Saltin & Astrand, 1967)

Table 4

Summary of Physiological Data

for Subjects (N = 17)

	Mean	Standard Deviation	Minimum	Maximum
Age (yr)	30.7	4.81	23	40
Weight (kg)	58.14	6.06	47.7	75.5
Height (cm)	167.4	5.10	158.75	177.8
% Fat	25.13	5.93	14.3	35.1
$\dot{V}O_{2max}$*				
($l \cdot min^{-1}$)	2.02	0.37	1.39	2.71
($ml \cdot kg^{-1} \cdot min^{-1}$)	35.35	5.52	29.09	46.72
HR ($b \cdot min^{-1}$)	185.57	7.28	170.0	196.0
$\dot{V}CO_2$ ($l \cdot min^{-1}$)	2.42	0.56	1.20	3.45
R	1.18	0.08	1.02	1.29

*only 14 subjects reached max.

and when compared to a normal population. The mean HR_{max} ($b \cdot min^{-1}$) was 185.57 with a standard deviation of 7.28. This value is within the estimated heart rate max for the subject's age (Astrand, 1977).

<u>Underwater and Treadmill Workbouts</u>

Evaluating the $\dot{V}O_2$ and heart rate measures of the subjects while submerged on scuba was the prime question of the present research. A paired *t* test was used to compare the values obtained between the two underwater workbout trials on each of the heart rate and $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) measures. No significant differences were found between the two trials for any of the three variables. Thus, the results of the two trials were averaged for each person for each variable, except in one case where the subject was unable to complete the second bout. The $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate ($b \cdot min^{-1}$) values for both scuba workbouts are reported in Table 5.

In comparing the submaximal $\dot{V}O_2$ values of the scuba workbout to the $\dot{V}O_{2max}$ test, the subject's scuba values were approximately an average of 67.1% and 69.9% of their $\dot{V}O_{2max}$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$), respectively. Untrained swimmers have been reported to have a $\dot{V}O_{2max}$ 20% lower than their maximal value on land (Astrand & Rodahl, 1977). Because the divers in this study averaged 30% below their $\dot{V}O_{2max}$ during their underwater workbout, the scuba workbouts were thought to be submaximal. Caution, however, must be used when a transfer of data occurs between running and swimming (Duffner &

Table 5

Means, Standard Deviations, and *t*-Statistics of Physiological Variables of the Two Underwater Scuba Workbouts (*N* = 16)

Variable	Workbout	Mean	*SD*	Mean Difference	*t*-Statistic	*p*-Value
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	1	20.55	4.62	-1.36	-1.66	.118
	2	21.92	4.88			
	$\bar{X}$*	21.24	4.46			
$\dot{V}O_2$ ($l \cdot min^{-1}$)	1	1.20	0.26	-0.075	-1.65	.120
	2	1.28	0.26			
	$\bar{X}$*	1.24	0.24			
HR ($b \cdot min^{-1}$)	1	137.2	26.2	-0.25	-0.13	.895
	2	137.4	26.7			
	$\bar{X}$*	137.3	26.2			

*average of both workbouts

Lanphier, 1960; Egstrom, 1982). Cardiorespiratory responses in swimming and diving may be different than running due to ventilation restriction, temperature differences, body position differences, and external pressure increases (Astrand & Rodahl, 1977).

Each subject swam a total of 720 feet (219.5 m) $\pm$ 9 feet in 6 minutes at a kick rate of 86 kicks per minute. This pace resulted in an average speed of approximately 1.36 mph (2.19 km/hr or 1.18 knots per hour). Using these speed approximations, the investigator was able to compare the results of the scuba workbout to several other scuba studies.

In one of the earlier scuba studies, Donald and Davidson (1954) reported an average $\dot{V}O_2$ ($l \cdot min^{-1}$) of 3.35 for males swimming at speeds between 1.0 and 1.4 knots (1.15 and 1.46 mph, respectively). They found that a top speed (1.2 knots) was exhausting for male subjects of any physical condition during the 15 minute bout. Their reported $\dot{V}O_2$ $l \cdot min^{-1}$ was higher than the $\dot{V}O_2$ $l \cdot min^{-1}$ reported in this study due to longer swimming bouts and higher work intensity. In addition, a higher $\dot{V}O_2$ would be expected in males compared to females because of body size and body composition differences.

Lanphier and Dwyer (1954) in a follow-up study reported a large range in individual $\dot{V}O_2$ ($l \cdot min^{-1}$) values with speed. The mean values, however, formed a smooth increasing curve as the swimming speed increased. At a submaximal speed these variations in $\dot{V}O_2$ ($l \cdot min^{-1}$) have been found to depend on a number of factors including the subject's degree of training, body dimensions, individual technique, and type of swimming stroke (Holmer et al., 1974). $\dot{V}O_2$'s were quite varied in the scuba workbout of this study (Appendix E). The $\dot{V}O_2$ $l \cdot min^{-1}$ of 1.24 reported in this study for 6 minutes of swimming at 1.36 mph was similar to the $\dot{V}O_2$ of 1.24 $l \cdot min^{-1}$ reported by Foley et al. (1967) for 20 minutes of swimming at speeds which varied from 1.08 to 1.52 mph. However, the length of the bout in this study was not as long as Foley et al.

Information on $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate were used to address the question, were the heart rate values obtained during the underwater exercise bout significantly different from the heart rate values obtained during a comparable workload on the treadmill. Before the question was answered, several procedures were completed.

Just as the two trials were performed underwater, the same procedure was used for the submaximal treadmill workbout. A paired t test was used to compare the values obtained during the two bouts on each of the values for heart rate and $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$). No significant differences were found between the two trials for any of the three variables (see Table 6). Consequently, the results were averaged for each person, except for three subjects' samples in which mechanical failure prevented one sample from being collected.

Table 6

Means, Standard Deviations, and p-Values of Physiological Variables of the Two Submaximal Treadmill Workbouts

(N = 15)

Variable	Workbout	Mean	SD	Mean Difference	t-Statistic	p-Value
$\dot{V}O_2$ ($l \cdot min^{-1}$)	1	1.49	0.42	-0.110	-1.15	.268
	2	1.60	0.43			
	$\bar{X}$*	1.55	0.38			
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	1	25.38	6.94	-1.972	-1.19	.255
	2	27.35	7.22			
	$\bar{X}$*	26.36	6.35			
HR ($b \cdot min^{-1}$)	1	160.67	27.17	-1.800	-1.37	.191
	2	162.47	27.72			
	$\bar{X}$*	161.57	27.33			

*average for both workbouts

Another paired t test was used to compare heart rate values (Table 7) of the underwater and submaximal treadmill workbout. Heart rate was found to be significantly lower in the underwater workbouts with a mean of 140.1 versus a mean of 159.6 for the submaximal treadmill.

An additional paired t test was used to compare the underwater and treadmill $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$). Significant differences were found in $\dot{V}O_2$ $l \cdot min^{-1}$ with a mean of 1.29 for the underwater workbout versus a mean of 1.53 for the submaximal treadmill workbout. Similarly, a significant difference was found between $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) for the underwater workbout (mean of 22.15) and the submaximal treadmill workbout (mean of 25.95) (see Table 7). With the data collected in this experiment it was not possible to statistically differentiate whether the heart rate differences found were due to noncomparable $\dot{V}O_2$ ($l \cdot min^{-1}$) levels and thus noncomparable work intensity or were due to cardiorespiratory differences between water and land work. Since the $\dot{V}O_2$s were significantly different and could not be considered equal in terms of energy expenditure in this study, the observed heart rate differences must be cautiously interpreted. Re-emphasis of the caution of the transfer of data between swimming and running must also be stated. A lower heart rate is generally expected underwater and $\dot{V}O_2$s are expected to be lower in water work than running on a treadmill (Holmer et al., 1974; Carroll, 1970; McArdle et al., 1976; & Bonen et al., 1980).

Table 7

Means and Standard Deviations of $\dot{V}O_2$ ($l \cdot min^{-1}$), $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), and Heart rate ($b \cdot min^{-1}$) of Underwater and Submaximal Treadmill Workbouts (*N* = 14)

Variable	Mean	*SD*	Mean Difference	*t*-Statistic	*p*-Value
$\dot{V}O_2$ ($l \cdot min^{-1}$)					
Underwater	1.29	0.22	-0.24	-2.98	.011
Treadmill	1.53	0.39			
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)					
Underwater	22.15	3.93	-3.8	-2.81	.015
Treadmill	25.95	6.33			
HR ($b \cdot min^{-1}$)					
Underwater	140.1	26.27	-19.46	-4.97	.0001
Treadmill	159.6	27.20			

Duffner and Lanphier (1960) have stated that energy expenditure may be equal between running and swimming at submaximal levels. $\dot{V}O_2$ differences in this study may have been affected by cardiorespiratory responses in swimming which are different than running due to environmental temperature, muscle mass, and position differences, and increases in external pressure (Astrand & Rodahl, 1977; Bonen et al., 1980; Carroll, 1970; Duffner & Lanphier, 1960; Egstrom, 1982; Holmer et al., 1974; McArdle et al., 1976; Nygaard & Nielsen, 1978). In addition, comparing $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) between treadmill and scuba is not recommended since less work is needed to support the body weight in scuba and the body position is difference (Egstrom, 1982; Holmer et al., 1974). In fact, upon submersion, blood volume, cardiac output ($\dot{Q}$), stroke volume (SV), central venous pressure, and peripherial vasconstriction are affected (Brobeck, 1974; Epstein et al., 1975). Blood volume is redistributed to the heart and intrathoracic vessels increasing central venous pressure, peripheral vasoconstriction and SV (Arborelius et al., 1972; Craig & Dvorak, 1968; Echt et al., 1974; Epstein et al., 1975; Lange et al., 1974). Water immersion also decreases the effect of gravity according to Epstein et al. (1975). Gravitational resistance in a standing position usually increases heart rate and reduces SV. Thus, one would expect the heart rate to be lower in a swimming position than in an upright position. Heart rate increases would be directly proportional to oxygen consumption and work rate (Brobeck, 1974).

Arborelius et al. (1972) found a $\dot{Q}$ increase of 32% with little change in heart rate during a head-out immersion study. Central blood volume also increased 0.7 liter. Other investigators (Craig & Dvorak, 1968; McArdle et al., 1976) have shown that $\dot{Q}$ was maintained at similar levels of energy expenditure in subjects in a horizontal position whether on land or in water. Decreases in heart rate were compensated by increases in SV of the heart. SV was also higher because of increased central blood volume and venous return. All of these hemodynamic changes could be factors in explaining the $\dot{V}O_2$ differences in the underwater and treadmill workbouts in this study.

Environmental temperature, whether in water or air, can affect $\dot{V}O_2$. Temperature has been found to be important in standardizing experimental conditions. Taylor et al. (1955) and Buskirk & Taylor (1957) indicated an ideal room temperature of 78 $\pm$ 4°F (25.6 $\pm$ 2°C) for experimental treadmill testing. Submaximal treadmill testing in the present study was conducted within this range. The scuba workbout, however, was conducted in a warmer pool environment of 31.3°C. This difference in temperature, therefore, could possibly be a factor in explaining $\dot{V}O_2$ differences found in this study. Other studies (Craig & Dvorak, 1968; Costill, 1965) have investigated effects of various water temperatures on $\dot{V}O_2$.

Changes in $\dot{V}O_2$ found with water temperature differences attributed the changes in hemodynamics. The increase in water temperature possibly resulted in an increase in heart rate in water compared to the response expected.

In addition, the sport divers in this study had fins for propulsion through the water. They did not use their arms and also needed a minimal muscle mass for body support (Holmer et al., 1974). In contrast, running on the treadmill required a greater involvement of muscle mass and gravitational forces. Since a smaller muscle mass was at work and water exercise requires lower thermoregulatory demands for skin circulation, the $\dot{V}O_2$s could understandably be significantly different.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to evaluate certified female sport divers on selected physiological variables obtained during treadmill and underwater workbouts. The primary research question was: What were the VO_2 and heart rate values of the subjects while submerged on scuba?

Another question was also addressed: Were the heart rate values obtained during the underwater exercise bout significantly different from heart rate values obtained during a comparable workbout on the treadmill?

Summary

Seventeen open water certified female sport divers volunteered to participate in this study. The divers were varied in physical abilities and in their diving expertise. Measures of fat percentage, maximal aerobic capacity, and physiological responses to an underwater scuba workbout and submaximal treadmill bout were obtained on the subjects.

The data were analyzed as follows: A descriptive program obtained the means, standard deviations, minimum, and maximum values for the variables. A paired _t_ test was run on the HR ($b \cdot min^{-1}$), VO_2 ($l \cdot min^{-1}$) and VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) among similar trials of both underwater and submaximal treadmill sessions to check for consistency of the trials. Since no significant differences were found, the measures were averaged across trails for consistency. Another paired *t* test was then run to check for significant differences between the underwater and treadmill workbouts.

1. $\dot{V}O_2$ ($l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate ($b \cdot min^{-1}$) measures were obtained from scuba subjects in a pool environment. The average values for $\dot{V}O_2$ ($l \cdot min^{-1}$), $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), and HR ($b \cdot min^{-1}$) for the scuba workbout were 1.24, 21.24, and 137.3, respectively.
2. There were statistically significant differences between the physiological measures obtained during the underwater workbout and submaximal treadmill workbout. Thus, the bouts were not comparable in energy expenditure. HR ($b \cdot min^{-1}$), $\dot{V}O_2$ ($l \cdot min^{-1}$), and $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) were significantly greater during treadmill exercise than during underwater exercises.

Conclusions

Based on the findings of this study, the following conclusions were made.

1. Expired air can be collected directly from an underwater sport diver in a pool environment without free flow.
2. Two trials were sufficient to obtain consistency among trials in both bouts.

3. Comparisons of the heart rate for the underwater and treadmill workbouts could not be made, since the $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) were not comparable. These differences could be attributed to researcher error and/or misuse of Margaria et al. (1963) chart. Other reasons possibly contributing to the $\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$ differences could be environmental temperature, muscle mass, position, and external pressure.

Recommendations

The findings and conclusions of this study suggest the following recommendations for further study:

1. Further study is definitely needed in the comparison of the energy cost of underwater and treadmill workbouts.
2. More research is needed in the sport diver area, not just with the female diver. This research needs to be standardized since many of the diving studies to date are not.
3. A larger sample of the sport diver population needs to be tested so generalizations may be made.
4. Other areas, such as psychological stress, need to be investigated.

BIBLIOGRAPHY

Agnostini, E., Gurtner, G., Torri, G., & Rahn, H. Respiratory mechanics during submersion and negative pressure breathing. Journal of Applied Physiology, 1966, 21, 251-258.

Arborelius, M., Jr., Balldin, U. I., Lija, B., & Lundgren, C.E.G. Hemodynamic changes in man during immersion with the head above water. Aerospace Medicine, 1972, 43, 592-598.

Astrand, P. O., & Rodahl, K. Textbook of work physiology. New York: McGraw-Hill, 1977.

Bearsleeper, J., & Bangasser, S. Women underwater. Crestline, Ca.: Deep Star Publishing, 1979.

Beckman, E., & Reeves, E. Physiological implications as to survival during immersion in water at 75°F. Aerospace Medicine, 1966, 37, 1136-1142.

Behnke, A. R., Thomson, R. M., & Motley, E. P. The psychological effects from breathing air at 4 atmospheres pressure. American Journal of Physiology, 1935, 112, 554-558.

Bennett, P. B., & Elliott, D. H. (Eds.). The physiology and medicine of diving and compressed air work. Baltimore: The Williams and Wilkins Co., 1975.

Bennett, P. B., & Towse, J. E. Compressed air intoxication at 180 feet, 200 feet, and 220 feet during exposures of 1 hour. London: Ministry of Defense, 1971.

Bonen, A., Wilson, B. A., Yarkony, M., & Belcastro, A. N. Maximal oxygen uptake during free, tethered, and flume swimming. Journal of Applied Physiology, 1980, 48(2), 232-235.

Bridges, L. Mask and flippers. Philadelphia: Chilton Company, 1960.

Brozek, J. F., Grande, F., Anderson, J. T., & Keys, A. Densitometric analysis of body composition: Revision of Some Quantitative Assumptions. Annals of the New York Academy of Sciences, 1963, 110, 113-140.

Buskirk, L. R. Underwater weighing and body density: A review of procedures. In J. Brozek (Ed.), Techniques for measuring body composition. Washington, D.C.: National Academy of Sciences, 1961.

Buskirk, L., & Taylor, H. L. Maximal oxygen intake and its relation to body composition with specific reference to chronic physical activity and obesity. Journal of Applied Physiology, 1957, 11, 72-78.

Carroll, P. J. Maximal oxygen consumption of scuba divers (Unpublished doctoral dissertation, Pennsylvania State University, 1970).

Consolanzio, C. F., Johnson, R. E., & Pecora, L. J. Physiological measurement of metabolic functions in man. New York: McGraw-Hill, 1963.

Costill, D. L. Effects of water temperature on oxygen consumption, rectal temperature, and heart rate during strenuous exercise (Unpublished doctoral dissertation, Ohio State University, 1965).

Cousteau, J. Y. World without sun. New York: Harper & Row, 1966.

Craig, A. B. Principles and problems of underwater diving. The Physician and Sports Medicine, 1980, 3, 72-83.

Craig, A. B., & Dvorak, M. Thermal regulation of man exercising during water immersion. Journal of Applied Physiology, 1968, 25, 28-35.

Donald, K. W., & Davidson, W. M. Oxygen uptake of booted and fin-swimming divers. Journal of Applied Physiology, 1954, 7, 31-37.

Dueker, C. W. Breathhold diving. In P. B. Bennett & D. H. Elliott (Eds.), The physiology and medicine of diving and compressed air work. Baltimore: The Williams and Wilkins Co., 1975.

Dueker, C. W. The undersea medical society. Undersea Journal (PADI), 3rd Quarter, 1981, pp. 27-29.

Duffner, G. J., & Lanphier, E. H. Medicine and science in sport diving. In W. R. Johnson (Ed.), Science and medicine of exercise and sports. New York: Harper and Brothers, 1960.

Duke dive called minature hell. Greensboro Daily News & Record. November 14, 1982, p. D-16.

Echt, M., Lange, L., & Gauer, O. H. Changes in peripheral venous tone and central transmural pressure during immersion in a thermoneutral bath. Pfluegers Arch, 1974, 352, 211-217.

Egstrom, G. Personal communication, February 1982.

Epstein, M., DeNuzio, A. G., & Ramachandran, M. Characterization of renal response to prolonged immersion in normal man. Journal of Applied Physiology, 1980, 49(2), 184-188.

Epstein, M., Pins, D. S., Arrington, R., Denunzio, A. G., & Engstrom, R. Comparison of water immersion and saline infusion as a means of inducing volume expansion in man. Journal of Applied Physiology, 1975, 39(1), 66-70.

Faulkner, J. A. Physiological characteristics of swimming. In B. Balke (Ed.), Physiological aspects of sports and physical fitness. Chicago: The Athletic Institute, 1968.

Foley, M. F., Billings, C. E., & Huie, C. R. Development of techniques for direct measurement of metabolism underwater. Aerospace Medicine, 1967, 38, 153-155.

Gandevia, S. C., McCloskey, D. I., & Potter, E. K. Reflex bradycardia occurring in response to diving, nasopharyngeal stimulation and ocular pressure, and its modification by respiration and swallowing. Journal of Physiology, 1978, 276, 383-394.

Goff, L. G., Brubach, H. G., Specht, H., & Smith, N. Effect of total immersion at various temperatures on oxygen uptake at rest and during exercise. Journal of Applied Physiology, 1956, 9, 59-61.

Goff, L. G., Bartlett, R. G. Elevated end-tidal CO_2 in trained underwater swimmers. Journal of Applied Physiology, 1957, 10, 203-206.

Goff, L. G., Brubach, H. F., & Specht, H. Measurements of respiratory responses and work efficiency of underwater swimmers utilizing improved instrumentation. Journal of Applied Physiology, 1957, 10, 197-202.

Goff, L. G., Frasseto, R., & Specht, H. Oxygen requirements in underwater swimming. Journal of Applied Physiology, 1956, 9, 219-222.

Greenbaum, L. J. Respiratory responses of underwater swimmers to oxygen. Journal of Applied Physiology, 1960, 15, 575-578.

Hanna, J. M. & Hong, S. K. Critical water temperature and effective insulation in scuba divers in Hawaii. Journal of Applied Physiology, 1972, 33, 770-773.

Hanson, J. S. Maximal exercise performance in members of the U.S. Nordic ski team. Journal of Applied Physiology, 1973, 35, 592-595.

Harris, D. V. Women in sports: Some misconceptions. Journal of Sports Medicine, March/April 1973, pp. 15-17.

Hempleman, H. V., & Lockwood, A. P. M. The physiology of diving in man and other animals. Southampton, England: Camelot Press, 1978.

Holmer, I. Physiology of swimming man. Acta Physiologica Scandinavica Supplement, 1974, 407, 1-53.

Holmer, I., Ludin, A., & Eriksson, B. O. Maximum oxygen uptake during swimming and running by elite swimmers. Journal of Applied Physiology, 1974, 36, 711-714.

Holmer, I., Stein, E. M., Saltin, B., Ekblom, H., & Astrand, P. O. Hemodynamic and respiratory responses compared in swimming and running. Journal of Applied Physiology, 1963, 37, 49-54.

Hong, S. K. Comparison of diving and non-diving women of Korea. Federal Proceedings, 1963, 22, 831.

Hong, S. K. Heat exchange and basal metabolism of ama. In H. Rahn & T. Yokoyama (Eds.), Physiology of breath-hold diving and the ama of Japan. Washington, D.C.: National Academy of Sciences, 1965.

Ingjer, F. Comparison of diving bradycardia and maximal aerobic power. Aviation Space Environment Medicine, 1978, 11, 1267-1270.

Irving, L. Respiration in diving animals. Physiological Review, 1939, 19, 112.

Irving, L. Bradycardia in human divers. Journal of Applied Physiology, 1963, 18, 489-491.

Kang, D. H., Kim, P. K., Kang, B. S., Song, S. H., & Hong, S. K. Energy metabolism and body temperature of the ama. Journal of Applied Physiology, 1965, 20, 46-50.

Kawakami, Y., Natelson, B. H., & DuBois, A. B. Cardiovascular effects of face immersion and factors affecting diving reflex in man. Journal of Applied Physiology, 1967, 23, 964-970.

Keatinge, W. R. Survival in cold water. Oxford, England: Blackwell, 1969.

Kiessling, R. J., & Maag, C. H. Performance impairment as a function of nitrogen narcosis. Journal of Applied Psychology, 1962, 46, 91-95.

Kizer, K. W. Women and diving. The Physician and Sportsmedicine, 1981, 9, 84-92.

Kollias, J., Bartlett, L., Bergsteinova, V., Skinner, J. S., Buskirk, E. R., & Nicholas, W. C. Metabolic and thermal responses of women during cooling in water. Journal of Applied Physiology, 1974, 36, 577-580.

Lange, L., Lange, S., Echt, M., & Gauer, O. H. Heart volume in relation to body posture and immersion in a thermoneutral bath. Pfluegers Arch, 1974, 352, 219-226.

Lanphier, E. H. Oxygen consumption in underwater swimming. Federal Proceedings, 1954, 13, 84.

Lanphier, E. H. Pulmonary function. In P. B. Bennett & D. H. Elliott (Eds.), The physiology and medicine of diving and compressed air work. Baltimore: The Williams and Wilkins Co., 1975.

Lanphier, E. H., & Dwyer, J. V. Oxygen consumption in underwater swimming. Washington, D.C.: U.S. Navy Experimental Diving Unit, 1954.

Margaria, R., Cerretelli, P., Aghemo, P., & Sassi, G. Energy cost of running. Journal of Applied Physiology, 1963, 18, 367-370.

Mathews, D. K., & Fox, E. L. The physiological basis of physical education and athletics. Philadelphia: Saunders College Publishing, 1981.

McArdle, W. D., Katch, F. I., & Katch, V. L. Exercise physiology: Energy, nutrition, and human performance. Philadelphia: Lea & Febiger, 1981.

McArdle, W. D., Magel, J. R., Lesmes, G. R., & Pechar, G. S. Metabolic and cardiovascular adjustment to work in air at 18, 25, and 33°C. Journal of Applied Physiology, 1976, 40(1), 85-90.

Miller, J. N., Wagensteen, O. D., & Lanphier, E. H. Ventilatory limitations on exertion at depth in underwater physiology. In C. J. Lambertsen (Ed.), Fourth Symposium of Underwater Physiology. New York: Academic Press, 1971.

Mount, T., & Ikehara, A. J. Practical diving: A complete manual for compressed air divers. Coral Gables, Florida: University of Miami Press, 1975.

Nadel, E. R., Holmer, I., Bergh, V., Astrand, P. O., & Stolwijk, J. A. A. Energy exchange of swimming man. Journal of Applied Physiology, 1974, 36, 465-571.

National Oceanic and Atmospheric Administration. Diving manual: Diving for Science and Technology. Washington, D.C.: U.S. Government Printing Office, 1975.

Nygaard, E., & Nielson, E. Skeletal muscle fibre capillarization with extreme endurance training in man. In B. Eriksoon & B. Furberg (Eds.), Swimming medicine IV. International series on sport sciences (vol. 6). Baltimore: University Park Press, 1978.

Phoel, W. C. The history, physics, and physiology of saturation diving. Marine Technical Society Journal, 1977, 7, 15-19.

Pollock, M. L., Laguridge, E. E., Coleman, B., Linnerud, A. C., Jackson, A. Prediction of body density in young and middle-aged women. Journal of Applied Physiology, 1975, 38, 745-749.

Poulton, E. C., Catton, M. J., & Carpenter, A. Efficiency at sorting cards in compressed air. British Journal of Independent Medicine, 1964, 21, 242-245.

Pugh, L. G. C., & Edholm, O. G. The physiology of channel swimmers. Lancet, 1955, 2, 761-768.

Russell, C. J. Some respiratory, metabolic and cardiovascular responses of scuba divers to increased pressure and cold while resting and exercising at various depths (Unpublished doctoral dissertation, University of Oregon, 1971).

Saltin, B. Oxygen transport by the circulatory system during exercise in man. In J. Keul (Ed.), Limiting factors of physical performance. Stuttgart, Germany: Thieme, 1973.

Saltin, B., & Astrand, P. O. Maximal oxygen uptake in athletes. Journal of Applied Physiology, 1967, 23, 353.

Schaeffer, K. E. Carbon dioxide effects under conditions of raised environmental pressure. In P. B. Bennett & D. H. Elliott (Eds.), *The physiology and medicine of diving and compressed air work*. Baltimore: The Williams and Wilkins Co., 1975.

Scholander, P. F., Hammel, J. T., Lemessurie, H., Hemmingsen, E., & Garey, W. Circulatory adjustment in pearl divers. *Journal of Applied Physiology*, 1962, *17*, 184-190.

Shephard, R. J. *Physiology and biochemistry of exercise*. New York: Praeger Publishers, 1982.

Sloan, A. W. Estimation of body fat in young men. *Journal of Applied Physiology*, 1967, *23*, 311.

Sloan, R. E. G., & Keatinge, W. R. Cooling rates of young people swimming in cold water. *Journal of Applied Physiology*, 1973, *35*, 371-375.

Song, S. H., Kang, D. H., Kang, B. S., & Hong, S. K. Lung volumes and ventilatory response to high CO_2 and low O_2 in the ama. *Journal of Applied Physiology*, 1963, *18*, 466-470.

Sparling, P. B. *Biological determinants of the sex differences in distance running performance among trained runners* (Unpublished doctoral dissertation, University of Georgia, 1979).

Specht, H., Goff, L. G., Brubach, H. F., & Bartlett, R. G. Work efficiency and respiratory response of trained underwater swimmers using a modified self-contained underwater breathing apparatus. *Journal of Applied Physiology*, 1957, *10*, 376-383.

Speck, D. F., & Bruce, D. S. Effects of varying thermal and apneic conditions on the human diving reflex. *Undersea Biomedical Research*, 1978, *5*, 9-14.

Sport diver manual. Denver: Jeppesen-Sanderson, 1978.

Sport diver manual: Advanced open water activities (Vol. II). Denver: Jeppesen-Sanderson, 1979.

Taylor, H. L., Buskirk, E., & Henschel, A. Maximal oxygen intake as an objective measure of cardiorespiratory performance. *Journal of Applied Physiology*, 1955, *8*, 73-80.

Tuttle, W. W., & Templin, J. I. A study of normal cardiac response to water below body temperature with special reference to a submersion syndrome. *Journal of Laboratory Clinical Investigation*, 1942, *28*, 271-276.

United States Department of Navy. U.S. Navy diving manual. Washington, D. C.: U.S. Government Printing Office, 1975.

Walder, D. N. The prevention of decompression sickness. In P. B. Bennett, & D. H. Elliott (Eds.), The physiology and medicine of diving and compressed air work. Baltimore: The Williams and Wilkins Co., 1975.

Webb, P. Cold exposure. In P. B. Bennett & D. H. Elliott (Eds.), The physiology and medicine of diving and compressed air work. Baltimore: The Williams and Wilkins Co., 1975.

Wells, G. Effect of external temperature changes on heart rate, blood pressure, physical efficiency, respiration, and body temperature. Research Quarterly, 1932, 3, 108.

Wells, P. Thermal stress in undersea activity. In C. J. Lambertsen (Ed.), Underwater Physiology: 5th Symposium Underwater Physiology. Bethesda, Maryland: Federation of American Sociologists, 1975.

Wilmore, J. H., & Behnke, A. R. An anthropometric estimation of body density and lean body weight in your women. American Journal of Clinical Nutrition, 1970, 23, 267-274.

Wilmore, J. J., & Haskell, W. L. Body composition and endurance capacity of professional football players. Journal of Applied Physiology, 1972, 33, 564.

Wittlieff, M. Volumetric gas usage of the basic sport diver in water temperatures of 18.3, 22.2, 25.6, and 29.4°C (Unpublished master's thesis, Kansas State University, 1976).

APPENDIX A

RECRUITING OF VOLUNTEERS FOR PARTICIPATION

THE UNIVERSITY OF NORTH CAROLINA
AT GREENSBORO

School of Health, Physical Education
and Recreation

P.O. Box 18064
Greensboro, N.C. 27419
January 7, 1982

Mr. Bill McDonald
PADI Headquarters
1243 East Warner Avenue
Box 15550
Santa Ana, Ca 92705-0550

Dear Bill,

Thank you for your suggestions. I really do appreciate every thing you have done to help me with my dissertation. As you know by our telephone conversation on December 9, 1981, my topic is "Physiological response of female sport divers to exercise during treadmill and underwater workbouts". The study will be conducted this spring at the University of North Carolina at Greensboro with 25 females, approximately 18 to 35 years of age. They will have at least an open water certification.

We also discussed that I have a problem of locating this many divers in my area. We decided that I would probably need to contact a minimum of 300 to insure an adequate number of participants. To prevent excessive travel I would like to have divers in this particular area notified (zip code of 272,273,274). As previously discussed, I will authorize you to spend up to $225 in helping me contact these subjects. Please let me know if this amount is not sufficient.

Enclosed you will find a copy of my proposal explaining the particulars of the study. I also have an example of a cover letter that PADI could use in a mailing, a letter to the subjects, and an example of a post card or form the subjects can return to me.

PADI is the only certification agency which has replied favorably in helping me obtain a random sample or at least some additional female divers.

Bill, I want to thank you again for the help PADI has given me. I look forward to hearing from you.

Sincerely,

Sue Graves, #10085 OWSI

THE UNIVERSITY OF NORTH CAROLINA
AT GREENSBORO

School of Health, Physical Education
and Recreation

P.O. Box 18064
Greensboro, N. C. 27419
February 18, 1982

Dear PADI Diver,

I am Sue Graves, a graduate student in the Physical Education Department at the University of North Carolina at Greensboro. As part of the requirements for my degree, I am conducting a physiological study of female sport divers, approximately 18 to 35 years of age.

The success of my study depends on your participation, because I need at least twenty-five certified divers. You will benefit personally by participating. Your body composition (% fat) and maximal aerobic capacity will be assessed. You will also be able to equate an underwater scuba preformance with a treadmill workbout. All of the tests will be conducted on the UNC-G campus and will take two to three hours of your time. The information will be confidential with all results analyzed as group data.

If you are interested in participating or would like more information, please mail the enclosed card to me by March 15, 1982. Thank you.

Sincerly,

Sue Graves
919-292-6110
PADI, OWSI #10085

Dr. Rosemary McGee
Committee Chair

PADI Professional Association of Diving Instructors
1243 East Warner Avenue • Santa Ana, California 92705 • (714) 540-PADI

Dear Diver:

Sue Graves, a PADI OWSI #10085, is conducting a study, "Physiological response of female sport diver to exercise during treadmill and underwater workouts" at the University of North Carolina at Greensboro. She has requested help from PADI to find female volunteers in the area.

PADI decided to help Sue in contacting subjects by mail, even though PADI is not involved with the study in any other way.

If you would like to participate, send Sue the enclosed card. Do not contact PADI.

Sincerely,

Dick Reilly
Administrative
Services Manager

DR/nr

Enclosure

Please check and return:

_____ YES, I would like to participate.

_____ NO, I do not want to participate, but would like to obtain the results.

Name ____

Address ____

____

Phone ________________________________(home)

________________________________(work)

APPENDIX B

INFORMED CONSENT, MEDICAL HISTORY FORM, INFORMATION SHEET, AND TESTING SCHEDULE

INFORMED CONSENT*

I, ____________________, without coercion of any kind, volunteered to participate in the research project entitled, "Physiological Response of Female Sport Divers to Exercise during Treadmill and Underwater Workbouts," to be conducted at the University of North Carolina at Greensboro during the Spring Semester, 1982 with Sue Graves as the principal investigator.

The procedures to be followed and their purposes have been explained to me and I understand them to be as follows:

The purpose of the study is to evaluate certified female sport divers on selected physiological variables obtained during treadmill and underwater workbouts.

Testing will be completed in five sessions. The first session will be an introduction and orientation meeting in which equipment and procedures will be explained. This meeting is at the Rosenthal Laboratory. The second session will involve body composition (% fat) determination by underwater weighing at the Home Economics Laboratory.

Session three involves a maximal incremental treadmill test also at the Rosenthal Laboratory. The subject will continue as long as possible and voluntarily terminate the test when fatigued.

Physiological measurements of the heart rate and oxygen uptake will be taken during the treadmill running. The subject will wear three electrodes on the chest, breathe through a one-way valve, and wear a nose clip.

Session four is an underwater submaximal workbout on scuba in the Rosenthal Swimming Pool. The subject wears a complete set of scuba gear. An alteration is made on the regulator exhaust port so that the expired air of the diver may be collected for analysis. Heart rate is also recorded by a telemetry system.

The final session is a submaximal workbout on the treadmill in the Rosenthal Laboratory. The subject works at the same VO_2 as underwater. Heart rate is again recorded.

The subject is free to terminate any of these tests at any time due to discomfort or other reasons.

The discomforts and risks to be expected by my participation as a subject in this project have been explained to me and I understand them as follows:

> The research involves a small potential risk as normally associated in exercise and scuba diving.

Benefits to be expected from my participation are as follows:

> An individual profile of the subject's measures will be provided. Group data results will also be provided with an explanation and interpretation of the findings, and implications for female sport divers.

I understand that this consent and data may be withdrawn at any time without prejudice. I am also guaranteed anonymity after the data collection.

I have been given the right to ask and have been answered any inquiry concerning the foregoing. Questions, if any, have been answered to my satisfaction. I have read and understand the foregoing.

____________________ WITNESS

____________________ SUBJECT

____________________ DATE

*Adapted from Sparling, 1979

SELF-ADMINISTERED PRE-EXERCISE MEDICAL HISTORY FORM

NAME________________________________ DATE________________________________

Check X if Yes

Past History: (Have you ever had?)		Family History: (Have any of your relatives had?)		Present Symptoms Review: (Have you recently had?)	
Rheumatic fever	( )	Heart attacks	( )	Chest pain	( )
Heart murmur	( )	High blood pressure	( )	Shortness of breath	( )
High blood pressure	( )	Too much cholestrol	( )	Heart palpitations	( )
Any heart trouble	( )	Diabetes	( )	Cough on exertion	( )
Disease of arteries	( )	Congenital heart disease	( )	Coughing of blood	( )
Varicose veins	( )	Heart operations	( )	Back pain	( )
Lung disease	( )	Other	( )	Swollen, stiff or painful joints	( )
Operations	( )				
Injuries to back, etc.	( )			Do you awaken at night to urinate?	( )
Epilepsy	( )				

Explain ____

____

Date of last complete physical examination________________________________

Did results of the examination indicate any medical problem that might make it dangerous for you to participate in vigorous exercise?_________. If yes, explain.

____

____

Risk Factors:

		Yes	No		
1. Smoking -	Do you smoke?	( )	( )		
	Cigarettes	( )	( )	How many? ______	How many years? ______
	Cigars	( )	( )	How many? ______	How many years? ______
	Pipe	( )	( )	How many times a day? ______	How many years? ______

How old were you when you started? ______

In case you have stopped, when did you? _________ Why? ________________

SELF-ADMINISTERED PRE-EXERCISE MEDICAL HISTORY FORM

2. Diet

What is your weight now? _____ 1 year ago _____ at age 21 _____

Are you dieting? _____ Why? ______________________________

3. Exercise

Do you presently engage in a systematic physical conditioning program? _____

If yes, indicate type and amount of conditioning ______________________

____

____

Do you engage in sports _____

What ______________________ How often ______________

How far do you think you walk each day? ______________________

Is your occupation - Sedentary ( )

Inactive ( )

Active ( )

Heavy work ( )

Do you have discomfort, shortness of breath or pain with moderate exercise?

__________. Specify ______________________________

____

Were you a schoolboy or college athlete? _____

Specify ______________________________________

Modified from the Physician's Handbook for Evaluation of Cardiovascular and Physical Fitness, 2nd Ed., prepared by the Tennessee Heart Association Physical Exercise Committee. Nashville: Tennessee Heart Association, 1972.

______________________ ______________________

Signature Witness

24-HOUR HISTORY

NAME________________________ HEIGHT________________________

AGE________________________ WEIGHT________________________

DATE________________________

TIME________________________

1. How much sleep did you get last night? (Please circle one)

   1/2 1 1-1/2 2 2-1/2 3 3-1/2 4 4-1/2 5 5-1/2 6 6-1/2 7 7-1/2

   8 8-1/2 9 9-1/2 10 (hours)

2. How much sleep do you normally get? (Please circle one)

   1/2 1 1-1/2 2 2-1/2 3 3-1/2 4 4-1/2 5 5-1/2 6 6-1/2 7 7-1/2

   8 8-1/2 9 9-1/2 10 (hours)

3. How long has it been since your last meal? or snack? (Please circle one)

   1/2 1 1-1/2 2 2-1/2 3 3-1/2 4 4-1/2 5 5-1/2 6 6-1/2 7 7-1/2

   8 8-1/2 9 9-1/2 10 (hours)

   List the items below:

4. When did you last have:

   A cup of coffee or tea

   Cigarettes

   Drugs (which include aspirin)

   Alcohol

5. What sort of physical exercise did you perform yesterday?

6. What sort of physical exercise have you performed today?

7. Describe your general feelings by checking one of the following:

   ____ Excellent
   ____ Very, very good
   ____ Very good
   ____ Good
   ____ Neither good nor bad
   ____ Bad
   ____ Very bad
   ____ Very, very bad
   ____ Terrible

INFORMATION SHEET

NAME ______________________________ DATE __________________

BIRTHDATE ________________ AGE _______ HEIGHT _____ WEIGHT ____

TYPE OF SCUBA CERTIFICATION (Check those which apply)

PADI _____
NASDS _____
NAUI _____
SSI _____
YMCA _____

HIGHEST LEVEL OF CERTIFICATION OBTAINED (Check one)

Open Water _____
Advanced Open Water _____
Divemaster _____
Assistant Instructor _____
Instructor _____
Master Instructor _____
Other: ____________________

APPROXIMATE NUMBER OF OPEN WATER DIVES LAST YEAR _______

How many of these were in salt water? _____
How many of these were in fresh water? _____

TOTAL NUMBER OF OPEN WATER DIVES SINCE CERTIFICATION _______

Approximate date of last open water dive ____________

Are you pregnant at this time _____yes _____no

Approximate date of the month for your menstrual cycle ________

- -

Body Composition Session:

Treadmill Session ($\dot{V}O_2$ max):

Underwater workbout:

Treadmill session (Submax):

TESTING SCHEDULE

NAME ______________________________

	Time	Date
Rosenthal Lab (104)		
1. Orientation session	________	________
Home Economics Laboratory		
2. Underwater weighing	________	________
Rosenthal Laboratory		
3. Treadmill Testing	________	________
Rosenthal Pool		
4. Underwater workbout	________	________
Rosenthal Laboratory		
5. Treadmill testing	________	________

Thank you very much for your cooperation.

Sue Graves
Lab 379-5708
Home 292-6110

TESTING INFORMATION

Diving Study

Test	Location	Attire	Facilities Available	Prior to Testing (Very Important)
Body Composition	Home Economics Building Room #302	Swimsuit Towel	Restroom for changing No showers	Do not eat for four hours before testing, no smoking for at least one hour
Max Test (Treadmill)	Rosenthal Lab Room #104	Tennis shoes T-shirts Shorts Towel	Restroom for changing No showers	Same as above
Scuba Work-bout (pool)	Rosenthal Pool	Swimsuit (2-piece if possible) Towel Diving mask	Shower facilities Hair dryer	Do not eat for two hours before testing, no smoking for at least one hour
Submax Test (Treadmill)	Rosenthal Lab Room #104	Tennis shoes T-shirts Shorts Towel	Restoom for changing No showers	Same as above

Introduction Session

The investigator will meet with the subjects on the UNC-Greensboro campus in the Rosenthal Lab to acquaint each with the purpose and procedures of the study. Consent and information forms will be completed at this time and a testing schedule established.

During this session, the subjects will be given a tour of Rosenthal Lab and swimming pool. All testing equipment utilized during the study will be explained.

Underwater Weighing

Body composition (% fat) will be determined by underwater weighing at the Home Economics Laboratory.

1. Subject Preparation
   a. The subject should refrain from eating for four hours prior to the underwater weighing test.
   b. Upon reporting to the laboratory, the subject is sent to the bathroom to urinate and expel, as much as possible, any gas or fecus from the bowels.
   c. The subject is instructed to put on a swim suit. A two-piece bathing suit is preferred for women.
   d. With the subject wearing only the bathing suit, the weight of the body in air (BWa) is measured to the nearest 25 grams on the Homs platform scale.
2. Measurement of underwater weight and residual lung volume.
   a. The investigator measures the barometric pressure and records on the data sheet and measures the temperature of the water in the tank.

b. The subject climbs into the underwater weighing tank. A 2-3 pound weight on a weight belt will be around the subject's waist so that the subject will sink properly when weighed.

c. The tare weight is the weight of all equipment suspended in the water and will be determined at this time.

d. The subject is instructed to sit on the basket.

e. To minimize the possibilities of having air trapped in the bathing suit, the subject should run her hands over the suit and then pull it out from the body in an attempt to replace the air with water.

f. Next, the underwater weighing procedure is practiced. The subject is instructed to bend forward at the waist until the head is completely submerged and the feet do not touch the tank bottom. The subject forcefully exhales as much air from the lungs as possible, and holds the air out for as long as possible. It is helpful to have the subject count slowly to seven before breathing. The scale is read during the period of time the subject is holding the breath under water. There will be considerable fluxation in the scale reading, but this will tend to stabilize within a relatively narrow range the longer the subject remains still holding the breath under water.

g. After the underwater weight is measured the subject sits up and resumes breathing. Feedback is given to the subject concerning stillness under water and the length of time the breath is held.

h. The underwater weighing procedure is practiced two or three times or until the subject can perform the procedure sufficiently well for a valid underwater weight to be obtained.

Treadmill (Maximal Incremental Test)

The subject should wear appropriate clothes and shoes for the treadmill test. After height and weight are recorded, electrodes will be attached for determination of heart rate. The head gear, mouth piece, and nose clip will also be adjusted for comfort.

The Bruce protocol will be used for the maximal TM (treadmill) test. This protocol is continuous, multistage, speed-, and grade-incremented. After a 5-minute warmup period walking at a set mph, the subject will rest for 2 minutes, then proceed. The time is three minutes at each stage.

The subject will walk/run to maximal volitional fatigue. A plateau of VO_2 and a heart rate within the estimated maximum for age, are the criteria for accepting the value as maximal. Measures of heart rate, ventilation, temperature of the expired gas, and percentages of oxygen and carbon dioxide in the expired gas will be obtained the last two minutes of the test.

Underwater Workout

1. The underwater workout will be conducted in the Rosenthal swimming pool. Each subject will wear a swim suit and should bring a change of clothes. Shower facilities are provided. Time will be allowed to adjust scuba gear.

2. The workbout will be submaximal with one subject being tested at a time. All scuba equipment utilized will be provided for each subject except the mask. No wet suits will be worn because of the water temperature and short workbout.

3. The subject will practice three minutes on the scuba equipment. During this time, buoyancy will be established at a depth of two and one-half to three feet. A rest period of two minutes will be given. The workbout of six minutes will then be started at a kick rate of 86 kpm.

During this time expired air will be collected in meteriological balloons and analyzed for O_2 and CO_2. Heart rate will be determined from an EKG by radiotelemetry.

Submaximal Testing

Submaximal testing will be conducted at least a day after the underwater workbout in the Rosenthal Laboratory. The subject should dress appropriately for a treadmill workbout. The subject will do submaximal work on the treadmill at the same $\dot{U}O_2$ as the underwater workbout.

APPENDIX C

DATA COLLECTION AND FORMS

Specific Data Collection Procedures

Body Density

Body density was determined by underwater weighing in a laboratory tank. The equation for calculating body density is as follows (Goldman & Buskirk, 1961):

$$Db = \frac{Wa}{\left(\frac{Wa - Ww}{Dw}\right) - (Rv + 100\ ml)}$$

where Db = body density (g/ml)

Wa = body weight in air

Ww = body weight in water

Dw = water density at a given temperature

Rv = volume of gas assumed to be in gastrointestinal tract.

Residual volume was estimated separately but at the same session as the underwater weighing. Three measures were taken and the mean used. This method of measuring the residual volume is highly reproducible and valid according to Wilmore (1969). He cited that limitations, such as the degree of gases in the lungs, subject position, and quantity of nitrogen, did exist, but the actual testing time was reduced.

The percentage of body fat from body density was calculated from the formula of Brozek et al. (1963):

$$\% \text{ fat} = \left[\left(\frac{4.570}{D_b}\right) - 4.142\right] 100$$

Treadmill

The Bruce protocol was used for the maximal TM test. This protocol is continuous, multistage, speed-, and grade-incremented. After a five-minute warm-up period walking at a set mph, the subject rested for two minutes, then proceeded through as many stages as possible.

Speed	Grade	Min
1.7	10%	3
2.5	12%	3
3.4	14%	3
4.2	16%	3
5.0	18%	3
5.5	20%	3
6.0	22%	3

The subject walked/ran to maximal volitional fatigue. Measures of ventilation, temperature of the expired gas, and percentages of oxygen and carbon dioxide in the expire gas were obtained the last two minutes of the test. Heart rate values were monitored during the last 10 seconds of each minute for the duration of the test.

Heart Rate

Heart rate was determined from electrocardiograph recordings obtained by telemetry in the pool and during the

TM tests. The telemetry unit was Narco Bio Systems, ECG-EMG-EEG transmiter, FM-1100-E2, serial #1493PB. The receiver was a Biotelemetry Receiver, Model FM-1100-6 from E & M Instrument Company in Houston, Texas. The recorder was a Beckman Type R411 multichannel recorder.

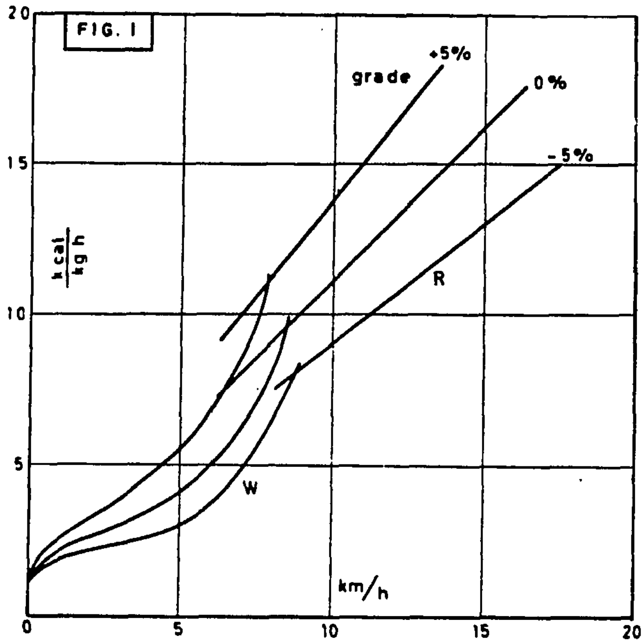


FIG. 1. Energy expenditure in kcal/kg hr as a function of speed in km/hr in walking, (W, lower curves) and running (R, upper straight lines) on a treadmill on the level (0%), uphill, and downhill at a 5% grade (1).

Source: Margaria, R., Cerretelli, P., Aghemo, P., & Sassi, G. Energy cost of running. Journal of Applied Physiology, 1963, 18, p. 368.

UNDERWATER WEIGHING FOR

FEMALE SCUBA DIVERS

NAME__________________________________DATE______________

Pbar____________________mmHg TIME______________

Estimate of Residual Volume:

Vital Capacity: (1) __________cc (2)__________(3)__________cc

Room Temperature____________°C BTPS Factor________________

VC X BTPS =________________cc

Females: RV = 0.28 X VC

__________cc = 0.28 X __________

Underwater Weighing: (Record in grams)

Trial: 1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

Tareweight: __________gms Water Temperature____________°C

Underwater weight (Highest Weight - Tareweight) ________________gms

Water Density______________gms/cc (5 decimal places)

Results:

Body Density________gm/cc

% Fat ________

FW ________kg

F FW ________kg

UNDERWATER
METABOLIC MEASUREMENTS

SUBJECT______________________ Date______________________

P_B______________________

TIME						
6. VE (ATPS)						
(l/min)						
7. Gastemp						
(°C)						
8. PH_2O						
$\%CO_2$						
9. $\%O_2$						
1. R_H						
2. H_2O Temp.						
3. Weight						
Air Consumption						
4. P_B						

1. $\dot{V}E$ (STPD)						
2. $\dot{V}O_2$ (l/min)						
3. $\dot{V}O_2$ (ml/kg.min)						
4. $\dot{V}CO_2$ (l/min)						
5. R($\dot{V}CO_2$)						
H.R. (beats/per min.)						

TREADMILL

METABOLIC MEASUREMENTS

SUBJECT________________________ DATE______________

______________ ______________ ______________

MAX $\dot{V}O_2$									SUBMAX $\dot{V}O_2$
P_B______mmHg					P_B______mmHg				
Weight______					Weight______				
TIME									TIME
1. UE-(ATPS) (l/min)									$\dot{V}E$
2. Gastemp (°C)									Gastemp
3. PH_2O									PH_2O
4. % CO2									% CO2
5. %O2									%O2
1. $\dot{V}E$ (STPD)									$\dot{V}E$
2. $\dot{V}O_2$ (L/min)									$\dot{V}O_2$ (l/min)
3. $\dot{V}O_2$ (ml/kg-min)									$\dot{V}O_2$ (ml/kg-min)
4. $\dot{V}CO_2$ (l/min)									$\dot{V}CO_2$ (l/min)
5. R($\dot{V}CO_2$) UO_2									R($\dot{V}CO_2$)
HR (beats/ Per min)									HR

APPENDIX D

COMPUTER PROGRAMS

```
C       THIS PROGRAM IS WRITTEN TO COMPUTE THE METABOLIC
C       MEASUREMENTS FOR FEMALE SCUBA DIVERS

C       INPUT VARIABLES
        INTEGER ID,
        1       SAMPLE

        REAL    BWA,    !BODY WEIGHT IN AIR - POUNDS!
        1       PBAR,   !BAROMETRIC PRESSURE!
        1       ATPS,   !AMBIENT TEMPERATURE PRESSURE SATURATED!
        1       TEMP,   !GAS TEMPERATURE - DEGREES CELSIUS!
        1       PH2O,   !VAPOR PRESSURE IN AIR!
        1       CO2,    !PERCENT OF CARBON DIOXIDE!
        1       O2,     !PERCENT OF OXYGEN!
        1       HRT     !HEART RATE!

C       OUTPUT VARIABLES

        REAL    FEO2,   !FINAL EXPIRED OXYGEN!
        1       FECO2   !FINAL EXPIRED CO2!
        1       BWKG,   !BODY WEIGHT IN AIR - KG!
        1       VESTPD, !STD TEMPERATURE PRESSURE DRY!
        1       VO2,    !VOLUME OF OXYGEN!
        1       VO2KG,  !VOLUME OF OXYGEN PER KG OF BODYWT!
        1       VCO2,   !VOLUME OF CO2!
        1       R       !RESPIRATORY QUOTIENT!

C       A LOOP WILL READ AND DO CALCULATIONS FOR UP TO 100 SUBJECTS
C       AN END OF FILE CONDITION EXITS FROM THE LOOP IF LESS
C       THAN 100 SUBJECTS.

        DO 100 I=1,100
        READ(5,10,END=1010)ID,SAMPLE,BWA,PBAR,ATPS,TEMP,PH2O,CO2,O2,HRT
10      FORMAT(I2,I1,3F5.0,F4.0,F5.0,2F4.0,F3.0)

C       CALCULATIONS OF METABOLIC MEASUREMENTS

        FEO2=O2/100
        FECO2=CO2/100
        BWKG=BWA/2.2
        VESTPD=((PBAR-PH2O)/760)*(273/(273+TEMP))*ATPS
        VO2=VESTPD*(((1-FEO2-FECO2)*.265)-FEO2)
        VO2KG=(VO2/BWKG)*1000
        VCO2=VESTPD*FECO2
        R=VCO2/VO2
C       PRINTING OF SUBJECT'S DATA

        PRINT 20,ID,SAMPLE,BWA,PBAR,ATPS,TEMP,PH2O,O2,CO2,FEO2,FECO2,
        1BWKG,VESTPD,VO2,VO2KG,VCO2,R,HRT
```

```
 0      FORMAT('1',//,T40,'INDIVIDUAL METABOLIC RESULTS - FEMALE',
        1' SPORT DIVERS',////,T57,'SUBJECT NUMBER ',I2,/T60,'SAMPLE NUMBER'
        1,I1,////,
        1T10,'BODY WEIGHT IN AIR:',F6.1,' POUNDS',
        1T70,'BAROMETRIC PRESSURE:',F6.1,//,
        1T10,'ATPS:',F6.1,
        1T70,'GAS TEMPERATURE:',F5.1,' DEGREES CELSIUS',//
        1T10,'VAPOR PRESSURE:',F6.2,//,
        1T10,'PERCENT OXYGEN:',F6.2,
        1T70,'PERCENT CO2:',F6.2,//,
        1T10,'FINAL EXPIRED OXYGEN:',F6.4,
        1T70,'FINAL EXPIRED CO2:',F6.4,//
        1T10,'BODY WEIGHT IN AIR:',F5.1,' KG',
        1T70,'VE - STPD:',F7.3,//
        1T10,'VOLUME OF OXYGEN:',F6.3,' L/MIN',
        1T70,'VOLUME OF O2 PER KG:',F6.2,' ML/KG',//
        1T10,'VOLUME OF CO2:',F6.3,
        1T70,'RESPIRATORY QUOTIENT:',F7.4,//
        1T10,'HEART RATE:',F4.0)
 00     CONTINUE
1010    CONTINUE
        PRINT 2000
2000    FORMAT('1')
        END
```

```
C       THIS PROGRAM IS WRITTEN TO COMPUTE THE BODY COMPOSITION FOR
C       FEMALES, BASED ON THE UNDERWATER WEIGHING TECHNIQUE

C       INPUT VARIABLES ARE:

        REAL     BWAP,    !BODY WEIGHT IN AIR (POUNDS)!
        1        VC,      !VITAL CAPACITY!
        1        RMTEMP,  !ROOM TEMPERATURE (C)!
        1        BTPS,    !BTPS FACTOR!
        1        HW,      !HIGHEST UNDERWATER WEIGHT (KG)!
        1        TW,      !TAREWEIGHT (KG)!
        1        H2OTEMP, !WATER TEMPERATURE (C)!
        1        DW       !WATER DENSITY!

C       COMPUTED VARIABLES ARE:

        REAL     AVC,     !ADJUSTED VITAL CAPACITY!
        1        RV,      !RESIDUAL VOLUME!
        1        BWW,     !UNDERWATER WEIGHT!
        1        DB,      !BODY DENSITY!
        1        PERFAT,  !PERCENT BODY FAT!
        1        FW,      !FATWEIGHT!
        1        FFW,     !FAT-FREE WEIGHT!
        1        BWA      !BODY WEIGHT IN AIR (KG)!

C       A LOOP WILL READ AND DO CALCULATIONS FOR UP TO 100 SUBJECTS
C       AN END OF FILE CONDITION EXITS FROM THE LOOP IF LESS
C       THAN 100 SUBJECTS

        DO 100 I=1,100
        READ(5,10,END=1010)ID,BWAP,VC,RMTEMP,BTPS,HW,TW,H2OTEMP,DW
10      FORMAT(I2,2F3.0,F4.0,F5.0,3F4.0,F5.0)

C       CALCULATIONS OF BODY COMPOSITION

        AVC=VC*BTPS
        RV=.28*AVC
        BWA=BWAP/2.2
        BWW=HW-TW
        DB=BWA/(((BWA-BWW)/DW)-RV)
        PERFAT=((4.57/DB)-4.142)*100
        FW=BWA*(PERFAT/100)
        FFW=BWA-FW

C       PRINTING OF SUBJECT'S RESULTS

        PRINT 20,ID,BWAP,VC,RMTEMP,BTPS,HW,TW,H2OTEMP,DW,AVC,RV,BWA,BWW,
        1        DB,FW,FFW,PERFAT
```

```
20      FORMAT('1',///,T37,'INDIVIDUAL BODY COMPOSITION RESULTS - FEMALE',
       1' SPORT DIVERS',////,T57,'SUBJECT NUMBER ',I2,/////,T10
       1'BODY WEIGHT IN AIR:',F4.0,' POUNDS',
       1T70,'VITAL CAPACITY:',F3.1,' CC',//,
       1T10,'ROOM TEMPERATURE:',F4.1,' C',
       1T70,'BTPS:',F6.4//,
       1T10,'HIGHEST UNDERWATER WEIGHT:',F5.2,' KG',
       1T70,'TAREWEIGHT:',F5.2,' KG'//,
       1T10,'WATER TEMPERATURE:',F4.1,' C',
       1T70,'WATER DENSITY:',F5.4,//,
       1T10,'ADJUSTED VITAL CAPACITY:',F7.4,' CC',
       1T70,'RESIDUAL VOLUME:',F9.6,' CC',//,
       1T10,'BODY WEIGHT IN AIR:',F6.2,' KG',
       1T70,'BODY WEIGHT IN WATER:',F5.2,' KG',//,
       1T10,'BODY DENSITY:',F6.4,' KG/CC',
       1T70,'FAT WEIGHT:',F8.4,' KG'//,
       1T10,'FAT-FREE WEIGHT:',F8.4,' KG',////,
       1T30,'PERCENT BODY FAT:',F6.2,' PERCENT')

100     CONTINUE

1010    CONTINUE
        PRINT 2000
2000    FORMAT('1')
        END
```

APPENDIX E

SUBJECT DATA

Subject Data

Subject	Wt (lb)	Ht (in)	% Fat	Body Density (kg/cc)	Max VO2 l/min	Max VO2 ml/kg	Max HR	Max R	Scuba VO2 l/min	Scuba VO2 ml/kg	Scuba HR	Scuba R	Submax TM VO2 l/min	Submax TM VO2 ml/kg	Submax TM HR	Submax TM R
1	123.0	67.0	22.02	1.0476	2.71	46.72	170	1.05	0.99	17.21	100.5	0.84	1.17	20.15	104.0	0.89
2	117.0	67.0	15.41	1.0638	1.84	34.44	180	1.29	1.51	24.97*	138.5	0.97	1.99	36.75	168.5	0.99
3	123.0	63.5	27.55	1.0345	1.73	30.79	180	1.19	0.76	18.69*	102.5	0.94	***	***	***	
4	130.0	70.0	21.99	1.0477	1.41	**	191	1.26	1.39	23.04	144.0	1.06	0.87	14.44	184.0	1.01
5	127.0	63.0	30.53	1.0276	1.69	29.09	196	1.19	1.30	22.26	170.0	1.06	1.72	29.87	184.0	2.03
6	154.0	65.0	32.78	1.0224	1.64	**	191	1.25	1.12	16.02	133.0	0.93	***	***	***	
7	120.0	67.0	24.68	1.0413	2.47	45.24	184	1.02	1.10	20.21	136.0	1.02	1.65	28.53	151.5	0.92
8	126.0	64.0	21.67	1.0485	2.12	36.24	184	1.26	1.37	23.78	123.0	1.00	1.59	27.24	161.0	1.05
9	121.0	66.0	20.86	1.0504	1.93	35.24	184	**	1.38	25.42	167.0	1.01	1.68	30.46	176.0	2.02
10	126.0	65.0	31.21	1.0260	1.72	30.37	188	1.16	0.93	16.32	212.0	0.91	1.03	18.17	129.5	0.87
11	130.0	65.0	30.65	1.0273	1.49	**	188	1.22	1.25	21.37	159.5	1.14	1.96	33.46	184.0	1.11
12	132.0	66.0	27.85	1.0338	1.81	30.40	196	1.17	1.62	29.85	188.0	1.23	1.80	30.31	189.5	1.15
13	137.0	67.0	20.13	1.0522	2.00	31.75	184	1.24	1.42	22.24	122.0	0.92	1.50	23.57	130.0	0.92
14	166.0	66.0	35.09	1.0172	2.40	31.26	196	1.22	1.57	20.49	165.6	1.03	2.11	27.95	182.0	0.97
15	123.0	68.5	27.09	1.0356	2.01	35.16	180	1.21	**	**	**		1.77	32.21	189.5	1.03
16	137.0	68.0	23.43	1.0443	2.43	39.30	188	**	1.05	17.17	111.5	0.87	1.22	19.89	126.0	0.89
17	105.0	62.5	14.26	1.0666	1.39	38.91	188	**	1.11	25.59	115.0	1.10	1.09	22.60	164.0	0.95

* Used only one value
** Individual did not reach max
*** Equipment failure