The Effects of Maternal Submaximal Aerobic Exercise on Infant Birth Weight

by

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Chapter I

Introduction

In recent years there has been an increase in public awareness of health and physical fitness, with concurrent alterations in attitudes regarding regular exercise. Paralleling this trend has been a developing philosophy of some health care professionals as well as the general population viewing pregnancy as a healthy, normal state. Consequently, an increased concern and need for knowledge regarding physical fitness during pregnancy has emerged among those practitioners providing obstetric care to pregnant women.

The concern surrounding exercise in pregnancy is based on the fact that during pregnancy the body is physiologically altered. Exercise too, creates physiological alterations within the body. What is unknown is the impact of these two physiologic alterations when they occur simultaneously. What is the impact of these alterations on the developing fetus? This study will address the influences of maternal exercise on infant birth weight.

A review of the literature reveals limited and conflicting information regarding the effects of maternal aerobic exercise on infant birth weight in human subjects. In order to determine if a significant association exists between these two variables, an experimental study investigating the effect of maternal submaximal aerobic exercise on infant birth weight was undertaken.

Literature Review

Introduction

Investigations of the effect of maternal submaximal aerobic exercise on infant birth weight requires a review of literature related to several variables. Factors influencing infant birth weight are numerous. In the limited scope of this investigation, factors included in review are exercise physiology, maximal aerobic capacity, physiologic effects of pregnancy, maternal exercise physiology, uterine blood flow, and the relationship between maternal exercise and infant birth weight.

Physiology of Exercise

Maintenance of homeostasis in the face of environmental disturbance is the major objective of cellular function (Astrand and Rodahl, 1977). Continuous exchange of nutrients and waste products is essential for internal equilibrium to be achieved. Living cells require oxygen for metabolism. The utilization of oxygen within the cell produces a pressure gradient that allows for its continual replenishment by diffusion. In like fashion, carbon dioxide (a by-product of oxygen metabolism) diffuses away from the cell. However, the mechanism for gaseous exchange is located away from the actual site of cellular metabolism in humans, and requires a mechanism for gaseous transport. This mechanism is a combination of the circulatory and respiratory systems.

Physical exercise alters the cellular environment by creating an increase in energy requirements for accelerated metabolism. This additional demand for energy produces physiologic alterations within the respiratory and cardiovascular systems including an increase in ventilation, cardiac output and arteriovenous oxygen difference.

Ventilatory Changes

Astrand and Rodahl (1977) describe pulmonary ventilation as the frequency of breathing multiplied by the mean expired tidal volume or depth of respiration. Astrand (1964) has demonstrated that ventilation increases during muscular work almost rectilinearly. In low intensity exercise it is primarily the tidal volume that is increased. As exercise intensity increases, respiratory frequency also increases.

Sutton and Jones (1979) and Mahler (1979) state that the regulation of ventilation during exercise is the result of several chemical and neural stimuli. Neural influences, inspiratory and expiratory neurons located in the medulla and stretch receptors located in the lung tissue cause an increase in depth of respiration as an immediate response to the increased oxygen needs associated with exercise. The change in gas concentrations in the blood (oxygen and carbon dioxide) associated with increased cellular respiration during exercise, cause chemoreceptors (sensitive neurons in the carotid and aortic bodies and in the central nervous system) to discharge neural signals to the medulla, which reflexively cause an increase in ventilation (McArdle, Katch, and Katch, 1981).

Hematological and Cardiovascular Changes

Although there is an increased supply of oxygen at the pulmonary level as a result of the increase in ventilation during exercise, the respiratory and cardiovascular systems must deliver this oxygen to the exercising tissue. There are several complex physiologic changes in the hematologic system associated with maternal exercise (Artal, Platt, Sperling, Kammula, Jilek, and Nakamura, 1981). However, in the limited scope of this investigation these alterations will not be explored in depth. The cardiovascular system provides rapid regulation of cardiac output and effective distribution of blood in the vascular system in response to the body's metabolic and physiologic needs.

Cardiac output is defined as the volume of blood ejected into the main artery by each ventricle per minute. Cardiac output is the product of stroke volume times heart rate. Stroke volume is the amount of blood ejected into the main artery by each ventricular beat and heart rate is defined as the number of ventricular beats per minute (Astrand and Rodahl, 1977).

Cardiac output increases in proportion to the intensity of exercise. This increase in cardiac output associated with exercise is the result of neural influences superimposed on the inherent, intrinsic rhythmicity of the myocardial muscle cells. These neurons originate in the cardiovascular center of the medulla and travel via the sympathetic and parasympathetic nervous systems. The parasympathetic nervous system utilizes acetycholine and the vagus nerve to inhibit or retard the intrinsic rhythmicity of the sinus node discharge. It is the sympathetic nervous system which speeds the heart rate, ultimately increasing cardiac output. Stimulation of the sympathetic cardio-accelerator nerves releases the catecholamines, epinephrine and norepinephrine. This release has two effects; it accelerates the depolarization of the sinus node causing the heart to beat faster, and it acts to significantly increase the contractibility of the myocardium, thus leading to a more efficient emptying of the heart chambers and increased stroke volume (Astrand and Rodahl, 1977). Cardiac output increases because of increases in both heart rate and stroke volume during exercise.

Arteriovenous Oxygen Difference Change

A final physiologic alteration found in the body during exercise is the change in arteriovenous oxygen difference. Arteriovenous oxygen difference is defined as the difference in oxygen content between the blood entering the capillaries and the blood leaving these capillaries. It has been described as a result of three additional physiologic factors: a redistribution of blood flow, a decrease in partial pressure of oxygen in active tissue and the Bohr and temperature effect.

Redistribution of blood flow during exercise was described by Astrand and Rodahl (1977) and is summarized as follows:

1. At rest, skeletal muscles do not receive their maximum blood flow since their arterioles are constricted by a continuous vasoconstrictor activity and spontaneous vascular tone. Heart rate is minimized by parasympathetic

outflow via the vagal nerve. Few capillaries are open, but individual capillaries open and close.

2. Preactivity anticipation and actual activity cause an inhibition of the parasympathetic outflow and increased sympathetic impulse traffic. The heart escapes parasympathetic inhibition and beats faster and with increased force. Sympathetic cholinergic fibers relay impulses from higher central nervous system centers and cause vasodilation of arterioles in exercising muscles, increasing their blood flow. On the other hand, sympathetic adrenergic fibers act on vessels of nonexercising muscles to cause vasoconstriction and decreased blood flow.

3. The appropriate adjustment in circulation occurs. In working tissues, capillaries are opened and arterioles dilate as a result of increased metabolism. Arterioles constrict in resting muscles and hormonal influences also contribute to the constriction of vessels in nonactive tissues.

Oxygen is transported in two ways. One is in physical solution, dissolved in the fluid portion of the blood. The second is in combination with hemoglobin, the iron containing protein molecule in the red blood cell. The percent of oxygen in solution is very small, but is physiologically important. McArdle et al. (1981)

report that the random movement of dissolved oxygen molecules establishes the partial pressure of oxygen in the blood and tissue fluids. This pressure is crucial for the loading and subsequent release of oxygen from hemoglobin in the lungs and tissue.

Under resting conditions, dissolved oxygen in plasma diffuses across the capillary membrane through tissue fluids and into the cell. Consequently, plasma oxygen is reduced below the partial pressure of oxygen in the red blood cells and hemoglobin is therefore unable to maintain this high oxygen saturation, causing release of oxygen from the blood cell, through the capillary wall and into the tissue (McArdle et al., 1981). During exercise, the cell's need for oxygen is increased and a larger quantity of oxygen is released from the hemoglobin to the cells because of the increasing pressure gradient. As a result, the arteriovenous oxygen difference increases (McArdle et al., 1981).

The Bohr and temperature effects are the third phenomenon associated with the arteriovenous oxygen difference. This phenomenon is a direct consequence of the local metabolic effect of exercise in which the actual molecular structure of the hemoglobin is altered. This effect is usually described in terms of an oxyhemoglobin dissociation curve. Any change in the local cellular environment changes the hemoglobin molecules effectiveness to load and unload oxygen. The pH decreases and temperature and carbon dioxide levels increase during exercise, causing a shift in the dissociation curve to the right. This shift causes the hemoglobin molecule to release more oxygen to the tissue. This shift is depicted in Figure 1.

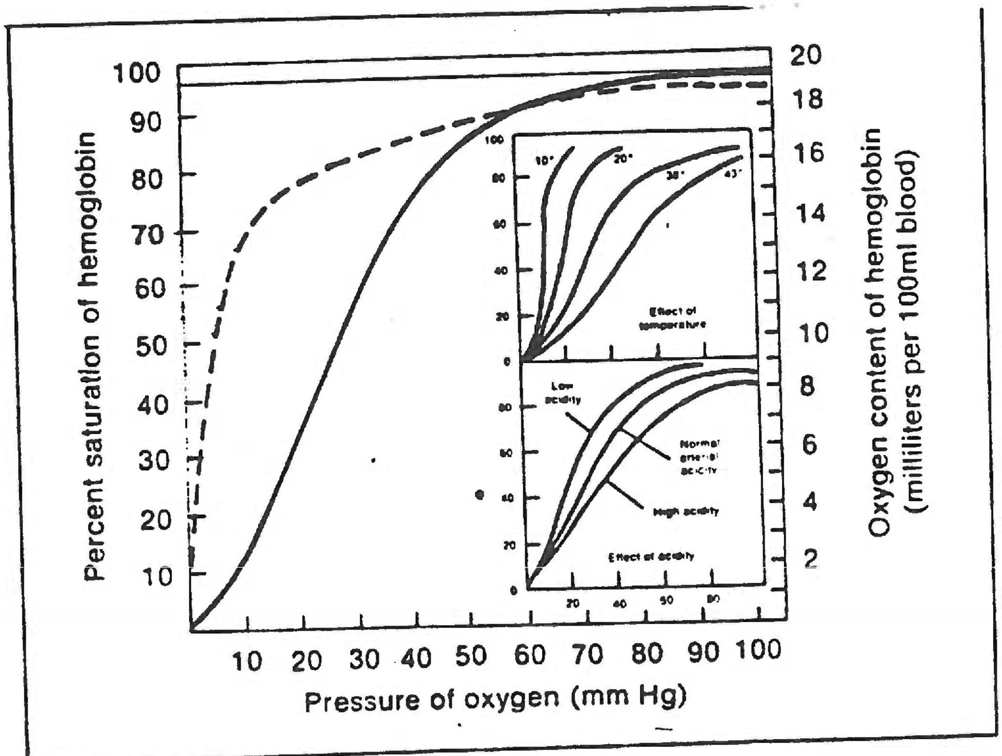

FIG. 1 *Percent saturation of hemoglobin (solid line) and myoglobin (dashed line) in relation to oxygen pressure. The quantity of oxygen carried in each 100 ml of blood under normal conditions is shown on the right ordinate. The insert curves indicate the effects of temperature and acidity in altering the affinity of hemoglobin for oxygen.*

Figure 1. The oxyhemoglobin dissociations curve

Note. From Exercise Physiology (p. 174) by W. D. McArdle, F. I. Katch and V. L. Katch, 1981, Philadelphia: Lea & Febiger. Copyright 1981 by Lea & Febiger. Reprinted by permission.

The Measurement of Maximal Aerobic Capacity

Measurement of maximal aerobic capacity is most accurately obtained by having the individual exercise to his/her maximal ability and directly evaluating the actual oxygen consumed. The procedure most often involves a stationary treadmill, adjusted to various inclinations throughout the testing period, on which the subject continues to exercise until unable to complete the workload. While performing this exercise, the subject is monitored by numerous gas collection and analyzing instruments. Although this method is extremely accurate, it is expensive both in terms of equipment and time. This procedure is also inappropriate for pregnant subjects due to the potential harmful effects to both the fetus and the mother of exercising to exhaustion.

The work of Astrand and Rhyming (1954) has shown a correlation between maximum oxygen uptake and heart rate response to exercise. This correlation has been used to assess maximum oxygen uptake from heart rate recorded during submaximal work. Additional studies by Karvonen (1957) and updated by Davis and Convertino (1975) report similar findings. It is thus reasonable to accept a more simplistic estimation of maximal aerobic work based on heart rate measure during submaximal aerobic exercise.

It has not been determined if any variance exists in estimation of maximal aerobic oxygen consumption from heart rate response to submaximal exercise due to pregnancy. The maximal attainable heart rate is, however, age specific. As age increases, maximal attainable heart rate decreases. Therefore, a new simpler estimation of aerobic work based on heart rate measure takes age into account. This formula requires subtraction of age from a theoretical maximum heart rate of two hundred and twenty to give an age-specific maximum heart rate.

The age range of subjects in this investigation is approximately ten years. Therefore, the heart rate decline associated with age in the pregnancy is probably not significant.

While accepted by investigators as a prediction of maximal oxygen consumption, the accuracy of this procedure is limited by the following assumptions as reported by Astrand and Rodahl (1977). The relationship of heart rate and oxygen consumption (work capacity) in some subjects may actually be more curved than linear during different exercise intensities. Also, there is a standard deviation of plus or minus ten beats per minute in the average maximal attainable heart rate of the individual. A third assumption is the constant mechanical efficiency of the equipment utilized. Finally, a fourth limiting factor is the day-to-day normal variations associated with individual heart rates. Thus, within the framework of these limitations, prediction of maximal oxygen uptake from submaximal exercise tests is accepted to generally fall within ten to twenty percent of actual measurements (Astrand and Rodahl, 1977).

Pregnancy Cardiovascular and Respiratory Physiology

Pernoll, Metcalfe, Schlenker, Welch, and Matsumoto (1975), in a study of twelve normal women tested monthly during pregnancy and at two, six and twelve weeks postpartum, found that resting respiratory rate significantly increases between twenty-seven and thirty weeks gestation and continues to increase until term. Tidal volume increases during pregnancy after nineteen weeks gestation (Guzman, 1970). As a result of these changes, a state of relative hyperventilation occurs during pregnancy (Hoversland, Metcalfe, Dhindsa, Gabbe, and Porter (1974); Goodland and Pommerenke, 1952).

Pregnancy is associated with a hypervolemic state, with blood volume increases of forty percent being reported at term in some individuals (Pritchard and McDonald, 1981). The altered blood volume contributes to an increase in stroke volume. Heart rate also rises an additional ten to fifteen beats per minute during pregnancy. The combined effect of the increased blood volume and the increased heart rate contribute to an increase in cardiac output during pregnancy of approximately forty percent (Artal et al., 1981; Guzman and Caplan, 1970; Ueland, Novy and Metcalfe, 1973).

Blood pressure is decreased during pregnancy due to a fall in peripheral vascular resistance. This fall in peripheral vascular resistance is attributed to the hormonal alterations associated with pregnancy (Dhindsa et al., 1978).

Thus, as a result of pregnancy several physiologic parameters are altered. Some of these parameters are the identical factors altered during exercise. During maternal exercise then, these physiologic alterations may have an additive effect with a theoretical potential of placing both the mother and the fetus at risk.

Physiology of Exercise During Pregnancy

Respiratory rate has been documented to increase during maternal exercise (Dhindsa et al., 1978; Pernoll et al., 1975). Pernoll et al. (1975) reported that tidal volume increases by approximately twenty percent over nonpregnant resting levels during pregnancy. It has also been determined that the hyperventilatory state associated with pregnancy is exacerbated during maternal exercise (Guzman and Caplan, 1970; Pernoll et al., 1975). In part, this may be due to the extra work required by the respiratory muscles secondary to the anatomical changes imposed on the diaphragm by the expanding gravid uterus (Pernoll et al., 1975).

The increase in cardiac output associated with maternal exercise is due principally to tachycardia. This finding suggests that the heart may have a limited ability to increase stroke volume during exercise especially as term approaches (Dhindsa et al., 1978).

During maternal exercise, peripheral vascular resistance declines even further (as compared with usual pregnancy decreases). This decline is regulated by the sympathetic nervous system catecholamines, which cause vasodilation of blood vessels near exercising tissue (Dhindsa et al., 1978). The implication here is that as a result of the redistribution of blood flow to exercising tissue, nonexercising (including uterine) tissue would not be adequately perfused. It is thus speculated that this might contribute to fetal hypoxia (Dhindsa et al., 1978).

The increased oxygen consumption associated with exercise is provided in the nonpregnant woman by an increased blood flow to the exercising tissue and an increase in the oxygen extracted by this tissue (an increased arteriovenous oxygen difference). However, exercising pregnant women increase their blood flow to the tissue only, and do not increase the oxygen extraction in order to meet the increased requirement during exercise.

Uterine Blood Flow

Fetal development is dependent in part on an adequate supply of oxygen to the uterus through placental intervillous spaces (Dhindsa et al., 1978; Pritchard and McDonald, 1980). As discussed in the review of exercise physiology, transport of oxygen is dependent on ventilation, cardiac output and arteriovenous oxygen difference. Exercising tissue demands an increase in oxygen and oxygen consumption increases during maternal exercise. Studies however have indicated that the oxygen debt (oxygen consumed during recovery in excess of the resting oxygen consumption) is larger after performing mild exercise during pregnancy as compared to the nonpregnant state. Investigators speculate that during the repayment period of the oxygen debt, less oxygen would be available to the fetus (Pernoll et al., 1975). A second factor potentially diminishing the oxygen supply to the fetus is the redistribution of blood flow associated with exercise. Vasoconstriction associated with the redistribution may interfere with uterine (nonexercising) blood flow, thereby reducing placental oxygen delivery and diminishing the total oxygen supply available to the fetus. Hon and Wohlgemuth (1961) arrived at this conclusion by measuring the pregnant subject's fetal heart tones before and after a strenuous exercise step test. However, these subjects were placed in a supine position for auscultation of fetal heart tones, a position in which one could possibly expect to find some degree of fetal bradycardia secondary to the obstruction of the vena cava by the gravid uterus. This obstruction would create a decrease in cardiac output secondary to a reduction in venous return, and would be further reduced after maternal exercise as a result of the redistribution of blood flow to the exercising muscles.

Studies on exercise and uterine blood flow by Emmanouilides, Hobel, Yashiro, and Klyman (1972) and Clapp (1980) disagree with studies by Orr, Ungerer, Will, Wernicke and Curet (1972) and Curet, Orr, Rankin and Ungerer (1976). Clapp (1980), in a study of ten pregnant ewes near term, found that a decrease in uterine blood flow was associated with an increase in the oxygen content difference across uterine blood flow. This finding supports a 1976 investigation by Erkkola and Rauramo, which speculated that after exercise a circulatory overflow occurred in the uterus in order to compensate for any fetal oxygen insufficiency. However, there is no documented evidence for this interpretation. These findings are significant as it has been determined that peripheral oxygen extraction (arteriovenous oxygen difference) during standard exercise is less in pregnant animals than after the pregnancy is terminated (Dhindsa et al., 1978). It is apparent that additional data and documentation of these occurences is necessary.

Other studies have indicated that fetal hypoxia resulting from decreased uterine blood flow occurred only when the experimental animal was exercised to the point of exhaustion as indicated by maternal hyperthermia or respiratory alkalosis (Dhindsa et al., 1978). Emmanouilides et al. (1972), in a study of twelve pregnant ewes, speculated that a deficit in oxygen transfer across the placenta during maternal exercise would cause the fetus to compensate by increasing fetal placental blood flow. He did not, however, actually measure the uterine blood flow or maternal cardiac output in this investigation. Hohimer, Metcalfe, Bissonnette, and Lawson (1980), in studies with Pygmy goats, have determined that during maternal exercise, uterine blood flow itself is redistributed in favor of the placenta at the expense of the myometrium. The mechanism for this occurrence is unknown.

A final concern is related to the birth weight of fetuses of chronic exercisers. Pgymy goats exercised regularly during pregnancy produced kids with diminished birth weights. However, this decrease in birth weight was not found to be statistically significant except in twin gestations (Dhindsa et al., 1978). Similar findings regarding decreased infant birth weight have been demonstrated in other animal studies as well (Gilbert, Nelson and Longo, 1980). However, Terada (1974) described conflicting reports in investigations involving birth weights of rats born to exercising mothers. It is evident that conflicting reports exist, and the controversies surrounding the birth weight of infants born to exercising animals have not been resolved.

Although these animal studies are significant, caution must be utilized when generalizing investigations employing experimental animals to those with human subjects. These animals are exercised forcibly, under laboratory situations, with elaborate equipment and procedures. It is possible that these unnatural situations could produce stress and fear in the animals, thus altering the physiologic parameters being investigated. It is assumed that human subjects volunteer for experimental investigations and therefore the data obtained would reflect the actual physiologic alterations taking place during exercise. However, human volunteers may be in better physical shape than the general population of pregnant females which could diminish the extent of the alteration on these physiologic parameters and decrease the ability to extrapolate values to the more typical non-exercising population.

It appears from the literature reviewed thus far that actual demands of pregnancy on the maternal cardiovascular and respiratory systems could compete with the additional requirements during exercise. A resulting hypoxia might jeopardize the developing fetus (Dhindsa et al., 1978; Hon and Wohlgemuth, 1961).

Maternal Exercise and Infant Birth Weight

In an early study by Pomerance, Gluck and Lynch (1974), an attempt was made to correlate maternal physical fitness score and fetal benefits. Their forty-one pregnant subjects were matched for several variables, such as age, race, health, and prepregnancy weight, in order to obtain a homogeneous low risk population. These subjects were exercised once between thirty-five and thirty-seven weeks gestation in a sitting position on a bicycle ergometer. The researchers controlled for exercise intensity by either maintaining the workload at a given, specified level, or increasing or decreasing the workload according to the subjects heart rate response to exercise. As an arbitrary measure of maternal physical fitness, maximum aerobic capacity was calculated according to the nomogram developed by Astrand and Rodahl (1977) during submaximal stationary cycling and used to compare between subjects. This figure was considered the subject's physical fitness score, with higher scores indicating more advanced levels of fitness. The investigators acknowledged the high correlation between maternal prepregnancy weight, weight gain during pregnancy and infant birth weight, and attempted to control for these variables. The study concluded that physical fitness as determined by physical fitness score was not significantly associated with infant birth weight. However, the investigators chose to assume that the physical fitness scores calculated for each subject were interval level data. The accuracy of this assumption is subject to question. It is difficult to acknowledge each interval on the physical fitness score as having an equal quantitative meaning. Therefore, the use of parametric tests of significance should also be questioned, leaving the significance of this investigation in question.

Two recent case studies, one by Dressendorfer and one by Ruhling, also utilized maximal aerobic capacity as a measure of physical fitness. Dressendorfer (1978) followed a female in her late twenties throughout her two normal pregnancies. During both of these pregnancies, she was involved in a strenuous jogging program (ten increasing to thirty five miles per week). The subject routinely obtained heart rates of one hundred and seventy beats per minute, eighty-nine percent of her maximal aerobic capacity. Both of her infants were healthy and both weighed approximately thirty-five hundred grams at term.

Ruhling, Cameron, Sibley, Christensen, and Bolen (1981) followed a thirty-six year old woman during her seventh normal pregnancy. This subject had been jogging for two years prior to this pregnancy, averaging approximately six kilometers per day and continued at this rate during the pregnancy. Her infant was born healthy at term and weighed 3740 grams.

Sibley, Ruhling, Cameron-Foster, Christensen, and Bolen (1981) utilized respiratory gas analysis during graded exercise testing on a treadmill as a measure of physical fitness in order to investigate the influence of a ten week swim conditioning program on physical fitness levels during pregnancy. A low oxygen consumption with a high work rate would indicate an exceptionally fit individual. The seven experimental subjects participated in a swimming program which was designed to gradually build and improve physical fitness over the specified time frame. Physical fitness measures as determined by respiratory gas analysis were made prior to and after completion of the swimming program. Evaluation was also made of maternal and fetal heart rates and maternal blood pressure, both during the conditioning program as well as the pre and post test. Maternal heart rate range was reported to be one hundred and ten to one hundred and sixty-three beats per minute during the exercise period. These results were not reported with the subject's age. Although the analysis did not reveal statistically significant improvements in the subject's physical fitness, it did suggest that women can maintain their level of fitness. The researchers also report that both maternal blood pressure and fetal heart tones were essentially the same prior to maternal exercise and at five minutes recovery. The investigator's concluded that it is possible for a woman to participate in aerobic exercise without harmful effects to self or the fetus, as determined by maternal blood pressure, pulse and fetal heart tones, infant birth weight and Apgar scores. However, this interpretation may be premature, as it has been determined that maximal heart rate declines with age (Astrand and Rodahl, 1977). It is therefore unclear what percent of maximal aerobic capacity these subjects reached.

Clapp and Dickstein (1983), in an unpublished manuscript, examined maternal exercise performance and pregnancy outcome in three hundred and thirty-six pregnancies. The data regarding actual level of intensity of the exercise performed was elicted from the participants twice during their pregnancies by subjective report and chart review. The study design itself was extremely complex and at times confusing due to the numerous groups (exercise, sedentary, intermediate) and subgroups based on technical criteria (high performance, medium performance and low performance) of data collected and the reporting of these groups with abbreviations after initial description. An inadequate description of the statistical analysis employed for each group further complicates interpretation of the data. The results indicate that continued endurance exercise during pregnancy significantly ($p<0.0001$) decreased birth weight. The investigator's conclusion that continued endurance exercise during pregnancy is associated with a significant, consistent reduction in birth weight for gestational age as well as other complications (earlier delivery, diminished maternal weight gain) should be regarded with some caution due to the methodological problems in the study design and reporting technique. It is assumed that editorial changes will be made prior to publication of this manuscript, facilitating interpretation of the findings and significance of this report.

Collings, Curet, and Mullin (1983) studied twelve pregnant women and their fetuses. In this investigation, intensity of the maternal exercise was controlled to sixty-five to seventy-five percent of maximal oxygen consumption. This percent was predicted by estimating maximal aerobic capacity plotted against maximal heart rate estimations as described by Astrand and Rodahl (1977). These subjects exercised at this level of intensity three times per week for approximately forty-five minutes during the second and third trimesters of their pregnancies. The twelve experimental subjects and their infants were compared with eight control subjects and their infants who did not participate in this exercise routine, by means of unpaired t tests. The investigators found that there were no statistically significant differences between the two groups, although greater mean birth weights were found in the exercise group. The researchers concluded that regular maternal aerobic exercise appears to have no beneficial or detrimental effects on fetal growth although the pregnant women did show an 18% improvement in aerobic capacity at completion of the exercise regime. The authors specified that more data are needed.

Maternal Factors Affecting Infant Birth Weight

Human fetal growth is dependent on an interplay of numerous variables including maternal, fetal and environmental factors (Miller and Merritt, 1979). An abbreviated review of common maternal variables known or presumed to affect infant birth weight is presented.

Socioeconomic status. Miller and Merritt (1979) summarize that research investigators worldwide support the observation that infants born to mothers of low socioeconomic status weigh less than infants born to women of higher socioeconomic status. They further report that efforts to identify the specific social and economic factors which account for these lower birth weights are difficult and unrewarding.

Prepregnancy weight. Several investigators have observed a positive relationship between maternal prepregnancy weight and infant birth weight. They report that mothers who were above average in their weight-height ratio at the time of conception deliver heavier infants than those who were below average in weight-height ratio (Niswander, Singer, Westphal and Weiss, 1969; Love and Kinch, 1965; Miller and Merritt, 1979).

Prenatal visits. Miller and Merritt (1979), in a study of six thousand mothers and infants, report that the incidence of low birth weight babies was high (19.2%) among the one hundred and twenty women who received zero to three prenatal visits. Although this figure is statistically significant, a large number (17.5%) gave birth prematurely, which would tend to lower their infants birth weights secondary to their diminished gestational age. Ninety-one women who received four to eight prenatal visits delivered low birth weight infants (incidence of 12.19%). The incidence of low birth weight in infants in this investigation born to women who had nine to twelve prenatal visits was reported as three percent.

Weight gain during pregnancy. There is agreement among researchers that a strong positive relationship exists between the amount of weight gained by the mother during the pregnancy and the birth weight of the offspring (Niswander et al., 1969; Love et al., 1965; Miller and Merritt, 1979). However, determination of the weight gained during pregnancy by the gravid woman, most often depends on her knowledge and subjective reporting of this prepregnancy weight, which is subject to error (Miller and Merritt, 1979). Worthington-Roberts, Vermeeresch and Williams (1981) report that a two to four pound average weight gain comprise the first trimester of pregnancy with a pound a week gain thereafter the norm. It is commonly accepted by the obstetric community that a twenty-five to thirty pound weight gain during pregnancy is "ideal," and twenty to thirty-five acceptable.

Cigarette smoking. Numerous reports describe the risks which confront the fetus whose mother smokes cigarettes during pregnancy, including a significant reduction in mean birth weight (Simpson, 1957), significant reduction in mean body length (Miller and Merritt, 1979), and increased incidence of low birth weight infants (22,500 grams) (Miller and Merritt, 1979). Rush

(1974) has suggested that the reduction in birth weight of infants may be mediated by the depressed caloric intake associated with woman who smoke and that this lower caloric consumption could be reflected in a lower maternal weight gain. However, this point has been refuted in a 1978 study by Meyers.

It is evident that many maternal variables accepted as influencing infant birth weight are associated and interrelated.

Conceptual Framework

Nursing involves promoting physical and psychological health. This professional discipline strives to limit potential health hazards. Physical activity is generally considered to be a health promoting behavior. In pregnancy, however, an activity which may benefit the mother physically or psychologically, could prove detrimental to the developing fetus. The purpose of this investigation is to examine the relationship between maternal submaximal aerobic exercise and the fetus.

A physiologic framework provides the basis for this study. The interrelatedness of the concepts of pregnancy physiology and exercise physiology specifically define this framework. These concepts provide a theoretical basis for predicting the effects of maternal submaximal aerobic exercise on infant birth weight. The physiologic concepts may be summarized as follows.

Physical work (exercise) and pregnancy both create physiologic alterations secondary to an increased need for energy. The additional energy demand in turn creates an increase in the tissue oxygen requirement. This additional need for oxygen is met by three physiologic factors, an increase in ventilation, cardiac output and a change in arteriovenous oxygen difference.

Arteriovenous oxygen difference itself consists of three physiologic influences, a redistribution of blood flow, a decreased partial pressure of oxygen in active tissue and the Bohr and temperature effect. It is the redistribution of blood flow during maternal exercise that is potentially hazardous to the developing fetus.

Fetal development is dependent on an adequate blood flow and oxygen supply to the uterus through placental intervillous spaces. During maternal exercise, circulating blood flow is redistributed within the body. A vasodilative response occurs in the working tissue thus increasing blood flow and subsequent oxygen supply to these needy tissues. The opposite effect occurs in nonworking tissues. It is thus speculated that the vasoconstrictive response associated with the redistribution, uterine (nonworking) blood flow could potentially deplete placental oxygen reserves and diminish total oxygen available for transport to the placenta. A resulting hypoxia could place the developing fetus at risk. Furthermore, if the fetal hypoxia was chronic in nature, it may present as a diminished infant birth weight. The purpose of this study is to explore the following hypothesis.

Hypothesis

Infant birth weight does not differ statistically in infants whose mothers perform submaximal aerobic exercise three times weekly during the second two trimesters of their pregnancies as compared to the weights of infants whose mothers did not perform this exercise.

Chapter II

Methodology

Research Design

An experimental research design was utilized in order to complete this investigation. This research design was employed to determine if a statistically significant difference exists in the birth weights of infants born to women who perform submaximal aerobic exercise during the second two trimesters of their pregnancies when compared with a control population. Maternal submaximal aerobic exercise was defined as exercise performed by the gravid woman which does not exceed seventy percent of her estimated aerobic capacity as determined by heart rate measurement. Aerobic capacity was defined as the maximal amount of oxygen the body can utilize during muscular work. Infant birth weight was defined as weight in grams of the neonate at time of delivery.

Population/Sample

The sample consists of pregnant women enrolled in a pregnancy fitness program in a northwest metropolitan community. This class meets twice weekly for one hour. The fitness program at this facility entails a half hour series of exercises aimed at maintaining physical fitness during pregnancy. Specifically, exercises in flexibility, strength and endurance are used. Each member then performs an enjoyable aerobic exercise (walking, jogging, cycling, swimming) for one half hour. Each participant is instructed to maintain aerobic performance at sixty to seventy percent of her calculated age adjusted estimated aerobic capacity, as determined by heart rate measurement (palpation of the carotid artery). All program members participated with the knowledge and approval of their health care professional. A health history, diet and exercise questionnaire were completed by the individual. Each participant also kept an exercise log. A sample of this log is found in Appendix A.

The experimental subjects for this investigation were eight volunteers from this pregnancy fitness program, who were expected to deliver during the data collection period. All of these women were unusually attentive to their health. None of them smoked cigarettes; few drank alcohol. They were without cardiorespiratory or other disease. Age range was from twenty-six to thirty-eight. One hundred percent were Caucasian.
It was expected that there would be approximately twenty subjects. During actual data collection it became apparent that it would be impossible to meet that expectation during a reasonable data collection period. It came as a suprise to note the high attrition rate

from the program during the third trimester of pregnancy. Therefore, subjective data from these subjects was elicited regarding their reasons for discontinuing the program and is reported in Chapter III. Consequently it became necessary to supplement the sample size by the use of retrospective data from this same population. The procedure for obtaining retrospective data is described in the Procedure and Instrumentation section.

The control group utilized in this investigation was that provided by Babson, Behrman and Lessel (1970). These investigators developed and utilized data on fetal growth as related to gestational age in a sample of forty thousand newborn infants born to women in a Pacifc Northwest metropolitan community between 1959-1966. This data has been accepted and used by other investigators in research involving infant birth weight (Metcalfe, unpublished). Only data regarding infants born between thirty-eight and forty-two weeks gestation was utilized in this investigation (n = 35,252).

Procedure and Instrumentation

The prospective data were obtained by the investigator measuring the heart rate of the exercising pregnant woman during her performance of this exercise. This information, along with data regarding the type of aerobic exercise performed, and the subject's average resting pulse as reported by the subject, and recorded on an anonymous data collection sheet. A copy of this data collection tool is located in Appendix B.

The population of potential subjects were approached as a group during the pregnancy fitness program. The investigator again introduced herself to the class and also stated that she was a nurse midwifery student interested in looking at the birth weights of infants born to women who exercise regularly during the second two trimesters of their pregnancies, as documented in their exercise log (see Appendix A). In order to examine this situation the investigator sought volunteers from the class whose expected dates of delivery fell within the data collection period. The investigator then described the data collection procedure.

Subjects continued to participate in the flexibility, stretching and strengthening exercises during the first half of the pregnancy fitness class, as usual. During the second half of the program, when the subject performed the aerobic exercise of their choice, the investigator accompanied the subject and observed and recorded her mode of exercise. After the subject had performed the exercise for at least three minutes, the investigator measured her carotid pulse rate by direct palpation for fifteen seconds. If the subject had been performing upright, large muscle exercise, such as walking or jogging, she was advised to assume a lateral recumbant position in order to avoid pooling of the increased venous circulation associated with exercise. If the subject was observed during swimming, she was requested to hold onto the edge of the pool and float during the measurement period.

The investigator palpated the subject's carotid pulse and counted the beats per minute. Subjects attaining heart rates in excess of seventy percent of their maximum aerobic capacity were excluded from this investigation. This information was recorded on the previously described data collection tool. The subject was then encouraged to continue the aerobic endurance exercise for the customary amount of time recommended in the pregnancy fitness class. All subjects were evaluated in this manner once during late pregnancy.

After an informed consent form was signed (see Appendix D), the subject was assigned an arbitrary number designated by the order in which the subjects volunteered for participation in the study. This number was recorded on the consent form and data collection tool. Names were no longer associated with the subjects in this study.

In order to obtain the necessary data related to neonatal birth weight, participant subjects were provided with an information sheet and a self-addressed, stamped envelope. The information sheet was marked with the subject's study identification number. The subject was asked to provide the following information: expected date of delivery; actual date of delivery; infant's birth weight; and her last documented weight. Only subjects reporting between a twenty and thirty-five pound weight gain were included in this investigation. Only subjects delivering between thirty-eight and forty-two weeks of gestation were included in this investigation. This data was mailed directly to the investigator by the subject. A copy of this data collection tool may be found in Appendix C.

Retrospective demographic data was obtained by a review of the health history, exercise log and hospital data sheet of class participants who delivered between July 1983 and March 1984. This data was available due to participation in a larger investigation in which subjects provided verbal consent for their data to be used for investigational purposes. Anonimity was guaranteed by assigning numbers to this data based on filing by delivery date. July was arbitrarily designated as a starting point for data collection.[1]

[1]This retrospective data was used by permission of the Heart Research Lab of Oregon Health Sciences University, under the supervision of James Metcalfe, M.D.

Reliability/Validity

Reliability of heart rate measurement was controlled in this investigation by having only one investigator performing the actual palpation of the subject's carotid pulse. Validity of heart rate measurement is assured by the face validity associated with carotid pulsation. Additional comments regarding reliability and validity can be ascertained from the investigator's professional background as a registered nurse.

Variables

As noted in the review of literature, there are numerous variables associated with infant birth weight. For the purpose of this investigation, the following variables were identified. Maternal submaximal aerobic exercise was considered the independent variable. Infant birth weight was considered the dependent variable. Intervening variables documented to have an effect on infant birth and controlled for in this investigation included maternal weight gain during pregnancy, maternal cigarette smoking, and gestational age at time of birth.

Analysis

The analysis consisted of a two-tailed statistical test between differences in mean infant birth weight as compared between the experimental and control groups. The Student's t test was used with a .05 level of significance.

Protection of Human Subjects

The subjects signed an informed consent form (see Appendix D). The subjects were informed that their participation in this investigation would not have any effect on their continued involvement in the pregnancy fitness class. All subjects remained anonymous and data collection tools were numerically coded.

Chapter III

Results and Discussion

The purpose of this investigation was to determine if a statistically significant difference exists in infant birth weight in infants born to women who perform regular submaximal aerobic exercise in the second two trimesters of their pregnancies, as compared to those infants whose mothers did not perform this exercise. This chapter includes a description of the sample and a presentation of the results of the investigation. A discussion of the implications of the findings concludes the chapter.

Sample

The sample consisted of pregnant women enrolled in a Pregnancy Fitness Program in a northwest metropolitan community. Eight of these subjects volunteered to participate in the study. Twenty-one subjects were previous program participants.

The control group utilized in this investigation was provided by Babson et al. (1970). Their report consisted of data on fetal growth related to gestational age in a sample of forty thousand newborn infants born to women in a Pacific Northwest metropolitan community.

Findings

Table 1 provides a description of the sample. Although the total sample size consists of twenty-nine subjects, thirteen women were excluded from the data analysis. Table 2 depicts reasons for these subjects exclusion.

Table 3 depicts the mean infant birth weight for gestational age in the sample population. Table 4 shows the same for the control population.

Analysis of the Data

A Student's t test was used to determine the significance of any difference in mean infant birth weight between the experimental and control groups. There was no significant difference between the groups as the t value obtained (0.28) was less than the critical value (2.13) at the .05 level of significance.

The calculated t derived in this investigation allows acceptance of the formulated null hypothesis based on this analysis. In accepting the null hypothesis, the conclusion is made that any variation in average birth weight in this sample is due to variables other than maternal exercise.

The hypothesis that there would not be a significant difference between these two groups of infant birth weights was tested. The results of this investigation support this hypothesis.

Table 1

Description of Sample

Subject[a] Number	Age	Target Heart Rate Zone	Exercise Pulse	Exercise Type	Gestational Age	Infant Weight	Total Weight Gain	Gravid Para
* 1	30	114 - 134	108	Walk	40 3/7	3515g	25#	G_2P_2
* 2	30	114 - 134	88	Walk	41 2/7	3742g	28#	G_2P_2
* 3	32	112 - 132	120	Swim	39 2/7	3685g	30#	G_3P_1
* 4	33	112 - 132	124	Cycle	39 6/7	3856g	20.5#	G_1P_1
* 5	29	114 - 134	124	Walk	39 1/7	3402g	28#	G_1P_1
x*6	27	115 - 135	88	Walk	39 2/7	3402g	18#	G_2P_2
x*7	33	112 - 132	108	Walk				
* 8	29	114 - 134	132	Walk	38 3/7	3090g	28#	G_1P_1
9	29	114 - 134	130	Walk	39 2/7	3118g	29#	G_3P_1
10	29	114 - 134	120	Swim	39 5/7	3090g	31#	G_1P_1
11	29	114 - 134	120	Walk	39 0/7	3118g	27#	G_2P_1
12	33	112 - 132	124	Swim	40 2/7	3657g	29#	G_1P_1
13	33	112 - 132	124	Swim	39 4/7	3232g	26#	G_3P_1
14	27	115 - 135	120	Swim	40 4/7	2410g	21#	G_1P_1
x15	31	113 - 133	152	Swim	41 1/7	3912g	42#	G_2P_1

(table continues)

Subject[a] Number	Age	Target Heart Rate Zone	Exercise Pulse	Exercise Type	Gestational Age	Infant Weight	Total Weight Gain	Gravid Para
16	32	112 - 132	120	Walk	39 3/7	3856g	35#	G_2P_2
17	30	114 - 134	160	Jog	39 1/7	3289g	26#	G_2P_2
18	33	112 - 132	112	Walk	38 5/7	3317g	33#	G_2P_2
19	32	112 - 132	115	Swim	41 0/7	4082g	30#	G_1P_1
x20	33	112 - 132	131	Walk	40 4/7	3856g	20#	G_3P_2
x21	29	114 - 134	131	Walk	41 1/7	3799g	35#	G_3P_1
x22	32	112 - 132	144	Walk	38 4/7	2863g	40#	G_1P_1
x23	35	111 - 131	116	Swim	42 5/7	3770g	20#	G_3P_3
x24	36	110 - 130	142	Walk	41 1/7	4111g		G_1P_1
x25	31	113 - 133	130	Cycle	39 6/7	3515g		G_5P_3
x26	26	116 - 136	124	Walk	40 6/7	3827g	40#	G_3P_1
27	38	109 - 127	122	Swim	39 6/7	4082g	33#	G_7P_3
x28								
x29	37	110 - 128			44 2/7	3572g	38#	

a* = prospective data

x = subjects excluded from data analysis

Table 2

Description of Excluded Subjects

Reason Excluded	Subject Number												
	6	7	15	17	20	21	22	23	24	25	26	28	29
Low weight gain	X												
Excessive weight gain			X				X				X		X
Incomplete data		X										X	X
Exercise pulse in excess of 70%			X	X			X		X				
Discontinued program					X	X			X	X			
Extended gestation								X					X

Table 3

Experimental Population Data

Subject Number	Infant Birth Weight	Gestational Age	Mean Infant Birth Weight for Gestational Age in this sample
1	3090g	38 3/7	3204g
2	3317g	38 5/7	
3	3685g	39 2/7	
4	3856g	39 6/7	
5	3402g	39 1/7	
6	3118g	39 2/7	3448g
7	3090g	39 5/7	
8	3118g	39 0/7	
9	3232g	39 4/7	
10	4082g	39 6/7	
11	3657g	40 2/7	
12	2410g	40 4/7	3194g
13	3515g	40 3/7	
14	3742g	41 2/7	
15	4082g	41 0/7	3978g
16	4111g	41 1/7	
Total = 16	Mean = 3469g	Mean = 39 6/7	

Table 4

Control Population Data

Gestational Age	Mean Infant Birth Weight
38 wks n = 3761	3185g
39 wks n = 6609	3333g
40 wks n = 15691	3462g
41 wks n = 6047	3569g
42 wks n = 3144	3637g
Total n = 35,252	Mean Infant Birth Weight = 3437g

Discussion

Hypothesis

It was found that the mean birth weight for infants born to women who perform regular submaximal aerobic exercise in the second two trimesters of their pregnancies was 3469 grams. The mean birth weight for the control group was 3437 grams. When comparing mean birth weight for gestational age as depicted in Table 5, the experimental group of infants were acutally heavier than the control

Table 5

Comparison of Birth Weight for Gestational Age

Gestational Age	Control Group	Experimental Group
38 wks	3185g	3204g
39 wks	3333g	3448g
40 wks	3462g	3194g
41 wks	3569g	3978g
42 wks	3637g	-

infants in all gestational age categories except forty weeks. The lower mean birth weight at forty weeks in this sample is attributable to one low birth weight infant (2410 grams) who skewed the data. Analysis of this infant's maternal data reveals an exercise heart rate in appropriate target zone of aerobic capacity and a weight gain of twenty-one pounds at forty and two sevenths weeks gestation. The infant was born healthy, with good Apgärs. No apparent reason for the diminished birth weight was found.

The finding of heavier infants in the experimental exercise group is consistent with that of Collings et al. (1983). These researchers determined that triweekly bike testing of pregnant subjects exercising at 65-70% of their estimated maximal did not adversely effect infant birth weight. A greater mean infant birth weight was found in the exercise group.

The results of the present study and the investigations by Collings et al. lend further credence to the hypothesis that continued maternal exercise during pregnancy does not adversely effect infant birth weight as was implied by Clapp and Dickstein (1983). These investigators conclude that continued endurance exercise during pregnancy is associated with a consistent reduction in birth weight for gestational age.

The present findings also support earlier investigations of physical fitness and infant birth weight by Pomerance et al. (1974), Dressendorfer (1978), and Ruhling et al. (1981) who conclude that there is no association between maternal exercise and infant birth weight. Dressendorfer's subject actually exercised at 89% of her estimated maximal aerobic capacity, exceeding the recommended level of 70% for pregnant women. None of the subjects in the present investigation attained such high levels; however, five subjects did exceed the 70% level. Although not included in the final data analysis, their data is depicted in Table 6. Of interest is the fact that the mean birth weight of these infants (3595g) was actually heavier than either the overall control (3437g) or experimental groups means (3469g). Only one subject (D) delivered an infant considered below the fiftieth percentile for a gestational age at thirty-eight weeks. No additional data for this infant was supplied; however, maternal data indicates an excessive rather than inadequate weight gain during pregnancy.

This supplementary data suggest that even at more intense levels of aerobic work, maternal exercise has a limited effect on infant birth weight. This finding again conflicts with the Clapp and Dickstein (1983) conclusion, as well as those in animal investigations

Table 6

Data for Subjects Exceeding 70% Aerobic Work

Subject	Target Heart Rate Zone	Exercise Pulse	Percent Aerobic Capacity	Infant Birth Weight
A	113 - 133	152	80%	3913g
B	114 - 134	160	84%	3289g
C	114 - 134	136	72%	3799g
D	112 - 132	144	76%	2863g
E	110 - 130	142	77%	4111g
		Mean infant birth weight = 3595g		

(Dhindsa et al., 1979; Gilbert et al., 1980). This investigator speculates that the differing data may reflect the varied exercise intensities of the subjects involved in these later studies. Additional data would be necessary prior to any change in the current recommendations for exercise intensity during pregnancy however.

Three subjects in this present investigation did not exercise at levels compatible with 60% of their estimated maximal capacity. These subjects, however, were included in the data analysis as it was assumed by this investigator that it is the higher levels of aerobic work (greater than 70% of maximal capacity) that are suggested to result in hypoxic fetal conditions (Artal et al., 1980; Hon and Wohlgemuth, 1961).

Although the infants in this investigation were slightly heavier than the control infants, one must acknowledge the rather unique sample from which these results were derived. These women were healthy, Caucasian females, who tended to be older and used to a regular exercise regime. These factors could have influenced the present findings. Care should be taken not to generalize these results to other, less homogenous populations.

Additional Data

In completing this investigation it was discovered that women often discontinued participation in the Pregnancy Fitness Program during the third trimester of pregnancy. Subjective data was obtained from five women out of the entire Pregnancy Fitness Program population who delivered between July 1983 and May 1984, regarding their reasoning for discontinuing the program. The most common response (n = 3) was fatigue associated with other commitments such as employment. One respondent stated she wished she had continued the program as the exercise made her feel "great." One subject reported that although she did not actually participate in the program, she did continue many of the exercises employed in the class at home. Two subjects were advised by their health care professional to discontinue all activity during late pregnancy for medical reasons. One had premature rupture of membranes in her eighth month; the other had third trimester bleeding. These were the only two reported pregnancy complications. Although these complications pose a potentially significant finding, due the small sample size statistical analysis was not carried out, however, further evaluation is warranted.

The gestational age in the experimental group was 39.6 weeks while the control group mean was 39.4 weeks. This finding refutes that of Clapp and Dickstein (1983) who report that women who performed vigorous endurance exercise during pregnancy delivered early.

This discrepency might be attributed to the higher levels of exercise intensity sustained by several of the subjects in the Clapp investigation. Further data is necessary to evaluate this point.

The mean maternal age in the present study was thirty-one, with a range from twenty-seven to thirty-eight. There were eleven (68%) primigravidas and five (31%) multigravidas. Mean pregnancy weight gain in the sixteen subjects was calculated to be 27.5 pounds, which is considered to fall within the "ideal" range for weight gain during pregnancy.

Chapter IV

Summary

This chapter includes a summary of the study and findings, identification of limitations and implications for nursing practice. In conclusion, recommendations for further investigation are suggested.

The purpose of this investigation was to determine if a significant difference exists in the birth weight of infants born to women who perform submaximal aerobic exercise regularly during the second two trimesters of their pregnancies as compared to those infants whose mothers did not perform this exercise. A physiologic framework provided the basis for this study.

The physiological framework suggests that during maternal exercise, blood flow is redistributed to the working tissue, thus diminishing the flow of oxygen and nutrients away from the developing fetus. This physiologic alteration was speculated to result in hypoxic conditions for the fetus as evidenced by a decrease in infant birth weight. This hypothesis has been supported by investigations utilizing experimental animals.

In order to explore this relationship and to determine if a difference does exist in infant birth weight, an experimental study was designed. Sixteen women enrolled in a Pregnancy Fitness Program in a Pacific Northwest metropolitan community served as the sample. The control group utilized was that provided by Babson et al. (1970), who developed and utilized data on fetal growth as related to gestational age in a sample of forty thousand newborn infants born to women in a Pacific Northwest community between 1959-1966. The data analysis revealed that no significant difference existed in the infants born to women who perform regular submaximal aerobic exercise in the second two trimesters of their pregnancies as compared to the birth weight of infants whose mothers did not perform this exercise. These results support several earlier investigations of the relationship between maternal physical fitness and infant birth weight in human subjects.

Limitations

The study is limited by the small sample size. It is further limited by the conventional method of reporting gestational age from last menstrual period calculations, which can be subject to error. Additionally, prepregnant weight was subjectively obtained from the participants in the investigation. Furthermore, systematic sampling was employed as a substitute for precise random sampling and this may have resulted in unknown bias.

The standard error for method of predicting maximum oxygen uptake may be as high as 15%. Data reported here could contain this error. Standard tables from which maximum oxygen uptake are calculated are based on nonpregnant women and may not accurately predict maximal oxygen uptake in pregnant women. The data regarding the amount of exercise performed by mothers in the control group is unknown, but assumed to be considerably less than "aerobic." At the time that data were collected, physical exercise was often discouraged in pregnancy. A bias may have been introduced by the investigator when describing the research as involving infant birth weight, as subjects could try to alter this variable in order to "please" the investigator.

Implications for Nursing

The results of this investigation imply that performance of regular submaximal aerobic exercise during the second two trimesters of pregnancy does not create hypoxic conditions for the fetus as evidenced by infant birth weight. The favorable results of this investigation may have been influenced by the modified exercise regime incorporated into the Pregnancy Fitness Program from which the subjects were recruited. Therefore health care providers may wish to discuss the following precautions when prescribing an exercise program for the pregnant woman.

1. The woman should be accustomed to exercise; pregnancy is not the time to initiate an exercise regime.

2. The woman should be considered healthy, with a normally progressing pregnancy.

3. The exercise performed in pregnancy needs to be of submaximal intensity.

4. It is recommended that heart rate measurement of aerobic capacity be utilized to determine aerobic work.

5. Sixty to seventy percent of maximal attainable heart rate is an accepted level of aerobic work in pregnancy. A simplified formula for this level is to subtract woman's age from 220, multiply this figure by point six to obtain sixty percent target, and then multiply the initial figure by point seven to obtain the seventy percent target. The figures between these two numbers represent the target heart rate zone for submaximal aerobic exercise in pregnancy for this woman.

6. Exercise during pregnancy needs to be performed at regular intervals. A suggested program is three times weekly for a minimum of twenty and maximum of sixty minutes as recommended by the American College of Sports Medicine.

7. The pregnant woman should continuously be

cautioned to discontinue any activity that causes discomfort or is associated with vaginal bleeding.

Under the above conditions, the pregnant woman should derive the physical and psychological benefits of regular exercise without causing harm to her developing fetus.

Recommendations for Future Study

1. The study could be duplicated employing a larger sample size and utilizing random sampling procedures and a more diverse population.

2. Additional fetal parameters such as Apgar, gestational length and neonatal complications could be included in the investigation.

3. Additional maternal parameters such as prenatal, intrapartal and postpartal complications could be included in the investigation.

4. Further investigations of exercise intensity (above and below seventy percent of estimated maximal aerobic capacity) and effect on fetal outcome in experimental animals could be conducted.

5. Systematic investigation of reasons for discontinuing exercise in pregnancy could be done.

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Appendices

HEALTH HISTORY: EXERCISE HEMODYNAMICS AND RESPIRATION IN PREGNANCY

Date______________

PERSONAL DATA

Name____________________________________ Occupation____________________

Address__________________________________ Phone(s) ____________ home

______________________________ zip ________ ____________ work

Caregiver: Name ____________________________ Address__________________
(obstetrician, midwife)
____

PHYSICAL DATA

Height__________ Weight pre-pregnant____________ Date of birth ____________

present____________

Date of last normal menstrual period_________________. Do you ordinarily have regular menstrual periods?___________________________

If not, please explain ____

Expected due date____

List previous pregnancies, including all miscarriages and abortions. Mark with a star if delivered by Cesarian.

Year	Length of pregnancy	Weight gain with pregnancy	Baby's Sex	Baby's Weight	Complications of pregnancy and delivery

Do you have or have you ever had any of the following?

	Present	Past	Dates	How long?	Treatment or prescription
I. Previous pregnancy with: (circle which ones)					
stillbirth					
overdue 2 weeks or more					
premature					
infant death (age)					
Rh baby needing transfusion					
baby at term weighing less than 5 lbs					
toxemia of pregnancy					
Uterine anatomical problems					
Incompetent cervix					
Premature rupture of membranes					
Premature onset of labor					
Induction of labor					
Breech delivery					
Excessive amniotic fluid					
Multiple pregnancy					
Abnormal Pap smear					
Small pelvis					
Rh sensitization					
Bleeding during pregnancy					
Fetal deformity					
II. High blood pressure					
Kidney disease					
Protein in the urine					
Heart murmur					
Orthopedic problems					

	Pre-sent	Past	Dates	How long?	Treatment or prescription
Heart disease	____	____	____	____	________
Diabetes	____	____	____	____	________
Family history of diabetes	____	____	____	____	________
Glandular disorder (thyroid, pituitary, etc.)	____	____	____	____	________
Sickle cell disease	____	____	____	____	________
Thrombophlebitis	____	____	____	____	________
Thromboembolism	____	____	____	____	________
Epilepsy	____	____	____	____	________
Infections: (circle which ones) flu	____	____	____	____	________
Herpes gonorrhea	____	____	____	____	________
syphilis hepatitis	____	____	____	____	________
measles other	____	____	____	____	________
Anemia	____	____	____	____	________
Pulmonary condition: (circle which one) asthma	____	____	____	____	________
tuberculosis chronic bronchitis	____	____	____	____	________
emphysema					
Weight less than 100 lbs	____	____	____	____	________
more than 200 lbs	____	____	____	____	________
Missed menstrual periods not due to pregnancy	____	____	____	____	________
Emotional problems	____	____	____	____	________

III. Do you smoke? what? how much? for how long? ______________________________

Do you use alcohol? what? how many ounces per week? for how long? ______________________________

Do you use any drugs or medicines regularly? what? how much? for how long? ____________________

Do you take any food supplements, nutritional aids, or vitamins regularly? what? how much? ____________________

Are you participating in prepared childbirth classes? which ones? ____________________

Do you plan to breast feed or bottle feed your baby? ____________________

Please use the remaining space for any questions or comments you have.

FITNESS HISTORY Name______________________ Date________

Do you participate in regular physical exercise?_____yes_____no.

If yes, for each type of exercise you do regularly, please specify:

	1	2	3
Type of activity	________	________	________
How many months have you done this activity regularly?	________	________	________
How many times per month?	________	________	________
How many minutes each time, on the average?	________	________	________

How would you describe the intensity of exertion for each activity? Mild? Moderate? Strenuous? (Examples: if you run, walk, or ride a bicycle, how many miles at how many minutes per mile; tennis: singles or doubles; skiing, downhill or cross country; swimming: recreational or laps?) In general, how hard are you working when you exercise? What pulse rate do you attain?

activity 1:______________________________

activity 2:______________________________

activity 3:______________________________

Have your exercise habits changed since you became pregnant? If so, how? Please use the back of the sheet if you wish.

m/9/78

Appendix B

Data Collection Tool

Study identification number: ____________

Type of exercise performed: ____________

Exercise pulse: ______________

Resting pulse: ______________

Heart Research Lab
UNIVERSITY OF OREGON
HEALTH SCIENCES CENTER
Portland, Oregon 97201
503/225-8440

Name (mother)________________________

(baby) ________________________

Regular contractions began

(date)__________ (time)______________

Baby was born (date)____________________

(time)_______ am pm (place)______________

____

Estimated delivery date was____________

Baby's weight__________ length__________

sex______ Apgar score: 1 min_____ 5 min_____

Placental weight_______________________

" condition_______________________

Type of delivery?______________________

Anesthesia?___________________________

Complications?________________________

Appendix D

The Oregon Health Science University
School of Nursing

Consent for Human Subject Research Project: The Effects of Maternal Submaximal Aerobic Exercise on Infant Birth Weight

Investigator: Susan L. Hassett, R.N., B.S.N.

Supervisors: Carol Howe, C.N.M., DNSc.

I am trying to determine if a significant difference exists in the birth weights of infants born to women who exercise during the three trimesters of their pregnancies, as compared to infants whose mothers do not exercise during their pregnancies. To help me determine if such a difference exists, I would like to take your heart rate once near the end of your pregnancy, by feeling the pulses on your carotid (neck) artery, for one minute, after you have performed the aerobic endurance exercise that you normally do for the second half of the pregnancy fitness program. Also, I will provide a form and self addressed stamped envelope so that you may provide me with the following information about your newborn baby: infant's birth weight, date of birth; due date, and your last documented weight. Completing this form should take less than five minutes and it can be mailed from the hospital directly to me.

Your willingness to participate in this study will not affect your continued participation or non participation in the pregnancy fitness program. All information is confidential and will be coded and not name-associated. Also, your participation in this will not benefit you directly. However, future mothers may benefit from learning more about the relationship between pregnancy and exercise. Thus, you may benefit if you have another child. I will be happy to answer any questions or concerns you may have. My telephone number is 503-221-4575.

> "I understand that I may refuse to participate or may withdraw from this study at any time without affecting my relationship with, or treatment at the Oregon Health Sciences University."

"I understand what will be required of me and agree to participate in this study as described above."

Date: ______________________

Subject's Name: ____

Abstract

The effect of maternal submaximal aerobic exercise on infant birth weight was investigated within a physiologic framework. Sixteen women enrolled in a pregnancy fitness program and their infants' birth weights were compared by means of Student's t test to a control population of infant birth weights. Maternal exercise intensity was controlled by heart rate measurement estimates of maximal oxygen capacity during submaximal aerobic work. The results revealed that there was not a statistically significant difference between the two groups of infant birth weight. In fact, the experimental infants were actually slightly heavier than the control group. The data suggests that maternal submaximal aerobic exercise performed regularly throughout the second two trimesters of pregnancy is not detrimental to the fetus as evidenced by birth weight.