ASSOCIATIONS BETWEEN RESISTANCE TRAINING DURING PREGNANCY AND BIRTH OUTCOMES IN EXERCISING WOMEN

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ABSTRACT

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Pregnancy is an opportune time to discuss healthy lifestyle behaviors because women are often more receptive to behaviors that can provide the optimal environment for the growing fetus. Physical activity (PA) is one healthy behavior for which benefits have been shown to outweigh the risks, even during pregnancy. Current U.S. guidelines for PA during pregnancy focus on aerobic activity, even though resistance training is the third most commonly reported activity among pregnant women. Resistance training can be implemented as a form of PA to improve muscular strength and endurance during pregnancy; however, due to unknown potential risks, physicians are generally hesitant to recommend it. Although there are many benefits of resistance training, only a few investigators have examined its effect during pregnancy directly. Therefore, the overall purpose of this study was to determine the associations between resistance training and adverse pregnancy and birth outcomes.

To accomplish this, a retrospective, cross-sectional study design involving a convenience national sample of women was used to assess various forms of exercise, emphasizing resistance training. Women (n = 222) were recruited from a national health club chain via posters and completed a one-time online survey. Specifically, the Physical Activity Survey (PAS) included questions regarding ten domains of exercise, activities of daily living (ADL), and pregnancy and birth outcomes including gestational diabetes mellitus (GDM), preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and length of infant.

Using multiple logistic and linear regression and Fisher exact tests, we tested the associations between weekly total physical activity (TPA) and exercise status and adverse pregnancy and birth outcomes. On average, 29% of participants engaged in resistance training 2.68 days/week for 28 minutes/session throughout gestation with a goal of improving their muscular endurance (i.e., low weight and high repetitions). Overall, the prevalence of GDM was 8.6%, preeclampsia/gestational hypertension were 11.3%, and preterm labor was 9.5%. 85.5% of participants delivered between 37-40 weeks gestation, and 65.3% had a vaginal delivery. Mean birth weights and infant lengths were 3.47 ± 0.54 kg and 51.3 ± 3.5 cm, respectively. After adjusting for prepregnancy body mass index (BMI), neither weekly TPA nor exercise status were significantly associated with any pregnancy or birth outcome. Although the logistic regression models did not achieve statistical significance, point estimates were lowest for adverse outcomes among participants who performed resistance training + aerobic exercise. There was a significant reduction in risk for preeclampsia/gestational hypertension ($p = 0.03$), while there was marginal significance for GDM ($p = 0.06$) and preterm labor ($p = 0.07$) by exercise status. No association was found between exercise status and birth weight (0.60), infant length (0.07), mode of delivery ($p = 0.39$), and gestational age at delivery (0.33). In general, prepregnancy BMI influenced the outcome more than weekly TPA or exercise status.

In summary, our results suggest that exercising women who perform resistance training for muscular endurance, approximately three days/week for thirty minutes, do not significantly increase their risk for an adverse outcome during pregnancy.

DEDICATION

This dissertation is dedicated to all those who have imparted wisdom upon me, allowing me to make this journey possible.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACOG	American College of Obstetricians and Gynecologists
ACSM	American College of Sports Medicine
ADL	Activities of Daily Living
AE	Aerobic Exercise
ANOVA	Analysis of Variance
BDI	Beck Depression Inventory
BMI	Body Mass Index
bpm	Beats Per Minute
BRFSS	Behavioral Risk Factor Surveillance System
cm	Centimeters
C-Section	Cesarean Section
CAS	Communication Arts and Sciences
CI	Confidence Interval
CSEP	Canadian Society for Exercise Physiology
DHHS	Department of Health and Human Services
EK	Erin Kuffel
FITT	Frequency, Intensity, Time, Type
GDM	Gestational Diabetes Mellitus
hr	Hour
HR	Heart Rate
HRSD	Hamilton Rating Scale for Depression
ICC	Intraclass Correlation Coefficient

kg	Kilogram
KPAS	Kaiser Physical Activity Survey
m	Meter
MAQ	Modifiable Activity Questionnaire
MET	Metabolic Equivalent Unit
min	Minute
NCPP	National Collaborative Perinatal Project
NDAR	National Database for Autism Research
NE	No Exercise
NHANES	National Health and Nutrition Examination Survey
NLSY	National Longitudinal Survey of Labor Market Experience, Youth Cohort
NMIHS	National Maternal and Infant Health Survey
OR	Odds Ratio
PA	Physical Activity
PAS	Physical Activity Survey
PASW	Predictive Analytics SoftWare
PIH	Pregnancy-Induced Hypertension
PIN3	Pregnancy, Infection and Nutrition Study
PPAQ	Pregnancy Physical Activity Questionnaire
PRAMS	Pregnancy Risk Assessment Monitoring System
RCT	Randomized Controlled Trial
RM	Repetition Maximum
RR	Relative Risk

RTAE	Resistance Training and Aerobic Exercise
SD	Standard Deviation
SOGC	Society of Obstetricians and Gynaecologists of Canada
SPSS	Statistical Package for the Social Sciences
SSL	Secure Sockets Layer
TPA	Total Physical Activity
WISH	Women and Infant Study of Healthy Hearts
WK	Week
yr	Year

CHAPTER 1
INTRODUCTION

Recently, the Los Angeles Times reported that medical personnel at Johns Hopkins Bayview Medical Center in Baltimore are conducting fitness testing on women to determine how much exercise is safe for the fetus and mother [45]. They are examining elite pregnant athletes as well as sedentary pregnant women. Dr. Andrew J. Satin, professor and vice chairman of the Department of Gynecology and Obstetrics for the Hopkins School of Medicine stated most physical activity (PA) and exercise recommendations are based on, "opinion and common sense." Satin believes that there is still a large gap in the literature regarding exercise during pregnancy that has not been addressed adequately, mostly due to a fear in testing pregnant women [45]. Satin's comments typify the feelings of many pregnancy researchers. That is, while research over the past few decades has provided important information, we do not yet have definitive knowledge regarding which forms of exercise, such as aerobic, muscular strength, muscular endurance, and/or flexibility, are most safe and efficacious for the pregnant woman.

Pregnancy is an opportune time to discuss a healthy lifestyle because women often are more receptive to health advice and lifestyle modifications, including PA and exercise, in order to provide the best environment for the growing fetus [46, 65]. PA is a health behavior shown to be beneficial to the maternal-fetal unit. Benefits of regular PA for the mother include, but are not limited to, reduction of backaches, constipation, sleeping difficulties [10, 32], bloating and swelling [10], and weight control [142]. Further, physically fit women have been shown to handle and meet the physical demands of pregnancy more easily than their non-fit counterparts [123, 132, 159]. Although PA offers many benefits, less than half of American women participate in sufficient PA during pregnancy [161]. This is especially disconcerting because PA levels generally decline throughout gestation [28, 56, 74]. According to the 2000 Behavioral

Risk Factor Survey, 65.5% of pregnant women reported engaging in some leisure time PA. The most commonly reported leisure time activity was walking, followed by swimming laps, weight lifting, gardening, and aerobics [54]. While pregnant women engage in a wide variety of physical activities, most investigators have studied the effects of aerobic, rather than resistance exercise, even though resistance training is the third most commonly reported activity [34, 37, 53, 150]. This lack of research is a major reason why resistance training has not been addressed adequately in recent pregnancy PA guidelines [7-9, 149].

The impact of PA during pregnancy gained national attention in 1985 when the first recommendations were developed by the American College of Obstetricians and Gynecologists (ACOG) [7]. At that time, recommendations were cautious and focused on maternal-fetal safety. For example, in 1985, ACOG recommended that maternal heart rate not exceed 140 beats/min, strenuous activities should not exceed 15 minutes in duration, exercise in the supine position should be avoided after the fourth month of gestation, the Valsalva maneuver should be avoided, and maternal core temperature should not exceed 38^{o}C [7]. In the revised 1994 Guidelines, ACOG recommended regular exercise at least three times per week while modifying the intensity based on maternal symptoms [8]. In its more recent 2002 Guidelines, ACOG recommended that women accumulate 30 minutes or more of moderate exercise a day on most, if not all, days of the week in the absence of either medical or obstetric complications [9]. It is clear that as more evidence has become available, ACOG recommendations have become less conservative and more proactive.

Most recent recommendations for PA during pregnancy have been introduced as part of the U.S. Department of Health and Human Services (DHHS) Physical Activity Guidelines for Americans [149]. These guidelines indicate that a woman with an uncomplicated pregnancy can perform the same amount of PA as is recommended for a nonpregnant woman [149]. Thus, the current recommendation is:

> "Healthy women who are not already highly active or doing vigorous-intensity activity should get at least 150 minutes (2 hours and 30 minutes) of moderate-intensity aerobic activity per week during pregnancy and the postpartum period. Preferably, this activity should be spread throughout the week. Pregnant women who habitually engage in vigorous-intensity aerobic activity or are highly active can continue physical activity during pregnancy and the postpartum period, provided that they remain healthy and discuss with their health-care provider how and when activity should be adjusted over time" [149].

While recommendations for PA during pregnancy have been modified based on the most current research, they focus almost exclusively on aerobic activities. There is little discussion of resistance training, defined as "physical activity, including exercise, that increases skeletal muscle strength, power, endurance, and mass" [149]. Currently, the Society of Obstetricians and Gynaecologists of Canada (SOGC) and Canadian Society for Exercise Physiology (CSEP) have jointly developed the only formal resistance training recommendations during pregnancy [46]. According to the Canadian SOGC/CESP Guidelines, "All women without contraindications should be encouraged to participate in aerobic and strength-conditioning exercises as part of a healthy lifestyle during their pregnancy [46]." However, there are no specific recommendations regarding the frequency, duration, or intensity of resistance training, during pregnancy or the postpartum period, due to lack of research in this area. Therefore, research designed to investigate the effects of resistance training on the maternal-fetal unit is needed.

Resistance training can be implemented as a form of PA to improve muscular strength and endurance and control and maintain weight during pregnancy and the postpartum period. More specifically, pregnant women should not overlook training for muscular endurance as this will most similarly simulate and prepare them for labor and delivery [31]. In addition, because muscular strength and endurance are components of health-related fitness [17], they should not be ignored in a comprehensive exercise program. However, due to unknown potential risks, physicians generally are hesitant to allow previously active women to continue resistance training during pregnancy [117].

Some potential risks associated with aerobic exercise include hyperthermia and maternal injury due to joint laxity. Interestingly, it has been proposed that aerobic exercise causes a more elevated maternal temperature than resistance training because the heart rate and body temperature remain elevated throughout the entire aerobic session, whereas resistance training includes a stimulus phase and a rest phase between sets and repetitions allowing an elevated heart rate to drop and body temperature to dissipate [159]. Also, due to increased joint laxity, a pregnant woman may be more susceptible to soft-tissue injuries than if she were not pregnant [121, 136, 159]. Accordingly, women need to listen to their bodies and be aware of the physiological changes they are experiencing and modify their exercise routines based on symptoms.

While current U.S. guidelines do not formally recommend resistance training during pregnancy, some investigators suggest beneficial effects [30, 48, 68, 121, 132, 136, 159]. For example, resistance training may allow a woman to better handle her increasing weight and center of gravity [48, 136, 159], improve her self-image, and decrease her pregnancy-related discomforts, particularly low-back pain [68, 159]. Training a pregnant woman's muscles with endurance type resistance exercises (i.e., low weight and high repetitions) can prepare her for labor and delivery and thus allow for a quicker recovery and reduced postpartum muscle soreness [31, 121, 132, 136]. Therefore, resistance training can be of overall benefit to the mother during pregnancy and reduce the discomforts often associated with increasing gestation.

Other advantages of performing resistance rather than aerobic training, especially late in pregnancy, is that it offers women an activity in which they can remain relatively stationary [30]. In contrast, women might find running or other weight-bearing activities to be uncomfortable as pregnancy continues. Also, offering women the opportunity to add resistance training to their exercise routines may increase compliance due to a wider variety of activity options available [30]. Not only can resistance training be beneficial during pregnancy, but also during the postpartum period in activities of daily living (ADL) and postnatal care [46, 121, 132, 159]. During pregnancy, upper and lower body strength have been shown to decline from pre-pregnancy to six weeks postpartum and women may not fully recovered by 27 weeks postpartum [146]. Thus, a resistance training program could help counteract or prevent normal postpartum losses in muscular strength and endurance.

Although there are a multitude of benefits of resistance training for a pregnant woman, only a few investigators have examined its effect during pregnancy directly. Current literature shows fairly consistent and favorable birth outcomes in women who resistance trained [21-23, 25]. For example, in a randomized control trial performed by Barakat et al., women who completed an intervention of light toning resistance exercises (n = 72) did not differ significantly in mean gestational age, percent of preterm deliveries, Apgar score at 1 min, Apgar score at 5 minutes, birth weight, birth length, head circumference, type of delivery, or length of labor, compared to controls (n = 70) [21-23]. However, larger studies with more diverse participants are necessary with a wider range of resistance training types and intensities to corroborate these results. In addition, Barakat's intervention included women performing 35 minutes, three days/week of resistance training (105 minutes/week total) [21-23], which is much less than women in other studies who resistance trained 3 days/week for 45 minutes (135 minutes/week total) [68], or the duration seen in well-conditioned women that performed an hour and twelve minutes of resistance training, twice a week (144 minutes/week total) [82]. Thus, the Barakat et al. [21-23] intervention was performed at a lower exercise duration than other investigations. Further exploration of varying durations and intensities of resistance training during pregnancy is needed.

Randomized controlled trials are the most rigorous way to test a causal relationship between resistance training and birth outcome. However, before such investigations can be undertaken, more information regarding the range of exercise frequencies, intensities, and durations typically performed must be determined. Given concerns in the medical community about potential negative effects of resistance training during pregnancy, ethical concerns prevent researchers from conducting rigorous interventions that involve more intense resistance training at this time. Examining women retrospectively who self-selected to engage in resistance training during pregnancy will allow for determination of the associations of their levels of training to pregnancy and birth outcomes, thus filling a vital gap in the existing research literature. Therefore, this study will add to the literature by examining wide variations in frequency, intensity, and duration of resistance training programs during pregnancy and the associations between pregnancy and birth outcomes. Results from this investigation can help future investigators determine the upper limit of intensity for safe and efficacious resistance training programs that can be designed for clinical trials.

Aims

Study participants included women who were members of a national health club chain and who gave birth within the past five years. They provided all information via an online survey developed by the investigators. It was not possible to assess resistance training independently because women eligible for the study who performed resistance training also performed aerobic exercise. Thus, study participants were classified by exercise status into three groups: 1) women who performed both leisure-time resistance training and aerobic exercise (RTAE) during pregnancy, 2) women who performed only leisure-time aerobic exercise (AE) during pregnancy, and 3) women who performed no leisure-time exercise (NE) during pregnancy. Energy expenditure associated with the amount of resistance and/or aerobic exercise performed was quantified into MET·hr/wk. In addition to determining whether women performed RTAE and AE during leisure-time, we assessed activities of daily living (ADL) for all women via the Pregnancy Physical Activity Questionnaire (PPAQ). ADL were also quantified into MET·hr/wk. Finally, each woman's weekly total physical activity (TPA) during pregnancy (MET·hr/wk) was quantified by adding her RTAE or AE values, if available, to her ADL values.

Specific Aim 1: To develop an online survey to assess various forms of exercise during pregnancy, specifically various forms of resistance training, aerobic training, flexibility, group exercise classes, home videos, yoga, and pilates.

This aim was specific to assessing leisure-time exercise and was not hypothesis driven.

Specific Aim 2: To determine the prevalence of both traditional (i.e., weight machines and free weights) and nontraditional forms (i.e., resistance bands, whole body exercises, kettlebells) of resistance training during pregnancy among women health club members.

This aim was not hypothesis driven, but rather descriptive in nature of the study sample.

Specific Aim 3: To describe and evaluate the activities of daily living (ADL) and exercise status of women health club members during pregnancy within the past five years.

3a. The first part of this aim was descriptive in nature of the study sample and was not hypothesis driven.

3b. In the second part of this aim, it was hypothesized that pregnant women who performed leisure-time exercise (RTAE or AE groups), would have lower ADL compared to pregnant women who did not perform leisure-time exercise.

Specific Aim 4: To evaluate the relationship between weekly TPA and adverse pregnancy and birth outcomes, including gestational diabetes, preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and length of infant.

4a. It was hypothesized that weekly TPA during pregnancy would be inversely associated with prevalence of gestational diabetes and preeclampsia/gestational hypertension.

4b. It was hypothesized that weekly TPA during pregnancy would be inversely associated with birth weight.

4c. It was hypothesized that weekly TPA during pregnancy would not be associated with preterm labor, gestational age at delivery, mode of delivery, and length of infant.

Specific Aim 5: To evaluate the relationship between exercise status and adverse pregnancy and birth outcomes, including gestational diabetes, preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and length of infant.

5a. It was hypothesized that leisure-time resistance training and aerobic exercise during pregnancy would be inversely associated with prevalence of gestational diabetes and preeclampsia/gestational hypertension.

5b. It was hypothesized that leisure-time resistance training and aerobic exercise during pregnancy would be inversely associated with birth weight.

5c. It was hypothesized that leisure-time resistance training and aerobic exercise during pregnancy would not be associated with preterm labor, gestational age at delivery, mode of delivery, and length of infant.

CHAPTER 2
REVIEW OF THE LITERATURE

Prevalence of Pregnancy and Physical Activity among Pregnant Women

In 2005, approximately 6,408,000 pregnancies were reported with 4.14 million live births, which was approximately 103.2 pregnancies per 1000 women aged 15-44 years [152]. Thus, pregnancy affects many women and their behaviors throughout gestation especially regarding healthier lifestyle habits such as physical activity (PA). PA is defined as any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal (resting) level [17]. Both non-pregnant and pregnant women engage in PA on a daily basis with activities such as household tasks, walking, or planned exercise sessions. Therefore, knowing the prevalence of women engaging in various activities is important to determine the risks and benefits to the maternal-fetal unit associated with an active and healthy lifestyle. In 1996, among women participating in the National Maternal and Infant Health Survey (NMIHS), a cross-sectional survey sampling in 48 states and the District of Columbia and New York City, approximately 42% of women reported engaging in exercise during pregnancy [161]. Moving forward, according to the 2000 Behavioral Risk Factor Surveillance System (BRFSS), in which a nationally representative sample of women provided data, 73.1% of nonpregnant women reported some leisure time PA in the past month compared to 65.6% of pregnant women [54]. Upon further examination, those percentages dropped dramatically to 26.1% in nonpregnant women and 15.8% among pregnant women when considering the percentage of women meeting PA guidelines of at least 30 minutes of moderate intensity activity five days/week and/or at least 20 minutes of vigorous intensity activity three days/week [54]. According to the most recent estimates from the 1999-2006 National Health and Nutrition Examination Survey (NHANES), 56.6% of pregnant women reported participating in moderate-to-vigorous leisure activity, but only 22.9% met recommendations of 150 min/week of moderate intensity aerobic activity [56]. Therefore, it has been established that women engage in a variety of forms of PA during pregnancy. However, to more fully investigate the effects of PA on the maternal-fetal unit more information regarding commonly performed activities is needed. Walking is by far the most commonly reported activity for pregnant women, with other activities being performed to a lesser extent [54, 56, 161]. According to the NMIHS cohort, the most commonly reported activities were walking (42.8%), swimming (11.8%), aerobics (11.6%), biking (7.6%), calisthenics (6.7%), other dancing (5.1%), jogging (3.9%), hiking (1.6%), and other (9%) [161]. Similarly, in the BRFSS cohort of pregnant women that met PA recommendations, the most commonly reported activities were walking (83.4%), swimming laps (11.6%), weight lifting (10.8%), aerobics class (10.7%), running (10.1%), gardening (8.6%), and other activities [54]. According to the 1999-2006 NHANES cohort of pregnant women, the most commonly reported leisure activities were walking (40.9%), recreational activities (18.6%), and indoor aerobic conditioning activities (11.8%) [56]. A limitation to the NMIHS and BRFSS cohorts was that the specific intensity or duration of activity being performed was not known. However, the NHANES cohort delineated both the time and intensity of specific activities performed. When examining the 8 years between 1999 and 2006, pregnant women on average performed 5.4 MET-hours/week of moderate leisure activity, 3.0 MET-hours/week of vigorous leisure activity, and 8.5 MET-hours/week of moderate-to-vigorous activity [56]. When examining more specific activities, on average women performed 1.5 hours/week of aerobic exercise (2008 recommendation is ≥ 2.5 hours/week [149]) and weight-lifted 1.3 times/week [56]. These results show that women engaged in aerobic as well as muscle strengthening activities. Accordingly, due to the high prevalence (~10%) of women engaging in muscle-strengthening activities throughout pregnancy, further investigation on the specific frequency, type, intensity, and duration of activities is warranted. However, few studies have focused on this topic

Statement of the Problem

While aerobic training throughout gestation is beneficial, pregnant women should also consider training for muscular endurance as this has been shown to help prepare them for labor and delivery [31]. Further, because muscular strength and endurance are components of health-related fitness [17], they should not be overlooked in a comprehensive exercise program. However, due to the unknown potential risks associated with resistance training during pregnancy, physicians generally are hesitant to allow previously active women to continue their exercise regimes, especially in regard to resistance training [117]. Resistance training is defined as "physical activity, including exercise, that increases skeletal muscle strength, power, endurance, and mass" [149]. Thus, resistance training will not only improve or at least help maintain muscular strength and endurance, but can also be used as a method to control and maintain weight gain during pregnancy and the postpartum period. Although muscular strength and endurance are two of the five components of health-related fitness, they are oftentimes overlooked during pregnancy and should not be.

History of Physical Activity Guidelines during Pregnancy in the United States

As stated earlier, women engage in a multitude of activities during pregnancy. In the early 1980's, women from the "baby boom" generation became interested in knowing the effects of being active during pregnancy and thus inspired a need for guidelines [158]. Accordingly, in 1985 the American College of Obstetricians and Gynecologists (ACOG) developed their first recommendations for PA during pregnancy and the postpartum period [7]. These recommendations were cautious and focused on keeping the maternal-fetal unit safe. Specifically, the ACOG recommended that maternal heart rate not exceed 140 beats/min, strenuous activities should not exceed 15 minutes in duration, exercise in the supine position should be avoided after the fourth month of gestation, the Valsalva maneuver should be avoided, caloric intake should be adjusted accordingly to accommodate the increased energy demands of both pregnancy and exercise, and maternal core temperature should not exceed 38°C [7]. The Valsalva maneuver is attempting to exhale against a closed airway and it is generally not recommended for all individuals; however, it is particularly important to avoid during pregnancy because it can alter blood flow to the fetus. These guidelines were very conservative and based primarily on intuition and "common sense" [7]. At that time, there was not enough scientific evidence to firmly establish increased benefits or risks of exercise during pregnancy. Also, due to the physiological changes that occur to women during pregnancy (joint instability, change in center of gravity, etc.) the recommendations were conservative to protect the maternal-fetal unit.

In 1994, ACOG updated their guidelines and recommended regular exercise at least three times per week while modifying the intensity based on maternal symptoms [8]. Further recommendations suggested that the pregnant woman should avoid the supine position after the first trimester, avoid standing motionless for prolonged periods of time, modify the intensity of the exercise based on maternal symptoms and not exercise to exhaustion, avoid exercises involving the potential risk of abdominal trauma, consume an additional 300 kcal/day, and ensure appropriate heat dissipation by adequately hydrating, wearing appropriate clothing, and exercising in optimal environments [8]. The 1994 guidelines also stated specifically that aerobically fit women can safely exercise to maintain cardiorespiratory and muscular fitness levels throughout pregnancy and the postpartum period [8]. Thus, the 1994 guidelines suggested that a woman can participate in more activity than previously recommended, but stated that there was still not enough evidence to demonstrate that exercise was beneficial for birth outcomes [8].

In 2002, ACOG stated explicitly that "in general, participation in a wide range of recreational activities appears to be safe" [9]. ACOG recommended that women accumulate 30 minutes or more of moderate exercise a day on most, if not all, days of the week in the absence of either medical or obstetric complications [9]. Similar to previous guidelines, it was also recommended that pregnant women should avoid the supine position and motionless standing as much as possible, as well as activities with a high risk of falling or abdominal trauma [9]. Hence, as more evidence became available, ACOG recommendations have followed by incorporating current research findings.

Based on the most recent literature, current guidelines set forth by the United States Department of Health and Human Services (DHHS) recommend the same amount of PA for non-pregnant women and pregnant women with uncomplicated pregnancies [149]. Thus, the current DHHS recommendation during pregnancy and the postpartum period is:

> "Healthy women who are not already highly active or doing vigorous-intensity activity should get at least 150 minutes (2 hours and 30 minutes) of moderate-intensity aerobic activity per week during pregnancy and the postpartum period. Preferably, this activity should be spread throughout the week. Pregnant women who habitually engage in vigorous-intensity aerobic activity or are highly active can continue physical activity during pregnancy and the postpartum period, provided that they remain healthy and discuss with their health-care provider how and when activity should be adjusted over time" [149].

Overall, guidelines for PA during pregnancy have evolved from a very conservative approach designed to protect the maternal-fetal unit, to an approach highlighting the benefits of PA for both the mother and fetus. Current DHHS guidelines address both the sedentary and the regularly active woman by recommending that previously sedentary pregnant women begin an exercise program and previously active women maintain their exercise regimes, provided that all women maintain a health pregnancy and contact with their health-care providers [149]. Thus, in a healthy pregnancy, a mother-to-be can engage in, and benefit from, similar amounts and intensities of activity compared to her nonpregnant counterpart.

While past and current recommendations have evolved as more research has become available, a limitation of current guidelines is the paucity of discussion regarding activities that are not aerobic in nature. As early as 1989, there were crude recommendations for other types of activities during pregnancy [132]. Shangold recommended aerobic exercise, weight lifting, and flexibility exercises for the pregnant woman [132]. Specifically, she recommended that if a woman is considering becoming pregnant she should first become fit to better prepare her for the increase in work load associated with pregnancy, labor, and delivery [132]. Shangold recommended aerobic exercise at a comfortable pace (as indicated by perceived exertion), weight training, calisthenics, and stretching [132]. Aerobic exercise could include a variety of activities that kept the heart rate elevated, such as running, stationary bicycling, swimming, etc., at an intensity the woman was accustomed to pre-pregnancy and at a conversational pace. Shangold stated that weight lifting should be avoided if women have cardiac disease or musculoskeletal injuries, however, all women, including sedentary women, could begin a weight lifting program. She believed that engaging in a weight lifting program would decrease the discomfort associated with pregnancy, including low back pain and an altered center of gravity

[132]. In addition, Shangold did not believe that a pregnant woman should perform different amounts or patterns of weight lifting compared to nonpregnant women. To ensure the safety of exercise, she suggested women to check their rectal temperatures after a "routine" workout early in pregnancy to determine the safety of intensity level. Shangold suggested that exercise could be considered safe if the core temperature was 101^{o}F (38.3^{o}C) or less, if greater than 101^{o}F, then the woman should modify her routine by wearing looser fitting clothes, drinking more liquids, reducing the intensity or duration of her workout, and exercising in a cooler environment or time of day [132]. She suggested other preventative measures including avoiding saunas and hot tubs, taking vitamin and mineral supplements, avoiding sports that potentially increase risk for abdominal trauma, and avoiding high altitude. Medical attention should be sought and exercise discontinued until determined safe if bleeding, rupture of membranes, or the fetus stops moving [132]. Therefore, as early as 1989 weight-lifting during pregnancy was of interest; however, the recommendations set forth by Dr. Shangold were not nationally recognized, nor were there data available to support her opinion.

The first formal guidelines that included resistance training during pregnancy likely came from the Joint Society of Obstetricians and Gynaecologists of Canada (SOGC) and the Canadian Society for Exercise Physiology (CSEP) [46]. According to the Canadian SOGC/CSEP Guidelines for Exercise in Pregnancy, "All women without contraindications should be encouraged to participate in aerobic and strength-conditioning exercises as part of a healthy lifestyle during their pregnancy [46, 158]." Further, the Joint SOGC/CSEP Canadian Guidelines recommended that women with or without previously sedentary lifestyles could begin an aerobic and strength conditioning program [46]. Specifically, they recommended muscular strengthening exercises for the upper and lower back, abdomen, upper body, and buttocks/lower limbs as well as pelvic floor exercise, and static stretching [158]. These exercises, when done properly, were believed to enhance or maintain general maternal fitness, good posture, assist with labor, and prevent low back pain, urinary incontinence, diastasis recti, and varicose veins [158]. To ensure safety of the maternal-fetal unit, the recommendations also stated that the supine position should be avoided after the fourth month of gestation, a woman should use good posture in daily activities, controlled static exercises rather than ballistic exercises should be performed, the Valsalva maneuver be avoided, and that abdominal exercises be discontinued if diastasis recti developed [158]. Thus, the SOGC and CSEP are the only major medical organizations that formally recommend resistance training, in addition to aerobic training, as part of a comprehensive and healthy exercise regime during pregnancy. However, the SOGC/CSEP guidelines for resistance training are very vague and do not recommend a specific frequency, intensity, or duration due to the lack of research. While these Canadian guidelines recommend resistance training during pregnancy, the DHHS and ACOG do not formally recommend resistance training during pregnancy, but many investigators have made suggestions, based on expert opinion, regarding what might be recommended when considering the pregnant woman (see Appendix A).

Three ACOG pamphlets, published in 2003, 2006, and 2009, stated the many benefits of exercise including reducing backaches and other pains, preventing or treating gestational diabetes, increasing mood and energy, strengthening muscles, improving flexibility, weight control, and getting back into shape after delivery [10-12]. ACOG promotes exercise as a way to prepare the mother for pregnancy, labor, and delivery, as well as a way to get back in shape postpartum. It highlights specific exercises, including walking, swimming, cycling, and aerobics, while stating that if women were active in running, racquet sports, or strength training prior to pregnancy they should be able to continue these activities in moderation [10]. ACOG stated that resistance training offers unique benefits to the pregnant woman including increasing her strength and preventing some of the aches and pains associated with pregnancy. However, there are no formal guidelines from ACOG recommending resistance training. In addition, there are no recommendations stating what type, intensity, frequency, or duration of resistance training is safe during pregnancy. In short, ACOG touts the benefits of resistance training, but does not provide specific recommendations.

Maternal Benefits of Aerobic Physical Activity and Exercise during Pregnancy

Although PA offers many benefits, less than half of American women participate at or above recommended levels during pregnancy [161]. In addition, PA levels generally decline throughout gestation, thus reducing the benefits associated with regular and continued activity [28, 56, 74]. Pregnancy is a valuable time to discuss healthy lifestyle habits because women are often more receptive to advice and lifestyle modifications, including PA and exercise, in order to provide the best environment for the growing fetus [46, 62, 65]. For instance, in the NMIHS cohort, 7% of women began exercising once they found out they were pregnant [161]. To determine the impact of PA during pregnancy, in 2005, the American College of Sports Medicine (ACSM) held a Roundtable discussion. The panel concluded that in women undergoing a normal pregnancy, the benefits of PA outweigh the risks, PA is safe to engage in, and the benefits extend to both mother and fetus [1, 65, 116]. Thus, pregnancy is a critical time to discuss the many benefits of PA.

Some commonly assessed maternal outcomes in pregnancy are gestational diabetes mellitus (GDM), preeclampsia and pregnancy-induced hypertension (PIH), lipidemia, mode of delivery, and weight gain. There is consensus that PA and exercise reduce the risk of GDM [1, 53, 62, 130]. In a study examining 12,799 women from the Central New York Regional Perinatal Data System, it was found that among women with a body mass index (BMI) > 33 kg/m^2 there was an increased risk of developing GDM if they did not exercise (OR 1.9 95% CI 1.2-3.1) versus women who exercised [53]. This was just one example of a population-based study in which exercise showed a beneficial association with GDM. While not every study has shown exercise to have a statistically significant effect in reducing the risk of GDM, several review articles showed the incidence rates were generally in the direction of a protective effect [1, 62, 105, 130]. Further, of the studies reviewed, none reported an adverse effect of aerobic exercise or PA on GDM. While exercise remains a positive adjunct therapy, due to the lack of evidence for specific frequency, intensity, duration, and type of exercise to produce the most optimal reductions in GDM, clear and consistent results are still lacking [105].

When examining the reduction in risk of preeclampsia, the general consensus was that exercise and PA are beneficial, but firm conclusions cannot be made regarding specific type, intensity, frequency, or duration for optimal regulation of blood pressure during pregnancy [1, 62, 130]. A review by Gavard and Artal showed that while not all studies examined achieved statistical significance, the observed trends were in a protective direction; however, the overall strength of association is unknown [62]. The authors state that overall, there may be a weaker association between exercise and preeclampsia due to selection bias, recall bias, and lack of control for potentially confounding variables [62].

Studies examining plasma lipid levels in early pregnancy have shown that habitual PA could reduce the risk of pregnancy-associated dyslipidemia [1, 34]. For example, type, frequency, and duration of PA were assessed in 925 normotensive, non-diabetic pregnant women. Among those women who expended more than 67.5 MET-hours/week in recreational

PA, there was a protective effect on triglycerides (OR 0.45 95% CI 0.27-0.76) and total cholesterol (0.55 95% CI 0.35-0.88) when compared to women who expended 0 MET-hours/week in recreational PA [34]. These results demonstrated that PA may attenuate dyslipidemia among pregnant women.

In a cohort of 1,955 women from the North Carolina Pregnancy Risk Assessment Monitoring System (PRAMS), mode of delivery was examined [29]. This large population-based cohort allowed for stratification of women delivering term and preterm infants. Among women who delivered term infants, there was no association between relative risk of cesarean section and women who exercised ≥ 5 days/week (RR 1.04 95% CI 0.66-1.64) or 1-4 days/week (RR 0.89 95% CI 0.69-1.15) [29]. However, among women who delivered preterm infants (defined as < 37 weeks gestation), there was a trend for a protective effect on delivering via cesarean section from exercising 1-4 days/week (RR 0.65 95% CI 0.38-1.13) and ≥ 5 days/week (RR 0.62 95% CI 0.29-1.33) [29]. In another study, among 44 women classified into two groups: 1) active women, defined as ≥ 30 minutes of moderate PA/day (n = 27) and 2) inactive, defined as < 30 minutes of moderate PA/day (n = 17), those in the active group showed a trend toward decreased chance of operative delivery (p = 0.06) [101]. Comparable conclusions were made in a review by Schlussel et al., as three studies did not show significant differences in mode of delivery while one study demonstrated an increased risk of cesarean section among sedentary women [130]. Thus, while not all point estimates were statistically significant for a reduction in cesarean section, the trend was for a protective effect.

Evidence regarding exercise and weight control, both during and after pregnancy, is mixed. A review by Schlussel et al., found five studies that demonstrated improved control, while three studies with the lowest methodological quality did not [130]. Overall evidence suggests that it is not clear what level of PA or exercise is needed to produce a beneficial effect on weight control during and after pregnancy; however PA is generally still recommended for weight management [16].

While there is a great deal of literature regarding the benefits of exercise during pregnancy stated above, there are other, less studied, maternal benefits of regular aerobic PA/exercise including reduction of backaches, constipation, sleeping difficulties [10, 32], bloating and swelling [10], and positive psychological health [1, 120]. PA and aerobic exercise also can increase a woman's energy levels [10, 32, 142] and allow for maintenance of long-term fitness levels and a low cardiovascular risk profile [1, 37]. Thus, aerobic exercise during pregnancy provides a wide range of maternal benefits.

Fetal Benefits of Aerobic Physical Activity and Exercise during Pregnancy

Not only are there many maternal benefits from PA during pregnancy, but the benefits also extend to the fetus. For example, weight-bearing exercise in early pregnancy has been shown to enhance fetoplacental growth [42]. Clapp et al. randomly assigned 46 women to either a no exercise group (control; n = 24) or a weight-bearing exercise group (n = 22) at eight weeks gestation. Women began weight-bearing exercise (i.e., treadmill, step aerobics, or stair stepper) for 20 minutes 3-5 days/week. Among the exercising women, offspring were heavier (3.75 ± 0.8 kg vs. 3.49 ± 0.7 kg) and longer (51.8 ± 0.3 cm vs. 50.6 ± 0.3 cm) when compared to the control group, respectively. Other measurements including ponderal index, head circumference, and body fatness were not significantly different between the groups [42]. Of particular interest was that the placental volume was significantly greater at 20 (225 ± 15 cm^3 vs. 181 ± 9 cm^3) and 24 weeks (327 ± 16 cm^3 vs. 264 ± 13 cm^3) gestation, and at delivery (462 ± 18 cm^3 vs. 414 ± 14 cm^3) among the exercisers vs. control group ($p < 0.05$) [42]. Not only does exercise appear beneficial to in utero growth, but also may help reduce preterm birth. Among 1,699 women who exercised vigorously, Evenson found a nonsignificant trend for reduced risk of preterm birth during the first (0.80 95% CI 0.48-1.35) and second (0.52 95% CI 0.24-1.11) trimesters of pregnancy [55].

Further support for a beneficial effect of PA during pregnancy was found by Rice and Fort [66]. In their prospective study, 24 women were divided into an active or sedentary group upon initial recruitment and then followed-up 2-5 days after delivery [123]. Active women were considered those who had planned on continuing to engage in 30 or more minutes of continuous aerobic activity at least 3 times/week throughout the duration of their pregnancy. Women who did not meet that criterion were considered sedentary. Approximately 2-5 days after delivery the women were asked a variety of questions by phone regarding their pregnancy and delivery. The authors found no differences between the active and sedentary groups, respectively, for length of gestation (39.9 ± 1.4 weeks vs. 39.5 ± 1.4 weeks), length of labor (6.1 ± 2.3 hours vs. 6.7 ± 3.1 hours), maternal weight gain (30.6 ± 7.9 lbs. vs. 29.2 ± 11.5 lbs.), fetal weight (7.7 ± 0.70 lbs. vs. 7.6 ± 0.99 lbs.), 1 minute Apgar scores (7.8 ± 0.72 vs. 7.3 ± 0.67), 5 minute Apgar scores (9.0 ± 0.43 vs. 8.8 ± 0.40), perceived exertion (during labor) according to the original Borg scale ranging from 6-20 (12.9 ± 1.4 vs. 14.1 ± 1.6), and time in labor (38.2 ± 32.8 minutes vs. 19.9 ± 10.3 minutes) [123]. While none of the results were significant, it is interesting to note that infants born to active women had slightly higher one and five minute Apgar scores and mothers had a lower rating of perceived exertion during labor. Thus, being active did not negatively affect the mother or infant, while improving the labor and delivery of the child. The active women perceived labor to be less strenuous than the sedentary women most likely due to performance of demanding workouts and possibly stronger abdominal muscles [123].

Effects of maternal exercise extend beyond delivery from five days to five years of age [40, 43, 44]. At just five days old, Clapp et. al., found that infants of exercising mothers scored significantly higher on orientation behavior and their ability to regulate state than of infants born to physically active women who did not engage in regular sustained bouts of exercise [43]. At one year, offspring of exercising women showed no significant differences in weight, length, percent body fat, and head, chest, or abdominal circumferences, even though they were significantly lighter and (3.38 ± 0.06 kg vs. 3.58 ± 0.07 kg) and leaner (9.5 ± 0.4% fat vs. 12.6 ± 0.6% fat) at birth when compared to control women, respectively [44]. Also, neurodevelopmental characteristics, such as mental and psychomotor scores from the Bayley scales were not clinically significantly different between the two groups, demonstrating proper postnatal growth within the first year of life [44]. Extending these results further, offspring of women who exercised during pregnancy showed no detrimental effects on growth or neurodevelopmental characteristics at five years of age [40].

In summary, overwhelming evidence has shown that a woman with a healthy pregnancy can benefit greatly from engaging in PA or aerobic exercise throughout pregnancy. Further, exercising will not cause harm to the fetus either in utero or during the first five years of life.

History of ACSM Resistance Training Guidelines for Healthy Adults in the United States

In 1978, the ACSM published its first guidelines titled, "The Recommended Quantity and Quality of Exercise for Developing and Maintaining Fitness in Healthy Adults" [13]. In these guidelines, the recommendations were based on available evidence with the purpose to develop or maintain cardiorespiratory fitness and body composition. The primary focus was on training effects which could be achieved by altering the frequency, intensity, and/or duration of aerobic exercise [13]. Resistance training recommendations were not provided because studies examining circuit training "showed little to no improvements in working capacity and VO_{2max}" [13]. However, the 1978 guidelines stated that weight lifting had value for increasing muscular strength and endurance, but because it had little improvement on VO_2, formal guidelines were not made. Moreover, specific guidelines for resistance training were not set due to a lack of research, rather than a lack of perceived importance [59]. In 1990, new guidelines were developed by ACSM which replaced the 1978 version [14]. In these guidelines, the focus switched from training effects ("fitness") to a more global perspective on "health benefits." ACSM acknowledged that there may be different recommended amounts of exercise depending on a person's goal – whether it is to improve fitness or to have general health benefits. In 1990, the ACSM first recommended strength training for the healthy adult. The guidelines stated that resistance training should be performed at least 2 days/week at a moderate intensity for a duration of one set with 8-12 repetitions of 8-10 exercises of the major muscle groups [14]. These guidelines also introduced the concept of using heavier weights and fewer repetitions if training for muscular strength, and lighter weights with more repetitions if training for muscular endurance. As a result, in their 1990 Guidelines, the ACSM added a weight lifting component to encompass a well-rounded training program, but warned that the participants' needs, goals, and initial abilities need to be considered before prescribing a specific exercise regimen. Also, rather than focusing primarily on improving one's aerobic fitness (VO_{2max}), these recommendations were based on available research that allows for maximal health benefits, while minimizing any associated risk of exercise (i.e., injury, muscle soreness) [14]. Further, the 1990 recommendations conclude with the following sentence demonstrating the importance of PA and not just exercise: "Emphasis should be placed on factors that result in permanent lifestyle change and encourage a lifetime of physical activity [14]."

In 1998, the ACSM revised their guidelines once again and set specifics for cardiorespiratory fitness, muscular strength and endurance, and flexibility [15]. These guidelines included slight changes to the recommendations for cardiorespiratory fitness, while recommendations for muscular strength and endurance were also revised to include changes in the frequency to 2-3 days/week, while the intensity and duration remained the same [15]. The 1998 ACSM guidelines also stated specifically the major muscle groups to include in a resistance training program are arms, shoulders, chest, abdomen, back, hips, and legs [15].

While the 1998 PA recommendations for muscular strength and endurance may seem minimal, the ACSM made the recommendations on the basis of three main principles. First was the amount of time it takes to complete a well-rounded program. The muscular strength and endurance recommendations had to be compatible and feasible to complete along with the cardiorespiratory guidelines. Second, while more substantial improvements may be seen with increased frequency, intensity, or duration of resistance training, the stated recommendations sufficed for general health. Again, this was a balance between feasibility, safety, and maximizing health benefits while minimizing injury. Last, the recommendations were safe for nearly all populations. While increasing sets or repetitions may be beneficial to younger individuals and allow for greater improvement, older or weaker individuals should be more cautious [15].

To achieve muscular strength and endurance, the ACSM currently recommends a frequency of 2-3 non-consecutive days/week, training major muscle groups with 2-4 sets of 8-12 repetitions, with 2-3 minutes rest between each set [17]. Historically it can be seen that the

ACSM guidelines for resistance training have evolved and become an integral component of a well-rounded fitness program for adults. Thus, while it took the ACSM until 1990 to prescribe resistance training for the general population, there are still no current guidelines for resistance training among pregnant women in 2011 so the issue requires further investigation.

Benefits of Resistance Training in Adults

Major organizations such as the ACSM and DHHS endorse resistance training, also known as strength training, for adults [17, 149]. There are many benefits of resistance training, in adult populations, that will be summarized next, including two review articles [118, 157]. Overall, resistance training has shown fairly consistent and strong relationships to increasing bone mineral density, lean body mass, muscular strength, insulin sensitivity, submaximal endurance time, maximal endurance time, bone strength, bone growth, basal metabolism, low back strength, resting metabolic rate, increased HDL levels, glucose metabolism, muscle mass, and dynamic balance [118, 149, 157]. Resistance training also has been shown to decrease body fat, basal insulin levels, systolic blood pressure, diastolic blood pressure, resting heart rate, and risk of falling [118, 157]. Not only do these benefits reduce the risk of certain forms of cancer, diabetes, and heart disease, but they also improve overall body strength and endurance allowing individuals to complete activities of daily living (ADL) more easily [149, 157]. Resistance training is also suggested by ACSM as a means to lose weight and prevent weight regain because it helps an individual maintain fat-free mass while augmenting fat loss [16]. In addition, improving muscular strength and endurance may allow overweight and obese individuals to become more physically active in daily life because they can more easily perform ADL [16, 59]. Thus, resistance training programs should be performed by adults in conjunction with aerobic exercise to maximize health benefits.

When specifically examining resistance training in women, Kraemer et al., randomly assigned 35 healthy women to one of four groups: 1) bench step aerobics for 25 minutes (n = 8; 31.8 ± 7.9 yr), 2) bench step aerobics for 25 minutes plus a resistance training program (n = 9; 33.0 ± 8.1 yr), 3) bench step aerobics for 40 minutes (n = 12; 37.3 ± 8.0 yr), or 4) control group who performed ADL (n = 6; 27.8 ± 6.9 yr) [83]. After 12 weeks of training, 3 days/week, women in the bench step aerobics and resistance training group had significantly improved both their 1-repetition max (1-RM) squat and shoulder press (26% and 17%, respectively), while the other two exercise groups only increased their 1-RM squat (9% in the bench step aerobics for 25 minutes and 17% in the bench step aerobics for 40 minutes groups). The bench step aerobics and resistance training group showed significant improvements in cycle time to exhaustion, shoulder power, and peak vertical jump power. There was also a trend (p = 0.08) for improvement in fat-free mass in the bench step aerobics and resistance training group [83]. Thus, this study demonstrated that resistance training could be added to an aerobic workout without negatively impacting fitness adaptations. Also, the addition of resistance training augmented improvements in aerobic fitness as well as improving muscular strength and power that was not seen from the bench step aerobics alone, even though the duration of both programs were similar [83]. These results lend encouraging evidence that resistance training can be added to an aerobic program for greater improvements in women's overall fitness profiles.

In another study, women's strength and power were assessed after a 24-week resistance training program [84]. Women were assigned to one of six exercise groups: 1) total body strength/power (n = 17), 2) total body strength/hypertrophy (n = 18), 3) upper body strength/power (n = 18), 4) upper body strength/hypertrophy (n = 15), 5) field plyometrics and partner-resisted exercises (n = 14), or 6) aerobic exercise (n = 11). The first four groups completed resistance training either for all the major muscle groups of the body (total body groups) or only upper body exercises (upper body groups). Groups that trained for strength/power completed 3 sets of 3-25 repetitions three days/week, while groups that trained for strength/hypertrophy completed 3 sets of 12-30 repetitions three days/week. In addition, all resistance training groups completed 25-35 minutes of aerobic exercise. In general, after 24 weeks, high-intensity physical performances (1-RM squat, 1-RM bench press, squat jump power, bench throw power, squat endurance, 1-RM box lift, repetitive box lift, two mile loaded run, push-ups, and sit-ups) were improved. Improvements were related to the type of training performed; for example, aerobic training did not significantly impact strength/power performances and resistance training programs were specific to the type of program used (upper versus total body) [84]. Thus, this six month resistance training program showed evidence for improvements in women's physical performance and functional capacity.

Other investigators have examined the effect of resistance training on more clinical outcomes. In one study, 40 moderately to severely depressed women (18-35 yr) were randomly assigned to either 1) an aerobic program, 2) a weight lifting program, or 3) were part of a control "wait list" group [51]. The aerobic program consisted of four days/week of a 5-10 minute warm-up and walking or running around an indoor track at 80% of estimated HRmax (220 – age), followed by a 5-10 minute cool-down. The weight lifting group was prescribed to exercise four days/week, with a 5-10 minute warm-up, 10-station program at 50-60% of HRmax, and then a 5-10 minute cool-down. While the wait-list control group were told that their exercise program would begin in 8 weeks [51]. At the end of the eight-week program, there were both statistically and clinically significant decreases in depression as assessed by the Beck Depression Inventory (BDI) and Hamilton Rating Scale for Depression (HRSD) when exercising women were compared to the control group. There were no significant differences in depression scores between the two exercising groups. Further, when these women were re-contacted one year later, most improvements were well maintained [51]. Some of the main implications from this study were that either aerobic training or weight lifting produced similar effects in reducing depression in this group of women and that a training effect on cardiovascular fitness was not necessary to derive improvements in depression. Also, since running and weight lifting elicited similar effects on depression, either treatment may be a viable option when prescribing exercise to a depressed woman [51].

In another study, Olson et al. examined the vascular health of sedentary, overweight (BMI > 25 kg/m^2), eumenorrheic women [112]. Thirty women were randomly assigned to either a resistance training group (two days/week, one year; n = 15) or a control group (n = 15). Each session began with a 5 minute warm-up, followed by abdominal and lower back exercises for core strength, then three sets of 8-10 repetitions using isotonic machines or free weights of the major muscle groups (quadriceps, hamstrings, gluteals, pectorals, latissimus dorsi, rhomboids, deltoids, biceps, and triceps), followed by a cool-down [112]. During the initial 16 weeks, the women met with a fitness specialist and then continued the progressive resistance program on their own except for meeting twice every 12 weeks with the fitness specialist. At the end of one year, the resistance training group showed significant improvement in flow-mediated dilation of the brachial artery, while not affecting the carotid artery intima-media thickness. The results were promising and the authors suggested using resistance training as a nonpharmacological modality in treatment of endothelial function of overweight women [112].

Based on evidence discussed here, and results of other studies, it appears clear that resistance training has a beneficial effect among non-pregnant women. Further, most studies examined a relatively short time frame (≤ 1 year) yet still showed benefits of performing resistance training. Thus, a resistance training program should be considered when developing an exercise program for the pregnant women who may gain similar benefits within the 40 weeks of gestation.

Benefits of Resistance Training during Pregnancy

The evidence discussed above showed benefits of resistance training to non-pregnant adult women; however, the unique benefits particular to pregnant women need to be examined. Specifically examining pregnancy, it has been suggested that more fit women handle and meet the physical demands of pregnancy more easily than non-fit pregnant women [123, 132, 159]. A pregnant woman who resistance trains may be better able to handle her changing weight, altered center of gravity, and pregnancy related discomforts, such as low back pain, as gestation continues [48, 68, 136, 159]. Also, women who participate in resistance training during pregnancy appear to recover quicker from labor and delivery and have reduced muscle soreness [31, 121, 132, 136].

Another advantage of resistance training rather than aerobic training during pregnancy is that it offers women a form of exercise that is relatively stationary and possibly more comfortable than weight-bearing exercise, especially later in gestation [30]. Further, offering women the opportunity to engage in resistance training rather than aerobic training exclusively may increase exercise compliance because of the increased options provided [30].

Not only does resistance training offer benefits during pregnancy, but also during the postpartum period. After pregnancy, the mother will be able to better handle ADL and postnatal care [46, 121, 132, 159]. Household activities and child care should prove easier as a function of increased muscular strength and endurance. Both upper and lower body strength declines from pre-pregnancy to 6 weeks postpartum and women may not be fully recovered by 27 weeks postpartum [146]. A regular resistance training program during pregnancy can act to combat the normal decreases in muscular strength and endurance coincident with pregnancy. Accordingly, training a pregnant woman's muscles with endurance type exercises (i.e., low weight and high repetitions) will prepare her for labor and help with pushing and relaxing during delivery. Specific muscles that should be targeted are the adductors, abductors, hamstrings, gluteals, quadriceps, and transverse abdominals which are all involved with pushing during delivery [31, 92]. Strengthening the upper back, posterior deltoids, rhomboids, and trapezius will assist with the increased weight of the abdomen and chest during pregnancy [31, 92]. In addition, the rectus abdominis will aide in preventing excess curvature of the lumbar spine and will be involved with heavy labor and hence should be strengthened accordingly during pregnancy [68, 121]. Exercises for the upper and lower back should likewise be performed to promote proper posture throughout pregnancy [121]. For strengthening and toning the pelvic muscles, kegel exercises have also been suggested [19, 92]. Kegel exercises assist in keeping reproductive organs in place as well as improving urinary incontinence [19, 46].

Effects of Exercise on Maternal Physiology during Pregnancy

During pregnancy, women experience a host of physiological changes including increases in heart rate, plasma volume, cardiac output, end diastolic volume, stroke volume, venous compliance, minute ventilation, tidal volume, total lung capacity, and resting oxygen consumption [7, 41, 98, 100, 133, 138]. While PA during pregnancy has overall been shown to be beneficial, there are still concerns regarding how much exercise is optimal before adversely affecting the maternal-fetal unit, either acutely or chronically [39]. Of particular concern for pregnant exercisers are blood flow distribution, hyperthermia, and maternal injury.

One major concern during exercise is blood flow distribution. The distribution of blood to the working muscles and skin is proportional to the exercise intensity, however, there are mixed findings regarding its effect on the fetus [7, 39, 132]. Particular concerns regarding redistributed blood flow to the working muscles include decreased fetal oxygen availability (hypoxia) and decreased glucose utilization which in turn could impair fetal growth [98]. This is a concern because up to 40-50% of maternal blood flow can be redistributed during exercise, which could adversely affect the fetus [39]. In the 1980's, with limited evidence available, two suggestions were made to minimize the danger of reduced fetal blood flow. First, it was suggested that the target heart rate be 25-30% lower during a given task during pregnancy, and secondly, 140-150 beats/min was suggested to be a safe upper limit to heart rate during exercise in which the fetus would not be deprived of blood flow [7, 132]. However, both suggestions were based more on opinion rather than empirical research. In addition, according to animal studies, up to 50% of uterine blood flow must be redistributed to the working muscles before it affects the fetus [7]. According to a 1997 review, most studies demonstrated that there was no evidence of low birth weight with exercise [138]. Thus, while human research is somewhat limited, it seems that there is a protective mechanism during exercise, such as increased oxygen extraction by the fetus, because they are born within a healthy birth weight range, demonstrating adequate fetal growth regardless of exercise [100]. Increased maternal blood volume and cardiac reserve may also potentially act as a protective mechanism because they help ensure adequate blood flow to the uterus in spite of cardiac output redistribution during exercise [41]. Thus, while blood flow redistribution is a theoretical concern, available evidence tends to demonstrate that there are protective mechanisms in place and that the fetus is not adversely affected.

Hyperthermia is another major concern among pregnant women exercising. Hyperthermia is a potential concern because during sustained exercise in the non-pregnant state, rectal temperature can easily increase above 39.2^{O}C, which is the teratogenic threshold in humans [39]. Therefore, it is imperative that women avoid overheating during exercise while pregnant [138]. One investigator's opinion is that the greatest danger for adverse outcomes due to hyperthermia is before the neural groove has closed (23-28 days gestation) [132], while other evidence suggests there is danger for restricted fetal growth later in gestation due to decreased uteroplacental blood flow [98]. The rise in maternal temperature is directly proportional to exercise intensity and may be heightened further if a woman has a low fitness level, is dehydrated, or through environmental conditions such as heat and humidity [39]. Therefore, to avoid maternal hyperthermia, ACOG suggests that pregnant women should avoid exercising in hot and humid conditions when their own mechanisms for heat dissipation are reduced [7]. Since maternal hyperthermia can also occur during sauna or hot tub exposure, there is concern over this activity as well [132]. However, there is little evidence suggesting that exercise alone induces these same changes in maternal temperature as seen from hot tub or sauna exposure and even fewer studies that have found congenital abnormalities caused by increasing maternal temperature from exercise [132]. Studies on temperature regulation in pregnant women have shown that they were able to self-pace their exercise and none were found to elevate their core body temperatures enough to harm the fetus [138]. Thus, most evidence regarding maternal hyperthermia is based on retrospective studies and animal data and is somewhat speculative since there are no randomized control trials to determine the effect of exercise on maternal core body temperature [39]. In addition, chronic exercise may actually improve the body's ability to dissipate heat due to increased plasma volume, allowing for enhanced maternal heat dissipation through blood flow to the skin [138]. With respect to exercise mode, it has been proposed that aerobic exercise causes a more elevated maternal temperature than resistance training because heart rate and body temperature remain elevated throughout the entire aerobic session, whereas in resistance training there is a stimulus phase and a rest phase between sets and reps allowing body temperature to drop [159]. Overall, while hyperthermia remains a concern, based on current evidence, self-paced exercise does not appear to induce increases in core temperature sufficiently to adversely affect the fetus.

Another common concern for pregnant exercisers is susceptibility to more soft-tissue injuries due to increased joint laxity [7, 121, 136, 159]. Accordingly, women need to "listen to their bodies" and be aware of physiological changes they are experiencing. However, in a recent study examining 1,469 pregnant women in the Pregnancy, Infection and Nutrition Study (PIN3), only 2% (34/1469) of the women experienced an injury due to PA [153]. The most common type of injury was a bruise or scrape (54.6%), followed by strain (22.7%), sprain (15.9%), fracture (4.6%), or concussion (2.3%) [153]. Therefore, while injuries were reported, numbers were small and most were minor. The PIN3 authors recommended that women continue to be physically active during pregnancy while being aware of the potential for injury [153]. While women experience physiological changes throughout pregnancy, the rate of progression and rate of change can vary; thus women need to maintain open communication with healthcare providers to minimize any risks associated with exercising.

In summary, it is difficult to determine the true role of exercise and PA on physiological changes during pregnancy, as they are numerous, and interrelated. However, we do know that frequency, intensity, type, and duration of exercise seem to play an important role in healthy birth outcomes [41]. Consequently, while concerns remain for the exercising pregnant women, available human studies do not support these concerns [41]. In addition, adverse pregnancy outcomes are infrequent among healthy women who comprise the majority of research participants, so it is often difficult to obtain a sufficiently diverse sample to study these effects appropriately. Thus, while the upper level of safe exercise has not yet been established, experts suggest that healthy women can begin or maintain regular exercise throughout gestation without causing harm to the fetus [39].

Occupational Physical Activity during Pregnancy

While pregnancy is a unique time in a woman's life, many women are employed during the majority of pregnancy. Therefore knowing the risks, if any, associated with occupational PA is necessary [95]. Determining the risks associated with occupational PA is difficult because many of the confounding factors associated with both the decision to work and the adverse pregnancy outcome are similar [95]. Early research showed occupational PA could be detrimental to birth outcomes [60, 72, 90, 109, 126, 128], but more recent evidence has not shown a consistent relationship [18, 26, 27, 75, 79, 96, 97, 119, 127, 148, 156]. Researchers have examined occupational exposures such as prolonged working hours in a given day or week, shift work, standing, heavy physical workload/effort, assembly line, piece work, use of a visual display unit, and environmental exposure to noise, vibration, hot, and cold [27, 95-97]. McDonald et al., conducted a study over a two year interview period (1982-1984), using 56,067 women from Montreal, Canada who completed a survey of pregnancy outcome and occupation. The interview occurred soon after a woman either delivered or suffered a spontaneous abortion. Information regarding demographics, occupation, and birth outcome were collected [96]. When considering 22,761 single live births of women who worked at least 30 hours or more a week at time of conception, only 7.4% delivered prematurely ($\leq$ 37 weeks gestation) [97]. Only 6.6% of these women delivered infants of low birth weight (≤ 2,500 grams) with 4.1% both preterm and low birth weight [97]. Women had a significantly increased risk of preterm birth if they were psychiatric nurses, worked in food and beverage service, or in an industrial sector with metal/electric [97]. Women in these jobs, particularly those in food and beverage service and psychiatric nurses, reported heavy lifting, physical effort, standing, long hours, and changing shifts. Similarly, women with an increased risk of low birth weight infants included occupations of food and beverage service, chambermaids, cleaners, and janitors, and industrial sector with metal/electric [97]. Therefore, rather than actual occupation, per se, it might be the physical stress or fatigue associated with the occupation that was more closely associated with preterm birth and low birth weight [97]. Another possibility is that unmeasured confounders contributed to the association rather than the actual physical requirements of the job, thereby not making the occupation itself a risk factor but other characteristics related to people who have a particular occupation.

When examining this same cohort more closely, each specific job was categorized into one of the following six main sectors of occupations 1) Managerial, 2) Health, 3) Clerical, 4) Sales, 5) Services, and 6) Manufacture. When examining the risk of preterm deliveries, there was an increased risk among the managerial, services, and manufacturing sectors only. Increased risk for preterm birth in those sectors was due to work requirements that included lifting heavy weights for 15 hours/day, long working hours (≥ 46 hours), and changing shifts [97]. When examining low birth weight, there was an increased risk among the health, services, and manufacturing sectors only. Increased risk for low birth weight in those sectors was due to work requirements that included lifting heavy weight for 15 hours/day, other physical effort, long working hours (≥ 46 hours), changing shifts, and use of a visual display monitor [97].

Further, when examining chromosomal, developmental (neural tube, cleft lip/palate, cardiac, and other), and musculoskeletal total congenital defects, only one sector (services) demonstrated an increased risk [96].

Overall, while there were some significant associations found between work requirements by occupational sector and preterm birth, low birth weight, and congenital defects, the risks were not consistent across sectors. In addition, while causality cannot be proven, the characteristics measured in this study may not necessarily be associated with adverse outcomes, but rather physical stress and fatigue associated with the occupation may mediate the relationship between occupation and adverse outcome. Therefore, McDonald recommended that when possible, heavy physical effort and unsatisfactory work conditions should be avoided [95], but acknowledged that there is insufficient evidence to require drastic changes in the workplace for pregnant women.

In another study of 768 pregnant workers, the association between work-related psychological stress and risk of preterm, low birth weight (< 38 weeks gestation and birth weight < 2,500 grams) delivery was investigated [75]. Women participated in the National Longitudinal Survey of Labor Market Experience, Youth Cohort (NLSY). This cohort included girls and young women between 14-21 years of age. Although Blacks, Hispanics, and economically disadvantaged Whites were oversampled, correction (weighting) in the analyses allowed for generalization to the entire US population of women [75]. Occupational characteristics were determined by an occupational job title-based system. Women were twice as likely to deliver a low birth weight, preterm infant (5.1% vs. 2.6%) if they had a job that had a high psychological demand and low job control compared to women in low exertion jobs, respectively [75]. Physical exertion, which was highly correlated with psychologically stressful jobs, was strongly associated with increased frequency of preterm, low birth weight infants. In unadjusted analyses, the lowest quartile of job exertion, only 1.03% of women delivered a preterm, low birth weight infant, whereas, the percentage increased to 1.25%, 7.01%, and to 5.07% in the highest quartile for job exertion, respectively [75]. A similar trend was seen when only considering low birth weight, increasing from 3.04% at the lowest quartile of exertion to 4.35%, 8.83%, to 9.05% in the highest quartile of exertion [75]. When adjusting the analyses for confounders and other maternal characteristics, none of the estimates remained significant for preterm, low birth weight (RR 1.3 95% CI 0.6-3.1) or low birth weight (RR 1.4 95% CI 0.75-6.8). Further, while these results showed an association between high demand/low control jobs and adverse pregnancy outcomes, they need further corroboration as the sample consisted of young women and the stresses of their occupation may change as they mature.

A recent review by Bonzini, Coggon, and Palmer [27] examined the effect of occupational exposures including prolonged working hours, shift work, lifting, standing, and heavy physical workload, in relation to preterm delivery, low birth weight, and preeclampsia/gestational hypertension. Overall, there were 35 studies focusing on preterm delivery, 32 on birth weight, and 8 on preeclampsia or gestational hypertension [27]. Prolonged working hours only showed a moderate association with preterm delivery, ranging in relative risks from 0.59-1.34. Considering five studies (of 16 total) of highest methodological quality of working hours, a pooled relative risk estimate was calculated at 1.20 (95% CI 0.98-1.47) [27]. Shift work showed similar results in that the four largest studies found little association, and when pooling eight (of 14 total) studies of highest methodological quality, the relative risk was 1.26 (95% CI 0.98-1.63). Standing was considered in twenty papers and when taking the six studies of highest methodological quality, relative risk was 1.26 (95% CI 0.96-1.66).

Occupational lifting was considered in twelve studies and in none of those did the estimate exceed 1.5 for preterm delivery, with only one study demonstrating statistical significance ($p < 0.01$) and all others having the 95% CI include unity. Lastly, physical workload was considered in twenty one studies and while the definitions varied greatly, in four of the five largest studies the risk was < 1.3, with none demonstrating significance (either $p > 0.05$ or 95% CI included unity) [27]. Considering 32 studies that assessed birth weight, working hours, and physical workload, both provided relative risk estimates close to or just below unity. A pooled risk estimate of shift work was 1.07 (95% CI 0.96-1.19), while risk estimates for standing and birth weight in seven of eight studies were < 1.5 (the eighth study had an odds ratio of 2.0 (0.7-5.4) for women standing ≥ 5 hours compared to ≤ 4 hours/day in the second trimester). In five studies examining lifting, none showed a significant positive or negative effect [27]. When examining gestational hypertension and preeclampsia, a group estimate could not be made because these concerns were investigated in only eight studies, and the definitions varied substantially. However, when examining weekly working hours, range of relative risks was 0.85-1.1, with all 95% CI's including unity. Similarly, the relative risks of shift work ranged from 0.9 to 1.3, with all 95% CI's including unity. Lifting had a range from 0.68-1.7, with only one of three 95% CI's demonstrating significance. The range for standing was 0.7-1.26, with none demonstrating significance by the 95% CI and physical workload ranged from 0.7-3.47 with two of the seven 95% CI's showing statistical significance. Overall, the evidence did not show a strong association between occupational exposures (prolonged working hours, shift work, lifting, standing, and heavy physical workload) and adverse pregnancy outcomes (preterm delivery, low birth weight, and preeclampsia/gestational hypertension) to warrant stringent restrictions to a pregnant employee [27]. Bonzini, Coggon, and Palmer stated several limitations to their review conclusions [27]. First, it was not obvious how to best classify cut-points for both occupational exposure and birth outcomes. There were a wide variety of definitions used for each outcome and exposure, which made direct comparisons between studies difficult. In addition, many of the exposure variables could be categorized in several ways, such as frequency of lifting, duration of lifting, or posture when lifting, and because the optimal classification of them is unknown, risks may be underestimated [27]. Second, only six studies examined occupational activity throughout gestation, with very few studies examining it in late gestation. For example, only one study examined the risk of preterm birth in all three trimesters, while all others examined only first or second trimester. Similarly, only two studies examined birth weight and preeclampsia/gestational hypertension into the third trimester while all others only examined through second trimester. Thus, while many associations were not seen, the timing of gestation could affect a woman differently and needs to be further examined throughout each trimester of gestation [27]. Third, there was a chance of differential bias in recalling occupational activities due to delivery outcome. For example, remembering the number of night shifts worked during pregnancy may be easier to recall than frequency, duration, posture, and weight of an object while working. In cases where the outcome was evident to the mother, such as in preeclampsia, she may remember exposures differently than women who did not have preeclampsia and did not have to monitor their activity. Therefore, perceived hazardous exposures may be over-reported by cases and under-reported by controls [27]. Consequently, the majority of evidence favors neither an adverse nor beneficial outcome between occupational PA and birth outcome. In summary, the authors advised women against long working hours, prolonged standing and heavy physical work, especially later in pregnancy until further evidence shows no association with adverse outcomes later in pregnancy [27].

Occupational Lifting during Pregnancy

Not only has occupational PA been studied, but more specifically, effects of occupational lifting in regards to pregnancy outcomes have also been investigated. Overall, there does not seem to be an adverse effect of occupational lifting on prevalence of low birth weight [4, 90, 126, 148], small for gestational age [60, 109, 119, 148], preterm birth [4, 26, 60, 72, 90, 103, 119, 126-128, 148], fetal death [4, 90], preterm labor [90], or preeclampsia/pregnancy-induced hypertension [79, 109, 156]. In contrast, Nurminen found an increased risk associated with occupational lifting when examining central nervous system defects and orofacial clefts, but not skeletal or cardiovascular defects [109]. Appendices B-D detail specific pregnancy-related outcomes, exposure variables, sample size, and risk estimates associated with occupational lifting.

While there were particular circumstances in which lifting or carrying objects during work were associated with an increased risk of an adverse outcome [18, 96, 97, 109, 148, 156], the majority of evidence did not point to an association [4, 26, 60, 72, 79, 90, 103, 109, 119, 126-128, 148, 156]. Of the studies that did not demonstrate an association between lifting or carrying objects during work and adverse pregnancy outcomes, several were prospective in nature, thus reducing the chance for differential recall [4, 72, 90, 103, 119]. Other reasons that risk estimates vary were due to differences in sample size, differences in comparison/reference groups, definitions of outcomes and lifting, and timing of exposure (i.e., first trimester versus all trimesters, etc.). Among studies that demonstrated an increased risk of adverse outcome [18, 96, 97, 109, 148, 156], there were no commonalities regarding the classification of lifting in which would lead to a better estimation of outcome. Of the four studies demonstrating an increased risk of small for gestational age and lifting, two classified lifting by frequency only ($\geq$ 15 times/day) and did not specify a specific weight for “heavy” [18, 97], one classified lifting as lifting 5-10 kg without a specific frequency [109], and the other specified a specific weight (12kg) and frequency (≤ 10 times/day) [148]. Only one of twelve studies demonstrated an association between preterm birth and lifting heavy weights 15 times/day, without stating a specific weight to describe “heavy” [97]. In the one study finding an increased risk of preeclampsia, lifting was classified by weight and frequency [156], while in the two studies examining pregnancy-induced hypertension, lifting was classified by weight only [79, 109]. Lastly, in two studies showing an increased risk of birth defects, lifting was classified by weight only in one [109] and a direct definition was not given in the other [96]. Overall, based on the many ways occupational lifting was categorized, it is difficult to ascertain a specific amount or frequency, if any, that is associated with an increased risk of an adverse outcome.

Due to many of the risk estimates being below 1.0 or approximating 1.0, this would suggest either a null or protective effect of occupational lifting. Other limitations included small sample sizes of women experiencing adverse outcomes once categorized by lifting habits; therefore, since only twelve of seventy-three risk estimates were statistically significant (i.e., 95% CI not including unity or $p > 0.05$, (Appendices B-D)) it does not appear that occupational lifting is associated with adverse outcomes. However, it must be noted that many studies did not collect data on modifications to job requirements and therefore the risk of an adverse effect may have been reduced because preventative measures were taken to reduce the amount of occupational lifting during pregnancy. For example, Ahlborg, Bodin, and Hogstedt found that heavy lifting did not increase risk of fetal death, preterm birth, or low birth weight, and it was postulated that the results might have been because of Sweden’s preventative routines and regulations [4]. Therefore, changes in occupational workload may be necessary to examine across all of gestation to paint a more accurate picture of the risks, if any, associated with adverse outcomes.

Resistance Training during Pregnancy

Very few studies have specifically addressed resistance training during pregnancy, but of those that did, resistance training was not found to be harmful to the maternal-fetal unit [20-23, 25, 68, 82, 89, 108]. In a retrospective study examining 845 pregnant women, Hall and Kaufman showed those in the highest exercise groups had the most beneficial pregnancies and birth outcomes [68]. Women were asked to exercise three days per week throughout pregnancy until onset of labor or medical contraindication. Based on the amount of exercise the women completed, they were divided into four groups: control ($n = 393$), low-exercise ($n = 82$), medium-exercise ($n = 309$), and high-exercise ($n = 61$). Average number of sessions completed during pregnancy was 0.8 in the control group, 15 in the low-exercise group, 32 sessions in the medium-exercise group, and 64 in the high-exercise group. Women in the exercise groups completed a treadmill or bicycle warm-up, 45 minutes of selected exercise machines 3 days/week, and an aerobic workout on exercise cycles [68]. Workouts on the exercise machines were done with the intention to strengthen or increase flexibility of the particular muscle group being worked: upper body, lower body, or trunk [68]. When comparing exercise groups with both objective and subjective birth outcomes, the high-exercise group showed more favorable outcomes. Specifically, compared to the control group, the high-exercise group showed rate of caesarean section (6.7%) to be lower ($p < 0.0001$), infant birth weight was 65-151 grams higher ($p = 0.06$), 1-minute Apgar scores were higher ($p < 0.05$), 5-minute Apgar scores were higher ($p < 0.05$), and mean length of hospital stays was shorter ($p < 0.001$) [68]. Also, when examining physiological responses during exercise, of particular note was that maternal heart rate increased appropriately with exercise while fetal heart rate remained normal (i.e., no fetal bradycardia observed) [68]. This was true both during the aerobic sessions and resistance training sessions. Subjective outcomes were also encouraging. That is, women who completed the conditioning program had an improved self-image and indicated fewer pregnancy-related discomforts, especially low-back pain [68]. Women stated that the exercise program reduced their tension and was beneficial to labor and delivery [68]. Therefore, based on Hall and Kaufman's results, women engaging in regular exercise, both aerobic and anaerobic, did not cause harm to the maternal-fetal unit, but did improve both objective and subjective maternal measures of pregnancy. Importantly, due to the physical changes during pregnancy, these women underwent regular examinations every 10 weeks and modified their programs accordingly. This may be particularly important in a pregnant population because many women are unaware of the gradual postural changes that occur as pregnancy continues and failure to address these issues early on can lead to future discomfort and pain [68]. Further, only four of 61 women in the high-exercise group were regular exercises before beginning the program, suggesting that the conditioning program influenced pregnancy outcomes favorably. Overall, regardless of outcome measures being subjective or objective, the conditioning program did not adversely affect the maternal-fetal unit.

In another study, Lotgering evaluated 15 healthy pregnant women between 29 and 35 weeks gestation who performed maximal isometric leg exercises. He investigated the effects of strenuous isometric exercise during pregnancy on the women's heart rate and blood pressure [89]. The women showed normal heart rate and blood pressure responses to maximal isometric leg exercises with heart rate, systolic pressure, mean pressure, and diastolic pressure all linearly increasing with increased force [89]. These normal cardiovascular responses demonstrated that pregnant women elicited similar responses to non-pregnant women during exercise. Avery et al., examined 12 pregnant and 12 non-pregnant healthy controls who performed 3 sets of 10 repetitions at 50, 70, and 90% of their 10-repetition maximum for handgrip, single-leg extension, and double-leg extension in seated and supine (30^o tilt) positions [20]. The pregnant women were measured during the third trimester at 31 ± 1 wk gestation. The investigators found that maternal heart rate did not increase significantly when the women changed from single-leg to double-leg extension, suggesting a blunted heart rate response with higher intensity. However, heart rate among both pregnant and non-pregnant controls tended to increase as the amount of muscle mass increased. When examining postural changes (supine 30^o tilt or seated), maternal heart rate was slightly higher in the seated position compared to the tilted supine position suggesting an altered maternal HR response to position, but the changes were not statistically significant [20]. Upon examination of blood pressure responses to resistance training, the investigators found no differences among pregnant women and non-pregnant controls [20]. Of major concern during resistance training is reduced uterine blood flow because cardiac output is redirected to the working muscles. However, in this sample of women, fetal heart rate was not significantly affected during or after maternal strength conditioning exercises [20]. There was a low incidence (~8%) of fetal bradycardia (fetal heart rate < 120 beats/min for ≥ 120 seconds) during and after exercise which may indicate a smaller degree of blood flow redistribution than during high-intensity exercise, which could act as a compensatory mechanism for the fetus to protect its oxygen availability [20]. Not only was the incidence of fetal bradycardia low, but maternal strengthening exercises appeared to arouse the fetus and accelerate fetal heart rate. Therefore, the exercises did not compromise the fetus nor did they experience hypoxia. These results provide evidence of the safety for healthy pregnant women to engage in a moderate-intensity resistance training program [20].

The findings of Avery et al. [20], were corroborated by Nesler et al., in which a group of 25 healthy, regularly exercising women performed supine exercise in the second and third trimesters (24-36 weeks gestation) [108]. The purpose of their investigation was to determine if the 1985 ACOG guideline, “no exercise should be performed in the supine position after the fourth month of gestation is completed” was warranted. Women received a nonstress test in the left lateral resting position at three time points: 20 minutes pre-exercise, during 5 minutes of supine exercise, and 20 minutes post-exercise, to measure fetal heart rate continuously. The supine exercises included abdominal strengthening exercises such as pelvic tilts, pelvic tilt with curl, leg sliding, and flexion/extension of the foot. Maternal heart rate was measured via carotid palpation while fetal heart rate was measured continuously with an external Doppler and uterine pressure recorder [108]. Similar to the findings of Avery et al., fetal heart rates in the second trimester did not differ regardless of the time-point in which they were measured (pre-exercise 137 ± 8 beats/min, exercise 142 ± 9 beats/min, and post-exercise 143 ± 8 beats/min, $p < 0.2$). Third trimester fetal heart rate results followed the same pattern (pre-exercise 134 ± 10 beats/min, exercise 134 ± 9 beats/min, post-exercise 138 ± 9 beats/min). These small, nonsignificant differences in fetal heart rate were not likely physiologically significant either. Thus, the results demonstrated that brief submaximal exercise in the supine position was safe and well-tolerated by both the mother and fetus through the 36th week of gestation [108].

Based on the cross-sectional studies discussed above, muscle strengthening exercises in the second and third trimesters do not appear to negatively affect the mother or fetus and may even promote fetal arousal. However, muscle strengthening exercises should be performed in a controlled environment with plenty of rest between sets to ensure maternal-fetal safety. In addition, women should avoid a tilted supine position in the third trimester [20]. Although these studies showed no detrimental effects of resistance exercise, the study samples were small and only healthy women were included. Further longitudinal research expanding the sample size is necessary, as well as monitoring women who chose to stop their activity due to abnormal responses.

The majority of evidence shows no detriment to the maternal-fetal unit with exercise. However, due to the unknown safe upper limits of exercise during pregnancy, there has been limited research on women who exercise in excess of ACOG guidelines. Further, many studies have examined only PA or aerobic exercise and birth weight, while fewer studies have examined resistance training as a form of exercise. One such investigation that examined women performing both aerobic exercise and resistance training who met or exceeded the guidelines was a prospective study of 148 pregnant women by Duncombe et al. [52]. Duncombe et al., defined 'vigorous exercise' two ways: 1) frequent sustained exercise: "≥ 30 minutes of swimming, cycling, aerobic classes, running and walking, including reports of puffing and a heart rate > 50% of age-adjusted heart rate (220 minus age in years x 0.5) ≥ 3 times a week" and 2) vigorous exercise (based on the 1985 ACOG recommendations): "≥ 3 weekly sessions of aerobic classes, swimming, cycling, running, walking, circuit training, weight training, martial arts or dance maintained for ≥ 15 continuous minutes at heart rates above 140 beats/min [52]." When examining the first definition of 'vigorous exercise' there were no significant differences in mean infant birth weight or mean gestational age at delivery regardless of whether the women performed no exercise throughout pregnancy, no aerobic exercise, insufficient exercise to meet criteria, only 1-2 vigorous sessions, 3-4 vigorous sessions, or 5 or more vigorous sessions.

Similar results for birth weight and gestational age were seen when using the second definition of exercise but classifying women into groups of no exercise performed, performing other exercise, performing exercise that did not meet the criteria, and exercise at > 140 beats/min for > 15 minutes 3 days/week [52]. Therefore, regardless of the definition used to describe vigorous exercise, there were no differences in mean birth weight or gestational age. This result demonstrated that a combination of activities that included weight lifting did not adversely affect the maternal-fetal unit; however this finding needs to be confirmed or refuted with a larger and more diverse sample and looking more specifically at the type of exercise performed (aerobic versus resistance training).

In a similar study examining both high levels of aerobic exercise and resistance training, Kardel and Kase studied 42 women who self-selected into a medium-exercise or high-exercise group [82]. The exercise groups performed muscle strength training, interval training, and endurance training. The strength training program was the same for both medium and high-intensity groups and consisted of 18 different exercises of the major muscle groups. Women completed 2 sets of 20-40 dynamic contractions that were held for 6 seconds duration. Total time to complete the strength program was 1 hour and 12 minutes. The interval training and endurance training differed by groups [82]. Results showed the high-exercise group experienced shorter onset of labor (39.0 weeks vs. 40.2 weeks), but only for women who gave birth to girls. When comparing exercise groups, there were no differences in the onset of labor (39.9 ± 1.2 weeks vs. 39.6 ± 1.6 weeks), duration of labor (6.7 ± 5.5 hours vs. 9.4 ± 5.9 hours), birth weight (3,590.5 ± 532 grams vs. 3,650.7 ± 515.8 grams), placental weight (643.3 ± 137.2 grams vs. 709.7 ± 88.7 grams), 1 minute Apgar scores (8.4 ± 0.9 vs. 8.8 ± 0.6), and 5 minute Apgar scores (9.1 ± 0.5 vs. 9.4 ± 0.5) between medium-exercise and high-exercise groups, respectively [82].

The investigators' main conclusion was that well-trained women may continue exercising during pregnancy at either a medium or high-intensity program (including 2 days/week each of strength training, interval training, and endurance training) without compromising fetal growth [82]. While these results were favorable, significant study limitations included lack of a control group and a sample of women who were highly health-conscious volunteers and self-selected their exercise program [82]. Moreover, other "healthy lifestyle" factors could have also influenced the results which were not taken into account.

In a study by O'Connor et al., 32 healthy women between 21-25 weeks gestation began a supervised strength training program [110]. Participants were 18-38 years of age and suffered back pain or a history of back pain. Participants began a 12 week, low-to-moderate intensity strength training program 2 times/week that included six resistance exercises (dual leg extension, dual leg press, dual arm lat pull, dual leg curl, lumbar extensions, and an abdominal exercise targeting the transverse abdominis) [110]. Each exercise session lasted approximately 45 minutes and consisted of two sets of 15 repetitions for each of the exercises except the abdominal exercise which consisted of eight repetitions with each repetition lasting approximately eight seconds. At the end of 12 weeks, there were no reported musculoskeletal injuries and problematic symptoms were reported infrequently. Only 1.7% reported symptoms that related directly to the resistance training. The symptom most commonly reported was dizziness, which underscores the importance of monitoring maternal symptoms and using them as an indication of intensity level. O'Connor et al. highly recommend monitoring symptoms throughout exercise, particularly during initial stages when the women were learning proper breathing and lifting techniques. They also found that absolute training load increased while relative perceived exertion remained at a low-to-moderate intensity level [110]. In summary, this study demonstrated that pregnant women with back pain or a history of back pain can engage in a low-to-moderate intensity exercise program and increase their strength without increased risk of injury. This further demonstrates that resistance training programs can be safely performed during pregnancy.

Using a case study design, Benton studied one woman who began a progressive resistance training program at 21 weeks gestation [25]. She exercised 3 days/week with 3 sets of 8-12 repetitions of 8 exercises (chest press, lat pull-down, leg curl, shoulder press, seated row, leg extension, triceps pushdown, and biceps curl) with a 1 minute break between sets. Maternal heart rate was monitored during all sessions and the program continued until 24 hours before active labor. After 18 weeks of training, her total training volume increased 58% and lean muscle mass, determined from bioelectrical impedance analysis, increased by 3.5 kg from pre-pregnancy. Also, from the start of the training program to 6 weeks postpartum, body fatness remained relatively stable (39.9% vs. 39.4%, respectively). Overall, the woman's progressive resistance training program promoted an increase in lean muscle mass with no harm to the maternal-fetal unit, even though she continued to increase the workload throughout the 18 week period [25].

In summary, engaging in either a medium- or high-exercise group [82] or participating in a progressive resistance training program [25] resulted in no adverse pregnancy outcomes. While both studies reported similar findings regarding resistance training, neither used a random sample and therefore study generalizability is limited. The most rigorous study design for determining causality is a randomized controlled trial (RCT). To the author's knowledge, there have been only two RCTs designed to examine resistance training and pregnancy outcomes. Brankston et al. designed a study to examine the role of diet and exercise on blood glucose levels among overweight pregnant women. After enrolling women with gestational diabetes mellitus (GDM), women were randomly assigned to either a diet or diet plus exercise group [30]. Both groups were given similar instructions on diet. Women in the exercise group completed a circuit-type resistance training program which included eight exercises with less than one minute of rest between stations for four weeks. During training, all exercises were modified so the women used rubber tubing rather than weights. Women were instructed to exercise at a "somewhat hard" intensity and ensure their heart rate did not exceed 140 beats/min [30]. Mean maternal age was 31.3 ± 5.0 years in the diet only group and 30.5 ± 4.4 years in the diet plus exercise group, with gestational age approximately 29 weeks in both groups [30]. After completion of the intervention, the authors found that the women in the diet plus exercise group required less insulin and had a longer latency period of initiation of insulin treatment than the diet only group. Further, there were no significant differences in gestational age at delivery, rate of caesarean deliveries, or birth weights [30]. These results suggest that the circuit type resistance training not only improved the women's glycemic control but also that circuit-type resistance training did not adversely affect fetal well-being. The exercise intervention administered in this particular study began at approximately 29 weeks gestation. The authors speculated that further improvement in glycemic control may have occurred if the exercise had been initiated earlier in pregnancy.

In the most recent RCT, Barakat et al., examined 142 women who performed light resistance and toning exercises and found no adverse effects in the mother or infant [21-23]. Specifically, previously sedentary women were randomized into two groups: training (n=72, 30.4 ± 2.9 yr, BMI = 24.3 ± 0.5 kg/m^2) or control (n = 70, 29.5 ± 3.7 yr, BMI = 23.4 ± 0.5 kg/m^2). Women resistance trained from the start of the second trimester to the end of the third trimester on three nonconsecutive days/week for approximately 35 minutes [23]. Each training session included a 7-8 minute warm-up, 20 minutes of toning exercises with very light resistance of the major muscle groups, and a 7-8 minute cool-down. Intensity was maintained at a light to moderate level (i.e., ≤ 80% age-predicted HR maximum), which was assessed via a heart rate monitor. Toning exercises included shoulder shrugs and rotations, arm elevations, lateral leg elevations, pelvic tilts, and rocks. Resistance exercises included abdominal curls, biceps curls, arm extensions, side arm lifts, shoulder elevations, seated bench press, seated lateral row, lateral leg elevations, leg circles, knee extensions, hamstring curls, and ankle flexion/extension with barbells (≤ 3 kg/exercise) or low-to-medium resistance bands [22]. Overall, the authors found that there was no difference between training and control groups in mean gestational age (39 weeks 4 days vs. 39 weeks 5 days, $p = 0.75$, respectively), percent of preterm (< 37 weeks) deliveries (2.8% vs. 4.3%, $p = 0.32$, respectively), Apgar score at 1 min (8.9 vs. 8.8, $p = 0.14$, respectively) or Apgar score at 5 min (10.0 vs. 9.9, $p = 0.48$, respectively) [23]. In addition, the training group and control group showed no significant differences in mean birth weight (3,165 g vs. 3,307 g, $p > 0.10$, respectively), birth length (49.5 cm vs. 49.7 cm, $p > 0.10$, respectively), head circumference (29.5 cm vs. 29.5 cm, $p > 0.10$, respectively), or gender of child (boys 44.4% vs. 57.1% and girls 56.6% vs. 42.9%, $p > 0.10$, respectively) [21]. Further, the type of delivery (natural [70.8% vs. 71.4%], instrumental [13.9% vs. 12.9%], or cesarean [15.3% vs. 15.7%]), use of epidural anesthesia (69.4% vs. 68.6%), labor time (dilation time [426 min vs. 378 min], expulsion time [32.0 min vs. 36.0 min], and childbirth time [8.1 min vs. 7.7 min]), did not differ between the training and control groups, respectively [22]. Therefore, the authors concluded that light-intensity resistance training during the second and third trimesters does not adversely affect a variety of pregnancy and birth outcomes [21-23]. Rather, Barakat et al.

concluded that "resistance exercise should be an integral component of any exercise training programme" [23]. Because this was a RCT, causality can more firmly be established. According to these results, there does not appear to be a deleterious effect of light toning exercises during pregnancy among previously sedentary women.

Statement of the Need for Additional Research Regarding Resistance Training during Pregnancy

From the combined evidence from RCTs performed by Brankston et al. [30] and Barakat et al. [21-23], as well as Benton et al.'s [25] case study, the evidence suggests that engaging in low intensity and/or progressive resistance exercise using elastic resistance bands is not harmful to the maternal-fetal unit; however, evidence is lacking on other forms of resistance training such as free weights and weight machines. Several previous, less rigorous studies support this finding [20, 52, 68, 82, 89, 108]. It appears that with proper precautions and modifications, pregnant women can and should perform some type of resistance training during pregnancy as the benefits appear to far outweigh the risks, while also making for a more comfortable pregnancy and delivery. While it is not known whether exercise provides direct benefits to the infant, there is no evidence to suggest any harm occurs to the maternal-fetal unit.

While evidence suggests that women can safely engage in a resistance training program during pregnancy, the optimal exercise prescription (Frequency, Intensity, Time, Type (FITT)) for health-related outcomes is still unknown. As previously stated, most recommendations for PA and exercise during pregnancy do not formally address resistance training. While the Canadian SOGC/CSEP guidelines for resistance training are formalized, they do not prescribe a specific frequency, intensity, time, or type of resistance training that pregnant women should perform. Therefore, larger studies examining multiple forms of exercise, including resistance training via weight machines, free weights, resistance bands, whole body weight, kettlebells, medicine balls, yoga, and pilates are necessary. Many women engage in what is more formally considered resistance training (i.e., weight lifting machines and free weights.), but women also partake in nontraditional modes of resistance training (i.e., yoga, pilates, etc.). Although these types of exercises may not traditionally be considered resistance training, many women consider them to be a form of resistance training and thus they should be investigated further. Conducting a retrospective study examining multiple modes and intensities of resistance training will better allow for determination of the frequency, intensity, duration (time), and type of exercise that is safest and most beneficial for the maternal-fetal unit.

In summary, even though the available literature suggests no harm of resistance training during pregnancy to the maternal-fetal unit, specific recommendations are not available in the United States. Therefore, further research investigating the effects of resistance training on the maternal-fetal unit in a large sample is necessary to provide the most comprehensive exercise guidelines to pregnant women.

CHAPTER 3
METHODS

Study Design

A retrospective cross-sectional design involving a national convenience sample of women was used to assess various forms of exercise (emphasizing resistance training), ADL, and pregnancy outcomes. Observational research offers many benefits including first and foremost, no unintentional investigator-induced harm to the maternal-fetal unit during pregnancy. In addition, current knowledge of which resistance training intervention strategy to utilize in a clinical trial is insufficient. Further, this design allowed for enhanced recruitment of women who were presumably more likely to participate in resistance training during pregnancy. Rather than specifying an exact protocol to follow (as in a randomized control trial), the women simply reported what they did during their pregnancy allowing for a potentially wide range of frequencies, intensities, durations, and types (i.e., weight machines, free weights, kettlebells, etc.) of resistance training. With sufficient sample size, this design would have allowed investigators to better evaluate and determine safe, effective exercises and cut-points during pregnancy for future studies.

Study Sample

Participants included women who were over 18 years old, spoke/read English, belonged to Anytime Fitness® and/or Anytime Health™, and had given birth in the past five years. For women who had been pregnant more than once in the previous five years, the most recent pregnancy was considered. Women were allowed to participate regardless of their exercise and PA habits during pregnancy. Anytime Fitness® is a 24-hour health club that offers a variety of cardiovascular equipment and resistance training machines (i.e., Nautilus, Life Fitness, Star Trac, and Precor). At the time of the study, 1,450 locations existed throughout the United States with 1,600 total clubs worldwide, approximately 1,000,000 members, and an average cost of membership of $39/month. In addition to the facilities, members have access to Anytime Health™, the official wellness website of Anytime Fitness®. Approximately fifty percent of Anytime Fitness® members are female, with 32% in their twenties, 24% in their thirties, 19% in their forties, and 18% aged fifty or older. Participants were sampled from Anytime Fitness® and Anytime Health™ to target physically active women in childbearing age who were likely active during their pregnancy.

The cut-point of five years postpartum was based on previous research from our laboratory which showed women recalled pregnancy PA accurately with the Modifiable Activity Questionnaire (MAQ) up to six years postpartum [24]. The MAQ queried women about their activity levels at 20 weeks gestation, 32 weeks gestation, and 12 weeks postpartum and found moderate to high correlations (r = 0.57, r = 0.85, and r = 0.86, respectively) at each time point from their pregnancy six years prior [24]. Thus, the five year recall time frame for this study was believed to be reasonable for moderate to high validity for accurately recalled PA habits, including resistance and aerobic training.

Participant Recruitment

Anytime Fitness® management was contacted prior to initiating the study and agreed to assist in the recruiting process. Anytime Fitness® posted fliers in each facility, posted an announcement electronically, and used a blog to recruit participants. Each poster (Appendix E) detailed the inclusion criteria, the main purpose of the study, and then directed them to the

Anytime Health™ website where the survey could be found. This project was approved by Michigan State University's Biomedical Institutional Review Board. A complete history of recruitment methods can be seen in Appendix F.

Survey Development

The Pregnancy Activity Survey (PAS) was developed to assess various forms of exercise, emphasizing resistance training, during pregnancy and the postpartum period. To begin the process of learning how to develop a survey, the study coordinator (EK) completed the Communication Arts and Sciences: Special Topics: Survey Design course (CAS 892) in the summer of 2010. The primary objective of the course was for EK to learn how to develop an effective survey while acknowledging the advantages and disadvantages of varying ways to administer it. Using the methods learned in class, a survey was developed for completion of course requirements. After developing a survey regarding exercise during pregnancy, a classmate and the instructor reviewed it. Using this feedback, the survey was revised and the course was completed. This survey was then used as the foundation of the PAS.

Using the survey developed from the CAS 892 course, further revisions were made to ensure it captured all necessary aspects of PA and variables known to influence pregnancy outcomes. Criterion validation of the survey could not be evaluated because the investigators did not have original PA and exercise data on women prior to the development of the PAS. However, EK was able to enhance the face validity of the survey. Face validity demonstrates the degree to which the sample of questions are representative of some defined domain [104].

PAS face validity was enhanced through two focus groups (n = 3, n = 2) and one phone interview (n = 1). Inclusion criteria included women who had given birth in the last five years and were over 18 years old. Recruitment was completed through word of mouth. The goal was to recruit a small convenience sample of women from the East Lansing, MI area with a wide range of exercise habits during pregnancy. In addition, by recruiting postpartum women with children of various ages, EK was able to improve various questions based on their feedback that was particular to the age of their children. The focus groups were not recorded; however, both EK and a research assistant took notes on all participant comments.

During the focus groups and phone interview, women responded to a set of questions regarding the survey comprehensibility and readability (Appendix G). The questions also focused on ensuring that the survey represented each of the ten intended domains of exercise (yoga, pilates, resistance training, whole-body exercises, light, moderate, and vigorous aerobic exercise, flexibility, group exercise classes, and home exercise videos) appropriately. The participants regarded two exercise domains (yoga and pilates) to be ambiguous. After all notes were complied, the PAS was revised and the two previously ambiguous questions/domains were resubmitted to the participants and deemed more understandable. Based on the participants' feedback, the readability, comprehensibility, and face validity of the PAS was determined to be satisfactory.

Once the focus groups were completed, Survey Monkey with Secure Sockets Layer (SSL) Security was used to create an online version of the survey. SSL allows for private information to be transmitted "through a cryptographic system that secures a connection between a client and a server. Many websites use the protocol to obtain confidential user information" [141]. This SSL system enabled the investigators to download the collected data over a secure channel. After the survey was online, it was proofread by seven individuals for grammatical errors and question sequencing and revised accordingly.

The PAS (Appendix H) took approximately 20-30 minutes to complete and began with an anonymous, mandatory online consent form. Participants were not allowed further access to the survey unless clicking on the "Next" button, which acted as an online consent. If a woman chose to decline the informed consent, she was redirected to a page asking her to close her web browser for completion. This mandatory question allowed the investigators to obtain informed consent from each participant while keeping the responses anonymous.

After consent was obtained, instructions were provided on how to complete the survey. Following these instructions, the participant was asked questions regarding her most recent pregnancy in the past five years. (See Appendix H for a complete list of questions on the PAS.) Questions focused on pregnancy and delivery, as well as demographic information about the child. These questions were revised from the National Database for Autism Research (NDAR) Autism Medical History Questionnaire [106]. The NDAR questionnaire was used because it included questions regarding relevant outcome variables under investigation and offered the most succinct and well-worded questions when compared to other surveys. Next, definitions of terms regarding exercise were explained (Table 1). While the study focused on resistance training, women were queried about other forms of exercise including yoga, pilates, whole-body exercises, light, moderate, and vigorous aerobic exercise, flexibility, group exercise classes, and home exercise videos. Most exercise questions were modified from the National Health and Nutrition Examination Survey 2005-2006 (NHANES) [107]. For example, the NHANES question for moderate aerobic activity read:

> "[Over the past 30 days] did (you/SP) do **moderate** activities for **at least 10 minutes** that caused only **light** sweating or a **slight to moderate increase** in breathing or heart rate? Some examples are brisk walking, bicycling for pleasure,

golf, or dancing. Here are some other examples of these types of activities. Please do not include house work or yard work that you have already told me about."

The revised question on the PAS read,

"While exercising or during your leisure-time, did you do moderate aerobic/cardio activities for at least 10 minutes that caused only light sweating or a slight to moderate increase in breathing or heart rate? Some examples are brisk walking, bicycling for pleasure, golf, or dancing. Please do NOT include exercises you have already told me about. (***Please check one.)*** Yes/No

Overall primary modifications from NDAR and NHANES surveys were the introductory segment to reflect the specific time point in pregnancy and only asking about leisure time exercise, rather than all PA. Similar transformations were performed for each exercise category (flexibility, group exercise classes, etc.). If the woman answered "yes" to any category, she was queried further regarding frequency, intensity, time, and types of activities performed. The survey asked the same ten exercise questions at five time points: 1) 30 days before she knew she was pregnant, 2) first trimester, 3) second trimester, 4) third trimester, and 5) last 30 days (i.e., the previous 30 days before completing the PAS). After completing all exercise questions, women were then asked about her overall exercise routine and if it changed in frequency, length of time, or intensity throughout the pregnancy. This question allowed the investigators to check the internal reliability of the PAS by comparing the responses from this question to the numerical exercise data.

After assessing the women's exercise habits, the survey then queried about general activities of daily living (ADL) throughout the entire pregnancy. Questions were taken from the

Pregnancy Physical Activity Questionnaire (PPAQ) [36]. However, there were two modifications necessary. First, the activity "shoveling snow" was added to the question, "When you are not at work, how much time do you usually spend mowing lawn using a walking mower, raking, gardening, [and shoveling snow]." Shoveling snow was added as an activity suggested by the focus group which was conducted in Michigan and was a common activity for many women. Second, the questions in the "exercise" domain were excluded because the PAS already included detailed questions regarding exercise. Therefore, by deleting the questions in the "exercise" domain, participant burden was reduced. Based on previous research, the PPAQ was considered to have moderate to high reliability and validity for activities ranging in type (household/caregiving and occupational) and intensity (sedentary to vigorous) during pregnancy [36]. Specifically, the PPAQ was able to assess a wide range of activities from sedentary (Intraclass correlation coefficient (ICC) = 0.78), to light (ICC = 0.78), to moderate (ICC = 0.82), and to vigorous (ICC = 0.81), with an overall ICC of 0.78 [36]. The survey ended with demographic questions about the participant and then a thank you page.

Table 1. Definitions of exercise, leisure time, physical activity, and the various domains of exercise the women were queried about. Definitions for the categories of exercises were modified from those used by the American College of Sports Medicine [17] and the 2008 Physical Activity Guidelines for Americans [149].

Category of Exercise	**Definition**
Exercise	A type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness (i.e., Cardiovascular endurance, Body composition, Muscular strength, Muscular endurance, and Flexibility) [17]
Leisure time	Time that is free from duties or responsibilities, such as lunch breaks or time away from work, including work breaks and lunch hours
Yoga	No definition provided
Pilates	No definition provided

Table 1 (cont'd)

Resistance training	Physical activities specifically designed to strengthen your muscles such as lifting weights, weight machines, resistance bands, kettlebells, or free weights
Strengthening exercises using your body weight as resistance	Activities such as sit-ups, push-ups, stability/exercise ball
Aerobic/Cardio exercises	Activities that cause your heart to beat faster than usual; using the body's large muscles to move in a rhythmic manner for a sustained period of time, for example brisk walking, running, bicycling, jumping rope, and swimming
Light intensity aerobic/cardio	Caused a very light sweat or only a very slight increase in breathing or heart rate; equivalent in effort to a slow walk
Moderate intensity aerobic/cardio	Caused only a light sweat or a slight to moderate increase in breathing or heart rate; equivalent in effort to a brisk walk
Vigorous intensity aerobic/cardio	Caused heavy sweating or large increases in breathing or heart rate; activities done to burn calories or maintain fitness; equivalent in effort to running or jogging
Flexibility/Stretching	No definition provided
Group exercise classes	Examples included aerobics, step, water aerobics, or Zumba
Home exercise classes	Classes on videotape or DVD
Physical activity (PA)	Any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal (resting) level [17].

Protocol

Women were recruited from posters displayed at Anytime Fitness® facilities across the United States and through the Anytime Health™ website. From the posters and/or website, the women were directed to the Anytime Health™ website where the survey was posted. By clicking on the link, they were automatically directed to the survey online. Participants completed the online survey at their leisure. It is estimated that the survey took the women approximately twenty to thirty minutes to complete. After survey completion, results were automatically transmitted to the Survey Monkey website.

Outcome Variables

While retrospective self-report has limitations, often it is the only feasible method available to collect data. In epidemiological studies examining early or later life events, data regarding pregnancy are obtained regularly. However, it may be financially difficult and not feasible to obtain medical records; therefore investigators rely on maternal recall. Thus, determining the accuracy of recalled pregnancy and birth outcomes is crucial. The PAS collected a variety of pregnancy/birth outcomes including gestational diabetes mellitus (GDM), preeclampsia/gestational hypertension, preterm labor, gestational age at delivery, birth weight, length of infant, mode of delivery, length of labor, and maternal weight gain. Based on available evidence regarding accuracy of recalled pregnancy events, the primary pregnancy outcome was preterm labor and primary birth outcomes were birth weight, gestational age at delivery, and mode of delivery. Previous research indicates that these outcomes can be recalled accurately [33, 64, 135, 145, 160] and thus were of primary interest in the current investigation. In contrast, the secondary pregnancy outcomes were GDM and preeclampsia/gestational hypertension, while a secondary birth outcome collected was length of infant. These secondary outcomes have been shown to be recalled less accurately than our primary outcomes [33, 135, 160] and thus were not the main focus of the present study. Two variables, maternal weight gain and length of labor were excluded from the present study due to the low accuracy of recall [33, 64, 145]. A detailed description regarding the accuracy of recall for the chosen variables follows.

Primary Outcome Variables

To assess the accuracy, or level of agreement, several statistical methods can be used, including kappa, sensitivity, specificity, percentage of positive agreement, and percentage of negative agreement. To assess agreement between categorical pregnancy outcomes, the kappa statistic is often used [86]. In general, kappa statistics of < 0.00 indicate a poor strength of agreement, 0.00-0.20 a slight strength of agreement, 0.21-0.40 a fair strength of agreement, 0.41-0.60 a moderate strength of agreement, 0.61-0.80 a substantial strength of agreement, and 0.81-1.00 an almost perfect agreement [86]. A model has high sensitivity if it accurately predicts true positives (i.e., an individual who has condition X has been correctly identified as having condition X) [113]. Conversely, a model has high specificity if it correctly identifies true negatives (i.e., individuals who do not have condition X are correctly identified as not having condition X) [113]. Percentage of positive agreement is defined as the percentage of cases correctly identified by the model that were actually observed in the sample [113]. Percentage of negative agreement is defined as the percentage of cases predicted not having a condition compared to the observed number in the sample without the condition [113].

The primary adverse pregnancy outcome was preterm labor as it has been shown to be recalled accurately. For example, Yawn et al. examined 281 women who completed a mailed survey 10-15 years postpartum and calculated a kappa statistic of 0.65, indicating substantial agreement between maternal recall and medical records of preterm labor [160]. Also, Githens examined 102 women who completed a telephone interview approximately 5.7 years postpartum and found a kappa statistic of 0.70 when participants were asked to recall whether they had preterm labor [64].

Birth weight was considered a primary outcome variable as it is commonly used as an overall index of fetal growth and has been shown to be recalled accurately up to thirty years postpartum [145]. Tomeo et al. examined 154 women who completed a mailed questionnaire approximately 32 years after delivery [145]. Recalled birth weight was highly correlated (r = 0.91) to National Collaborative Perinatal Project (NCPP) records. The investigators postulated that birth weight was recalled accurately because it was information almost all health care providers share with the mother as well as pregnancy being a salient event in most women's lives [145]. Yawn et al. examined 281 women who completed a mailed survey 10-15 years after delivery and compared those responses to medical records. The authors found the ICC to be 0.99 for recall of infant birth weight [160]. Among 208 Taiwanese women, the correlation between recalled birth weight and medical records 3-9 years postpartum was r = 0.95 [135]. Similarly, among 96 women completing a telephone interview approximately 22 years postpartum, Buka et al. reported an ICC of 0.74 when participants were asked to recall exact birth weight compared to NCPP records [33]. Adegboye and Heitmann found that among 1,271 Danish women, 68% recalled the exact birth weight of their children six years postpartum when compared to the national Danish Medical Birth Register [3]. Further, 98% accuracy was seen for women recalling birth weight within 100g [3]. Collectively, it has been demonstrated that women are able to recall birth weight accurately over extended periods of time.

Gestational age at delivery is also commonly assessed and was a primary outcome in the present study. Maternal recall of gestational age has been shown to be moderate to substantial. Among 96 women who recalled gestational age via a telephone interview approximately 22 years postpartum, the ICC was 0.64 when compared to NCPP records [33]. However, among 208 Taiwanese women, the correlation between recalled gestational age and medical records 3-9 years postpartum was much higher at r = 0.93 for women who delivered a preterm infant and r = 0.83 for women who delivered a term infant [135]. Finally, Adegboye and Heitmann found that among 678 Danish women, there was overall agreement (ICC = 0.76) between recalled gestational age six years postpartum when compared to the national Danish Medical Birth Register [3]. Thus, because gestational age can be recalled with reasonable accuracy and is an important indicator for infant health, it was considered a primary outcome in the present study.

Mode of delivery (i.e., vaginal or caesarean section) is a potentially important outcome variable as it can be indicative of maternal and/or fetal complications during delivery. Further, cesarean sections occur in approximately 32% of all live births in the United States, thus making it clinically significant [69]. Of all the outcomes considered, mode of delivery is the most accurately recalled [145]. Perfect sensitivity (1.00) and specificity (1.00) were found in a group of 154 women who completed a mailed questionnaire at least thirty years postpartum [145], among 208 women who completed a telephone interview 3-9 years postpartum [135], and among 96 women who completed a telephone interview 22 years postpartum [33]. In addition, 281 women completed a mailed survey 10-15 years postpartum and their recalled responses showed perfect agreement (kappa=1.00) with medical records [160]. Using the data of Yawn et al., the percentage of positive agreement was 98.6% and percentage of negative agreement was 99.8%, suggesting highly accurate recall of mode of delivery [160]. Finally, Githens et al. found that women (n = 102) were also able to recall mode of delivery up to 4-6 years postpartum with a kappa value of 0.79 [64]. Thus, evidence clearly demonstrates women’s ability to recall mode of delivery up to at least 22 years postpartum with excellent accuracy and thus was a primary outcome variable in the present study.

Secondary Outcome Variables

GDM and pregnancy hypertensive disorders are outcome variables relevant to this study, as both have been shown to be related to maternal PA behavior [122, 124, 125, 134, 144]. However, since women are less able to recall them as accurately as the primary outcome variables discussed above, they were considered secondary outcome variables for the present investigation.

GDM affects 4.1% of Non-Hispanic White and Black women and up to 11.9% of Korean women in the United States [71]. Further, in a study examining the trends of GDM in the United States, researchers reported a relative increase of 122% in GDM from 1989-1990 to 2003-2004 [63]. Thus, the increasing prevalence of GDM makes it an important outcome to assess. However, women are not able to recall GDM as well as outcomes such as birth weight and mode of delivery. For example, Yawn et al. examined 281 women who completed a mailed survey ten to fifteen years postpartum, and compared their responses to medical records. The result was a kappa statistic of zero for GDM [160]. This is because the percentage of positive agreement for GDM was zero, indicating that when GDM was reported in the medical records, a woman did not report GDM on the survey. In contrast, the percentage of negative agreement was 99.4% indicating that women accurately self-reported no GDM, when in fact she did not have GDM [160]. This could also be a function of low GDM prevalence and small sample size. In a study by Sou et al., 208 Taiwanese women completed a telephone interview 3-9 years after delivery and their responses were compared to medical records [135]. Among women who delivered term infants, there was a likelihood ratio of 11.11 for GDM (indicating a high correlation between self-reported GDM and the medical records showing GDM). However, due to the rarity of GDM among this sample, the authors concluded that, in general, recall of GDM was not valid

[135]. Hosler et al. examined 2,854 women two to six months postpartum in New York and found only moderate agreement (kappa = 0.53) between questionnaire reported GDM compared to medical records [77].

The prevalence of some type of hypertensive disorder (i.e., mild preeclampsia, severe preeclampsia, chronic hypertension, or gestational hypertension) is 83.4 per 1,000 deliveries and thus, is an important adverse pregnancy condition [85]. However, while clinically relevant, preeclampsia and/or gestational hypertension have not been shown to be recalled with high accuracy. Yawn et al. showed among 281 women who completed a mailed survey ten to fifteen years postpartum, preeclampsia/eclampsia was found to have a kappa statistic of 0.49 when their responses were compared to medical records [160]. The percentage of positive agreement was 51.6 and percentage of negative agreement was 96.9 [160]. This could have occurred due to the lack of differentiating between medical jargon and a woman's perception of understanding perinatal events. The authors also believed that decreased recall accuracy could be related to the thoroughness of the explanation provided by the health care provider [160]. In a study by Buka et al., 96 women completed a telephone interview 20 or more years after delivery [33]. When comparing recalled data and prospectively collected data during pregnancy about "high blood pressure" defined as systolic pressure > 160 mmHg or diastolic pressure > 110 mmHg, the kappa statistic was 0.34 [33]. In Sou et al.'s study among 208 Taiwanese women, gestational hypertension had a sensitivity of 100% and specificity of 99%, thus demonstrating accurate recall. However, for preeclampsia, sensitivity was 66.7% and specificity 100.0%. Sou et al. postulated that the more accurate recall of gestational hypertension and preeclampsia in the sample was due to gestational hypertension being a major obstetric event and possible cultural differences that need further investigation [135]. Therefore, the results of Buka at al., Yawn et al., and Sou et al. demonstrate only a “fair” strength of agreement when recalling some form of high blood pressure during pregnancy.

Compared to the other outcome variables, accuracy of recall for length of infant has not been well-investigated. To the author’s knowledge, there is only one study examining recall of infant length [147]. Troude et al. examined 557 French women and found excellent agreement (kappa = 0.98) between questionnaire reported birth length and medical records [147]. While the kappa statistic showed close to perfect agreement, these women answered the questionnaire shortly after delivery (6 weeks) and had access to the infant’s Personal Child Health Record. These factors potentially lead to better accuracy than if she was asked to recall infant length at a later period of time.

Covariates

Prepregnancy BMI was considered as a covariate in the present study and determination of its accuracy was necessary. In an investigation of 200 women recruited from prenatal care sites, reported and measured prepregnancy weights were compared. There were no significant differences between the mean weights between reported and clinical records (138.8 ± 29.6 vs. 139.5 ± 29.1 lbs) [87]. Further, when the women were classified into underweight, normal weight, overweight, and obese, there was a significant difference of over-reporting by 2.4 lbs only among the underweight women [87]. Thus, the authors suggest that a mother’s report for prepregnancy weight is a satisfactory substitute for clinical record data. In another study, self-reported weights among 550 American adults, self-reported weights were remarkably accurate, even among obese people [140]. However, in contrast to these reports, Stewart et al. found that among 1,598 men and women aged 35-65, 75% of participations reported weight accurately within 2.4 kg and height within 3.5 cm of measured weight and height [139]. Overall, Stewart et al. found that participants generally overestimated height and underestimated their weight, which resulted in an underestimation of relative body weight. Therefore, based on the available literature, it is reasonable to assume that weight may be accurately recalled or slightly underestimated and height most likely overestimated.

Excluded Outcome Variables

We measured other variables related to pregnancy and delivery that were considered in the present investigation. However, because of previous research indicating a lack of recall accuracy, they were not included. Excluded variables were maternal weight gain and length of labor.

Maternal recall of weight gain has been shown to be relatively inaccurate. Specifically, among 503 women participating in the Women and Infant Study of Healthy Hearts (WISH) study, self-reported weight gain was only moderately correlated (r = 0.63) with recorded weight gain in medical charts 4-12 years postpartum (mean = 8 years) [94]. In addition, when 96 women were queried 22 years postpartum about gaining 25 or more pounds during pregnancy, Buka et al. found the kappa statistic to be 0.15 [33]. Others have found similar results. When 102 women were asked to recall weight gain within 5 pounds four to six years postpartum, Githens et al. found the kappa statistic to be -0.352 [64]. In an investigation of 154 women queried at least 30 years postpartum, Tomeo et al. found the Spearman correlation between recalled and recorded weight gain values to be only 0.42 [145]. Overall, it appears that maternal recall of weight gain is rather poor, both in the short term (4-6 years postpartum) [64] and over longer periods of time (30 years postpartum) [145]. Further, it was not possible to assess whether the amount of weight gained was an appropriate amount for an *individual* participant. Therefore, we did not feel confident examining weight gain as it is a natural occurrence during pregnancy and women may be advised to gain more or less weight based on current weight status and previous health history.

Regarding length of labor, Buka et al. found the kappa statistic to be 0.43 when 96 women were queried about whether they encountered prolonged labor (> 12 hours) at least 20 years postpartum [33]. While length of labor has been studied as an outcome variable previously [68, 82, 123], due to its relatively low strength of agreement when recalled, it was not evaluated in the present study.

Factors Affecting Maternal Recall

Accuracy of maternal recall varies based on the outcome women are asked to recall and several factors affect the ability of a mother to recall specific events. Tomeo et al. suggested that women recall pregnancy events more accurately when they have reported them previously, or have been told about them [145]. For example, women are often told the birth weight of the child and it is reported on the birth certificate, as well as it is commonly repeated among family and friends following delivery, thus allowing for better memory of birth weight. Yawn et al. suggests that there is a high level of value associated with telling family and friends birth weight and is therefore recalled more accurately than other measures [160]. Also, medical conditions are generally recalled with less accuracy possibly due to medical and technical jargon used by healthcare providers making it less understandable for a woman to recall [145].

There are other possibilities for reduced accuracy for recalling medical conditions/procedures. During labor and delivery, women may be given medication which may alter their states of consciousness and ability to remember events when medicated [33]. Physicians may not tell a woman of certain possible events that could harm the infant if they can be handled quickly without involving the mother [64]. Further, infrequent pregnancy events, such as GDM and preeclampsia may not be accurately recalled because of their rarity [160]. For events like these, percent negative agreement has been high, demonstrating that women could accurately report not having a condition, but the percent positive agreement was much lower suggesting that women could not accurately recall when they did have one of those conditions [160].

While maternal recall of pregnancy-related events has its limitations, there are several maternal characteristics related to more accurate recall. Maternal education level has been consistently been shown to improve maternal recall [33, 64, 135]. Specifically, more accurate recall has been found among women who have completed 12 or more years of education [33]. Since most women in the current sample have completed some college (1-3 yr) or more, their recall ability is likely better than less educated women. While maternal education is the only consistent factor related to recall accuracy, certain events have been found to be recalled with greater accuracy. Specific pregnancy events such as preterm delivery, first birth order, and lower total parity were found to improve maternal recall; however, none of these events consistently demonstrate improved recall for all birth outcomes [135]. In addition, Githens et al. found no differential misclassification based on whether the mother experienced an adverse outcome [64].

Statistical Analyses and Data

All analyses were completed using Predictive Analytics SoftWare (PASW) Statistics 18.0 (SPSS Inc., Chicago, IL). For all analyses, an Alpha level of $P \leq 0.05$ was considered statistically significant.

Study participants included women who were members of a national health club chain and who have given birth within the past five years. They provided all information via an online survey developed by the investigators. It was not possible to assess resistance training independently because women eligible for the study who performed resistance training also performed aerobic exercise. Thus, study participants were classified by exercise status into three groups: 1) women who performed both leisure-time resistance training and aerobic exercise (RTAE) during pregnancy, 2) women who performed only leisure-time aerobic exercise (AE) during pregnancy, and 3) women who performed no leisure-time exercise (NE) during pregnancy.

Quantification and Transformation of Variables

Exercise and Physical Activity Variables

Resistance training exercise was transformed into MET·hr/wk through several steps. Resistance training was assigned a MET value, defined as the ratio of work metabolic rate to a standard resting metabolic rate [5]. The value of 5.7 METs was derived from averaging three MET values corresponding to circuit training (Code 02040), weight lifting of light or moderate effort (Code 02130), and weight lifting of vigorous effort (Code 02050) from the Updated Compendium of Physical Activities [5]. This was done because the exact intensity (based on repetitions and sets) of resistance training was unknown, but by averaging these three values, resistance training from light to vigorous intensity was captured. Then, 5.7 METs was multiplied by both the frequency and duration of resistance training to obtain MET·hr/wk for each trimester that resistance training was reported. The MET·hr/wk values of resistance training from each trimester were then summed to obtain a single value of weekly energy expenditure. Lastly, the summed value was then divided by three (trimesters) to obtain the mean weekly energy expenditure (MET·hr/wk) obtained through resistance training throughout gestation (Figure 1).

Aerobic exercise training was transformed similarly. The corresponding MET value was applied based on the intensity of aerobic exercise from the Updated Compendium of Physical Activities [5]. Light intensity aerobic exercise was assigned a value of 2.5 METs, which was derived from the activity “walking, 2.0 mph, level, slow pace, firm surface” (Code 17152). Moderate intensity aerobic exercise was assigned a value of 3.3 METs, which was derived from the activity “walking, 3.0 mph, level, moderate pace, firm surface” (Code 17190). Vigorous intensity aerobic exercise was assigned a MET value of 8.0 METs, which was derived from the activity “running at 8.0 mph” (Code 12150). Each MET value was then multiplied by frequency and duration and then summed to obtain the total MET·hr/wk of aerobic exercise throughout gestation. Lastly, the summed value was divided by three (trimesters) to obtain the mean weekly energy expenditure (MET·hr/wk) obtained through aerobic exercise throughout gestation (Figure 1).

ADL were assessed via the PPAQ [36] and transformed into a continuous value of energy expenditure (MET·hr/wk). The PPAQ queried about ADL during a typical week of gestation throughout the entirety of gestation. Thus, the duration of each activity was multiplied by the corresponding MET value according to the Updated Compendium of Physical Activities [5] to obtain a final value of MET·hr/wk (Figure 1). If a woman was missing two or fewer values (< 10% of sample) for duration of activity on the PPAQ, data were imputed. To replace the values, a mean substitution was used for duration of activity according to each individual woman’s responses for similar activities within a category (i.e., caregiving, transportation, heavy household chores, and occupation). To calculate the missing value, the durations were averaged and the mean duration was then imputed into the missing data point. Although a mean substitution has its limitations, it is one of the most widely used methods and it allowed us to keep more of our sample in an already underpowered study [67].

Women were assigned to one of three exercise groups, depending on their responses. Women who reported resistance and aerobic exercise training were assigned to the resistance and aerobic (RTAE) group. Women who reported only aerobic exercise training were assigned to the aerobic (AE) group. Women who did not report either resistance or aerobic exercise training were assigned to the no exercise (NE) group.

To derive mean weekly total physical activity (TPA) throughout gestation, mean MET·hr/wk values from each category were summed accordingly (Figure 1). For example, mean energy expenditure for a woman in the RTAE group was calculated by summing the mean MET·hr/wk from resistance training, aerobic training, and ADL. Mean energy expenditure for a woman in the AE group was calculated by summing the mean MET·hr/wk from aerobic exercise and ADL. Lastly, for women in the NE group, the mean weekly energy expenditure from ADL was used.

Outcome Variables

Pregnancy outcome variables included gestational diabetes, preeclampsia/gestational hypertension, and preterm labor and were dichotomous in nature. Women were asked, "During your pregnancy, did a doctor or health care worker ever tell you that you had any of the following medical conditions? *(Please check the most appropriate box.)*" Response options were: Yes, No, Don't Know. Responses were then categorized into two groups (yes/no) and were classified as missing data if she reported "don't know" ($n \leq 6$). Preeclampsia and gestational hypertension and preterm labor requiring bed rest and preterm labor requiring medication were collapsed into two single variables to reduce potential recall error.

Birth outcome variables included birth weight, gestational age at delivery, mode of delivery, and length of infant. Birth weight was transformed from maternal reported pounds and ounces to kilograms (kg) by the formula [(Pounds + (Ounces/16))/2.2]. Gestational age (weeks) at delivery was dichotomized into pre/post term (defined as delivering ≤ 36 wk or ≥ 41 wk gestation) or term (37-40 wk gestation) due to the narrow range of data points. Mode of delivery was dichotomized into vaginal or cesarean section. Length of infant was transformed from maternal reported inches to cm by multiplying inches by 2.54.

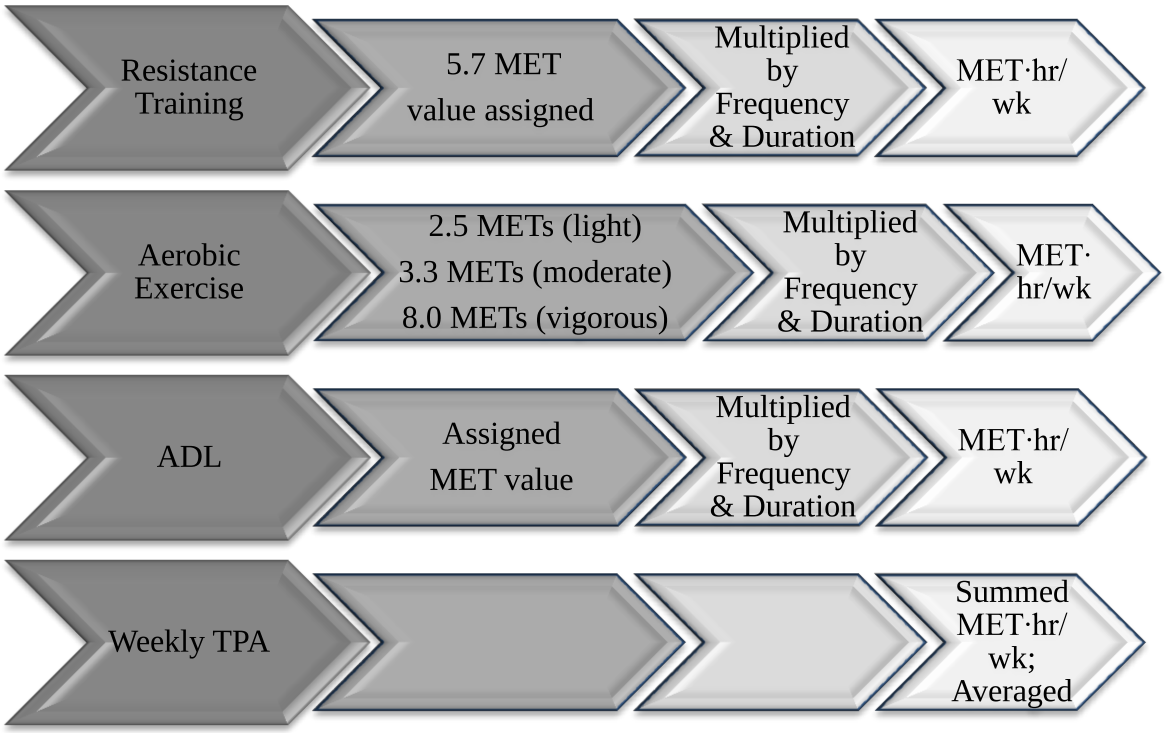
Covariates

Covariates included maternal age at delivery and prepregnancy body mass index (BMI). These two variables were chosen because they are some of the most often controlled for variables when evaluating pregnancy and birth outcomes [125, 144]. Other possible covariates such as maternal education, household income, parity, and fruit and vegetable consumption were not included in the present analyses due to the relatively small sample size and number of independent predictor variables in the final model. In addition, maternal education and household income had a fairly narrow range and would provide little valuable information due to the limited variability in the current sample. Thus, while these other covariates are important to consider, the present sample size did not allow for complete adjustment. Maternal age at delivery was self-reported on the PAS in years. Participants reported prepregnancy weight in pounds and current height in feet and inches. Current maternal height was assumed to be the same as pregnancy height. Weight was converted to kilograms by dividing pounds by 2.2. Height was converted to meters by multiplying inches by 0.0254. Prepregnancy BMI (kg/m^2) was calculated using the equation (prepregnancy weight in kg)/(current height in m)^2. All analyses were run using unadjusted and adjusted models.

Analyses

Descriptive statistics were run to evaluate potential differences of demographic data of study participants.

Figure 1. Transformation of exercise and activity variables.



<u>Specific Aim 1: To develop an online survey to assess various forms of exercise during pregnancy, specifically various forms of resistance training, aerobic training, flexibility, group exercise classes, home videos, yoga, and pilates.</u>

Aim 1 was accomplished through completion of a course (CAS 892), a meeting among the dissertation committee, two focus groups, and one phone interview. This aim was not hypothesis driven and required no statistical analysis.

<u>Specific Aim 2: To determine the prevalence of both traditional (i.e., weight machines and free weights) and nontraditional forms (i.e., resistance bands, whole body exercises, kettlebells) of resistance training during pregnancy among women health club members.</u>

Data analysis included descriptive statistics to assess the frequency of women performing each type of traditional forms (weight machines and free weights) and nontraditional forms (resistance bands, whole body, and kettlebells) of resistance training during pregnancy.

Specific Aim 3: To describe and evaluate the activities of daily living (ADL) and exercise status of women health club members during pregnancy within the past five years.

Hypothesis 3a:

Data analysis included descriptive statistics (means and standard deviations) to assess the amount of ADL accrued by women in each exercise status category.

Hypothesis 3b:

To evaluate the relationship between ADL by exercise status, one-way analysis of variance (ANOVA) was used. The independent variable, exercise status, was categorized into three groups: RTAE, AE, and NE. The dependent variable, ADL, was quantified into MET·hr/wk as stated above.

Specific Aim 4: To evaluate the relationship between weekly TPA and adverse pregnancy and birth outcomes, including gestational diabetes, preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and length of infant.

Hypothesis 4a:

The association between weekly TPA and prevalence of adverse pregnancy outcomes was assessed using logistic regression. The independent variable, weekly TPA, was continuous (MET·hr/wk). The dependent variables, gestational diabetes and preeclampsia/gestational hypertension, were dichotomous.

Hypothesis 4b:

The association between weekly TPA and birth weight was assessed using linear regression. The independent variable, weekly TPA, was continuous (MET·hr/wk). The dependent variable, birth weight, was also continuous.

Hypothesis 4c:

The association between weekly TPA and preterm labor, gestational age at delivery, and mode of delivery was assessed using logistic regression. The independent variable, weekly TPA, was continuous (MET·hr/wk). The dependent variables, preterm labor, gestational age at delivery and mode of delivery, were dichotomous.

The association between weekly TPA and infant length was assessed using linear regression. The independent variable, weekly TPA, was continuous (MET·hr/wk). The dependent variable, infant length, was also continuous.

Specific Aim 5: To evaluate the relationship between exercise status and adverse pregnancy and birth outcomes, including gestational diabetes, preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and length of infant.

Hypothesis 5a:

The association between leisure-time resistance training and aerobic exercise and prevalence of adverse pregnancy outcomes was assessed using logistic regression. The independent variable, exercise status, was categorized into three groups: RTAE, AE, and NE. The dependent variables, gestational diabetes and preeclampsia/gestational hypertension, were dichotomous.

To evaluate the association between the mode of exercise and adverse pregnancy outcomes, Fisher-exact tests were used to determine significance. Women were categorized into two groups RTAE and AE + NE for analysis.

Hypothesis 5b:

The association between leisure-time resistance training and aerobic exercise and birth weight was assessed using linear regression. The independent variable, exercise status, was coded into two dummy variables, RTAE, AE, while NE was the referent group. The dependent variable, birth weight, was continuous.

The association between leisure-time resistance training and aerobic exercise and birth weight was also assessed using one-way ANOVA. The independent variable, exercise status, was categorized into three groups: RTAE, AE, and NE. The dependent variable, birth weight, was continuous. When combining women in the AE and NE groups, an independent t-test was used, with exercise status as the independent variable and birth weight as a continuous dependent variable.

Hypothesis 5c:

The association between leisure-time resistance training and aerobic exercise and preterm labor, gestational age at delivery, and mode of delivery was assessed using logistic regression. The independent variable, exercise status, was categorized into three groups: RTAE, AE, and NE. The dependent variables, preterm labor, gestational age at delivery and mode of delivery, were dichotomous.

The association between leisure-time resistance training and aerobic exercise and infant length was assessed using linear regression. The independent variable, exercise status, was coded into two dummy variables, RTAE, AE, while NE was the referent group. The dependent variable, infant length, was continuous.

The association between leisure-time resistance training and aerobic exercise and infant length was also assessed using one-way ANOVA. The independent variable, exercise status, was categorized into three groups: RTAE, AE, and NE. The dependent variable, infant length, was continuous. When combining women in the AE and NE groups, an independent t-test was used, with exercise status as the independent variable and infant length as a continuous dependent variable.

CHAPTER 4
RESULTS

Study Flow of Participants

Between October 12, 2010 and June 15, 2011, 513 women responded to the Pregnancy Activity Survey (PAS) by clicking the online PAS link. Figure 2 shows the flow of participants from study recruitment to survey completion. The total usable sample size (i.e., completed ≥ 90% of the PAS [67]) was 222 women (43%). Maternal demographics are listed in Table 2. There was a statistically significant difference in age and prepregnancy BMI between the three exercise statuses. Specifically, the NE group was significantly younger than the RTAE group and both AE and NE groups had significantly higher prepregnancy BMI's ($p < 0.05$).

The overall frequency and prevalence of adverse pregnancy outcomes among this sample are listed in Table 3. Seventeen women (7.7%) delivered at 36 weeks gestation or earlier and fifteen women (6.8%) delivered at 41 weeks gestation or later. Most women delivered at 40 weeks gestation (28.5%) or 39 weeks gestation (21.7%). Of the women who delivered via cesarean section, 28 women (38.9%) had an elective cesarean section, while 44 (61.1%) had an emergency cesarean section. Table 4 describes infant birth weight and length. Ten women (4.5%) delivered an infant less than 2.5 kg, while thirty-five women (16.5%) delivered an infant greater than 4 kg.

Specific Aim 1: Development of an Online Survey

The PAS was developed according to the methodology previously described in Chapter 3: Methods – Survey Development section. To expand upon the survey development, more specific comments regarding modifications made will be detailed next. First, EK created a short survey for completion of the CAS 892 class. Based on the original survey, several comments were made from a classmate including moving demographics from the beginning of the survey to the end, deleting the response choice "Do not wish to answer", changing the layout of the pregnancy questions to a stem-an-branch format, and giving more detailed directions as to how to navigate through the questions. Also, minor grammatical errors were noted and corrected and the survey was rewritten in the second person so it would flow more easily for the reader. The revised survey was then assessed by the instructor. The instructor had three major comments: 1) use a shorter and friendlier title, 2) format directions/instructions different from the questions, and 3) "Recruiting by poster is likely to produce a response rate more on the order of .3% rather than 30%. You might consider mailing or emailing questionnaires to a randomly selected sample of members. With appropriate cash incentives and multiple contacts you should get a 30% response rate among those you sample. And the result [sic] will be more credible". Thus, based on the instructor's feedback, the title and formatting of directions/instructions was changed. However, the recruitment method was not. Colorful posters, created by Anytime Fitness® personnel, were hung in facilities across the United States.

It was not possible to determine the true response rate because total number of potential participants was unknown. Determining the total number of participants would have required knowing the number of eligible pregnant women belonging to either Anytime Fitness® or Anytime Health™ who had access to the survey. Thus, only a survey completion rate was calculated.

Among women who clicked on the survey link a completion rate of 43% was elicited with no cash incentive. According to the focus group participants, the survey took approximately 30 minutes to complete in pen-and-paper format. The primary concerns raised about the survey included the time it took to complete, that an online format would be better, and the questions regarding yoga and pilates were too confusing. Based on their feedback, the questions about yoga and pilates were moved to the beginning of the exercise questions and the women had the opportunity to state whether they also considered it part of their aerobic or resistance training regime. Other more minor concerns were related to grammatical issues and issues regarding skip sequences in the paper-and-pen format, which were corrected and alleviated in the online format.

Specific Aim 2: Prevalence of Traditional and Non-traditional Forms of Resistance Training

Overall, 65 women (29%) performed resistance training during at least one trimester. On average, they engaged in resistance training 2.68 days/week for 28 minutes/session throughout gestation. Table 5 shows the mean frequency and duration of resistance training by trimester. As gestation progressed, the number of women who performed resistance training decreased from 59 during first trimester to 39 during third trimester. Among those who performed resistance training, women were more likely to train for muscular endurance (i.e., low weight and high repetitions) than for muscular strength (i.e., high weight and low repetitions) especially as gestation progressed (Tables 6-8). Approximately 75% of women engaged in two different modes of resistance training throughout gestation. Traditional forms of resistance training, defined as using weight machines or free weights, were performed more frequently than non-traditional forms of resistance training, defined as using resistance bands, whole body exercises, or kettlebells. Of the non-traditional forms of resistance training, resistance bands were used most often.

Figure 2. Flow of study participants.

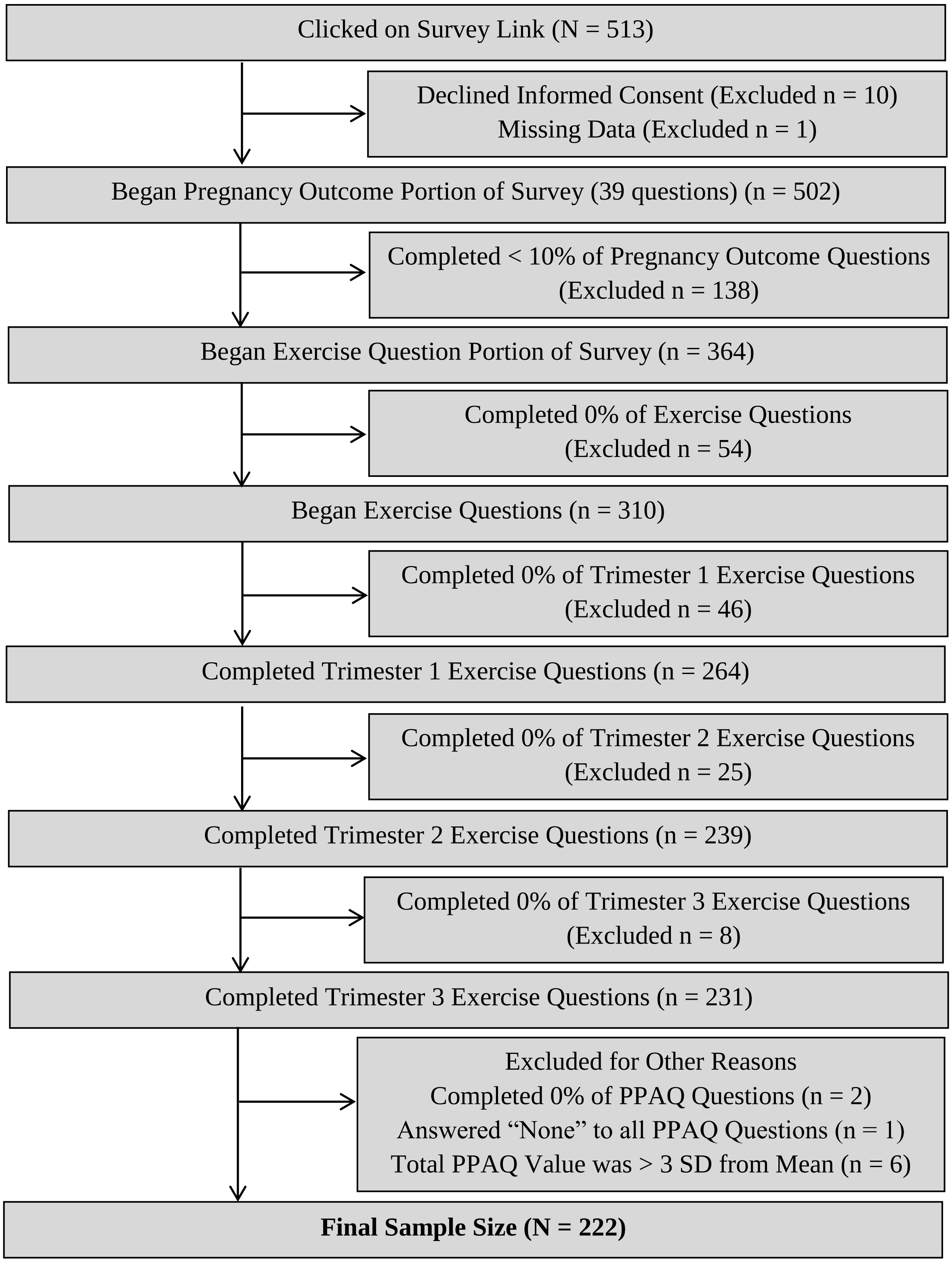


Table 2. Maternal age, prepregnancy body mass index (BMI), and weekly total physical activity (TPA) (MET·hr/wk) (Mean ± Standard Deviation), and demographic characteristics (%) among women health club members according to exercise status: Resistance Training + Aerobic Exercise (RTAE), Aerobic Exercise only (AE), or No Exercise (NE).

Characteristic	RTAE (n = 65)	AE (n = 109)	NE (n = 44)
Maternal age (yr)	29.0 ± 4.4	27.6 ± 5.5	25.8 ± 5.9*
Prepregnancy BMI (kg/m^2)	25.9 ± 6.2	29.0 ± 6.5*	29.7 ± 7.8**
Activities of Daily Living (MET·hr/wk)	293.5 ± 117.8	316.5 ± 144.5	348.5 ± 179.8
Aerobic Exercise (MET·hr/wk)	14.9 ± 14.0	9.1 ± 17.6*	0.0 ± 0.0**
Resistance Training (MET·hr/wk)	5.4 ± 4.0	0.0 ± 0.0*	0.0 ± 0.0**
Weekly TPA (MET·hr/wk)	312.5 ± 122.3	321.9 ± 142.3	335.0 ± 162.7
Maternal Race			
White (Non-Hispanic) (%)	86	91	90
Hispanic or Latino (%)	3	4	5
Black or African American (%)	2	3	3
Other (%)	9	2	2
Marital Status			
Married (%)	85	77	68
Divorced/Separated (%)	2	1	5
Never Married (%)	1	8	7
Living with Partner (%)	12	14	20
Maternal Education			
Grades 9-11 (%)	0	3	0
Grade 12 or GED (%)	9	11	15
College 1-3 years (%)	29	51	49
College 4+ years (%)	62	35	36
Annual Household Income			
≤$24,999 (%)	2	20	29
$25,000 - $49,999 (%)	18	22	32
$50,000 - $74,999 (%)	29	22	14
$75,000 - $104,999 (%)	25	17	22
$105,000 + (%)	23	12	3
Don't Know/Not sure (%)	3	7	0

*Significantly different from RTAE group, $p < 0.05$.

**Significantly different from RTAE and AE groups, $p < 0.05$.

Note: Individual values do not always equal total values due to incomplete data which did not exceed10%.

Table 3. Frequency and prevalence (%) of pregnancy outcomes (preterm labor, mode of delivery, gestational age at delivery, gestational diabetes mellitus, and preeclampsia/gestational hypertension) among women study participants.

	Frequency (n)	Prevalence (%)
Preterm Labor	21	9.5
Mode of Delivery		
Vaginal	145	65.3
Cesarean Section	77	34.7
Gestational Age at Delivery		
Term (37-40wk)	166	85.5
Pre/Post Term (≤ 36 wk or ≥ 41 wk)	55	14.5
Gestational Diabetes Mellitus	19	8.6
Preeclampsia/gestational hypertension	25	11.3

Note: Individual values do not always equal total values due to incomplete data which did not exceed10%.

Table 4. Description of birth weight and infant length among infants of study participants.

Outcome	Mean ± SD	Range	Minimum	Maximum
Birth weight (kg)	3.47 ± 0.54	3.61	1.56	5.17
Infant length (cm)	51.3 ± 3.5	27.9	30.5	58.4

Table 5. Mean frequency (days/week) and duration (minutes/session) of resistance training, by trimester, among study participants who have given birth in the past five years.

	n	Mean	Standard Deviation
Frequency of resistance training Trimester 1 (days/week)	59	2.86	0.93
Duration of resistance training Trimester 1 (minutes/session)	59	30.00	13.90
Frequency of resistance training Trimester 2 (days/week)	48	2.73	0.74
Duration of resistance training Trimester 2 (minutes/session)	48	27.17	12.77
Frequency of resistance training Trimester 3 (days/week)	39	2.44	0.82
Duration of resistance training Trimester 3 (minutes/session)	39	25.26	12.24

Table 6. Frequency and prevalence of intensity of resistance training (muscular endurance or muscular strength) and traditional and non-traditional forms of resistance training among study participants during first trimester (n = 59).

	Frequency	Percent
Intensity		
Endurance	43	72.9
Strength	16	27.1
Primary Mode		
Traditional Forms		
Weight machines	22	55.9
Free weights	33	37.3
Nontraditional Forms		
Resistance bands	4	6.8
Whole body exercises	0	0.0
Kettlebells	0	0.0
Secondary Mode		
Traditional Forms		
Weight machines	20	34.5
Free weights	20	34.5
Nontraditional Forms		
Resistance bands	5	8.6
Whole body exercises	0	0.0
Kettlebells	1	1.7
Did not have a secondary mode	12	20.7
Tertiary Mode		
Traditional Forms		
Weight machines	4	6.8
Free weights	0	0.0
Nontraditional Forms		
Resistance bands	7	11.9
Whole body exercises	0	0.0
Kettlebells	2	3.4
Did not have a tertiary mode	46	78.0

Note: Individual values do not always equal total values due to incomplete data which did not exceed10%.

Table 7. Frequency and prevalence of intensity of resistance training (muscular endurance or muscular strength) and traditional and non-traditional forms of resistance training among study participants during second trimester (n = 48).

	Frequency	Percent
Intensity		
Endurance	41	85.4
Strength	7	14.6
Primary Mode		
Traditional Forms		
Weight machines	17	35.4
Free weights	27	56.3
Nontraditional Forms		
Resistance bands	3	6.3
Whole body exercises	0	0.0
Kettlebells	1	2.1
Secondary Mode		
Traditional Forms		
Weight machines	15	31.3
Free weights	19	39.6
Nontraditional Forms		
Resistance bands	4	8.3
Whole body exercises	0	0.0
Kettlebells	0	0.0
Did not have a secondary mode	10	20.8
Tertiary Mode		
Traditional Forms		
Weight machines	3	6.4
Free weights	1	2.1
Nontraditional Forms		
Resistance bands	5	10.6
Whole body exercises	0	0.0
Kettlebells	3	6.4
Did not have a tertiary mode	35	74.5

Note: Individual values do not always equal total values due to incomplete data which did not exceed10%.

Table 8. Frequency and prevalence of intensity of resistance training (muscular endurance or muscular strength) and traditional and non-traditional forms of resistance training among study participants during third trimester (n = 39).

	Frequency	Percent
Intensity		
Endurance	36	92.3
Strength	3	7.7
Primary Mode		
Traditional Forms		
Weight machines	16	41.0
Free weights	18	46.2
Nontraditional Forms		
Resistance bands	4	10.3
Whole body exercises	0	0.0
Kettlebells	1	2.6
Secondary Mode		
Traditional Forms		
Weight machines	10	25.6
Free weights	18	46.2
Nontraditional Forms		
Resistance bands	3	7.7
Whole body exercises	0	0.0
Kettlebells	0	0.0
Did not have a secondary mode	8	20.5
Tertiary Mode		
Traditional Forms		
Weight machines	2	5.1
Free weights	0	0.0
Nontraditional Forms		
Resistance bands	6	15.4
Whole body exercises	0	0.0
Kettlebells	1	2.6
Did not have a tertiary mode	30	76.9

Note: Individual values do not always equal total values due to incomplete data which did not exceed10%.

<u>Specific Aim 3: Evaluation of ADL Patterns by Exercise Status</u>

Overall, women who did not perform any exercise throughout gestation (NE, n = 44) had the highest energy expenditure from ADL compared to the AE and RTAE groups (p = 0.07) (Table 2). Thus, because the results were not statistically significant, they do not support hypothesis 3b.

Specific Aim 4: Weekly TPA and Adverse Pregnancy and Birth Outcomes

Aim 4 assessed the main effect of weekly TPA in MET·hr/wk in relation to pregnancy and birth outcomes. Pregnancy and birth outcomes included GDM, preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and length of infant. GDM and preeclampsia/gestational hypertension were dichotomous (yes/no). Birth weight and length of infant were continuous, while preterm labor, gestational age at delivery, and mode of delivery were dichotomous (yes/no, ≤ 36 wk and ≥ 41 wk or 37-41 wk, vaginal/cesarean section, respectively). Results are presented for unadjusted and adjusted models (adjusted for maternal age at delivery and prepregnancy BMI).

The unadjusted model between weekly TPA and GDM was not statistically significant $\chi^2 = 0.981$ (n = 174, df = 1), p = 0.32, indicating that it was not able to distinguish between women with and without GDM. The unadjusted model was able to explain between 0.5% (Cox and Snell R Square) and 1.1% (Nagelkerke R Square) of the variance. However, the adjusted model was statistically significant $\chi^2 = 17.99$ (n = 178, df = 3), $p < 0.001$, indicating that the model was able to distinguish between women with and without GDM. The adjusted model was able to explain between 9.6% (Cox and Snell R Square) and 20.0% (Nagelkerke R Square) of the variance. As shown in Table 9, only prepregnancy BMI contributed significantly to the prediction of having GDM ($p < 0.001$). Women with higher prepregnancy BMI had a 14% higher odds of developing GDM (95% CI 1.06-1.21). The ORs for weekly TPA and maternal age at delivery approximated 1.0 indicating neither a protective nor adverse association with GDM, which was further demonstrated by tight 95% CIs. While the adjusted model was significantly better than the unadjusted model, hypothesis 4a was not supported because weekly TPA did not contribute significantly to an inverse relationship with GDM.

The unadjusted model between weekly TPA and preeclampsia/gestational hypertension was not statistically significant $\chi^2 = 3.246$ (n = 189, df = 1), p = 0.07, indicating that it was not able to distinguish between women with and without preeclampsia/gestational hypertension. The unadjusted model was able to explain between 1.7% (Cox and Snell R Square) and 3.2% (Nagelkerke R Square) of the variance. Similarly, the adjusted model was not statistically significant $\chi^2 = 7.59$ (n = 175, df = 3), p = 0.06, indicating that the model was not able to distinguish between women with and without preeclampsia/gestational hypertension. The adjusted model was able to explain between 4.2% (Cox and Snell R Square) and 7.7% (Nagelkerke R Square) of the variance. As shown in Table 10, weekly TPA (p = 0.04) and prepregnancy BMI (p = 0.02) contributed significantly to the prediction of having preeclampsia/gestational hypertension. The ORs for maternal age at delivery approximated 1.0 indicating neither a protective nor adverse association with preeclampsia/gestational hypertension, which was further demonstrated by tight 95% CIs. Therefore, hypothesis 4a was not supported when considering preeclampsia/gestational hypertension because the overall adjusted model was not statistically significant even though weekly TPA demonstrated an inverse relationship.

When examining the association between weekly TPA and birth weight there was no statistically significant contribution of weekly TPA, maternal age at delivery, or prepregnancy BMI (Table 11). The adjusted model explained 1.7% of the variance. Mean birth weight for the entire sample was 3.47 ± 0.54 kg, which was within a normal range. Thus, these results suggest no increase or restriction of growth in utero, and subsequently birth weight, based on the amount of energy a woman expended (MET·hr/wk) during a typical week during gestation. Therefore, hypothesis 4b was not supported because there was not an inverse relationship.

The unadjusted model between weekly TPA and preterm labor was not statistically significant χ^2 =0.175 (n = 188, df = 1), p = 0.68, indicating that it was not able to distinguish between women with and without preterm labor. The unadjusted model was able to explain between 0.1% (Cox and Snell R Square) and 0.2% (Nagelkerke R Square) of the variance. Similarly, the adjusted model was not statistically significant χ^2 = 5.14 (n = 174, df = 3), p = 0.16, indicating that it was not able to distinguish between women with and without preterm labor. The adjusted model was able to explain between 2.9% (Cox and Snell R Square) and 6.6% (Nagelkerke R Square) of the variance. As shown in Table 12, while none of the independent variables contributed significantly, prepregnancy BMI was marginally significant (p = 0.07). The ORs for weekly TPA and maternal age at delivery approximated 1.0 indicating neither a protective nor adverse association with preterm labor, which was further demonstrated by tight 95% CIs. Thus, hypothesis 4c was supported because there was no association between weekly TPA and preterm labor.

The unadjusted model between weekly TPA and delivering pre/post term (≤ 36 wk or ≥ 41 wk) versus term (37-40 wk gestation) was not statistically significant χ^2 = 1.315 (n = 191, df = 1), p = 0.25, indicating that it was not able to distinguish between women delivering pre/post term and term infants. The unadjusted model was able to explain between 0.7% (Cox and Snell R Square) and 1.0% (Nagelkerke R Square) of the variance. Similarly, the adjusted model was also not statistically significant χ^2 = 1077 (n = 177, df = 3), p = 0.78, indicating that the model was not able to distinguish between women delivering pre/post term and term infants. The adjusted model was able to explain between 0.6% (Cox and Snell R Square) and 0.9% (Nagelkerke R Square) of the variance. As shown in Table 13, none of the independent predictors contributed significantly to predicting gestational age at delivery. The ORs for weekly

TPA, maternal age at delivery, and prepregnancy BMI approximated 1.0 indicating neither a protective nor adverse association with delivering pre/post term or term, which was further demonstrated by tight 95% CIs. Thus, hypothesis 4c was supported when considering gestational age at delivery because there was no relationship between weekly TPA and gestational age at delivery.

The unadjusted model between weekly TPA and likelihood of delivering via cesarean section was not statistically significant $\chi^2 = 0.197$ (n = 192, df = 1), p = 0.66, indicating that it was not able to distinguish between women who delivered via cesarean section and vaginally. The unadjusted model was able to explain only 0.1% (Cox and Snell R Square, Nagelkerke R Square) of the variance. However, the adjusted model was statistically significant $\chi^2 = 8.136$ (n = 178, df = 3), p = 0.04, indicating that it was able to distinguish between women who delivered via cesarean section and vaginally. The adjusted model was able to explain between 4.5% (Cox and Snell R Square) and 6.1% (Nagelkerke R Square) of the variance of mode of delivery. As shown in Table 14, only prepregnancy BMI contributed significantly to the prediction of having delivered via cesarean section (p = 0.01). The ORs for weekly TPA and maternal age at delivery approximated 1.0 indicating neither a protective nor adverse association with cesarean section, which was further demonstrated by tight 95% CIs. Thus, hypothesis 4a was supported when considering mode of delivery based on weekly TPA. When considering only women who delivered via cesarean section (n = 65), the amount of weekly TPA did not influence whether it was an elective or emergency cesarean section, thus demonstrating no increased risk of weekly TPA on emergency cesarean sections (Table 15). In the adjusted model, weekly TPA continued

Table 9. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of gestational diabetes mellitus (GDM) from weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
Weekly TPA	-0.002	0.002	0.905	1	0.17†	1.00	0.99	1.00
Constant	-1.690	0.633	7.129	1	0.01	0.19		
Adjusted								
Weekly TPA	-0.002	0.002	1.170	1	0.14†	1.00	0.99	1.00
Maternal Age at Delivery	0.057	0.050	1.280	1	0.13†	1.06	0.96	1.17
Prepregnancy BMI	0.127	0.033	14.616	1	<0.001†	1.14	1.06	1.21
Constant	-6.970	1.954	12.722	1	<0.001†	0.001		

†P value reported is for a one-sided test.

Table 10. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of preeclampsia/gestational hypertension from weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
Weekly TPA	-0.003	0.002	2.829	1	0.05†	1.00	0.99	1.00
Constant	-0.970	0.577	2.828	1	0.05†	0.38		
Adjusted								
Weekly TPA	-0.003	0.002	3.158	1	0.04†	1.00	0.99	1.00
Maternal Age at Delivery	-0.031	0.043	0.516	1	0.24†	0.97	0.89	1.06
Prepregnancy BMI	0.063	0.029	4.540	1	0.02†	1.07	1.01	1.13
Constant	-1.787	1.496	1.427	1	0.12†	0.17		

†P value reported is for a one-sided test.

Table 11. Unadjusted and adjusted multiple linear regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for the association between birth weight (kg) and weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	Unstandardized Coefficients		Standardized Coefficients				
	B	Std. Error	Beta	t	P	95% CI Lower	Upper
Unadjusted							
Weekly TPA	0.000	0.000	0.059	0.812	0.21†	0.00	0.00
Constant	3.401	0.098		34.632	< 0.001†	3.21	3.60
Adjusted							
Weekly TPA	0.000	0.000	0.065	0.865	0.20†	0.00	0.00
Maternal Age at Delivery	0.011	0.008	0.112	1.491	0.07†	0.00	0.03
Prepregnancy BMI	0.002	0.006	0.021	0.280	0.39†	-0.01	0.01
Constant	3.032	0.284		10.660	< 0.001†	2.47	3.59

†P value reported is for a one-sided test.

Table 12. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of preterm labor from weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
Weekly TPA	0.001	0.002	0.179	1	0.67	1.00	1.00	1.00
Constant	-2.554	0.643	15.762	1	<0.001	0.08		
Adjusted								
Weekly TPA	0.001	0.002	0.271	1	0.60	1.00	1.00	1.01
Maternal Age at Delivery	0.068	0.051	1.773	1	0.18	1.07	0.97	1.18
Prepregnancy BMI	0.060	0.034	3.245	1	0.07	1.06	1.00	1.13
Constant	-6.435	2.019	10.161	1	0.001	0.002		

Table 13. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of delivering pre/post term (≤ 36 wk or ≥ 41 wk) from weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI	
							Lower	Upper
Unadjusted								
Weekly TPA	0.001	0.001	1.338	1	0.25	1.00	1.00	1.00
Constant	-1.559	0.422	13.627	1	<0.001	0.210		
Adjusted								
Weekly TPA	0.001	0.001	0.287	1	0.59	1.00	1.00	1.00
Maternal Age at Delivery	-0.023	0.033	0.472	1	0.49	0.98	0.92	1.04
Prepregnancy BMI	-0.013	0.027	0.238	1	0.63	0.99	0.94	1.04
Constant	-0.407	1.250	0.106	1	0.745	0.67		

Table 14. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of delivering via cesarean section from weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI	
							Lower	Upper
Unadjusted								
Weekly TPA	0.000	0.001	0.195	1	0.66	1.00	1.00	1.00
Constant	-0.381	0.374	1.034	1	0.31	0.68		
Adjusted								
Weekly TPA	-0.001	0.001	0.232	1	0.63	1.00	1.00	1.00
Maternal Age at Delivery	0.035	0.030	1.399	1	0.24	1.04	0.98	1.10
Prepregnancy BMI	0.058	0.024	6.055	1	0.01	1.06	1.01	1.11
Constant	-3.027	1.146	6.975	1	0.01	0.05		

Table 15. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of delivering via an emergency cesarean section from weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
Weekly TPA	-0.001	0.002	0.367	1	0.55	1.00	1.00	1.00
Constant	0.806	0.636	1.608	1	0.21	2.24		
Adjusted								
Weekly TPA	-0.002	0.002	0.955	1	0.33	1.00	0.99	1.00
Maternal Age at Delivery	-0.173	0.060	8.163	1	0.004	0.84	0.75	0.95
Prepregnancy BMI	-0.015	0.039	0.139	1	0.71	0.99	0.91	1.06
Constant	6.664	2.493	7.144	1	0.01	783.57		

Table 16. Unadjusted and adjusted multiple linear regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for the association between infant length (cm) and weekly total physical activity (TPA) among study participants who gave birth in the last five years.

	Unstandardized Coefficients		Standardized Coefficients				
	B	Std. Error	Beta	t	P	95% CI Lower	Upper
Unadjusted							
Weekly TPA	0.002	0.002	0.089	1.217	0.23	0.00	0.01
Constant	50.532	0.644		78.505	< 0.001	49.26	51.80
Adjusted							
Weekly TPA	0.002	0.002	0.10	1.314	0.19	0.00	0.01
Maternal Age at Delivery	0.069	0.050	0.104	1.382	0.17	-0.03	0.17
Prepregnancy BMI	-0.025	0.039	-0.049	-0.652	0.52	-0.10	0.05
Constant	49.273	1.855		26.566	< 0.001	45.61	52.93

to be non-significant, but maternal age at delivery was significantly associated with whether cesarean section was elective or emergency ($p = 0.004$).

When examining the association between weekly TPA and infant length there was no statistically significant contribution of weekly TPA, maternal age at delivery, or prepregnancy BMI (Table 16). The adjusted model explained 2.1% of the variance. Mean infant length for the entire sample was 51.2 ± 3.5 cm, which was within a normal range. Thus, these results suggest no benefit or restriction of growth in utero, and subsequently infant length, based on the amount of energy a woman expended (MET·hr/wk) during a typical week during gestation. Therefore, hypothesis 4c was supported as there was no relationship between weekly TPA and infant length.

Specific Aim 5: Exercise Status and Adverse Pregnancy and Birth Outcomes

Aim 5 assessed the main effect of exercise status (RTAE, AE, NE) in relation to pregnancy and birth outcomes. Pregnancy and birth outcomes included GDM, preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and length of infant. GDM and preeclampsia/gestational hypertension were dichotomous in nature (yes/no). Birth weight and length of infant were continuous, while preterm labor, gestational age at delivery, and mode of delivery were dichotomous (yes/no, ≤ 36 wk and ≥ 41 wk or 37-41 wk, vaginal/cesarean section, respectively). Results are presented for unadjusted and adjusted models (adjusted for maternal age at delivery and prepregnancy BMI). While logistic regression was used as a conservative approach to evaluate the dichotomous variables, a Fisher-exact test was also used. A Fisher-exact test was utilized due to the small sample size, as well as for a simplistic model to show the associations between exercise status and adverse outcomes without adjusting for any potential confounding variables.

Table 17 describes the frequency and prevalence of adverse pregnancy outcomes by exercise status. The prevalence of GDM, preeclampsia/gestational hypertension, and preterm labor was lowest among women in the RTAE group. Also, approximately 75% of infants delivered across RTAE, AE, and NE groups were considered term (37-40 wk). Chi-square analyses could not be utilized to test the statistical significance due to several outcomes having cell sizes that were too small (< 5). When comparing women (using the Fisher exact test) who performed resistance training to all other women (RTAE versus AE + NE), the prevalence of preeclampsia/gestational hypertension was significantly lower among women in the RTAE group and marginally significant for GDM and preterm labor (Table 18). However, there was no association between mode of delivery and gestational age at delivery.

Table 19 describes infant birth weight and length, which did not differ significantly by exercise status; however, there was marginal significance for women in the NE group to have shorter infants. When combining the women from the AE and NE groups, there were no significant differences in birth weight or infant length (Table 20), thus suggesting no in utero growth restriction regardless of exercise status.

The unadjusted model between exercise status and GDM was statistically significant $\chi^2 = 6.541$ ($n = 218$, $df = 2$), $p = 0.04$, indicating that it was able to distinguish between women with and without GDM. The unadjusted model was able to explain between 3.0% (Cox and Snell R Square) and 6.8% (Nagelkerke R Square) of the variance. Similarly, the adjusted model was statistically significant $\chi^2 = 21.774$ ($n = 204$, $df = 4$), $p < 0.001$, indicating that it was able to distinguish between women with and without GDM. The adjusted model was able to explain between 10.1% (Cox and Snell R Square) and 22.5% (Nagelkerke R Square) of the variance. As shown in Table 21, only prepregnancy BMI contributed significantly to the prediction of having

GDM (p < 0.001). The ORs for exercise status had wider 95% CI indicating that the model could not accurately predict GDM based on exercise status alone. The OR for maternal age at delivery approximated 1.0 indicating neither a protective nor adverse association with GDM,

Table 17. Frequency and prevalence (%) of pregnancy outcomes (preterm labor, mode of delivery, gestational age at delivery, gestational diabetes mellitus, and preeclampsia/gestational hypertension) among study participants who gave birth in the last five years by exercise status: Resistance Training + Aerobic Exercise (RTAE), Aerobic Exercise only (AE), or No Exercise (NE).

Outcome	RTAE (n = 65)		AE (n = 109)		NE (n = 44)	
	N	%	N	%	N	%
Preterm Labor	3	4.6	12	11.4	6	13.6
Mode of Delivery						
Vaginal	44	67.7	70	64.2	29	65.9
Cesarean Section	21	32.3	39	35.8	15	34.1
Gestational Age at Delivery						
Term (37-40wk)	50	78.1	80	73.4	33	75.0
Pre/Post Term (≤ 36 wk or ≥ 41 wk)	14	21.9	29	26.6	11	25.0
Gestational Diabetes Mellitus	2	3.1	14	12.8	2	4.5
Preeclampsia/gestational hypertension	3	4.6	16	15.1	6	13.6

Table 18. Frequency and prevalence (%) of adverse pregnancy outcomes (preterm labor, mode of delivery, gestational age at delivery, gestational diabetes mellitus, and preeclampsia/gestational hypertension) comparing study participants who performed Resistance Training and Aerobic Exercise (RTAE) versus Aerobic Exercise only and No Exercise (AE + NE).

Outcome	RTAE (n = 65)		AE + NE (n = 155)		Fisher's Exact Test (one-sided)
	N	%	N	%	
Preterm Labor	3	4.6	18	11.9	0.07
Mode of Delivery					0.39
Vaginal	44	67.7	100	64.5	
Cesarean Section	21	32.3	55	35.5	
Gestational Age at Delivery					0.33
Term (37-40wk)	50	78.1	115	74.2	
Pre/Post Term (≤ 36 wk or ≥ 40 wk)	14	21.9	40	25.8	
Gestational Diabetes Mellitus	2	3.1	16	10.3	0.06
Preeclampsia/gestational hypertension	3	4.6	22	14.5	0.03

Table 19. Description of birth outcomes (Mean ± Standard deviation) of study participants who gave birth in the last five years according to exercise status: Resistance Training + Aerobic Exercise (RTAE), Aerobic Exercise only (AE), or No Exercise (NE).

Outcome	RTAE (n = 65)	AE (n = 109)	NE (n = 44)	P-value
Birth weight (kg)	3.51 ± 0.47	3.50 ± 0.58	3.34 ± 0.53	0.60
Infant length (cm)	51.4 ± 2.5	51.4 ± 4.2	50.7 ± 3.1	0.07

Table 20. Description of birth outcomes (Mean ± Standard deviation) according to study participants who gave birth in the last five years who performed Resistance Training and Aerobic Exercise (RTAE) versus women who performed only Aerobic Exercise or No Exercise (AE + NE).

Birth Outcome	RTAE (n = 65)	AE + NE (n = 153)	P-value
Birth weight (kg)	3.51 ± 0.47	3.47 ± 0.57	0.51
Infant length (cm)	51.4 ± 2.5	51.2 ± 3.9	0.56

which was further demonstrated by a tight 95% CI. Thus, hypothesis 5a was not supported because there was no association between exercise status and risk of GDM.

The unadjusted model between exercise status and preeclampsia/gestational hypertension was not statistically significant $\chi^2 = 5.236$ (n = 215, df = 2), p = 0.07, indicating that it was not able to distinguish between women with and without preeclampsia/gestational hypertension. The unadjusted model was able to explain between 2.4% (Cox and Snell R Square) and 4.7% (Nagelkerke R Square) of the variance. Similarly, the adjusted model was not statistically significant $\chi^2 = 7.102$ (n = 201, df = 4), p = 0.13, indicating that it was not able to distinguish between women with and without preeclampsia/gestational hypertension. The adjusted model was able to explain between 3.5% (Cox and Snell R Square) and 6.6% (Nagelkerke R Square) of the variance. As shown in Table 22, none of the independent variables contributed significantly to the model, with only marginal significance for prepregnancy BMI (p = 0.06). The ORs for exercise status, maternal age at delivery, and prepregnancy BMI approximated 1.0 indicating neither a protective nor adverse association with preeclampsia/gestational hypertension, which was further demonstrated by tight 95% CIs, especially for maternal age at delivery and prepregnancy BMI. Thus, hypothesis 5a was not supported when considering preeclampsia/gestational hypertension because there was not an inverse relationship between exercise status preeclampsia/gestational hypertension.

When examining the unadjusted model for birth weight, there was marginal significance for belonging in AE group; however, after adjustment, this no longer persisted. When examining the adjusted model for birth weight, there was no statistically significant contribution of exercise status, maternal age at delivery, or prepregnancy BMI (Table 23). The adjusted model explained 2.4% of the variance in birth weight. Mean birth weight for the entire sample was 3.47 ± 0.54 kg, which was within a normal range. Thus, these results suggested no benefit or restriction of growth in utero, and subsequently birth weight, based on the exercise status of a woman during gestation. Hypothesis 5b was not supported due to the lack of an association between exercise status and birth weight after controlling for potentially confounding variables.

The unadjusted model between exercise status and preterm labor was not statistically significant $\chi^2 = 3.374$ (n = 214, df = 2), p = 0.19, indicating that it was not able to distinguish between women with and without preterm labor. The unadjusted model was able to explain between 1.6% (Cox and Snell R Square) and 3.3% (Nagelkerke R Square) of the variance. Similarly, the adjusted model was not statistically significant $\chi^2 = 6.047$ (n = 200, df = 4), p = 0.20, indicating that the model was not able to distinguish between women with and without preterm labor. The adjusted model was able to explain between 3.0% (Cox and Snell R Square) and 6.4% (Nagelkerke R Square) of the variance. As shown in Table 24, none of the independent variables contributed significantly, however, prepregnancy BMI was marginally significant (0.10). The ORs for exercise status and maternal age at delivery approximated 1.0

indicating neither a protective nor adverse association with preterm labor, which was further demonstrated by tight 95% CIs. Thus, hypothesis 5c was supported due to no association between exercise status and prevalence of preterm labor.

The unadjusted model between exercise status and delivering pre/post term (≤ 36 wk or ≥ 41 wk) was not statistically significant $\chi^2 = 0.490$ (n = 217, df = 2), p = 0.78, indicating that it was not able to distinguish between women delivering pre/post term and term (37-40 wk) infants. The unadjusted model was able to explain between 0.2% (Cox and Snell R Square) and 0.3% (Nagelkerke R Square) of the variance. Similarly, the adjusted model was also not statistically significant $\chi^2 = 2.448$ (n = 203, df = 4), p = 0.65, indicating that the model was not able to distinguish between women delivering pre/post term and term infants. The adjusted model was able to explain between 1.2% (Cox and Snell R Square) and 1.8% (Nagelkerke R Square) of the variance. As shown in Table 25, none of the independent variables contributed significantly to prediction of gestational age at delivery. While not statistically significant, the point estimate OR for belonging to the RTAE group was 0.67 demonstrating a protective association between resistance training and gestational age at delivery. The ORs for RTAE and AE exercise statuses, maternal age at delivery, and prepregnancy BMI were close to 1.0 indicating neither a protective nor adverse association with delivering a pre/post term infant, which was further demonstrated by the 95% CI close to 1.0. Therefore, hypothesis 5c was supported because there was no association between exercise status and gestational age at delivery.

The unadjusted model between exercise status and cesarean section delivery was not statistically significant $\chi^2 = 0.221$ (n = 218, df = 2), p = 0.90, indicating that it was not able to distinguish between women who delivered via cesarean section and vaginally. The unadjusted model was able to explain 0.1% (Cox and Snell R Square and Nagelkerke R Square) of the variance. Similarly, the adjusted model was not statistically significant $\chi^2 = 6.607$ (n = 204, df = 4), p = 0.16, indicating that the model was not able to distinguish between women delivering via cesarean section and vaginally. The adjusted model was able to explain between 3.2% (Cox and Snell R Square) and 4.4% (Nagelkerke R Square) of the variance. As shown in Table 26, only prepregnancy BMI contributed significantly to the prediction of delivering via cesarean section (p = 0.04). The ORs for exercise status and maternal age at delivery approximated 1.0 indicating neither a protective nor adverse association with cesarean section, which was further demonstrated by 95% CIs also close to 1.0. Thus, hypothesis 5c was supported because there was no association between exercise status and mode of delivery. This hypothesis was further supported when examining only women who delivered via cesarean section (n = 69). There was no significant association between exercise status and whether a woman had an elective or emergency cesarean section, demonstrating no increased risk of emergency cesarean section with resistance training and/or aerobic exercise (Table 27). However, in the adjusted model, exercise status continued to be non-significant, but maternal age at delivery was significantly associated with whether the cesarean section was elective or emergency (p = 0.010).

When examining both unadjusted and adjusted models for infant length, there were no statistically significant contributions of exercise status, maternal age at delivery, or prepregnancy BMI (Table 28). The adjusted model explained 1.4% of the variance in infant length. Mean infant length for the entire sample was 51.2 ± 3.5 cm, which was within a normal range. Thus, these results suggested no enhancement or restriction of growth in utero, and subsequently infant length, based on the exercise status of a woman during gestation. Hypothesis 5c was supported due to the lack of association between exercise status and infant length.

Table 21. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of gestational diabetes mellitus (GDM) from exercise status among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
NE			5.464	2	0.04†			
AE	1.130	0.778	2.107	1	0.08†	3.10	0.67	14.23
RTAE	-0.405	1.020	0.158	1	0.35†	0.67	0.09	4.92
Constant	-3.045	0.724	17.969	1	< 0.001†	0.05		
Adjusted								
NE			4.400	2	0.06†			
AE	1.313	0.842	2.431	1	0.06†	3.72	0.71	19.35
RTAE	-0.003	1.093	0.000	1	0.50†	1.00	0.12	8.49
Maternal Age at Delivery	0.068	0.051	1.763	1	0.09†	1.07	0.97	1.18
Prepregnancy BMI	0.122	0.034	13.192	1	< 0.001†	1.13	1.06	1.21
Constant	-8.884	2.083	18.197	1	< 0.001†	0.00		

†P value reported is for a one-sided test.

Table 22. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of preeclampsia/gestational hypertension from exercise status among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
NE			4.048	1	0.07†			
AE	0.119	0.516	0.053	1	0.41†	1.13	0.41	3.10
RTAE	-1.183	0.737	2.579	1	0.06†	0.31	0.07	1.30
Constant	-1.846	0.439	17.655	1	< 0.001†	0.16		
Adjusted								
NE			2.846	2	0.12†			
AE	0.093	0.529	0.031	1	0.43†	1.10	0.39	3.10
RTAE	-1.018	0.762	1.878	1	0.09†	0.36	0.08	1.61
Maternal Age at Delivery	-0.001	0.042	0.001	1	0.49†	1.00	0.92	1.08
Prepregnancy BMI	0.045	0.029	2.384	1	0.06†	1.05	0.99	1.11
Constant	-3.072	1.412	4.738	1	0.02†	0.05		

†P value reported is for a one-sided test.

Table 23. Adjusted and unadjusted multiple linear regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for the association between birth weight (kg) and exercise status among study participants who gave birth in the last five years.

	Unstandardized Coefficients		Standardized Coefficients				
	B	Std. Error	Beta	t	P	95% CI Lower	Upper
Unadjusted							
AE	0.159	0.097	0.147	1.641	0.05†	-0.03	0.35
RTAE	0.164	0.106	0.139	1.549	0.06†	-0.05	0.37
Constant	3.346	0.082		40.929	< 0.001†	3.19	3.51
Adjusted							
AE	0.145	0.101	0.134	1.442	0.08†	-0.05	0.34
RTAE	0.146	0.114	0.124	1.285	0.10†	-0.08	0.37
Maternal Age at Delivery	0.009	0.007	0.089	1.236	0.11†	-0.01	0.02
Prepregnancy BMI	0.003	0.006	0.037	0.520	0.30†	-0.01	0.01
Constant	3.026	0.256		11.805	< 0.001†	2.52	3.53

†P value reported is for a one-sided test.

Table 24. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of preterm labor from exercise status among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI	
							Lower	Upper
Unadjusted								
NE			2.798	2	0.25			
AE	-0.202	0.536	0.142	1	0.71	0.82	0.29	2.34
RTAE	-1.183	0.737	2.579	1	0.11	0.31	0.07	1.30
Constant	-1.846	0.439	17.655	1	< 0.001	0.16		
Adjusted								
NE			1.414	2	0.49			
AE	-0.180	0.589	0.093	1	0.76	0.84	0.26	2.65
RTAE	-0.891	0.786	1.285	1	0.26	0.41	0.09	1.92
Maternal Age at Delivery	0.046	0.045	1.058	1	0.30	1.05	0.96	1.14
Prepregnancy BMI	0.052	0.031	2.733	1	0.10	1.05	0.99	1.12
Constant	-4.786	1.634	8.578	1	0.003	0.001		

Table 25. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of delivering pre/post term (≤ 36 wk and ≥ 41 wk) from exercise status among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
NE			0.482	2	0.79			
AE	0.084	0.410	0.042	1	0.84	1.09	0.49	2.43
RTAE	-0.174	0.461	0.143	1	0.71	0.84	0.34	2.07
Constant	-1.099	0.348	9.957	1	0.002	0.33		
Adjusted								
NE			1.200	2	0.55			
AE	0.050	0.433	0.013	1	0.91	1.05	0.45	2.46
RTAE	-0.402	0.518	0.601	1	0.44	0.67	0.24	1.85
Maternal Age at Delivery	-0.018	0.031	0.310	1	0.59	0.98	0.92	1.03
Prepregnancy BMI	-0.026	0.027	0.939	1	0.33	0.97	0.92	1.03
Constant	0.118	1.127	0.011	1	0.92	1.13		

Table 26. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of delivering via cesarean section from exercise status among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI	
							Lower	Upper
Unadjusted								
NE			0.220	2	0.90			
AE	0.074	0.376	0.039	1	0.84	1.08	0.52	2.25
RTAE	-0.080	0.414	0.038	1	0.85	0.92	0.41	2.08
Constant	-0.659	0.318	4.297	1	0.04	0.52		
Adjusted								
NE			0.335	2	0.85			
AE	-0.006	0.399	0.000	1	0.99	0.99	0.45	2.17
RTAE	-0.208	0.461	0.203	1	0.65	0.81	0.33	2.01
Maternal Age at Delivery	0.033	0.029	1.367	1	0.24	1.03	0.98	1.09
Prepregnancy BMI	0.045	0.022	4.038	1	0.04	1.05	1.00	1.09
Constant	-2.834	1.041	7.418	1	0.001	0.06		

Table 27. Unadjusted and adjusted logistic regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of delivering via emergency cesarean section from exercise status among study participants who gave birth in the last five years.

	B	S.E.	Wald	df	P	OR	95% CI Lower	Upper
Unadjusted								
NE			3.753	2	0.15			
AE	-0.405	0.615	0.435	1	0.51	0.67	0.20	2.22
RTAE	0.758	0.735	1.063	1	0.30	2.12	0.51	9.01
Constant	0.405	0.527	0.592	1	0.44	1.50		
Adjusted								
NE			2.915	2	0.23			
AE	-0.144	0.710	-.041	1	0.84	0.87	0.22	3.49
RTAE	1.079	0.915	1.389	1	0.24	2.94	0.49	17.68
Maternal Age at Delivery	-0.134	0.052	6.564	1	0.01	0.87	0.79	0.97
Prepregnancy BMI	0.029	0.041	0.475	1	0.49	1.03	0.95	1.12
Constant	3.298	2.037	2.622	1	0.11	27.07		

Table 28. Adjusted and unadjusted multiple linear regression model with odds ratios (OR) and 95% Confidence Intervals (CI) for the association between infant length (cm) and exercise status among study participants who gave birth in the last five years.

	Unstandardized Coefficients		Standardized Coefficients				
	B	Std. Error	Beta	t	P	95% CI Lower	Upper
Unadjusted							
AE	0.655	0.638	0.093	1.026	0.31	-0.60	1.91
RTAE	0.745	0.698	0.097	1.067	0.29	-0.63	2.12
Constant	50.701	0.539		94.094	< 0.001	49.64	51.76
Adjusted							
AE	0.543	0.661	0.077	0.822	0.41	-0.76	1.85
RTAE	0.489	0.747	0.063	0.656	0.51	-0.98	1.96
Maternal Age at Delivery	0.058	0.048	0.087	1.212	0.23	-0.04	0.15
Prepregnancy BMI	-0.019	0.038	-0.037	-0.515	0.61	-0.09	0.06
Constant	49.784	1.683		29.583	< 0.001	46.47	53.10

Table 29. Summary for unadjusted and adjusted odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of reporting a primary adverse pregnancy outcome including preterm labor, gestational age at delivery, and mode of delivery among study participants who gave birth in the last five years.

	Unadjusted			Adjusted*		
	95% CI for OR			95% CI for OR		
	OR	Lower	Upper	OR	Lower	Upper
Preterm Labor						
Weekly TPA	1.00	1.00	1.01	1.00	1.00	1.01
Exercise Status						
NE						
AE	5.35	0.30	96.58	6.02	0.22	162.70
RTAE	2.50	0.03	234.99	4.60	0.04	504.80
Interactions						
TPA*NE						
TPA*AE	1.00	0.99	1.00	0.99	0.99	1.00
TPA*RTAE	0.99	0.98	1.01	0.99	0.98	1.00
Age at Delivery (yr)	-	-	-	1.08	0.97	1.19
Prepregnancy BMI (kg/m^2)	-	-	-	1.06	0.99	1.14
Gestational Age at Delivery						
Weekly TPA	1.00	0.99	1.00	0.99	0.99	1.00
Exercise Status						
NE						
AE	0.08	0.01	0.68	0.06	0.01	0.66
RTAE	0.03	0.002	0.47	0.01	0.001	0.25
Interactions						
TPA*NE						
TPA*AE	1.01	1.00	1.02	1.01	1.00	1.02
TPA*RTAE	1.01	1.00	1.02	1.01	1.00	1.02
Age at Delivery (yr)	-	-	-	0.98	0.92	1.05
Prepregnancy BMI (kg/m^2)	-	-	-	0.98	0.92	1.04
Mode of Delivery						
Weekly TPA	1.00	1.00	1.00	1.00	1.00	1.00
Exercise Status						
NE						
AE	1.53	0.25	9.42	1.15	0.17	8.02
RTAE	1.51	0.18	12.78	1.30	0.13	13.28
Interactions						
TPA*NE						
TPA*AE	1.00	0.99	1.00	1.00	0.99	1.01
TPA*RTAE	1.00	0.99	1.01	1.00	0.99	1.01
Age at Delivery (yr)	-	-	-	1.04	0.98	1.10
Prepregnancy BMI (kg/m^2)	-	-	-	1.06	1.01	1.11

*Adjusted for maternal age at delivery and prepregnancy BMI.

Table 30. Summary for adjusted and unadjusted odds ratios (OR) and 95% Confidence Intervals (CI) for predicting the likelihood of reporting a secondary adverse pregnancy outcome including gestational diabetes mellitus (GDM) and preeclampsia/gestational hypertension among study participants who gave birth in the last five years.

	Unadjusted			Adjusted*		
	95% CI for OR			95% CI for OR		
	OR	Lower	Upper	OR	Lower	Upper
Gestational Diabetes Mellitus	1.00	0.99	1.01	1.00	0.99	1.01
Weekly TPA						
Exercise Status						
NE	3.26	0.09	118.96	3.61	0.03	414.53
AE	754.89	1.22	468,861	364.40	0.30	447,393
RTAE						
Interactions						
TPA*NE	1.00	0.99	1.01	1.00	0.99	1.01
TPA*AE	0.97	0.93	1.00	0.97	0.94	1.01
TPA*RTAE	-	-	-	1.05	0.94	1.17
Age at Delivery (yr)	-	-	-	1.15	1.06	1.24
Prepregnancy BMI (kg/m^2)						
Preeclampsia/Gestational Hypertension						
Weekly TPA	1.00	0.99	1.00	0.99	0.99	1.00
Exercise Status						
NE						
AE	0.49	0.04	7.00	0.32	0.02	5.48
RTAE	1.64	0.01	210.6	0.93	0.01	112.04
Interactions						
TPA*NE						
TPA*AE	1.00	0.99	1.01	1.00	1.00	1.01
TPA*RTAE	0.99	0.97	1.01	0.99	0.97	1.01
Age at Delivery (yr)	-	-	-	0.98	0.90	1.06
Prepregnancy BMI (kg/m^2)	-	-	-	1.06	0.99	1.13

*Adjusted for maternal age at delivery and prepregnancy BMI.

CHAPTER 5
DISCUSSION

The purpose of this study was to determine the associations between resistance training and adverse pregnancy and birth outcomes. It is well established that the benefits of PA and exercise during gestation far outweigh the risks [115]. However, most current literature examines aerobic exercise or PA [38, 53, 76, 88, 115, 130, 137, 144], despite the fact that resistance training is the third most commonly reported activity among pregnant women [54]. Therefore, because pregnant women are engaging in resistance training, it is important to determine its safety on the maternal-fetal unit. Very few investigators have examined resistance training and pregnancy outcomes to date, but of those that have, all have found either favorable or neutral results [21-23, 30, 47, 68]. However, more data are needed on frequencies, intensities, durations, and types of resistance training to help to provide safe guidelines for muscular strength and endurance training during pregnancy [149].

In this investigation, we sought to determine the associations between weekly TPA, exercise status (resistance training + aerobic exercise, aerobic exercise only, or no exercise), and the interaction between weekly TPA and exercise status and pregnancy and birth outcomes among women health club members who have given birth in the last five years. To accomplish this purpose, we sampled women from Anytime Fitness® and Anytime Health™, a nationwide fitness club with an adjoining health website. We believed that sampling from these entities would allow us to capture women who engage in resistance training and were likely to be active during pregnancy so we could determine the associations between resistance training and pregnancy and birth outcomes. With over one million members and half being female, we hoped to engage a large sample. However, despite repeated recruitment strategies, this did not occur. Due to a limited sample size (n = 222), statistical power for the study was low. Power analyses for dichotomous variables were calculated by G*Power 3.1 [58]. Power was estimated to be 0.05-0.06 for all dichotomous variables. Birth weight and birth length were calculated to have power ranging from 0.3-0.4. Therefore, with low power we did not find statistical significance for many of the main effects or interaction terms, including weekly TPA, exercise status, or the interaction between them. Although most results were not statistically significant, many of the point prevalence estimates were in a protective direction suggesting either a beneficial association or, at the very least, no increase in risk when women engaged in resistance training. Thus, in many cases, the null hypothesis was supported, which one could argue was expected due to the final sample size and low power. However, we felt it correct to hypothesize a neutral result in instances when most, if not all, previous data indicate that this is likely to be the case. While low statistical power may have precluded us from finding more statistically significant results, this study still adds to the literature due to the wide range of frequency, duration, and modes of resistance training performed by our study sample. In addition, the study is ongoing, so we will continue to monitor additional responses, and rerun analyses when the sample size becomes significantly greater. Based on recent conversations with the Anytime Fitness® general management, we are hopeful of this occurring.

A baseline needed to be set to determine if resistance training, in general, is safe for the maternal-fetal unit before more rigorous studies can be conducted. Approximately one in ten pregnant women engage in resistance training [54], however, the appropriate amounts that are safe for the maternal-fetal unit are unknown and thus research is necessary. Overall, we found that women who performed resistance training for muscular endurance, approximately three days/week for thirty minutes did not significantly increase their risk for an adverse outcome including GDM, preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, or length of infant. Thus, our results suggest neither a beneficial nor adverse association with exercising throughout gestation. An overview of the current results and prior literature are provided in the following text separated by each specific aim of the study.

Specific Aim 1: Development of an Online Survey

Aim 1 was not hypothesis driven, but pivotal to the design of the current study. To ascertain both the exposure and outcome variables, one comprehensive survey needed to be developed. We attempted to obtain complete information regarding the women's exercise and PA habits during pregnancy as well as major adverse pregnancy and birth outcomes. However, current pregnancy surveys focus mainly on ADL because 24-40% of total energy expenditure among pregnant women comes from household/caregiving activities [131]. For example, the Pregnancy Physical Activity Questionnaire (PPAQ) [36] and the Kaiser Physical Activity Survey (KPAS) [6] focus primarily on ADL and while they query about exercise, the questions are very broad. In contrast, the current study focused on all forms of PA, especially resistance training and other forms of exercise, and thus an appropriate survey was developed to further examine these domains. The PAS queried women about ten domains of exercise including, yoga, pilates, resistance training, whole body exercises, light, moderate, and vigorous aerobic exercise, flexibility exercises, group exercise classes, and home exercise videos as well as using the PPAQ to ascertain ADL, occupational, and transportation PA, thus capturing multiple modes of PA.

The PAS is an improvement over current surveys that are limited by numerous factors, such as measurement of only leisure-time PA, focus only on vigorous intensity, and lack of assessment of frequency, intensity, and duration [131]. Specifically considering resistance training, many studies do not investigate the associations between resistance training and pregnancy outcomes, such as GDM or birth weight, but only investigate the safety (i.e., injuries) and efficacy of strength training during pregnancy [25, 110] or fetal heart rate responses [20, 108].

Although the PAS included previously validated exercise questions used by NHANES [107], we chose to examine its internal validity. To determine internal validity of the PAS, post hoc descriptive statistics and frequencies were calculated for the frequency of exercise. First the numeric value for frequency from all forms of exercise was summed. This result was compared to the question, "Did your exercise routine change in frequency?" Possible responses were: 1) it increased in frequency, 2) it decreased in frequency, or 3) it stayed about the same. If the numeric value matched the correct response, it was considered 'accurate' whereas, if the numeric value did not match the response it was considered 'inaccurate.' For example, if a woman's numeric value changed from 7 sessions/week during the first trimester to 5 sessions/week during the third trimester and she responded to the question as her routine decreased, she was counted as having an accurate case; however, if she said it "stayed about the same" it was counted as an inaccurate case. Comparing 222 total responses to frequency of exercise, 126 (56.8%) were classified as accurate. Of those who had inaccurate cases, women over-reported by 1.5 ± 9.2 sessions/week. Women were more likely to report inaccurately if they stated their routines "stayed about the same" (Table 39). Because we asked about exercise frequency in ten minute bouts, it is possible that accuracy might have been reduced due to the relatively short bout duration. Therefore, the accuracy was re-analyzed allowing a difference of up to two sessions/week between an accurate and inaccurate case. We found the PAS to be more accurate when allowing responses to be within one session/week (i.e., or one 10 min bout) (73.4%) and even further accuracy when allowing responses to be within two sessions/week (i.e., 20 min total) (78.8%). Thus, we believe satisfactory PA internal validity was achieved based on this internal check of frequency of resistance training.

We also examined the maternal demographic characteristics and resistance training habits between women who answered the PAS retrospectively and a comparison group of women (n = 50) who are being followed prospectively and completing the PAS at the end of each trimester for another study (Table 40). There were no significant differences between the retrospective sample and prospective sample for race (p = 0.48), marital status (p = 0.77), household income (p = 0.66), or prepregnancy BMI (p = 0.62). There were statistically significant differences in maternal age (p = 0.04) and maternal education (p = 0.04) (Table 40). While participants in the retrospective study were slightly younger, 85% of women in both samples completed some college (≥ 1-3 year). Therefore, we do not think these differences had practical significance. We are reasonably confident that the retrospective and prospective samples are similar and internal validity regarding the frequency of resistance training during first trimester can be determined.

Among women who engaged in resistance training during first trimester, there were no significant differences for frequency of resistance training, or primary, secondary, or tertiary modes of resistance training between the two samples. There was significance (p = 0.05) for a difference in the duration of resistance training between the retrospective and prospective samples (Table 41). However, overall, we are confident that participants in the current study accurately recalled exercise up to five years postpartum due to the close similarities between women's responses in the prospective sample.

Table 31. Post hoc analysis demonstrating frequency and prevalence of accurate and inaccurate responses as determined by the question, "Did your exercise routine change in frequency?" among study participants who gave birth in the last five years.

	Responses Based on Question					
Numeric Value	More Frequent (n)	(%)	Less Frequent (n)	(%)	About the Same (n)	(%)
More Frequent	12	75.0	17	17.9	23	20.7
Less Frequent	4	25.0	62	65.3	36	32.4
About the Same	0	0.0	16	16.8	52	46.8

Table 32. Maternal age and prepregnancy body mass index (BMI) (Mean ± Standard Deviation), and demographic characteristics (%) among study participants according to cohort status.

Characteristic	Retrospective Sample (n = 222)	Prospective Sample (n = 48)
Maternal age (yr)	27.6 ± 5.3	29.4
Prepregnancy BMI (kg/m^2)	25.3 ± 5.0	24.7 ± 6.2
Maternal Race		
White (Non-Hispanic) (%)	89.4	91.7
Hispanic or Latino (%)	3.7	4.2
Other (%)	6.9	4.1
Marital Status		
Married (%)	76.6	83.3
Divorced/Separated (%)	2.3	0.0
Never Married (%)	6.4	4.2
Living with Partner (%)	14.7	12.5
Maternal Education		
Grades 9-11 (%)	1.4	0.0
Grade 12 or GED (%)	11.0	4.2
College 1-3 years (%)	45.0	31.3
College 4+ years (%)	42.7	64.6
Annual Household Income		
≤$24,999 (%)	16.5	12.7
$25,000 - $49,999 (%)	23.0	19.2
$50,000 - $74,999 (%)	23.0	17.0
$75,000 - $104,999 (%)	19.8	23.4
$105,000 + (%)	13.4	25.5
Don't Know/Not sure (%)	4.1	2.1

Table 33. Intensity of resistance training (muscular endurance or muscular strength) and prevalence of traditional and non-traditional forms of resistance training among study participants categorized by cohort status.

	Retrospective Cohort (n = 58)	Prospective Cohort (n = 31)	p-value
RT Frequency (days/wk)	2.9 ± 0.9	2.8 ± 1.3	0.83
RT Duration (min/session)	30.0 ± 13.9	23.5 ± 15.7	0.05
Intensity (%)			
Endurance	72.9	87.1	0.12
Strength	27.1	12.9	
Primary Mode			0.39
Traditional Forms			
Weight machines	37.3	29.0	
Free weights	55.9	64.5	
Non-Traditional Forms			
Resistance Bands	6.8	3.2	
Whole Body Exercises	0.00	3.2	
Kettlebells	0.00	0.00	
Secondary Mode			0.93
Traditional Forms			
Weight machines	34.5	41.9	
Free weights	34.5	32.3	
Non-Traditional Forms			
Resistance Bands	8.6	6.5	
Whole Body Exercises	0.0	0.0	
Kettlebells	1.7	3.2	
Did not have a Secondary Mode	20.7	16.1	
Tertiary Mode			0.62
Traditional Forms			
Weight machines	6.8	6.5	
Free weights	0.0	0.0	
Non-Traditional Forms			
Resistance Bands	11.9	22.6	
Whole Body Exercises	0.0	0.0	
Kettlebells	3.4	3.2	
Did not have a Tertiary Mode	78.0	67.7	

As stated previously, a true response rate could not be calculated due to several unknown factors, but our completion rate was 43%. We believe that potential reasons for a 43% completion rate had to do with several methodological steps. According to Dillman et al., there are several ways to increase the benefits of participating, including, but not limited to: providing information about the survey, asking for help or advice, saying thank you, and informing people that opportunities to respond are limited [50]. Thus, we used those tips and provided a very brief description of the survey and its overall purpose. To engage potential study participants on a more personal level, we asked for their help in determining safe and effective guidelines for resistance training during pregnancy, which currently do not exist. While women had an unlimited time to respond, the potential participant pool was somewhat limited because the survey was exclusive to Anytime Fitness® and Anytime Health™ members, thus increasing its legitimacy and perceived importance. In addition, we reduced participant burden by making it convenient to respond in an online format and using primarily button options or pull-down menus to reduce the amount of work needed to complete the survey. Based on these strategies, our completion rate was 43% but could possibly have been higher had we changed two primary factors. First, we could have reduced the number of questions on the PAS and second, we could have offered incentives to participants for completing it. Both of these strategies have been found to elicit improved responses from participants [50]. However, based on the opportunity available to us at the time, the survey was slightly longer than intended and no incentives were given due to financial constraints.

Specific Aim 2: Prevalence of Traditional and Non-traditional Forms of Resistance Training

Aim 2 was also not hypothesis driven, but rather descriptive of the study sample. Overall, frequency and duration of resistance training decreased as gestation continued.

Specifically, prevalence of women performing resistance training decreased from 26.6% (n = 59) during the first trimester to 17.6% (n = 39) during the third trimester. Our values were approximately 10% higher than those previously seen by Haakstad et al. in which 16.5% of pregnant women reported strength training in a fitness center during first trimester and 6.4% during third trimester [66]. Our higher prevalence was most likely due to our sampling method which included using women from a health club rather than patients from a medical center.

In the current study, a majority of women engaged in training for muscular endurance (defined as low weights and high repetitions) rather than for muscular strength (defined as high weights and lower repetitions). This finding was expected because as gestation progresses it is more difficult for women to maintain high intensity activity, primarily due to their increased size. These results were also supported with anecdotal evidence from 130 women who completed the open-ended question on the PAS that asked, "Why did your exercise routine change?". Nineteen percent (n = 25) of women mentioned 'getting bigger/weight gain' and twenty-seven percent (n = 35) mentioned 'feeling tired/lack of energy' as reasons why their exercise routines became less intense as gestation progressed. With respect to intensity, several women also commented on why their exercise routine needed to change. For example, one woman stated, "I didn't feel comfortable running, which is what I normally do, so I began doing more resistance/stability training and more moderate aerobic exercise." Another woman stated, "my cardio became less intense as I got bigger, as bouncing/too much movement was uncomfortable." These representative quotes suggest that women switched their training intensities toward muscular endurance rather than muscular strength, especially as gestation progressed.

Several women also commented on the mode of exercise performed. One woman commented, "as I got bigger, balance was an issue. Went from more free weights to machines for the stability." Another woman stated, "I became to[o] large to use the machines." Another woman stated, "I had to start using machines a little more just to take the focus off of my core." Lastly, a woman commented, "used dumbbells during 1st and 2nd [trimester] but only resistance bands during the 3rd [trimester]." Thus, these are all examples of why women changed their modes of exercise during gestation. It was not surprising to find that most women used free weights to counteract the effects of getting larger and/or weight machines to allow for more stability. As demonstrated by the previous comments, some women switched from free weights to weight machines for additional stability, while other women avoided machines due to their size. Very few women engaged in non-traditional forms of resistance training, which may be due to two primary reasons. First, not all Anytime Fitness® facilities offer the exact same forms of exercise options. Not having resistance bands and kettlebells available may have led to fewer women participating in non-traditional forms of resistance training. Second, women may have a fear of using non-traditional forms of resistance training when pregnant. If a woman did not know how to use a kettlebell or resistance band effectively and safely, it is plausible that she would more likely use traditional modalities.

Specific Aim 3: Evaluation of ADL and Exercise Status

We hypothesized that pregnant women who performed leisure-time exercise (RTAE or AE groups), would have lower ADL compared to pregnant women who did not perform leisure-time exercise. Our hypothesis was based on the idea that women with mostly sedentary jobs would feel more compelled to exercise because they sit all day, while women with very active jobs or lives would not make exercise a priority because they spend significant time performing various activities during their normal living. Previous research has shown support for this idea. Among forty minority women, most participants did not consider themselves to be "exercisers" but felt that they met the CDC/ACSM recommendations for PA (30 minutes of moderate-intensity activity most days of the week) if they could include housework, caregiving, and workday activities [57].

While statistical significance was not achieved, the results suggested some support for the hypothesis both through point prevalences and anecdotal evidence. Women who belonged to the RTAE group had the lowest energy expenditure from ADL (15.8% and 7.3% lower from the NE and AE groups, respectively). In addition, when examining weekly TPA, women in the RTAE group had the lowest energy expenditure even when energy expended during either resistance training or aerobic exercise was included (Table 2). Thus, while mean differences in energy expended via ADL or weekly TPA were not statistically significant, the direction of the differences suggested support for our hypothesis. Our results were in contrast to those of Jurj et al. who examined prospectively 74,942 Chinese women 40-70 years of age [81]. When participants were dichotomized into two groups (non-exercisers and exercisers), women in the exercise group spent more total energy (105.5 MET·hr/wk) in activity, while non-exercisers spent less (96.7 MET·hr/wk) [81]. However, in a highly powered study with over seventy-four thousand participants, it was not surprising that the authors found statistical significance with even a small, 8.8 MET·hr/wk difference between groups. However, if the energy expended from activities other than exercise were examined (transportation, daily activity, stair climbing, and household activities) in the Jurj et al. study, then the non-exercisers spent more energy (96.7 MET·hr/wk) compared to the exercisers (92.1 MET·hr/wk) showing support for the current results. Thus, the higher overall energy expenditure among the exercisers was due to performing exercise. It should also be noted though that the Chinese women spent considerably less energy overall (105.5 MET·hr/wk) compared to the participants in the current study (312.5-335.0

MET·hr/wk). One possible reason for this large difference in energy expenditure is that over 90% of the Chinese women reported engaging in non-exercise activities (i.e., transportation, daily activity, stair climbing, and household activities), while in the current sample only 20% reported engaging in no exercise. Also, the current sample is much younger (27.6 ± 5.3 yr) than Jurj's sample (52.1 ± 9.1 yr) and thus may account for overall reduced energy expenditure as a function of age.

Anecdotally, our hypothesis was supported somewhat by participant's responses to two open-ended questions: 1) Why did your exercise routine change? and/or 2) Is there anything you think we should know and did not ask you about regarding exercise during your pregnancy? One woman replied, "I am an x-ray tech at a trauma center…I walked, lifted, moved patients, etc. all shift. It led to being too tired to exercise during my free time." Similarly, another woman responded, "I just wanted to say that I worked a job on my feet 7-10 hours daily… Besides that I still did all of the housework, cleaning/washing cars etc. So I really didn't have the time or energy left to exercise." These two statements show support for women with high levels of energy expended by ADL not exercising because they already felt they engaged in enough PA. In contrast, one woman stated, "changed jobs, no more physical exercise at work, made up for it by working out at home." This participant showed support for the hypothesis as a woman with low ADL feeling more compelled to exercise. Thus, our results suggest support for the patterns of activities women engaged in based on whether their job or daily lives were more or less active.

Although not statistically significant, when examining weekly TPA by exercise status, there was a difference of 9.5 MET·hr/wk between the AE and NE groups and a difference of 22.5 MET·hr/wk between the RTAE and NE groups. Assuming a pregnant woman engaged in a moderate intensity activity (3 METs), this translates to a difference of 3.2-7.5 hr/wk of activity. These results suggest that women who did not exercise spent approximately 3-7 more hours/week engaging in a moderate intensity activity when compared to exercisers. Over the course of 40 weeks of gestation, this translates to 120-280 extra hours of moderate intensity activity among non-exercisers, which may be clinically relevant.

Specific Aim 4: Weekly TPA and Adverse Pregnancy and Birth Outcomes

We hypothesized that weekly TPA would be inversely related to adverse pregnancy outcomes including GDM and preeclampsia/gestational hypertension. This hypothesis was based on previous results by Sorensen et al. and Tobias et al. [134, 144]. The overall prevalence of GDM in our sample was 8.6%, which is within the range of 4.1-11.9% typically found among an ethnically diverse group of women [71]. We failed to show an inverse association between weekly TPA and GDM, as the odds ratios were 1.00 (95% CI 0.99-1.00) in both the unadjusted and adjusted models. A meta-analysis of five studies by Tobias et al. demonstrated a 24% reduced risk of developing GDM for women in the highest quartile of early pregnancy PA compared to women in the lowest quartile of early pregnancy PA (pooled OR 0.76 95% CI 0.70-0.83) [144]. While our results did not support the Tobias et al. meta-analysis, they corroborated findings of Dempsey et al. [49] and Dye et al. [53]. Dempsey et al. examined 909 women and found that there was a non-significant reduction in GDM risk among women who reported any recreational PA during gestation compared to women who reported no recreational PA (RR 0.69 95% CI 0.37-1.29) [49]. Dye et al. also found no association between exercise (defined as 30 or more minutes of activity above their usual activities during pregnancy) and GDM [53]. Overall, Dye et al. found that nonexercisers had a 2.9% prevalence of GDM, while exercisers had a prevalence of 2.8% (OR for nonexercisers 1.0 95% CI 0.8-1.3) [53]. When Dye et al. stratified women by BMI, women with a BMI > 33 who exercised had a lower prevalence of GDM (5.7%) compared to nonexercisers with BMI > 33 (10.3%) (OR for nonexercisers 1.9 95% CI 1.2-3.1) [53]. Results from the current study also showed a significant difference in BMI among participants who reported having GDM (27.6 ± 6.5 kg/m^2) and those who did not report GDM (34.7 ± 6.5 kg/m^2) ($p < 0.001$). Specifically, those with a high prepregnancy BMI increased their odds of developing GDM by 14%. Therefore, our results suggest that prepregnancy BMI may have confounded any association we found between weekly TPA and GDM, as nonexercisers had the highest BMI values. However, participants who did not exercise had the highest weekly TPA values. Thus, it appears that in this sample, having a high prepregnancy BMI is more influential on risk of GDM than the amount of PA performed during pregnancy. This is important because previous literature has shown that women with GDM who deliver normal weight infants had a 67% rate of childhood overweight status and women with GDM who delivered a child of any weight had consistently higher BMIs up to eight years of age [129]. Therefore, reducing the prevalence of GDM has both short and long term implications on child weight status. There are two potential reasons for the lack of an association between weekly TPA and GDM. First, women with a high prepregnancy BMI may have been less active during pregnancy due to her weight status thus causing BMI to be more influential than PA in the development of GDM. Second, it is possible that higher intensity activity may be necessary to positively influence GDM. While participation in regular PA and been found to prevent or delay onset of Type 2 Diabetes Mellitus in adults, most evidence suggests activity needs to be at least of a moderate intensity [2]. There is also evidence for a dose-response relationship with Type 2 Diabetes Mellitus for both intensity and duration of activity, however, risk reduction has been found regardless of intensity or duration of PA [78]. Specifically, Oken et al. found a non-significant reduction in GDM among 1,805 women who participated in any light/moderate activity (OR 0.70 95% CI 0.41-1.21) or any vigorous activity (OR 0.90 95% CI 0.47-1.70) when compared to women who performed no LTPA during pregnancy [111]. Thus, current evidence regarding the optimal frequency, intensity, or duration of PA necessary to reduce risk of GDM is inconclusive. Therefore, although participants in the current study who did not exercise had the highest overall weekly energy expenditure values, it might not have been intense enough or long enough to initiate translocation of GLUT-4, which reduces insulin resistance, a postulated mechanism in reducing GDM [35]. ADL were assessed using the PPAQ and the average intensity overall was 2.8 METs, which would be classified as low intensity (< 3 METs); therefore it is possible that participants engaging in only ADL may not be reaching a sufficient intensity to positively affect glucose uptake. It may be that the greatest benefit of PA in GDM prevention is to modify the relationship between prepregnancy BMI and GDM or act on BMI directly by reducing it.

We believe that BMI may have acted as a confounder in our study as it exerted a greater influence than any of the activity variables evaluated in our models. We chose to adjust for prepregnancy BMI as it is known to influence GDM [144] and had we not considered it, our results could have been biased. While it could be argued the PA may have mediated the relationship between prepregnancy BMI and GDM, our primary purpose was to investigate the associations between activity and GDM, and thus to consider PA as a mediator would have been decided post hoc. Therefore, we believe it appropriate to have adjusted for BMI in the present study.

The overall prevalence of preeclampsia/gestational hypertension in our sample was 11.3%, which is similar to the national average of 10% in the United States [154]. We hypothesized that weekly TPA would be inversely associated with preeclampsia/gestational hypertension; however, the current results did not support our hypothesis. Our results were inconsistent with those of Sorensen et al. that showed a decreased risk of preeclampsia with women who engaged in regular PA during the first 20 weeks of gestation (OR 0.65 95% CI 0.43-0.99) [134]. Sorensen et al. also found a decreased risk (p for trend = 0.01) with increasing energy expenditure during the first 20 weeks of gestation [134]. There are two possible reasons for the inconsistency: 1) the timing of the PA measurement and 2) the intensities of activity investigated. First, the timing of measuring PA seems to be particularly important in determining whether an association is found with preeclampsia/gestational hypertension. Because Sorenson et al. only examined the first 20 weeks of gestation and preeclampsia is generally not diagnosed until later, it is possible that assessing activity across all of gestation, as was done in the present study, may have attenuated any protective effect. However, women were queried only about recreational activities and thus there may be a stronger inverse relationship with recreational activities and hypertensive disorders primarily because of the intensity level. In Sorensen et al.'s study, only one woman reported engaging in light-intensity recreational activities. Thus, a beneficial association of PA on pregnancy hypertensive disorders may require moderate or vigorous intensities. In contrast, the current study examined weekly TPA which largely consisted of ADL with a mean intensity of 2.8 METs, which is considered light activity. Thus, differences in the types/domains of activities queried may have attenuated the association with preeclampsia/gestational hypertension in the current study. We chose to include ADL in our energy expenditure measurement because up to 40% of caloric expenditure may come from household/caregiving activities during gestation [131] and thus it is important to consider when examining the pregnant woman. In addition, because we quantified activity into a weekly estimate across all of gestation due to small sample size, we may have missed a differential influence of PA by trimester. Specifically, our active participants performed 13.2 ± 27.4 MET·hr/wk of exercise during the first trimester and 8.1 ± 12.7 MET·hr/wk of exercise during the third trimester. In addition, Sorensen et al. examined activity only in the first 20 weeks of gestation and many women usually are not diagnosed with gestational hypertension until after 20 weeks, thus potentially impacting their significant findings.

Our results corroborated those of Rudra et al. who found no association in a cohort of 2,241 women between preeclampsia and performing any recreational PA during early gestation (~15 weeks) (OR 1.07 95% CI 0.67-1.69) [124]. When Rudra et al. examined energy expenditure in early pregnancy, there was also no trend ($p = 0.55$) for increased risk of preeclampsia between no (0.0 MET·hr/wk) or high energy expenditure (> 31.50 MET·hr/wk) (OR 0.96 95% CI 0.52-1.75) [124]. In the current study, our 95% CIs were much closer to 1.0 suggesting neither a beneficial nor adverse association of weekly TPA with preeclampsia/gestational hypertension, whereas Rudra et al. found wider 95% CIs. The difference in the 95% CI could be due to the fact that Rudra et al. limited questions to only recreational PA, whereas the current study examined all forms of PA including leisure-time exercise and ADL. The current results were also similar to those of Fortner et al. who examined the association between PA and preeclampsia and hypertensive disorders during gestation in a group of 1,043 Hispanic women [61]. Fortner et al. found marginally significant associations between total activity and risk of hypertensive disorders (OR 0.3 95% CI 0.1-1.0) and preeclampsia (OR 0.1 95% CI 0.01-1.3) in their adjusted models [61]. Similar to our results, Fortner et al. found that BMI was positively associated with risk of hypertensive disorders and thus appeared to play a more influential role than weekly TPA.

We hypothesized that there would be an inverse relationship between weekly TPA and birth weight; however, the hypothesis was not supported as no association was found. Our hypothesis was based on previous findings from a study by Perkins et al., suggesting lighter infants from mothers in the highest quartile of exercise [114] and a report by Clapp who studied well-conditioned women [38]. Perkins et al. found that women who engaged in 1.63-2.21 METs/day of activity had infants who were 608 g lighter than those of women who performed 1.17-1.29 METs/day of activity (3,399 ± 381 versus 4,007 ± 488 g, respectively) [114]. Clapp found that well-conditioned women who continued to exercise throughout gestation delivered lighter, leaner infants (3,369 ± 318 g) than those of well-conditioned women who discontinued exercise after the first trimester (3,776 ± 401 g) ($p = 0.01$) [38]. Because our sample had similar demographics to those in the studies of Perkins et al. and Clapp, we hypothesized that there would be an inverse association between weekly TPA and birth weight. One explanation for the difference in results was that the Perkins et al. and Clapp studies included PA data collected prospectively, which would have added to its validity.

While aforementioned studies have demonstrated an inverse association between birth weight and exercise, the current results corroborated those of Melzer et al., who found no significant differences between birth weight among 27 active (defined as ≥ 30 minutes of moderate PA per day) and 17 inactive (< 30 minutes of moderate PA/day) (3,448 ± 310 g and 3,518 ± 418 g, respectively, $p = 0.53$) [101]. In addition, Juhl et al. examined 76,692 liveborn singletons from the Danish National Birth Cohort (DNBC) and found a non-significant trend ($p = 0.13$) for decreased birth weight with increasing hours/wk of leisure time PA [80]. Likewise, Rice et al. found no significant difference in birth weight when categorizing women into active (i.e., participating in continuous aerobic activity at least 30 minutes, 3 days/wk throughout gestation, (n = 12)) or sedentary (n = 11) groups (3.5 ± 0.32 kg versus 3.45 ± 0.45 kg, respectively, $p = 0.43$) [123]. Horns et al. found similar mean birth weights among 53 sedentary and 48 active women (15-30 minutes of continuous activity at least three times per week) [76]. Further, in a meta-analysis by Lokey et al., there were no significant differences between a comparison of birth weight among women who exercised (3.4 ± 2.1 kg) or a control group (3.5 ± 1.8 kg) [88]. There continued to be no relationship even when examining women who exercised at an intensity within the 1985 ACOG guidelines (≤ 140 bpm) or women who exercised above the 1985 ACOG recommendations (> 140 bpm) (3,472.8 ± 84.6 versus 3,471.3 ± 236.6, respectively) [88]. Collectively, the current results corroborated most, but not all previous studies. Of particular note, was that all mean birth weight values in the previously mentioned studies and ours were within a "normal" range (2.5-4.0 kg), with very few low or high birth weight infants, suggesting no significant restricted intrauterine growth associated with increasing levels of PA. Reduced fetal blood flow has been a concern in exercise studies during pregnancy due to decreased oxygen and nutrients to the fetus [7, 39, 132], however, current results suggest that this either does not occur or has no adverse effect on fetal growth.

The overall prevalence of preterm labor in our sample was 9.5%, which is within the national average of 6-10% [102]. We hypothesized there would be no association between maternal TPA and preterm labor, which was supported by our results. Our findings corroborated those of Clapp who examined 87 well-conditioned women who continued to exercise regularly at a high intensity throughout gestation (either running or aerobics classes) and 44 well-conditioned women who discontinued regular exercise throughout gestation [38]. Clapp found that continuing running or aerobics at high intensities (≥ 50% of preconception levels) did not significantly increase the incidence of preterm labor (defined as onset of labor before 37.5 weeks gestation) [38]. Similarly, Veille et al. examined 17 women enrolled in a YMCA exercise program who were randomized to either a walking group (30 minutes around a level track) or stationary bike (50-60 revolutions/min, 50 W, 10-15 min) at a mean gestational age of 35 ± 2 weeks [151]. Veille et al. found no differences in uterine activity in the fifteen minutes immediately post exercise [151]. These results were very similar to those of Mayberry et al. who found minimal changes in the frequency of uterine contractions after 20 minutes of exercise in a group of 10 women between 28-31 weeks gestation [93]. Thus, some historical concerns about exercise initiating preterm labor were not supported by current study results or those of Clapp [38], Mayberry [93], or Veille [151]. However, Clapp's and Veille et al.'s studies only included women who were previously active and therefore the results may not extend to others who do not have a desire to join a health club or initiate an exercise program. It is possible that women who were active before becoming pregnant had already physiologically adapted to the additional stress of exercise and thus exercising throughout gestation did not induce preterm labor in these samples.

Of the 25% of women who delivered pre/post term, 7.7% delivered preterm and 17.1% delivered post term. These values are slightly lower than national averages for preterm births (10-15%) [102] and slightly higher than averages for post term births (4-14%) [73]. We hypothesized that there would be no association between gestational age at delivery and weekly TPA, which was supported by the current results (Table 13). Previous researchers have found similar results. Specifically, among 388 women classified into four exercise categories, Sternfeld et al. found no difference in gestational age between any of the four categories (data not shown) [137]. Similarly, Horns et al. found no difference in gestational age at delivery between 48 sedentary women (39.2 ± 4.3 wk) and 53 active women (39.9 ± 1.4 wk) [76]. When comparing 232 nonexercisers and 325 exercisers, women who exercised at a low-moderate level (defined as ≤ 1000 kcal/wk) were not at an increased risk for delivering early (RR 1.11 95% CI 0.88-1.39) [70]. Likewise, Rice et al. compared twelve active women (defined as participating in continuous aerobic activity at least 30 minutes, 3 days/wk throughout gestation) to eleven sedentary women and found no difference in gestational age at delivery between the two groups (39.9 ± 3.6 wk and 39.5 ± 1.5 wk, respectively) ($p = 0.25$) [123]. Lastly, in a meta-analysis by Lokey et al., the summary statistic showed no significant difference when comparing gestational age at delivery among women who exercised (39.8 ± 1.1 wk) to a control group (39.9 ± 0.2 wk) [88]. Lokey et al. also examined women who exercised in excess of the 1985 ACOG recommendations and found that women who exercised at a heart rate ≤ 140 beats/min did not differ significantly in gestational age from women who exercised at > 140 beats/min, 40.2 ± 0.2 wk and 40.1 ± 0.1 wk, respectively [88]. Thus, our findings were consistent with previous literature with a majority (74.8%) of participants delivering term infants and no significant association between weekly TPA. A null finding between weekly TPA and gestational age should still be considered to be a clinically positive outcome because amount of TPA was not associated with inducing preterm birth in this sample. While these results were encouraging, it may be that women health club members are in general, healthier than women who do not belong to health clubs and consequently may have a reduced risk for delivering pre/post term infants due to healthy lifestyle factors beyond exercise.

In the current sample, 34.7% delivered via cesarean section, which is similar to the national average 32% [69]. We hypothesized that weekly TPA would not be associated with mode of delivery, which was supported by the results (Tables 14-15). Further, upon examination of only women who delivered via cesarean section ($n = 65$), weekly TPA was not associated with whether the procedure was elective or emergent. Our results support most earlier research. Bovbjerg and Siega-Riz examined a sample of 1,342 women delivering at term, and found that exercising for 30 or more minutes was not associated with an increased risk for cesarean delivery, either if a woman exercised 1-4 times/wk (RR 0.89 95% CI 0.69-1.15) or ≥ 5 times/wk (RR 1.04 95% CI 0.66-1.64) [29]. Results of Bovbjerg and Siega-Riz also corroborated those of Sternfeld et al. in which there was no difference in rate of cesarean deliveries among 388 women classified into four exercise groups [137]. Further, Horns et al., found no difference in cesarean delivery rates among 101 primiparous women who were classified as active (defined as at least 15-30 minutes of continuous activity at least 3 times/wk) or sedentary (defined as women who did not meet the active criteria) [76]. In contrast, our results were inconsistent with those from a study by Clapp. He found a significantly lower rate of cesarean sections among 87 highly active women who continued exercise throughout gestation (6%) versus 44 women who discontinued their exercise throughout gestation (30%) ($p = 0.01$) [38], demonstrating a potentially beneficial association. Bovbjerg and Siega-Riz suggested two potential reasons for a lack of association between exercise and cesarean section. One suggestion was that women who engage in exercise may have stronger abdominal muscles allowing them to progress through the second stage of labor and not need a cesarean section [29]. They also suggested that because exercise improves self-efficacy, women who exercise are more likely to have a "can do" attitude and therefore are less likely to have an elective cesarean delivery. Thus, it is possible these same mechanisms existed in our sample of women. Further, there are many reasons why a woman may choose to have an elective cesarean section, such as hypertension, multiple gestation, or other conditions [99]. Without additional information, it is not possible to draw firm conclusions regarding the association between weekly TPA and elective cesarean sections.

The mean infant length was 51.3 cm, which is within a normal range for term infants [91]. It was hypothesized that weekly TPA would not be associated with length of infant, which was supported by our results (Table 16) and those of others. Juhl et al. examined 79,692 live-born singletons from the DNBC [80]. The mean infant length was 52.2 cm among infants in the DNBC and was 51.2 cm in the current sample thus demonstrating consistency of results regardless of how exercise was categorized. Further, Juhl et al. found no trend for infant length with increasing hours/week of exercise ($p = 0.20$) [80]. Both Juhl et al. and the current study found the 95% CIs were very tight indicating very little variation in infant length based on exercise level. Thus, our results do not appear to show either a significant beneficial or adverse association with PA and infant length. This is an important finding because historic concerns about exercise restricting intrauterine growth [7, 39] are not supported by our results.

Overall, our adjusted models showed no statistically significant associations between weekly TPA and any of the adverse pregnancy or birth outcomes evaluated. However, when using more a simpler analytic approach (i.e., Fisher-exact test) we found a lower prevalence of adverse outcomes among the women in the RTAE group when compared to women in the AE and NE group. While we did not expect a null finding for all outcomes, these results were still encouraging because they suggest that women can perform higher levels of PA without causing undue harm to the fetus. Additionally, it is possible that other unmeasured confounders contributed to the lack of associations between variables.

Specific Aim 5: Exercise Status and Adverse Pregnancy and Birth Outcomes

We hypothesized that exercise status would be inversely related to adverse pregnancy outcomes including GDM and preeclampsia/gestational hypertension. This hypothesis was based on previous study results from other investigators [30, 47, 61, 134]. Results showed that our hypothesis was not supported in the adjusted statistical models (Table 21). As previously mentioned, aerobic exercise has been shown to be associated with decreased risk of GDM [2, 53, 144]. We expected to see a similar decreased risk of GDM with resistance training because this exercise engages significant skeletal muscle activity. Therefore, we thought there would be similar mechanisms occurring, such as initiation of translocation of GLUT-4, which reduces insulin resistance, thus possibly lowering GDM risk. It was unexpected to see the AE group have the highest prevalence of GDM, however, due to our group stratification, we believe that the unadjusted model may have been significant for two reasons. First, due to the retrospective design of the study, we were not able to determine temporality of events. We can speculate that nonexercising women who developed GDM midway through gestation were encouraged to begin walking. In our study, such a woman would have been placed in the AE group. To be stratified into the AE group, a woman had to report a minimum of one ten minute walk/week for exercise. Thus, our stratification method might have artificially inflated the prevalence of GDM in the AE group with women who exercised at a very low level. Second, women in the RTAE group had the lowest prepregnancy BMIs (Table 2), which contributed to the adjusted model being significant, although not as we hypothesized. Thus, when we adjusted for prepregnancy BMI, exercise status no longer contributed to the model because prepregnancy BMI played a more influential role in development of GDM.

While an inverse association was not seen between exercise status and GDM, a null finding is reassuring as it demonstrates that, given the limitations of our study, participating in resistance exercise did not increase a woman's risk of contracting the disease. Our results, however, are somewhat inconsistent with previous research showing a beneficial association between resistance training and GDM. Specifically, Brankston et al. randomly assigned 32 women with GDM into a diet alone (n = 16) or diet plus resistance exercise group (n = 16) between 26 and 32 weeks gestation [30]. Comparing the two groups, women in the resistance exercise group required less insulin ($p < 0.05$) and had a longer latency period before initiating insulin treatment (approximately 2.5 weeks; $p < 0.05$) [30]. Similarly, de Barros et al. randomly assigned 64 women with GDM into a resistance exercise group (n = 32) or a control group (n = 32) between 24-34 weeks gestation [47]. de Barros et al. found that when comparing women in the resistance exercise group and control group, fewer women in the resistance exercise group required insulin (21.9% versus 56.3%, respectively, $p < 0.01$). However, there was no statistical difference in the amount of insulin required ($p = 0.40$) or latency period to insulin treatment (0.72) between the two groups [47]. Overall, our results and those of Brankston et al. [30] and de Barros et al. [47] do not consistently suggest a beneficial role of resistance exercise, but do demonstrate no increased risk with resistance exercise. However, Brankston et al. and de Barros et al. did not control for prepregnancy BMI, which may have influenced their findings, as was the case in the present study. In addition, the current study did not examine the amount of insulin required, nor the time to treatment, which may have differed between exercise statuses. Our main goal was to determine if any type of resistance training a woman performed negatively affected the maternal-fetal unit, thus we analyzed GDM more globally than Brankston et al. and de Barros et al.. Therefore, at the very best, these results suggest either a beneficial relationship or no additional harm to performing resistance training and aerobic exercise and pregnancy and birth outcomes.

We hypothesized that exercise status would be inversely associated with prevalence of preeclampsia/gestational hypertension, which was not supported by the current results (Table 22). As previously mentioned, aerobic exercise during pregnancy has demonstrated either no association [124], a slight beneficial association [61], or a significant beneficial association [134] with hypertensive disorders during pregnancy. Our results showed no association between exercise status and risk of developing preeclampsia/gestational hypertension. This was somewhat unexpected, but it is plausible that stratifying women into three exercise categories may have influenced the results. It is clear from Tables 17-18 that there was a reduced point prevalence of preeclampsia/gestational hypertension in the RTAE group and this could be because participants who were in that group were habitual exercisers. In contrast, a participant could easily be stratified into the AE group without habitual exercise habits. To be stratified into the AE group, a participant had to report a minimum of one 10-minute bout of light intensity walking. Thus, the high prevalence of preeclampsia/gestational hypertension in the AE group could be due to participants who were not habitual exercisers. In contrast, it is unlikely that a participant in the RTAE group decided to only occasionally participate in resistance training. It is more likely that a participant may have engaged sporadically in moderate aerobic activity (such as walking) throughout gestation if she believed that some activity would be beneficial to her or the fetus. Although the logistic regression model did not achieve statistical significance, the point estimates for belonging in the RTAE group were in the protective direction and further supported by the Fisher-exact test. Accordingly, our results demonstrated no significant reduced risk of preeclampsia/gestational hypertension, but there was a trend for protection if a participant engaged in resistance training, most likely due to her habitual exercise regimen.

We hypothesized an inverse relationship between exercise status and birth weight, but this was not supported by the results (Table 23). While previous studies have demonstrated reduced birth weight among chronic exercisers [38, 114], these studies only examined aerobic activities. To the authors' knowledge, only two other studies have examined the relationship between resistance training and birth weight and our results corroborated those of Barakat et al. [21] and de Barros et al [47]. Barakat et al. randomized previously sedentary women into an intervention group who began light toning resistance exercises at 12-13 weeks gestation (n = 72) or a control group (n = 70) [21]. No significant differences were found between birth weights of intervention group (3,165 ± 411 g) or control group (3,307 ± 477) (p > 0.10) participants [21]. de Barros et al. examined previously sedentary women with GDM and found that after circuit-type resistance training with elastic bands, no differences existed in birth weight between the exercise and control groups (3.30 ± 0.49 kg versus 3.23 ± 0.45 kg, p = 0.53) [47]. Both studies investigated the effects of previously sedentary women performing resistance exercises using elastic resistance bands and/or light barbells. Thus, the lighter intensity associated with resistance bands may not have been sufficient to elicit a protective effect. However, because the women were previously sedentary in both studies, they may have perceived the intensity as higher than that of a woman who exercises habitually. Regardless, our results may be more robust due to the varying frequencies, intensities, and durations of resistance training in a more physically diverse (i.e., not all women were previously sedentary) sample of women. Of particular note is that mean infant birth weights in the current study and those of Barakat et al. and de Barros et al., were all within a normal range (2.5-4.0 kg) demonstrating no adverse association with engaging in resistance training during gestation.

We hypothesized that exercise status would not be associated with preterm labor, which the current results supported (Table 24). While preterm labor is an important clinical measure, few studies have evaluated its association with resistance training. Our results showed no association, which suggests that performing resistance exercise during pregnancy did not significantly increase the risk of preterm labor. This finding is important as it suggests that women can engage in resistance training approximately 3 days/week for 30 minutes during gestation without adversely affecting late pregnancy and the birthing process. In addition, it was encouraging that the point estimates for risk of preterm labor and being in the AE or RTAE groups were in the protective direction, which suggests a potential benefit of aerobic and/or resistance exercise during gestation.

Our hypothesis that exercise status would not be associated with gestational age at delivery was supported by our results (Table 25). Due to the narrow range of length of gestation, the data were dichotomized as presented. While not statistically significant, the point estimates in both unadjusted and adjusted models were in the protective direction. This suggests that belonging to the RTAE group increased the likelihood of a woman delivering at term, as defined by 37-40 weeks. Belonging to the RTAE group may have demonstrated this protective effect because women who resistance trained during pregnancy were also more conscious of beneficial dietary, physical, and life-style choices for the fetus, and thus were less likely to deliver pre/post term regardless of exercise status. The mean gestational age at delivery for the RTAE group was 39.4 weeks, 39.0 weeks for the AE group, and 38.5 weeks for the NE group, which is consistent with previous work by Barakat et al. in which the intervention group delivered at 39 wk 3 days ± 1 day and the control group delivered at 39 wk 4 days ± 1 day, with no statistical difference between groups ($p = 0.75$) [23]. Thus, our results were consistent with those of Barakat et al. [23] in showing no association between resistance training and gestational age at delivery.

We hypothesized that exercise status would not be significantly associated with mode of delivery which was supported by the current results (Tables 26-27). As discussed above, these results corroborated those of Bovbjerg et al. [29], Sternfeld et al. [137], and Horns et al. [76] who all evaluated aerobic activity. Our results also support those of Barakat et al. who performed a randomized controlled trial in previously sedentary women (control group n = 70 and intervention group n = 72) [22]. Barakat et al. found that having women engage in light resistance and toning exercises from 12 weeks gestation to delivery did not affect mode of delivery. Eleven women in the intervention and control groups delivered via cesarean section, which was not significantly different (15.3% versus 15.7%, respectively; $p > 0.10$) [22]. While our results also show support for lack of an association for mode of delivery, our findings add to those of Barakat et al. because study participants engaged in higher intensity resistance training that included free weights and weight machines. In addition, Barakat et al. examined previously sedentary women while the current study examined women who belonged to a health club. Since results have been similar regardless of women's exercise histories, it is plausible that regardless of previous activity levels, women can safely engage in resistance training without increasing risk of a cesarean section.

We hypothesized that exercise status would not be associated with infant length, which was supported by the results (Table 28). Previous literature examining aerobic exercise also found no association with infant length [80]. Our results regarding resistance training corroborated those of Barakat et al. [21] who found no difference between infant length in the control group (49.7 ± 1.8 cm) or the intervention group (49.5 ± 1.8 cm) ($p > 0.1$) who performed light toning resistance exercises beginning at 12-13 weeks gestation [21]. Also of note, mean birth length values were within a normal range for term infants (48-53 cm) [91]. The current results and those of Barakat et al. [21] demonstrate no adverse association with engaging in either light or more intense resistance training programs. Our results also do not show support for previous concerns (e.g., reduced fetal blood flow) regarding resistance training during pregnancy on intrauterine growth.

In summary, exercise status was not significantly associated with preeclampsia/gestational hypertension, birth weight, preterm labor, gestational age at delivery, mode of delivery, and infant length and only marginally associated with GDM. These results demonstrate neither a harmful nor beneficial association with mode of exercise and pregnancy and birth outcomes. Thus, the fear of adverse effects of resistance training as a result of inadequate blood flow to the fetus during exercise [98] is not supported. Even if uterine blood flow is somewhat restricted during exercise, there is likely a compensatory mechanism, such as increased oxygen extraction by the fetus [98, 138], which ensures adequate oxygen and nutrient supply. To better understand the association between resistance training during pregnancy and pregnancy/birth outcomes, future studies must include larger sample sizes that will allow subanalyses of trimester specific data. Trimester specific data will allow for better determination of the effects of resistance training at different time points, which may have a more profound effect during late gestation when the fetus grows the most and women are more often diagnosed with GDM and preeclampsia/gestational hypertension.

Study Limitations and Strengths

This study had both limitations and strengths. One limitation was that women already knew the outcome of their pregnancies, which could have led to differential bias in their survey responses. For example, if a woman exercised throughout gestation and then had a difficult or abnormal pregnancy or delivery, she may recall her activity patterns differently than a woman who exercised similarly but had a normal pregnancy and delivery. Another limitation was that women self-reported all data up to five years postpartum. However, women who belong to health clubs tend to be more conscious of their exercise habits and therefore may report more accurately than women who do not belong to a health club, even five years later. Also, it has been found that among adult males, conditioning activities were recalled best while home or leisure and job activities followed [143], thus demonstrating an improved propensity for recalling exercise-related activities. Further, previous work from our lab has shown that women can recall trimester-specific pregnancy PA with the Modifiable Activity Questionnaire (MAQ) up to six years postpartum with moderate to high validity [24]. Thus, we believed the time frame of five years used in the current study was acceptable for accurately recalled exercise and PA habits throughout pregnancy. To further acknowledge a potential for recall bias, we stratified our outcome variables into primary and secondary variables based on previous reports regarding recall accuracy. Primary outcomes included preterm labor, birth weight, gestational age at delivery, and mode of delivery because they are recalled with high accuracy. Secondary outcomes included GDM, preeclampsia/gestational hypertension, and length of infant due to reduced accuracy of recall discussed earlier. Thus, the lack of associations between weekly TPA and exercise status and GDM and preeclampsia/gestational hypertension may be partly due to the decreased accuracy in recall of these conditions. During data analysis, we also discovered that prepregnancy BMI played an influential role. Based on previous research, women may underreport rather than accurately report prepregnancy BMI; however there is no reason to believe that differential recall bias occurred among women belonging to different exercise groups. Thus the relationships observed in the current study would persist. If clinical data were used instead of self-reported data, the association between prepregnancy BMI and adverse outcomes may have been even stronger.

Because women who chose to belong to a health club were surveyed, it is possible that healthier or more health conscious women would participate, leading to potential sample bias. Thus, the generalizability of current results may not extend to other women, especially sedentary women, who do not have the desire to belong to a health club. While it was our goal to recruit women health club members because they were more likely to engage in resistance training during pregnancy, it also limited the number of adverse pregnancy outcomes. Many women who engaged in resistance training did not develop an adverse pregnancy outcome, thus our sample size for women with adverse outcomes was small and we were not able to draw firm conclusions. Future studies examining larger and more diverse sample sizes are necessary.

Temporality could not be established due to the retrospective nature of the study. It was not known whether a woman exercised because she developed an adverse outcome, such as GDM, and her health care provider suggested that she begin exercising, or whether she exercised before developing GDM and then continued or discontinued exercise. While our open-ended questions allowed for women to comment on these possibilities, our participants did not choose to share such comments. In addition, there was not a question on the PAS that specifically asked whether a participant initiated or stopped exercising due to her physician's directions. Therefore, due to the retrospective nature of the study, we were not able to determine the time sequence of exercise habits. However, we were able to establish that, within limitations of our study, there were no adverse pregnancy and delivery effects related to performing resistance training. Such data are needed before larger, more exotic study designs can be developed.

Another limitation was our small and fairly homogeneous sample. Our sample included primarily white (non-Hispanic), married women, with at least 1-3 years of college education. The relatively small sample size limited our ability to investigate the associations between adverse outcomes and trimester-specific exercise, especially in regards to resistance training, which was the primary focus of the current study as discussed earlier. Consequently, our results should be confirmed in a larger and more diverse group of women. However, we believe our results can be generalized to women with a similar demographic profile.

Additionally, a complete validity check of the PAS was not conducted in the present study. There was a small internal validity check to the PAS using the frequency of resistance training. However, the rest of the exercise questions were not evaluated thoroughly with a pilot group of pregnant women and this should be done for future studies. Also, due to limited resources, we were not able to compare the accuracy of recalled adverse outcomes to medicals charts. Thus, overall, while the PAS was developed primarily from previously validated questionnaires an overall check of validity should be conducted. This could be done using the prospective cohort of women previously mentioned and having them complete the PAS five years postpartum to determine its accuracy.

Although there were inherent limitations to a retrospective, cross-sectional, self-reported survey design, the primary benefit was the safety of the maternal-fetal unit, while setting a baseline for more rigorous studies in the future. Due to the many physiological changes that occur during pregnancy, it is possible that exercise affects the maternal-fetal unit differently at various time points. Using a retrospective survey addressed this issue by asking trimester specific questions regarding exercise participation. However, due to inadequate sample size, we were not able to analyze trimester specific results. Also, from a practicality and feasibility stand-point, using a retrospective survey should have allowed for a higher participation rate. However, with limited resources available for this study, we were not able to provide incentives for women to complete an exercise routine, such as during a randomized controlled trial, for the duration of their pregnancy or for a longitudinal assessment of multiple surveys given throughout a woman's pregnancy. Therefore, to have the greatest chance for success, we chose a one-time survey hoping that this would not be too burdensome given no financial remuneration.

Another benefit of conducting a retrospective study was that randomized controlled trials generally exclude women with abnormal pregnancies in the final analyses. However, by conducting a study retrospectively, major pregnancy and birth outcomes were captured and the association with exercise was determined. For example, during a randomized control trial, if a woman developed an unfavorable condition, such as GDM or preeclampsia/gestational hypertension, she may need to drop out of the study. Conversely, the current study was able to include all women regardless of pregnancy outcome. However, while a retrospective study allowed inclusion of all women for analyses, it was limited by not being able to randomize participants or control for potential confounders as in a randomized controlled trial. Further, a retrospective study relies on participants accurately recalling all events rather than measuring variables concurrently. Overall, while a retrospective design is not nearly as rigorous as a randomized controlled trial, it allows for a foundation to be built in an area with limited previous research.

A final strength of the current study was that it is one of the first investigations to evaluate a wide range of frequencies, intensities, and durations of resistance training along with pregnancy and birth outcomes. While Barakat et al. utilized some of the most rigorous and current methodologies, they investigated only light toning resistance exercises [21-23]. Due to the circuit-type training (i.e., very light-to-moderate intensity of one set of ≤ 10-12 repetitions with resistance bands or ≤ 3 kg barbells), Barakat et al.'s intervention may have been more aerobic than true resistance training. In the current study, the majority of women used free weights and weight machines rather than resistance bands, thus we were able to capture a wider range of women performing resistance training. Further, although O'Connor et al., examined a low-to-moderate intensity strength training program during pregnancy and found it to be safe, they did not examine any pregnancy or birth outcomes [110]. Therefore, there is some evidence that a woman can safely engage in a strength training program, but results regarding the effects of this exercise on the maternal-fetal unit are limited. Thus, the current study adds to the current literature as it examines a wide range of resistance exercise, aerobic exercise, ADL, and pregnancy/birth outcomes. Since women often perform more than one type of exercise in addition to ADL, we were able to examine total PA from all sources in relation to pregnancy/birth outcomes.

Future Directions and Conclusion

Due to the various limitations of the present study, continued research in this area is necessary. Due to the relatively small and homogeneous sample size, especially with respect to race and education, our results should be replicated in a larger and more diverse group of study participants. In addition, following women prospectively will allow for determination of temporality of exercise and PA and adverse pregnancy and birth outcomes. When surveys are utilized in future studies, it is critical to ask questions regarding why a woman stopped or initiated exercising during pregnancy. Questions regarding prior history of adverse outcomes and exercise habits would also add considerably to a researcher's ability to interpret study results.

In conclusion, we found no increased risk of exercising women engaging in resistance training three days/week for thirty minutes at a suitable intensity to improve or maintain muscular endurance (i.e., low weight and high repetitions) among women health club members who have given birth in the last five years. Moreover, most of our point prevalences suggest a protective effect. While our results did not show a significant benefit of weekly TPA, exercise status, or the interaction between them and pregnancy and birth outcomes, we also did not find adverse associations. Of particular importance, we found that having a normal/low prepregnancy BMI exerted a greater influence on birth outcomes regardless of PA behavior. Our findings suggest no increased risk with performing both aerobic and resistance exercise during gestation. Overall, our results provide valuable baseline information regarding an understudied area of research in the exercise and pregnancy field.

APPENDICES

APPENDIX A

Table 34. Informally proposed recommendations for resistance training during pregnancy based on the available literature and expert opinion.

Recommendation	References
Engage in muscular endurance training (low resistance and high repetitions; 1-2 sets of 12-15 repetitions) of all muscle groups Use free weights or machines for 1 set, 2x/week of 10-15 muscle groups Particular attention should focus on muscles that will be used in labor and delivery Rest 2-4 minutes between sets for heart rate recovery	[20, 31, 92] [159] [31, 68, 92] [20]
Use proper form and discontinue exercise if uncomfortable or proper alignment is not possible due to growing fetus. Substitute free weights, tubing, and calisthenics if machines are too difficult due to size or decreased balance	[31, 92]
Practice proper, controlled breathing, especially avoiding the Valsalva maneuver (i.e., holding your breath)	[92, 121, 136]
Avoid ballistic movements and heavy resistance training	[92]
Use machines early in pregnancy and some in later pregnancy	[92, 121]
Reevaluate the exercise prescription at regular intervals throughout pregnancy	[68]
Avoid maximal lifts (one repetition maximums [1-RM])	[132, 136, 159]
Seek qualified personnel	[136, 159]
Listen to your body	[159]
Obtain physician's approval before initiating exercise during pregnancy	[121]
Avoid supine position in second and third trimesters Avoid supine position after the first trimester	[20, 121] [136]
Avoid lunges, squats, and stiff-leg deadlifts	[121]
Heart rate ≤150 beats/min	[132]
Women should become fit before becoming pregnant to better handle the increased workload associate with pregnancy, labor, and delivery	[132, 155]
Avoid activities that pose abdominal trauma to the abdomen and fetus and high-altitude activities	[132]
Check rectal temperature post-exercise early in pregnancy. If the rectal temperature is ≤38.3°C (101°F) she can confidently exercise at that intensity throughout pregnancy	[132]
If a woman experiences adverse symptoms, such as pain, bleeding, rupture of membranes, or absence of fetal movement, she should stop exercising and seek medical attention before exercising again	[132]
Begin an exercise program during the second trimester to avoid the nausea and fatigue of the first trimester and the increased size during the third trimester	[46]

APPENDIX B

Table 35. Risk estimates for occupational lifting and low birth weight and small-for-gestational age (SGA).

First Author (Year)	Outcome	Exposure	N	Risk (95% CI)
Ahlborg (1990) [4]	Low birthweight** with gestational age in the model	No heavy lifting at work Any weight < 10 times/week <12 kg ≥ 10 times/week ≥12 kg 10-50 times/week ≥12 kg >50 times/week	3389	Reference 0.57 (0.25-1.28) 0.56 (0.17-1.79) 0.88 (0.41-1.87) 0.65 (0.24-1.77)
Magann (2005) [90]	Intrauterine Growth Restriction	Lifting 25 pounds or more than 6 times/hour	814	0.59 (0.20-1.74)
Armstrong (1989) [18]	Small for Gestational Age	Lifting heavy weights (≥15 times/day)	1,071	99.1 (98.3-99.9)‡
Fortier (1995) [60]	Small for Gestational Age***	Lifting no objects Lifting 1-9 kg objects Lifting ≥10 kg objects Unknown	2,500 876 578 436	Reference 1.03 (0.77-1.38) 1.03 (0.71-1.51) 1.11 (0.75-1.65)
Nurminen (1989) [109]	Small for Gestational Age	Sedentary work Moderate physical load (lifting/carrying 5-10 kg)	2,950	Reference 2.4 (1.3-4.6)†
Pompeii (2005) [119]	Small for Gestational Age Birth***	Lifting 25 pounds in First Trimester 0 times/week 1-12 times/week >13 times/week	1,609	 Reference 1.2 (0.8-1.6) 1.2 (0.7-2.0)
Pompeii (2005) [119]	Small for Gestational Age Birth***	Lifting 25 pounds in Second Trimester 0 times/week 1-12 times/week >13 times/week	1,542	 Reference 1.0 (0.7-1.5) 1.2 (0.6-2.2)
McDonald (1988) [97]	Low birthweight**	Lifting heavy weights 15 times/day	22,761	1.26 $p < 0.01$†
Saurel-Cubizolles (1987) [126]	Low birthweight**	Heavy load carried No Yes	2,387	 4.2% 5.7% NS

Table 35. (cont'd)

Tuntiseranee (1998) [148]	Low birthweight**	Lifting more than 12 kg/day None ≤10 times/day ≥11 times/day	1,797	 Reference 0.5 (0.2-1.2) 0.3 (0.0-7.4)
Tuntiseranee (1998) [148]	Low birthweight**	Carrying more than 12 kg/day None ≤10 times/day ≥11 times/day	1,797	 Reference 2.5 (1.1-5.9)† 1.4 (0.1-38.9)
Tuntiseranee (1998) [148]	Small for Gestational Age***	Lifting more than 12 kg/day None ≤10 times/day ≥11 times/day	1,797	 Reference 0.5 (0.1-1.7) No SGA
Tuntiseranee (1998) [148]	Small for Gestational Age***	Carrying more than 12 kg/day None ≤10 times/day ≥11 times/day	1,797	 Reference 3.1 (0.8-11.5) No SGA

**Defined as birthweight <2,500 grams
***Defined as birthweight below the 10th percentile of the birthweight distribution specific for their gender and gestational age
NS: Non-significant
†Significant either by 95% Confidence intervals not including unity or $p < 0.05$.
‡Percent predicted birth weight for age and 90%CI

APPENDIX C

Table 36. Risk estimates for occupational lifting and preterm birth/delivery (defined as gestation/delivery <37 weeks, unless otherwise noted).

First Author (Year)	Outcome	Exposure	N	Risk (95% CI)
Ahlborg (1990) [4]	Preterm Birth	No heavy lifting at work Any weight < 10 times/week <12 kg ≥ 10 times/week ≥12 kg 10-50 times/week ≥12 kg >50 times/week	3389	Reference 1.02 (0.62-1.67) 0.83 (0.37-1.86) 0.69 (0.41-1.17) 1.29 (0.69-2.40)
Berkowitz (1983) [26]	Preterm Delivery	Lifting on the job, weight of object lifted or carried, frequency of lifting	488	No differences between cases and controls
Fortier (1995) [60]	Preterm Birth	Lifting no objects Lifting 1-9 kg objects Lifting ≥10 kg objects Unknown	2,500 876 578 436	Reference 0.96 (0.66-1.41) 0.87 (0.52-1.45) 0.95 (0.56-1.62)
Henriksen (1995) [72]	Preterm Delivery	Lifting loads of ≥12 kg/day Never <10 times/day ≥10 times/day	4,529	 3.9% 3.2% 3.6% p = 0.7
Magann (2005) [90]	Preterm Birth*	Lifting 25 pounds or more than 6 times/hour	814	1.14 (0.32-3.18)
McDonald (1988) [97]	Preterm Birth	Lifting heave weight 15 times/day	22,761	1.25 $p < 0.01^{\dagger}$
Misra (1998) [103]	Preterm Birth	Lifting heavy objects on the job Yes No	 39 1,127	 Reference 1.49 (0.70-3.19)
Pompeii (2005) [119]	Preterm Delivery	Lifting 25 pounds in First Trimester 0 times/week 1-12 times/week >13 times/week	1,796	 Reference 0.8 (0.6-1.1) 1.3 (0.9-1.8)

Table 36. (cont'd)

Pompeii (2005) [119]	Preterm Delivery	Lifting 25 pounds in Second Trimester 0 times/week 1-12 times/week >13 times/week	1,711	 Reference 0.9 (0.7-1.2) 1.3 (0.8-2.1)
Pompeii (2005) [119]	Preterm Delivery	Lifting 25 pounds in Weeks 28-31 0 times/week 1-12 times/week >13 times/week	444	 Reference 1.0 (0.6-1.5) 1.3 (0.6-2.9)
Saurel-Cubizolles (1987) [126]	Preterm Delivery	Heavy load carried No Yes	2,387	 4.6% 6.1% NS
Saurel-Cubizolles (1991) [127]	Preterm Delivery	Lifting heavy weights never or sometimes Lifting heavy weights often or always in conjunction with either standing and/or other arduous positions	875	1.4 (0.6-3.1) 1.2 (0.5-2.5)
Saurel-Cubizolles (2004) [128]	Preterm Birth	No loads carried More than 5 kg loads carried More than 20 kg loads carried	6,378	Reference 1.0 (0.9-1.1) 1.02 (0.8-1.2)
Tuntiseranee (1998) [148]	Preterm Birth	Lifting more than 12 kg/day None ≤10 times/day ≥11 times/day	1,797	 Reference 0.9 (0.4-2.1) 1.6 (0.1-20.4)
Tuntiseranee (1998) [148]	Preterm Birth	Carrying more than 12 kg/day None ≤10 times/day ≥11 times/day	1,797	 Reference 1.4 (0.5-3.6) 0.5 (0.0-13.6)

*Defined as a birth after 20 weeks of gestation but before 37 weeks of gestation
NS: Nonsignificant
†Significant either by 95% Confidence intervals not including unity or $p < 0.05$.

APPENDIX D

Table 37. Risk estimates for occupational lifting and other pregnancy-related outcomes (fetal death, preterm labor, pregnancy-induced hypertension, preeclampsia, and birth defects).

First Author (Year)	Outcome	Exposure	N	Risk (95% CI)
Ahlborg (1990) [4]	Fetal Death	No heavy lifting at work Any weight < 10 times/week <12 kg ≥ 10 times/week ≥12 kg 10-50 times/week ≥12 kg >50 times/week	3384	Reference 1.03 (0.70-1.53) 0.97 (0.53-1.78) 1.11 (0.77-1.58) 1.06 (0.62-1.81)
Magann (2005) [90]	Perinatal Death	Lifting 25 pounds or more than 6 times/hour	814	0.82 (0.23-2.22)
Magann (2005) [90]	Preterm Labor	Lifting 25 pounds or more than 6 times/hour	814	1.22 (0.27-3.92)
Irwin (1994) [79]	Pregnancy-Induced Hypertension in Nulliparous Women	Lifting Low (≤10 pounds during the day) Medium (lifts 10-30 pounds during the day) High (≥30 pounds during the day)	5,605	 Reference 0.99 (0.80-1.2) 0.84 (0.67-1.1)
Irwin (1994) [79]	Preeclampsia in Nulliparous Women	Lifting Low (≤10 pounds during the day) Medium (lifts 10-30 pounds during the day) High (≥30 pounds during the day)	5,605	 Reference 0.76 (0.55-1.1) 0.68 (0.47-0.98)[†]
Irwin (1994) [79]	Pregnancy-Induced Hypertension in Parous Women	Lifting Low (≤10 pounds during the day) Medium (lifts 10-30 pounds during the day) High (≥30 pounds during the day)	5,605	 Reference 1.7 (1.1-2.7)[†] 1.2 (0.70-2.2)
Irwin (1994) [79]	Preeclampsia in Parous Women	Lifting Low (≤10 pounds during the day) Medium (lifts 10-30 pounds during the day) High (≥30 pounds during the day)	5,605	 Reference 2.0 (0.87-4.5) 0.87 (0.28-2.7)
Nurminen (1989) [109]	Pregnancy-Induced Hypertension	Sedentary work Moderate physical load (lifting/carrying 5-10 kg)	2,950	Reference 1.1 (0.4-3.2)

Table 37. (cont'd)

Wergeland (1997) [156]	Preeclampsia	Lifting heavy (10-20 kg) loads	3,321	
		>20 times/day		1.4 (0.8-2.6)
		10-20 times/day		1.7 (1.1-2.7)†
		>20 times/week		2.0 (1.2-3.2)†
		<20 times/week		1.0 (0.6-1.5)
		Rarely or never		Reference
McDonald (1988) [96]	Birth defects and hernias	Lifting heavy weights 20-31 weeks	6,628	
		Club foot		1.15 NS
		Other musculoskeletal defects		0.73 NS
		Hernias		1.46 $p < 0.05$†
Nurminen (1989) [109]	Birth defects	Lifting and carrying objects 5-10 kg compared to sedentary work	2,950	
		Central nervous system defects		3.0 (1.6-5.5)†
		Orofacial clefts		1.8 (1.1-3.0)†
		Skeletal defects		0.9 (0.5-1.8)
		Cardiovascular defects		1.7 (0.7-4.0)

†Significant either by 95% Confidence intervals not including unity or $p < 0.05$.

APPENDIX E

Figure 3. A reduced-scale flier that was approved by Michigan State University to use for promotion and recruitment of participants in Anytime Fitness® facilities. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

APPENDIX F

Table 38. Detailed history of recruitment strategies.

Date	Event
June 2-5, 2010	EK and JP met with Mark Daly (National Media Director for Anytime Fitness®) and Brian Zehetner (Director of Anytime Health™) at the Annual ACSM Meeting. We discussed the partnership between Michigan State University, Anytime Fitness®, and Anytime Health™.
October 15, 2010	The Physical Activity Survey (PAS) was posted online on Anytime Health's™ website. A blog was also posted online.
October 27, 2010	Brian sent out a reminder to Anytime Fitness® facilities to hang the poster.
December 7, 2010	Brian sent out a reminder to all franchisees strongly encouraging them to hang more than one poster in their facility (i.e., gym, locker rooms, etc.). Brian made another post on the Anytime Health™ website.
February 2, 2011	EK sent out individual emails to each franchisee. The email encouraged managers to hang posters in multiple places in their facility as well as possibly send out individual emails to each female member.
February 14, 2011	EK was contacted by a manager about an error on the website. Brian re-sent each poster to the facility due to the error explaining the circumstances. Revised posters were hung in facilities.
May 31, 2011	EK and JP met with Mark Daly and Brian Zehetner at the Annual ACSM Meeting. We discussed further options to increase participation including: • Having an Anytime Fitness® intern calling the 100 most successful clubs to ask for their support and encourage them to hang posters in their facilities • Potentially calling the most successful clubs in the states that do not have a single person participating if the above strategy is successful • Mark will send out another email reminder to franchisees • Potentially setting up a raffle to encourage participation

APPENDIX G

DETERMINATION OF A SURVEY TO EXAMINE: EXERCISE HABITS AND PREGNANCY OUTCOMES

Questions to be asked during the focus groups:

1. What was your overall experience taking the survey?
    a. How long did it take?
    b. What suggestions do you have to improve the survey taking experience?
2. Were there any problems overall that you had?
    a. How would you correct the problem(s) that you had?
3. How was the overall format of the survey?
    a. Would you suggest anything differently?
4. Were the instructions clear?
5. What did you think of when I asked you this question?
6. Were any of the words unfamiliar or were there any words that should have been clarified better?
7. Is there anything you think we should have asked that was not covered?
8. Do you have any further comments you would like to share now that we have gone over everything?

These questions will be standardized, however, if an issue comes up during the focus group, we will allow for open-ended questions and responses to follow up with the issue. These questions will be answered for one time point during pregnancy. I will follow up asking if any comments change as we progress through the five time points (pre-pregnancy, 1st trimester, 2nd trimester, 3rd trimester, or currently) we are assessing. If there are no additional comments, I will use the same set of comments from one time point and apply them to all time points. By doing this, this will reduce participant burden as the participants will not have to repeat their thoughts regarding the exercise questions as they are verbatim from time point to time point.

APPENDIX H

A. Welcome to our survey!

Welcome! We greatly appreciate your willingness to help. Anytime Fitness® and Michigan State University are conducting a survey looking at how different types of physical activity during pregnancy affected you and your baby.

We would like you to think back to your most recent pregnancy (within the past 5 years) and take this survey keeping your most recent pregnancy in mind. Please answer all questions to the best of your ability by either clicking or typing in the best response. Keep in mind that all your answers will be confidential. In addition, since you are not providing any identifiable information, we will not be matching your responses with your name and/or address. If you have any problems or questions when completing this survey please email Erin Kuffel, MS at kuffeler@msu.edu or James Pivarnik, PhD at jimpiv@msu.edu or call (517)884-1396 or (517)353-3520.

B. Informed Consent *Required

INVESTIGATION OF EXERCISE HABITS AND PREGNANCY OUTCOMES

We would like your assistance in studying the benefits of exercise during pregnancy. This study is examining the effects of various types of exercise (weight lifting, cardio, flexibility, and group exercise classes) on mother and child outcomes. Your response is very important to us as we would like to gather data to develop guidelines regarding the amount of exercise that is deemed safe for both mother and child during pregnancy. Your participation would be greatly appreciated, regardless of the amount of physical activity you do.

To participate, you must be 18 years or older, speak English, and be a member of Anytime Fitness®. We need about 20-30 minutes of your time. You will be asked a series of questions in an online survey regarding your pregnancy and exercise habits. The risks associated with your participation are minimal and are limited to the release of private information you supply in completing the survey. Your privacy will be protected to the maximum extent allowable by law. Your answers are completely confidential and your name will not be linked to the data in any way. This survey is completely voluntary; you can stop at any time or not answer any questions that you are uncomfortable with. We will re-contact you with follow-up information only if you give us permission to do so by entering your email address in the questionnaire when asked to do so.

If you have any questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact Dr. Jim Pivarnik, at (517) 353-3520, online at jimpiv@msu.edu, or Erin Kuffel, M.S., at (517) 884-1396, online at kuffeler@msu.edu, or by mail at Room 27 IM Sports Circle Building, MSU, East Lansing, MI 48824. If you have any questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this research study, you may contact, anonymously if you wish, Michigan State University Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu, or regular mail at: 207 Olds Hall, MSU, East Lansing, MI 48824.

Thank you again for your participation. If you do not wish to participate, please close this window or click Decline. By clicking the "Next" button below, you accept the above conditions and are willing to participate voluntarily in this online survey. If you click Decline we will not contact you in the future.

-Next

-Decline

You have declined the informed consent. If you wish to complete the survey, you must accept the guidelines set forth in the informed consent before participating. To complete the survey, please exit this window and start over. By clicking the "Decline" button below, you are declining informed consent and will not be able to participate in the survey.

C. Declined Informed Consent*

-Decline

-I have reached this page in error and would like to re-read the informed consent.

D. Instructions to finish the survey

Please answer each question to the best of your ability. This survey is voluntary so you can stop at any time or not answer any questions you do not feel comfortable with. The time point we are asking about will be labeled in the purple header at the top of each page, if you forget what time point we are asking
about, please look at the purple header.

Please use the "***Previous***" and "***Next***" buttons (on the bottom of the page) to go back and forth in the survey. After answering the questions on the page, please click "Next" to proceed to the following page.

E. Screening questions:

1. To your knowledge, are you pregnant now? ***(Please choose one.)***

-Yes

-No

If Yes:

Thank you for your willingness to participate!

Due to the nature of the study, we would like to contact you at four time points: after your 1st trimester, 2nd trimester, 3rd trimester, and 3 months postpartum. To be included in this study you must be willing to provide your email address so that we can send you a survey at each time point. The survey is completely voluntary and should take you no longer than 10-15 minutes at each time point to complete. If you would like to take part in this exciting research opportunity, please enter your contact information in the following screen and a survey will be sent to you by email within 2 weeks.

1a. Would you be willing to be contacted by email to complete the survey? ***(Please check one.)***

-Yes

-No

If Yes, they are redirected to a separate web page to enter contact information.

<u>F. Instructions</u>

First, we have a few questions about your **MOST RECENT PREGNANCY IN THE PAST 5 YEARS**. Please keep this pregnancy in mind while you fill out the remainder of the survey. We know it may be hard to remember, but please do your best!

<u>G. Most recent pregnancy in past 5 years</u>

2. Was this child part of a multiple (i.e., twins, triplets, etc.) pregnancy? ***(Please select one.)***

-Yes

-No

If Yes:

Thank you for your willingness to participate!

Due to the nature of having more than one child in a pregnancy, we would like to contact you in a separate survey. This will allow us to better determine the effects of exercise on a multiple birth pregnancy (ex. twins, triplets, etc.). To be included in this study you must be willing to provide your email address so that we can send you a survey by email. The survey is completely voluntary and should take approximately 20-30 minutes to complete. If you would like to take part in this exciting research opportunity, please enter your contact information in the following screen and a survey will be sent to you by email within 2 weeks.

2a. Would you be willing to be contacted by email to complete this study? ***(Please check one.)***

-Yes

-No

If Yes, they are redirected to a separate web page to enter contact information.

3. What was your age on the date of delivery of your most recent pregnancy in the past 5 years? ***(Please select the number of years.)***

-Drop down box of choices ranging from: 18-60 in 1 year increments

4. In the month before you knew you were pregnant, about how much did you weigh without shoes? ***(Please type in the number of pounds.)***

-Text box

5. During your pregnancy, about how much total weight did you gain? ***(Please type in number of pounds gained.)***

-Text box

6. In the 3 months before pregnancy, how many cigarettes did you smoke each day? ***(Please select one.)***

-Drop down box of choices ranging from: 0-24 cigarettes in 1 cigarette increments, then 1 pack to 3 packs or more in 0.5 pack increments

6a. Did you quit smoking once you became pregnant? ***(Please select one.)***

-Yes
-No
-No, but I cut back

7. In the 3 months before pregnancy, how often did you drink beer, wine, hard liquor, or mixed drinks? ***(Please select one.)***

-Drop down box of choices ranging from: Never, 1-2 times each month, 1 day/week to 7 days/week in 1 day/week increments

7a. When you did, how many drinks did you have? ***(Please check one.)***

1 2 3 4 5 6 7 8 or more

7b. Did you stop drinking once you found out you were pregnant? ***(Please check one.)***

-Yes
-No
-No, but I cut back

8. How often did you eat any of the following: carrots, green salad, potatoes (not including French fries, fried potatoes, or potato chips), or vegetables? ***(Please select number of***

servings/day. One serving from the vegetable group would be 1 cup of raw or cooked vegetables or vegetable juice, or 2 cups of raw leafy greens. For example, a serving of vegetables at both lunch and dinner would be two servings.)

-Drop down box of choices ranging from: 0 to 11 or more in 0.5 serving increments

9. How often did you eat fruit or drink fruit juices (such as orange, grapefruit, or tomato)? ***(Please select number of servings/day. One serving from the fruit group would be 1 cup of fruit or 100% fruit juice, or ½ cup of dried fruit. For example, a serving of fruit at both lunch and dinner would be two servings.)***

-Drop down box of choices ranging from: 0 to 11 or more in 0.5 serving increments

10. During your pregnancy, did a doctor or health care worker ever tell you that you had any of the following medical conditions? ***(Please check the most appropriate box.)***

	Yes	No	Don’t Know
Gestational Diabetes Mellitus ("Diabetes")			
Pregnancy-Induced Hypertension or Preeclampsia ("High Blood Pressure")			
Pre-term labor requiring bed rest			
Pre-term labor requiring medication			
Pre-term birth ("Birth less than 37 weeks gestation")			

11. Did your pregnancy end in a miscarriage? ***(Please check one.)***

-Yes
-No

12. About how many weeks were you pregnant with your child at the time of delivery? Please give your best estimate. A term pregnancy is about 38-42 weeks long. ***(Please select the number of weeks.)***

-Drop down box of choices ranging from: 1 to 45 or more in 1 week increments

13. How much did your child weigh at birth? ***(Please enter the weight in pounds and ounces.)***

(pounds): Text box
(ounces): Text box

14. How long was your child at birth? ***(Please enter length in inches.)***

-Text box

15. What was your child's head circumference at birth? ***(Please select circumference in centimeters.)***

-Drop down box of choices ranging from: Don't Know, 20 or less, 21 to 50 or more in 1 cm increments

16. What were your child's APGAR scores? APGAR scores are used by doctors as a simple way to quickly determine the health of a new born infant. They refer to Appearance, Pulse, Grimace, Activity, and Respiration. Generally scores that are below 3 are considered "critically low," scores between 4-6 "fairly low," and above 7 generally "normal." ***(Please check the correct score.)***

First APGAR (at minute 1) Likert Scale from 0 to 10 and Don't Know
Second APGAR (at 5 minutes) Likert Scale 0 to 10 and Don't Know

17. What is the sex of your child? ***(Please check one.)***

-Male
-Female

18. How was your child born? ***(Please check one.)***

-Cesarean Section (C-Section)
-Vaginally

18a. Was your Cesarean Section (C-Section):

-Elective
-Emergency

19. Did your doctor use forceps to deliver your baby? ***(Please check one.)***

-Yes
-No

20. About how long was your labor? ***(Please select one.)***

-Drop down box of choices ranging from: 30 minutes or less to 36 hours in 30 minute increments, and 36 hours or more

21. During your delivery, did you have an epidural? ***(Please check one.)***

-Yes
-No

22. How would you best describe your child's race? ***(Please check all that apply.)***

-White

-Hispanic or Latino
-Black or African American
-Asian
-Native Hawaiian or Pacific Islander
-American Indian, Alaska Native
-Multiracial (Having parents of more than one race)
-Member of race not listed above

22a. If member of race not listed above, please specify.
-Text box

23. What is your child's age currently? ***(Please select best option.)***
-Drop down box of choices ranging from: 1 week to 8 weeks in 1 week increments, 3 months to 24 months in 1 month increments, 3 to 5 years in 1 year increments

24. How much does your child weigh currently? ***(Please enter the weight in pounds and ounces.)***
-Pounds: Text box
-Ounces: Text box

25. How long/tall is your child currently? ***(Please select length/height.)***
-Feet: Drop down box of choices ranging from: 0 to 5 in 1 foot increments
-Inches: Drop down box of choices ranging from: 0 to 11 in 1 inch increments

H. Exercise and Pregnancy Questions.
Now we will ask questions about your exercise levels **DURING YOUR MOST RECENT PREGNANCY**. We will be asking about 5 different time points: 1) the month before you knew you were pregnant, 2) first trimester, 3) second trimester, 4) third trimester, and 5) the past 30 days. We know it may be hard to remember, but please do your best!

I. Definitions
We will define some of the terms and categories of exercise we will be asking you about here.

Definitions:
Exercise: a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness (i.e., Cardiovascular endurance, Body composition, Muscular strength, Muscular endurance, and Flexibility)

Leisure time: time that is free from duties or responsibilities, such as lunch breaks or time away from work, including work breaks and lunch hours

Next, you will be asked to complete questions regarding your exercise habits during pregnancy. Please read the following categories to determine which categories best describe the types of exercise/s you did.

Categories of Exercises

o**Yoga**

o**Pilates**

o **Resistance training**: physical activities specifically designed to strengthen your muscles such as lifting weights, weight machines, resistance bands, kettlebells, or free weights

o **Strengthening exercises using your body weight as resistance**: activities such as sit-ups, push-ups, stability/exercise ball

o **Aerobic/Cardio exercises**: activities that cause your heart to beat faster than usual; using the body's large muscles to move in a rhythmic manner for a sustained period of time, for example brisk walking, running, bicycling, jumping rope, and swimming.

o **Light intensity**: caused a very light sweat or only a very slight increase in breathing or heart rate; equivalent in effort to a slow walk

o **Moderate intensity**: caused only a light sweat or a slight to moderate increase in breathing or heart rate; equivalent in effort to a brisk walk

o **Vigorous intensity**: caused heavy sweating or large increases in breathing or heart rate; activities done to burn calories or maintain fitness; equivalent in effort to running or jogging

o **Flexibility/Stretching**

o **Group exercise classes** such as aerobics, step, water aerobics, or zumba

o **Home exercise classes** on videotape or DVD

J. Exercise Suggestions/Advice

26. Did you talk with your doctor or health care provider about exercising? ***(Please check one.)***

-Yes
-No

27. Was your doctor/health care provider supportive of you exercising? ***(Please check one.)***

-Yes
-No

28. Did your doctor/health care provider make any suggestions to you? ***(Please check one.)***

-Yes
-No

29. Please describe what your doctor/health care provider told you. (Please describe in 250 words or less).

-Text box

30. If your doctor/health care provider made any suggestions or gave you advice, how much of it did you follow? ***(Please check one.)***

-None of the suggestions/advice
-Some of the suggestions/advice
-Most of the suggestions/advice
-All of the suggestions/advice

K. Exercise during the 30 DAYS BEFORE YOU KNEW YOU WERE PREGNANT

We will now ask questions regarding exercise during the **30 DAYS BEFORE YOU KNEW YOU WERE PREGNANT**

31. While exercising, during your leisure-time, did you take a yoga class? ***(Please check one.)***

-Yes
-No

31a. How often did you take a yoga class per week? ***(Please check the number of times per week.)***

1 2 3 4 5 6 7 8 or more

31b. On those days when you did yoga, about how long did you spend doing this each time? ***(Please select the average number of minutes for each session.)***

-Drop down box of choices ranging from: 5 to 120 minutes in 5 minute increments

31c. When you did yoga, did you consider this to be your aerobic/cardio exercise? *(Please check one.)*

-Yes
-No

31d. When you did yoga, did you consider this to be your resistance training/strength training exercise? *(Please check one.)*

-Yes
-No

31e. When you did yoga, did you consider this to be your flexibility/ strengthening exercise? *(Please check one.)*

-Yes
-No

32. While exercising, during your leisure-time, did you take a pilates class? *(Please check one.)*

-Yes
-No

32a. How often did you take a pilates class per week? *(Please check number of times per week.)*

1 2 3 4 5 6 7 8 or more

32b. On those days when you did pilates, about how long did you spend doing this each time? *(Please select the average number of minutes for each session.)*

-Drop down box of choices ranging from: 5 to 120 minutes in 5 minute increments

32c. When you did pilates, did you consider this to be your aerobic/cardio exercise? *(Please check one.)*

-Yes
-No

32d. When you did pilates, did you consider this to be your resistance training/ strength training exercise? *(Please check one.)*

-Yes

-No

32e. When you did pilates, did you consider this to be your flexibility exercise? *(Please check one.)*

-Yes
-No

33. Did you do any resistance training? That is, exercises specifically designed to strengthen your muscles such as lifting weights, weight machines, resistance bands, kettlebells, or free weights? Please do NOT include yoga and pilates which you have already told me about. *(Please check one.)*

-Yes
-No

33a. How often did you do resistance training? ***(Please check number of times per week.)***

1 2 3 4 5 6 7 8 or more

33b. On those days when you did resistance training, about how long did you spend doing this each time? ***(Please select the number of minutes in each session.)***

-Drop down box of choices ranging from: 5 to 120 minutes in 5 minute increments

33c. Which best describes your resistance training? ***(Please check one.)***

-Resistance training to improve muscular endurance, that is using lower weights with higher repetitions (reps)
-Resistance training to improve muscular strength, that is using higher weights with lower repetitions (reps)

33d. When thinking about resistance training, what was your most frequent type? *(Please check one.)*

-Free weights
-Weight machines (such as Nautilus, LifeFitness, Star Trac and Precor)
-Resistance bands
-Kettlebells

33e. When thinking about resistance training, what was your second most frequent type? ***(Please check one.)***

-Did not have a second exercise type
-Free weights

-Weight machines (such as Nautilus, LifeFitness, Star Trac and Precor)
-Resistance bands
-Kettlebells

33f. When thinking about resistance training, what was your third most frequent type? (*Please check one.)*

-Did not have a third exercise type
-Free weights
-Weight machines (such as Nautilus, LifeFitness, Star Trac and Precor)
-Resistance bands
-Kettlebells

33g. When thinking about resistance training, what was your fourth most frequent type? (*Please check one.)*

-Did not have a fourth exercise type
-Free weights
-Weight machines (such as Nautilus, LifeFitness, Star Trac and Precor)
-Resistance bands
-Kettlebells

34. Did you do any strengthening exercises that involved using your body weight as resistance such as situps, push-ups, or stability/exercise ball exercises? Please do NOT include yoga and pilates which you have already told me about. *(Please check one.)*

-Yes
-No

34a. How often did you do strengthening exercises using your body weight? *(Please check number of times per week.)*

1 2 3 4 5 6 7 8 or more

34b. On those days when you did strengthening exercises using your body weight, about how long did you spend doing this each time? *(Please select the number of minutes in each session.)*

-Drop down box of choices ranging from: 5 to 120 minutes in 5 minute increments

34c. When thinking about strengthening exercises using your body weight, what did you do most often? *(Please check one.)*

-Sit-ups and push-ups, etc.
-Stability/Exercise ball exercises

34d. When thinking about strengthening exercises using your body weight, what was did you do second most often? *(Please check one.)*

-Did not have a second exercise type

-Sit-ups and push-ups, etc.

-Stability/Exercise ball exercises

35. While exercising or during your leisure-time, did you do light aerobic/cardio activities for at least 10 minutes that caused only a very light sweat or a very slight increase in breathing or heart rate? Some examples are walking for pleasure or walking your dog. Please do NOT include exercises you have already told me about. *(Please select one.)*

-Yes

-No

35a. How often did you do light aerobic/cardio activities? *(Please check the number of times per week. For example, if you took 2 slow walks/day on 5 days, you would answer 10 times/week.)*

-Drop down box ranging from: 1 to 40 or more in 1 unit increments

35b. On average, about how long did you do light aerobic/cardio activities each time? *(Please select average number of minutes in each session.)*

-Drop down box of choices ranging from: 10 to 120 minutes in 5 minute increments

36. While exercising or during your leisure-time, did you do moderate aerobic/ cardio activities for at least 10 minutes that cause only light sweating or a slight to moderate increase in breathing or heart rate? Some examples are brisk walking, bicycling for pleasure, golf, or dancing. Please do NOT include exercises you have already told me about. *(Please check one.)*

-Yes

-No

36a. How often did you do moderate aerobic/cardio activities? *(Please check number of times per week. For example, if you took 2 brisk walks/day on 5 days, you would answer 10 times/week.)*

-Drop down box ranging from: 1 to 40 or more in 1 unit increments

36b. On average, about how long did you do moderate aerobic/cardio activities each time? *(Please select number of minutes in each session.)*

-Drop down box of choices ranging from: 10 to 120 minutes in 5 minute increments

37. While exercising or during your leisure-time, did you do any vigorous aerobic/cardio activities for at least 10 minutes that caused heavy sweating or large increases in breathing or heart rate? Some examples are running, lap swimming, aerobics classes or fast bicycling. Please do NOT include exercises that you have already told me about. ***(Please select one.)***

-Yes
-No

37a. How often did you do vigorous aerobic/cardio activities? ***(Please check number of times per week. For example, if you did 2 jogs or runs/day on 5 days, you would answer 10 times/week.)***

-Drop down box ranging from: 1 to 40 or more in 1 unit increments

37b. On average about how long did you do vigorous aerobic/cardio activities each time? ***(Please select number of minutes in each session.)***

-Drop down box of choices ranging from: 10 to 120 minutes in 5 minute increments

38. Did you do any flexibility/stretching exercises? Please do NOT include exercises you have already told me about. ***(Please check one.)***

-Yes
-No

38a. How often did you do this? ***(Please check number of times per week.)***

1 2 3 4 5 6 7 8 or more

38b. On average, about how long did you do flexibility/stretching exercises? ***(Please select number of minutes in each session.)***

-Drop down box ranging from: 5 to 120 minutes in 5 minute increments

39. Did you do any group exercise classes, such as aerobics, step, Zumba, water aerobics, or Fitness on Demand? Please do NOT include exercises you have already told me about. ***(Please check one.)***

-Yes
-No

39a. How often did you do this? ***(Please check number of times per week.)***

1 2 3 4 5 6 7 8 or more

39b. On average, about how long did you do group exercise classes? ***(Please select number of minutes in each in each session.)***

-Drop down box ranging from: 5 to 120 minutes in 5 minute increments

39c. Were any of these classes specifically designed as a prenatal class? ***(Please check one.)***

-Yes
-No
-Don't Know

40. Did you do any home exercise classes, on videotape or DVD? Please do NOT include exercises you have already told me about. ***(Please check one.)***

-Yes
-No

40a. How often did you do this? ***(Please check number of times per week.)***

1 2 3 4 5 6 7 8 or more

40b. On average, about how long did you do home exercise classes? ***(Please select number of minutes in each in each session.)***

-Drop down box ranging from: 5 to 120 minutes in 5 minute increments

40c. Were any of these videos/DVDs specifically designed as a prenatal class? ***(Please check one.)***

-Yes
-No
-Don't Know

41. Considering all the exercises you answered about exercise in the 30 days before you knew you were pregnant, did you work with a personal trainer? ***(Please check one.)***

-Yes
-No

41a. How often did you work with your personal trainer? ***(Please check one.)***

-Every session
-More than half of the sessions
-Half of the sessions
-Less than half of the sessions
-Only for the initial assessment and follow-ups

L. Exercise during your FIRST TRIMESTER

Next, these questions regard exercise during the your **FIRST TRIMESTER** (generally from conception to 12 weeks)

Repeat questions 31-41

M. Exercise during your SECOND TRIMESTER

These next questions will regard your exercise during the **SECOND TRIMESTER** (generally from 12 weeks to 28 weeks)

Repeat questions 31-41

N. Exercise during your THIRDTRIMESTER

This set of questions will regard your exercise during the **THIRD TRIMESTER** (generally 28 weeks to 40 weeks)

Repeat questions 31-41

O. Exercise during the LAST 30 DAYS

This section of questions regards your exercise during the **LAST 30 DAYS**

Repeat questions 31-41

P. Exercise Habits Throughout ENTIRE Pregnancy

Please answer these next questions in relation to your exercise during your **ENTIRE** pregnancy.

42. Did your exercise routine change in frequency (days/week), length of time (minutes/session), or intensity throughout your pregnancy? ***(Please check one.)***

-Yes
-No

42a. Did the number of days per week you exercised become: ***(Please check one.)***

-More frequent
-Less frequent
-About the same frequency

42b. Did the length of time (minutes/session) become: ***(Please check one.)***

-More time (minutes) per session
-Less time (minutes) per session

-About the same time (minutes) per session

42c. Did the intensity of your exercise routine become: ***(Please select one.)***

-More intense
-Less intense
-About the same intensity

42d. Why did your exercise routine change? ***(Please briefly describe in 250 words or less.)***

-Text box

<u>Q. Physical activity during ENTIRE pregnancy</u>

These next questions pertain to your **ENTIRE** pregnancy on average. We want to know about your overall physical activity habits while you were pregnant.

Physical activity: any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal (resting) level.

<u>R. Physical activity during ENTIRE pregnancy when you were NOT at work</u>

On average, during your entire pregnancy, when you were **NOT at work**, how much time did you usually spend:

43. Preparing meals (cook, set table, wash dishes): ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

44. Dressing, bathing, feeding children while you were sitting: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

45. Dressing, bathing, feeding children while you were standing: ***(Please check one.)***

-None

- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

46. Playing with children while you were sitting or standing: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

47. Playing with children while you were walking or running: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

48. Carrying children: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

49. Taking care of an older adult: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

50. Sitting and using a computer or writing, while not at work: ***(Please check one.)***

-None

- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

51. Watching TV or a video: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-2 to almost 4 hours per day
-4 to almost 6 hours per day
-6 or more hours per day

52. Sitting and reading, talking, or on the phone, while not at work: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-2 to almost 4 hours per day
-4 to almost 6 hours per day
-6 or more hours per day

53. Playing with pets: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

54. Light cleaning (make beds, laundry, iron, put things away): ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

55. Shopping (for food, clothes, or other items): ***(Please check one.)***

-None

- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

56. Heavier cleaning (vacuum, mop, sweep, wash windows): ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

57. Mowing lawn while on a riding mower: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

58. Mowing lawn using a walking mower, raking, gardening, shoveling snow: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

<u>S. Going Places</u>

Going Places... On average, during your entire pregnancy, how much time did you usually spend:

59. During your pregnancy, how much time did you usually spend walking slowly to go to places (such as to the bus, work, visiting). Not for fun or exercise: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day

-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

60. During your pregnancy, how much time did you usually spend walking quickly to go to place (such as the bus, work, or school). Not for fun or exercise: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

61. During your pregnancy, how much time did you usually spend driving or riding in a car or bus: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 1 hour per day
-1 to almost 2 hours per day
-2 to almost 3 hours per day
-3 or more hours per day

<u>T. Physical activity during ENTIRE pregnancy AT WORK</u>

If you did not work outside the home, please answer "None" to the following questions.

On average, during your entire pregnancy, when you were **AT WORK**, how much time did you usually spend:

62. During your pregnancy, how much time did you usually spend sitting at work or in class: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 2 hours per day
-2 to almost 4 hours per day
-4 to almost 6 hours per day
-6 or more hours per day

63. During your pregnancy, how much time did you usually spend standing or slowly walking at work while carrying things (heavier than a 1 gallon milk jug): ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 2 hours per day
-2 to almost 4 hours per day
-4 to almost 6 hours per day
-6 or more hours per day

64. During your pregnancy, how much time did you usually spend standing or slowly walking at work not carrying anything: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 2 hours per day
-2 to almost 4 hours per day
-4 to almost 6 hours per day
-6 or more hours per day

65. During your pregnancy, how much time did you usually spend walking quickly at work while carrying things (heavier than a 1 gallon milk jug): ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 2 hours per day
-2 to almost 4 hours per day
-4 to almost 6 hours per day
-6 or more hours per day

66. During your pregnancy, how much time did you usually spend walking quickly at work not carrying anything: ***(Please check one.)***

-None
- Less than 1/2 hour per day
-1/2 to almost 2 hours per day
-2 to almost 4 hours per day
-4 to almost 6 hours per day
-6 or more hours per day

U. Motivations to Exercising

These next questions regard your reasons/motivations to exercise while you were pregnant.

67. What was/were your motivation/s to exercise during pregnancy? ***(Please select one for each trimester.)***

First Motivation Second Motivation Third Motivation

First Trimester

Second Trimester

Third Trimester

-Drop down box with choices: Fitness, Tone and strength, Weight control, Relieve stress, Enjoyment, Have a regular routine, Stay healthy, Be with friends/socialize, Other

67a. If other, please describe:

-Text box

68. What were the top THREE barriers that you think interfered with your ability to participate in regular physical activity during pregnancy? ***(Please select the top 3 that apply for each trimester.)***

Top Barrier Second Barrier Third Barrier

First Trimester

Second Trimester

Third Trimester

-Drop down box with choices: Lack of time/Too busy, Lack of motivation, Lack of childcare, Lack of energy/Tiredness, Pregnancy-related illness (ex. nausea), Non-Pregnancy-related illness (ex. cold/flu), On bed rest/doctor told me, Dislike exercise, Weather, Work/Worktime, Scheduling, Wanting to spend time with children, Injury, Lack of sleep, Kid preparation time, Laziness/excuses, Family demands/housework, Accessibility, Money, Boredom, Guilt, Apathy/lethargy, Felt too unwell, Exercise was not safe, Unsure what exercise was safe, Exercise was too uncomfortable, None

V. Feelings toward exercising during my pregnancy

69. Exercise during my pregnancy was: ***(Please check one number for each category.)***

Likert Scales 1-7

69a. 1 = Useless, 7 = Useful

69b. 1 = Harmful, 7 = Beneficial

69c. 1 = Bad, 7 = Good

69d. 1 = Foolish, 7 = Wise

69e. 1= Unpleasant, 7 = Pleasant

69f. 1= Unenjoyable, 7= Enjoyable

69g. 1 = Boring, 7 = Interesting

70. People who are important to me thought that I should exercise during my pregnancy. ***(Please check one number.)***

-Likert Scale 1 = Strongly Disagree, 7 = Strongly Agree

71. For me to exercise during my pregnancy was: ***(Please check one number.)***
-Likert Scale 1 = Extremely Difficult, 7 = Extremely Easy

72. If I had wanted to, I could have easily exercised during my pregnancy: ***(Please check one number.)***
-Likert Scale 1 = Strongly Disagree, 7 = Strongly Agree

73. How much control did you have over exercising during your pregnancy? ***(Please check one number.)***
-Likert Scale 1 = Very Little Control, 7 = Complete Control

74. It was my intention to exercise _____ days a week during my pregnancy. ***(Please check one number.)***
1 2 3 4 5 6 7

W. Current Maternal Questions

Lastly, we are going to ask some questions about you. Please answer these questions as they pertain to you **CURRENTLY**

75. What is your age currently? ***(Please answer in years.)***
-Drop down box with choices ranging from: 18 to 60 in 1 year increments

76. Which one of these groups would you say best represents your race? ***(Please check all that apply.)***
-White (Not Hispanic/Not Latino)
-Hispanic or Latino
-Black or African American
-Asian
-Native Hawaiian or Pacific Islander
-American Indian, Alaska Native
-Multiracial (Having parents of more than one race)
-Member of race not listed above

76a. If member of race not listed, please specify:
-Text box

77. Which one of these groups would you say best represents your marital status? ***(Please select one.)***

-Married
-Widowed/Widower
-Divorced
-Separated
-Never married
-Living with partner
-Don't know/Not sure

78. What is the highest grade or year of school you completed? ***(Please select one.)***
-Never attended school or only attended kindergarten
-Grades 1 through 8 (Elementary)
-Grades 9 through 11 (Some high school)
-Grade 12 or GED (High school graduate)
-College 1 year to 3 years (Some college or technical school)
-College 4 years or more (College graduate or post graduate degree)

79. What is your annual household income from all sources currently? ***(Please select one.)***
-Less than $10,000
-$10,000 - $14,999
-$15,000 - $19,999
-$20,000 - $24,999
-$25,000 - $34,999
-$35,000 - $49,999
-$50,000 - $74,999
-$75,000 - $89,999
-$90,000 - $104,999
-$105,000 or more
-Don't know/Not sure

80. What state do you currently live in? ***(Please select state.)***
-Drop down box with choices of each State

81. About how much do you weigh without shoes currently? ***(Please enter weight in pounds.)***
-Text box

82. About how tall are you without shoes currently? ***(Please select height in feet and inches.)***
-Feet: Drop down box with choices ranging from: 1 to 7 in 1 foot increments
-Inches: Drop down box with choices ranging from: 1 to 11 in 1 inch increments

83. How many pregnancies (live births, miscarriages, or abortions) have you had in the last five years? *(Please check one.)*

-1
-2
-3
-4
-5 or more

84. How many total children do you have currently? *(Please check one.)*

-0
-1
-2
-3
-4
-5
-6
-7 or more

85. How long would you consider yourself to be a regular exerciser? *(Please select number of years.)*

-Drop down box with choices ranging from: Less than 1 year, 1 to 36 or more years in 0.5 year increments

86. How long have you been a member of Anytime Fitness? *(Please select number of years.)*

-Drop down box with choices ranging from: Less than 1 year, 1 to 36 or more years in 0.5 year increments

87. Is there anything you think we should know and did not ask you about regarding exercise during your pregnancy? Please feel free to share with us anything you think is relevant to this questionnaire but did not ask. *(Please type your response in less than 500 words.)*

-Text box

88. Would you be willing to be contacted for future follow-up studies? If you choose yes, you will be redirected to another web page so your answers are not linked to your name. *(Please check one.)*

-Yes
-No

If Yes:

Please click on "Done" to be redirected to another web page for you to complete your contact information.

If No:
Directed to next page.

<u>X. Thank you!</u>

Thank you for participating in this groundbreaking research! Your help is greatly appreciated! You have successfully completed the survey. Please close the browser window to exit.
If you have any questions, comments, or concerns regarding the study, please contact Erin Kuffel, M.S. (kuffeler@msu.edu) or James Pivarnik, Ph.D. (jimpiv@msu.edu).

The current physical activity guidelines for women during pregnancy and the postpartum period:

Healthy women who are not already highly active or doing vigorous-intensity activity should get at least 150 minutes (2 hours and 30 minutes) of moderate-intensity aerobic activity per week during pregnancy and the postpartum period. Preferably, this activity should be spread throughout the week.

Pregnant women who habitually engage in vigorous-intensity aerobic activity or are highly active can continue physical activity during pregnancy and the postpartum period, provided that they remain healthy and discuss with their health-care provider how and when activity should be adjusted over time.

For more information please visit:
<u>http://www.health.gov/paguidelines/guidelines/chapter7.aspx</u>

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REFERENCES

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