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VALIDATION OF A HISTORICAL PHYSICAL ACTIVITY RECALL TOOL; THE EFFECTS OF PAST PREGNANCY PHYSICAL ACTIVITY ON CURRENT PHYSICAL ACTIVITY, BARRIERS TO PHYSICAL ACTIVITY, AND BODY SIZE

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ABSTRACT

VALIDATION OF A HISTORICAL PHYSICAL ACTIVITY RECALL TOOL; THE EFFECTS OF PAST PREGNANCY PHYSICAL ACTIVITY ON CURRENT PHYSICAL ACTIVITY, BARRIERS TO PHYSICAL ACTIVITY, AND BODY SIZE

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Physical activity (PA) is a key element of health promotion and disease prevention. Historically, PA was not universally recommended for pregnant women due to limited research and fear of unknown risks to the mother and fetus. However, recent studies have shown PA to have positive effects on a healthy pregnancy, as well as the postpartum period. Methodology for assessing PA has not been consistent among studies; therefore comparing results has been difficult. Current research has focused on an individual's ability to recall historical PA, and relate this behavior to current disease states. Using historical recall to assess past pregnancy PA could assist with determining the relationship between pregnancy and long-term weight changes.

This investigation involved a six-year follow-up of a cohort of women who participated in a previous research study (Maternal Activity Measurement and Assessment study). Fifty-six women had their PA energy expenditures quantified carefully throughout pregnancies from between 1997-1999. Thirty of these women agreed to participate in follow-up research. The purposes of this study were to evaluate the ability of women to recall their PA during three time points previously assessed during a pregnancy six years ago (20 weeks gestation, 32 weeks gestation, 12 weeks postpartum); and to examine the effects of past pregnancy PA on current body size, PA levels, and barriers to exercise. The Modifiable Activity Questionnaire (MAQ) was used

to assess current and past pregnancy PA. The Perceived Barriers Efficacy Questionnaire (PBEQ) was used to assess current barriers to PA and percent confidence in overcoming those barriers.

Results showed the MAQ values to be significantly related to the original physical activity recall (PAR) values at all time periods of interest. Correlations from this study are similar (r=0.57-0.86) to those found in previous PAR and MAQ validation studies. The women's ability to recall past pregnancy PA did not differ based on current PA.

The median value for postpartum weight retention (PPWR) was 2.8 kg with a wide individual range. When separated into current PA level groups ($\geq$ or $\leq$ 20 MET/wk), the more active women showed significantly lower weight, BMI and %fat, and PPWR values compared to the less active women. A significant inverse relationship was found between current PA and BMI (r=-0.55) and %fat (r=-0.70). Past pregnancy PA was found to be correlated with current PA at all time points of interest [20 weeks gestation (r=0.49), 32 weeks gestation (r=0.71), and 12 weeks postpartum (r=0.73)]. Further analysis showed current PA to be the proximate cause of current body size; though it is likely past pregnancy PA behaviors may influence current PA levels. The top three barriers (and their frequencies) were time (22), motivation (7), and childcare (6). Average percent confidence score for overcoming these barriers was 65.6 % (±24.5).

Overall, the MAQ was found to be an accurate PAR for past pregnancy PA. Sixty percent of women studied met current CDC/ACSM PA guidelines. Both recalled and current PA were shown to be related to percent confidence in overcoming barriers to PA. Future studies should use larger heterogeneous samples and include longer follow-up.

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KEY TO ABBREVIATIONS

ACOG	American College of Obstetricians and Gynecologists
ACSM	American College of Sports Medicine
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
CDC	Center for Disease Control and Prevention
EE	Energy Expenditure
EKG	Electrocardiogram
FFM	Fat Free Mass
IAQ	Interviewer Administered Questionnaire
IOM	Institute of Medicine
LBW	Low Birth Weight
LTPA	Leisure Time Physical Activity
MAMA	Maternal Activity Measurement and Assessment
MAQ	Modifiable Activity Questionnaire
MET	Metabolic Equivalent
NIDDM	Non-Insulin Dependent Diabetes Mellitus
PA	Physical Activity
PAR	Physical Activity Recall
PBEQ	Perceived Barrier Efficacy Questionnaire
PPWR	Postpartum Weight Retention
SAQ	Self-Administered Questionnaire
SE	Self-Efficacy

SES	Socioeconomic Status
SPAWN	Stockholm Pregnancy and Women's Nutrition
WIC	Women Infant and Children program

CHAPTER 1
Introduction

Background

Physical activity (PA) significantly impacts health promotion and disease prevention. Benefits of a physically active lifestyle include reduced risk of chronic disease, increased overall physical and mental well being, and enhanced weight management (Surgeon General's Report, 1996). The Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) suggest 30 minutes of moderate activity most days of the week for health benefits (Pate et al., 1995). The American College of Obstetricians and Gynecologists (ACOG) recently updated their guidelines for exercise during pregnancy to incorporate these CDC/ACSM PA recommendations (ACOG, 2002).

Historically, PA was not universally recommended for pregnant women due to limited research and fear of unknown risks to the mother and fetus. In recent decades, research has shown exercise during pregnancy should rarely be contraindicated, but rather, may be beneficial for both mother and child (Johnston, 1991; Clapp, 2000; Larsen-Meyer, 2002; Wang, 1998). Maternal benefits include improved cardiac function, limited weight gain and fat retention, improved mental state, improved fitness, and less complicated labor. Fetal benefits may include improved stress tolerance and enhanced neurobehavioral maturation (Clapp, 2000).

Proposed benefits of PA during the postpartum period include reduction of excessive weight retention/gain, improvements in aerobic fitness and insulin sensitivity, increased bone mineral density, and enhanced psychological well-being (Larsen-Myer, 2002). Data from a longitudinal study of factors that affect weight changes during and after pregnancy support the notion that return to pre-pregnancy weight is most likely to occur in women who implement healthy exercise habits (Ohlin and Rossner, 1996). The prevalence of physical inactivity is high among culturally diverse segments of the U.S. population including low-income groups, the elderly, and women (Surgeon General's report, 1996). Life events unique to pregnancy and the postpartum period may place women at greater risk for decreased PA compared to men (Downs and Hausenblaus, 2004).

During the postpartum period women may initiate lifestyle changes with a renewed focus on weight loss. Conversely, changes in activity behavior toward a more sedentary lifestyle due to family obligations may result in higher weight retention after pregnancy. Thus, weight retained from a pregnancy can remain indefinitely and may increase a woman's risk of becoming overweight or obese (Greene et al., 1988; Rookus, 1987; Rooney and Schauberger, 2002). The relationship between pregnancy and body weight changes is complex and not well-understood. It is affected by lifestyle factors before and after pregnancy such as eating behavior, PA, smoking, and breastfeeding status (Linne, 2002). Methodology for assessing these variables, especially PA, has not been consistent among studies; therefore comparing results can be difficult.

PA can be measured in many different ways in field studies including, heart rate monitoring, accelerometry, and physical activity recall (PAR) (Montoye and Taylor, 1984). Each method has advantages and disadvantages with respect to cost, reliability, and practicality with large study samples. Valid assessment of PA during pregnancy and the postpartum period is essential for presenting and interpreting findings from studies of the role of PA on weight gain and retention. To better obtain more complete data, PAR tools are now being used to assess historical or lifetime PA. Studies using historical PAR can give insight into the effect of lifetime or past PA on current disease status or risk. However, there is strong reliance on a participant's ability to recall past information with historical PA studies and true validation is difficult because in most cases, past PA was not measured at the time it was performed.

PA participation is a lifestyle factor that can be a target for intervention studies aimed at postpartum weight retention (PPWR). Self-efficacy (SE) is one of many factors that can affect PA participation. SE beliefs are defined judgements concerning a person's ability to perform specific tasks in the face of obstacles to produce a given outcome (McAuley, 1992). SE beliefs for exercise are important due to their significant role in a person's decision, effort, and persistence to continue to exercise (Feltz, 1988). For example, Miller et al. (2002) found that SE affected the PA behaviors of mothers with small children. The connections between SE factors, PA, and PPWR have not been directly addressed. New information will help health care and exercise professionals to determine the best intervention strategies to address the changes in lifestyle factors that occur during the child-bearing years.

Study Summary

This investigation involves a six-year follow-up of a cohort of women who participated in a previous research study (Maternal Activity Measurement and Assessment study [MAMA]) (Pivarnik et al., 2002; Stein et al., 2003). Fifty-six women were studied meticulously throughout pregnancy, and their PA behaviors were carefully assessed. Thirty of these women agreed to participate in follow-up research.

This dissertation is divided into two parts, each consisting of a literature review and a manuscript. Some parts of the dissertation, especially the methods sections, will be somewhat repetitive, but should assist in reading comprehension.

Part I focuses on the ability of a woman to recall PA that occurred during a pregnancy six years ago. Current PAR tools allow researchers to assess historical PA levels. The strength of this portion of the dissertation is that we can assess the validity of one such tool by comparing the study participants' recall to actual data collected during the pregnancy five years ago. Part I includes chapters 2 and 3. Chapter 2 is a literature review regarding physical activity, and recall using current and historical questionnaires. Chapter 3 consists of the introduction, methods, results, discussion points, and future directions for the present study.

Part II focuses on assessing current PA behaviors and anthropometrics of the study participants. New findings are compared to data collected previously during the original MAMA study, while also addressing barriers that may affect current PA behaviors. Part II includes chapters 4 and 5. Chapter 4 is a literature review regarding physical activity during pregnancy and postpartum weight retention. Chapter 5 consists of the introduction, methods, results, discussion points, and future directions for the present study.

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CHAPTER 2
Validation of an historical physical activity recall tool

Introduction

The Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) recommend that every American participate in moderate physical activity (PA) for greater than or equal to 30 minutes on most if not all days of the week (Pate et al., 1995). According to Healthy People 2010, PA is the number one leading health indicator targeted for improvement, due to its relationship with all the major chronic diseases (www.healhtypeople2010.gov). Physical activity is defined as any body movement produced by contraction of skeletal muscle that results in energy expenditure (Casperson, Powell, and Christenson, 1985). According to Casperson et al, everyone performs PA in order to sustain life; however, the amount is mostly dependent on personal choice and can vary greatly between different people as well as for the same person over time (Casperson, Powell, and Christenson, 1985). In a 1984 review by Montoye and Taylor of current "state of the art" assessments of habitual PA, the authors stated that physical activities can be divided into those performed on the job (occupational) and those performed during leisure time (Montoye and Taylor, 1984). The authors believed that during the latter part of the twentieth century, leisure time activity should be considered the most important source of energy expenditure beneficial to long term health. Leisure time physical activity (LTPA) was labeled as the only volitional, off the job pursuit that differentiates people on the basis of PA (Montoye and Taylor, 1984).

Physical Activity and Chronic Disease

In the 1980's, results from two large longitudinal studies evaluating PA and chronic disease (The Harvard Alumni and The Framingham Study), were published.

These large longitudinal cohort studies continue to follow groups of people for 20 years or more and assess the effects of PA on cardiovascular health as well as mortality and morbidity (Paffenbarger et al., 1984; Paffenbarger et al., 1986; Kannel et al., 1986). These studies have played a strong role in our current understanding of long-term PA benefits.

In 1986, Paffenbarger et al. published a paper evaluating the role of PA in all-cause mortality and longevity in college alumni. Men who entered Harvard University through the years 1916-1950 were recruited to participate. Personal and lifestyle characteristics data were recorded for over 16,000 men, with follow-up data on cause of death and estimated length of life also collected (Paffenbarger et al., 1986). The authors found that death rates declined steadily as energy expended on activity increased from 500-3500 kcal per week, beyond which rates increased slightly. Death rates were one quarter to one third lower among alumni expending 2000 or more kcal per week than among those who were sedentary. In general it was concluded that alumni mortality rates were significantly lower among the physically active (Paffenbarger et al., 1986).

The Framingham Study began in 1948, following a cohort of 520 people from a community in Massachusetts biennially to track the development of cardiovascular morbidity and mortality. In 1986, Kannel et al. published a paper from the Framingham study, examining physical activity and physical demand on the job and risk of cardiovascular disease and death (Kannel et al., 1986). The overall results showed active persons, as assessed by a 24-hour physical activity index, lived longer and suffered less cardiovascular mortality. The cardiovascular and coronary heart disease mortality improved with increasing level of PA at all ages, including the elderly (Kannel et al., 1986).

In a summary of a workshop on public health aspects of PA and exercise, Powell and Paffenbarger (1987) noted the beneficial effects of PA were becoming more apparent as the amount of research increased during the 1980's. Ten scientific papers regarding PA and health were presented and conclusions about the benefits of exercise were made. Topics ranged from epidemiologic research issues regarding physical activity to disease-specific benefits and risks, mental health, and promotion. Based on the presentations, it was concluded that while physically active individuals were at lower risk for coronary heart disease than less active persons, PA is a complex behavior for which there is no standard measurement (Powell and Paffenbarger, 1987; Casperson, Powell, and Christenson, 1985; LaPorte, Montoye, and Casperson, 1985: Siscovick, LaPorte, and Newman, 1985; Iverson et al., 1985).

The Nurses Health Study was a large cohort study initiated in 1976, designed to evaluate health behaviors of female registered nurses. Participants initially completed a mailed questionnaire and every two years follow-up questionnaires were sent to obtain updated information on potential risk factors and identify newly diagnosed cases of coronary heart disease or other illnesses (Manson et al., 1999). In a prospective study by Manson et al. (1999), the association between total PA, walking, and vigorous exercise and the incidence of coronary events was examined using approximately 72,000 female nurses who were 40-65 years of age in 1986. Results showed a strong graded inverse relationship between PA and the risk of coronary events. Sedentary women who became active in middle adulthood or later had a lower risk of coronary events than their counterparts who remained sedentary. The authors concluded that brisk walking and vigorous exercise were associated with substantial and similar reductions in the incidence of coronary events among women (Manson et al., 1999).

Physical Activity Measurement

To truly understand the role of physical activity in the prevention of chronic disease it is important to ensure that PA measurement is accurate. In a review article about the spectrum of PA, cardiovascular disease and health, LaPorte et al. (1984) noted a lack of framework from which to measure physical activity, especially in epidemiologic studies. The authors stated that in order to minimize PA measurement errors, assessments must be valid, specific, reproducible, quantitative, practical, and inexpensive (LaPorte et al., 1984). In a similar article regarding methodologic issues in measuring PA and physical fitness, Haskell and Kiernan stated that the two are complex entities comprised of numerous diverse components that present a challenge in terms of accurate, reliable measurement (Haskell and Kiernan, 2000). PA can be assessed by a variety of questionnaires, diaries and logs, and by monitoring body movement or physiological responses. The selection of the measurement method depends on the purpose of evaluation, nature of the study population, and resources available (Haskell and Kiernan, 2000). Surveys are often used because of practicality and low cost of assessing PA in large populations. Recall surveys have been used for time frames ranging from one day to lifetime PA. Either precise details about PA and/or general estimates can be obtained for the time frame of interest (Haskell and Kiernan, 2000).

In 1986, Washburn and Montoye published a review on the assessment of PA by questionnaire (Washburn and Montoye, 1986). Typical PA questionnaires require recall of specific physical activity behaviors and can be immediate, by subjects maintaining a detailed activity diary, or delayed, where individuals are asked to recall PA over a specific time period. Delayed recall has been deemed the most practical and least burdensome method, therefore is most commonly used (Washburn and Montoye, 1986). The review assessed the validity, reliability, practicality, and relationship to disease of several commonly used PA recall tools during that time period. Major survey differences exist in the complexity of the questionnaires, time to completion, detail of recall expected, time frame assessed, and type of measurement scale from which to determine the outcome (Washburn and Montoye, 1986). Lack of a criterion assessment tool makes adequate validation of PA questionnaires difficult. To help with the validity and reliability of a PA recall questionnaire, the researcher must consider population size, amount of detail required for data analysis, as well as age, sex, socioeconomic status, and racial make up of the target population (Washburn and Montoye, 1986). Since questionnaires may be used to gather a variety of information from many diverse groups, understanding the target population and pre-determining the outcomes of interest are important steps in the instrument creation process. The validity and reliability of each questionnaire then must be tested and documented before wide-spread use is acceptable.

Physical Activity Recall (PAR) validation and reliability studies

PAR tools have been used to examine the relationship between activity and chronic diseases for more than 50 years. In 1962, Wessel, Montoye, and Mitchell developed a PAR record and format to score activity questionnaires. During the fall and winter of 1962-63 100 men and women completed the Self-Administered Questionnaire (SAQ). Activity categories included occupational, leisure time, and combined. At this time, an appointment was made for a meeting with a trained interviewer. An Interviewer

Administered Questionnaire (IAQ) was then completed. Once the two administration techniques were completed, three judges independently reviewed the responses and classified the participant as very active, active, moderate, or light and the responses from the SAQ and IAQ were compared (Wessel, Montoye, and Mitchell, 1965). The results indicated that there was greater agreement when classifying women into activity groups than men, and that the SAQ form was more satisfactory in classifying women than men. Even with those promising results, disagreements existed in classifying both genders in all categories. The authors noted that vague questions and point scale were the main reason for disagreements, and concluded further work was needed in developing the tool and scoring format (Wessel, Montoye, and Mitchell, 1965).

In 1967 the SAQ was revised as used as a part of the Tecumseh Community Health Study (Reiff et al., 1967). The preliminary attempt to assess PA by self-administration encountered some of the same misinterpretation problems as the original SAQ. Therefore, the authors concluded that a personal interview may be necessary to obtain accurate estimates. Questions were designed to gather information regarding occupation, hours worked, transportation to and from work and participation in major home repairs and maintenance. Leisure time sports, gardening and other physical activities were checked on a list. Intensities for different physical activities as well as energy expenditure values were collected and calculated. The overall results show the revised interview administered questionnaire was easier to use and score (Reiff et al., 1967).

Many more efforts were undertaken to create PA questionnaires after the earlier attempts in the 1960's and 70's. However, questions about their reliability and validity remained. In 1984, Taylor et al. compared a seven-day activity recall tool, a self-report PA log and direct PA measurement (Vitalog, minicomputer) to identify bias that might exist among the three instruments (Taylor et al., 1984). Thirty White males from 34-69 years of age were recruited to participate. Some were members or cardiac rehabilitation programs while the majority participated in an unsupervised YMCA exercise program. All subjects completed daily self-report PA logs and underwent the seven-day interview administered recall. Fifteen subjects the Vitalog, for the first three of the seven day report and recall periods (Taylor et al., 1984).

The self-report log was designed to be compatible with the recall, and required subjects to rate their activities on a scale from light, to very hard and note the type and duration of activity. The recall was administered by a trained interviewer and could be completed in approximately 15 minutes. Subjects were asked to recall the types of activities in which they participated, as well as estimate total hours spent in moderate, hard, and very hard activities based on examples provided. The Vitalog monitor uses three chest electrodes to monitor heart rate via R-R wave detection, as well as a mercury motion sensor to detect body movement (Taylor et al., 1984).

The recall data were compared with the YMCA attendance logs for 10 subjects. Correlations between the self-report and recall PA data were strongest for very hard weekend activity (r=0.90) and weakest for hard and very hard weekday activity (r=0.39), but all values were significant at $P = \leq 0.05$. Twenty-six classes were noted by the YMCA log, all but two were reported by recall. Overall agreement between the self-report and Vitalog frequency of episodes of moderate, hard, or very hard activity was 94%. The authors concluded that a seven-day recall accurately reflects mean energy expenditure. They noted each method had advantages and disadvantages, but ease of use and lower cost of the recall may give it the greatest potential for applicability to population studies (Taylor et al., 1984).

In the 1990's, other recall tools were analyzed for reliability and validity. Examples included the Tecumseh, the Five-City, and the Minnesota Leisure Time Physical Activity questionnaires. Ainslie et al. (2003) examined the correlations between these questionnaires and the gold standard of doubly labeled water. The overall results showed that the Tecumseh (r=0.64) and Minnesota Leisure Time Physical Activity (r=0.74) validation studies, but not the Five City Questionnaire (r=0.42), showed significant agreement with doubly labeled water. Noted advantages of the recall instruments included short time needed to complete the questionnaire, simple scoring systems, low cost, ability to study large samples, and unlimited duration of use. The authors concluded that the preferred method to determine energy expenditure principally depends on factors such as the number of subjects, time period of measurement, and finances available (Ainslie et al., 2003).

In 2001, Norman et al. conducted a study analyzing the validity and reproducibility of self-reported total PA indexed by BMI. One-hundred and eleven men, aged 47-78, completed a questionnaire and activity records. The questionnaire was sent twice a year, and included questions on level of PA at work, hours per day of walking/biking, home/household work, leisure time activity/inactivity, and sleeping. Two seven-day activity records, performed six months apart, were used as the reference method. Results showed significantly higher validity correlations for self-report in men below, versus above a BMI of 26 (Norman et al., 2001).

Historical PARs

In 1991, Blair et al. assessed the reliability of long-term PA participation recall by middle-aged men and women enrolled in a worksite health study. LTPA was assessed at baseline, and energy expenditure spent in total, light, moderate, and vigorous activities was calculated. The long-term recall of baseline LTPA was determined one to ten years after the examination (Blair et al., 1991). Correlations were modest (ranging from r=0.20-0.50) and percent agreement was 60-75% between baseline and recalled activity. Multiple regression analysis suggested that recalled activity was a significant predictor of baseline activity, but recall interval and age were not important. The authors concluded that questionnaire assessment of long-term PAR appeared reliable, length of recall interval up to ten years was not an important factor, and that individuals were better able to recall vigorous, compared to less intense activities (Blair et al., 1991).

In 1997, Torgen et al. (1997) published the results from a study that evaluated the reproducibility of a questionnaire for the assessment of past and present PA. In 1970, a survey regarding requirements of medical and social services was conducted with 2500 men and women between the ages of 18-65 living in Stockholm County, Sweden. In 1993, the previous survey participants, below the age of 59 years, were asked to participate in a follow-up piece focusing on musculoskeletal function and health. Torgen et al. (1997) then investigated a sub-sample of the 1993 study population to analyze the reproducibility of the PA questionnaire data twelve months later.

Results showed the reproducibility of questions on PA at work was higher than that of during leisure time. The authors stated that reliable retrospective information about LTPA could perhaps not be collected by self-administered questionnaires and other methods such as interview-based questionnaires may be more suitable (Torgen et al., 1997).

Previous studies support the use of PA recall surveys for different time frames in similar populations, but what has not been confirmed is the reliability of PAR from the distant past. In 1999, Falkner et al. examined the quality of historical recall of PA in a cohort of western New York residents followed since 1960 in the Buffalo Health Study (Falkner et al., 1999). The Buffalo Health Study was developed in the 1950's to explore the relations between blood pressure and social, environmental, and genetic factors in a general population of randomly selected residents in Buffalo, New York. Surviving residents from the original study who were 47 years old or less represented the follow-up sample used. Two-hour recall interviews took place between August 1992 and August 1996 (Falkner et al., 1999).

Results showed that the recalled reports underestimated past weekday activities when overall activity was examined. Estimates closer to the original 1960 data were found when activity levels were examined. Both men and women were better able to recall weekday light and moderate activities. Most participants underestimated overall weekend-day activity, but males overestimated weekend-day hard activity. Correlations for weekend-day activity were highest for summer sports in females, and winter sports for both sexes. Correlations ranged from r=0.29-0.45. The authors believed that based on the length of time between the original assessment and follow-up recall interviews, the correlations were close to those from other studies where recalls were ten years or less (Falkner et al., 1999). Differences between PAR and gender may need more study based on these results. Also, with the low correlations for lower intensity activities such as walking, distant past recall might be effected by activity intensity.

In 2002, the reproducibility of self-administered lifetime PA questionnaire was assessed using a recall tool designed to assess duration, frequency, and intensity of lifetime household and recreational activity (Chasen-Taber et al., 2002). A modified version of the Historical Leisure Time Activity Questionnaire was used to assess PA of female college alumni over four time periods (menarche to 21, 22-34, 35-50, and 51-65). For assessment of questionnaire reproducibility, the PA questionnaire was repeated at the end of the subsequent year. Interclass correlation coefficients for reproducibility were r=0.82 for total PA, 0.80 for moderate lifetime activity, 0.86 for vigorous activity, 0.87 for lifetime recreational activity, and 0.78 for household activity. The authors stated that the PA questionnaire was reproducible and provided a useful measure of average lifetime activity, but also made a point that the omission of household activities, especially for women, may underestimate total activity (Chasen-Taber et al., 2002).

In 2002, Evenson et al. conducted a study involving female adult lifetime activity (Evenson et al., 2002). The Women's Health Initiative began in 1992 to investigate the effects of selected interventions and risk factors on morbidity and mortality of cancer, cardiovascular disease, and osteoporotic fractures among postmenopausal women. Evenson et al used a sub-sample of women (approximately 70,000) from the health initiative cohort to assess differences in vigorous PA at various times over the life span, assess whether reports of participation in vigorous PA were associated with self-reported current PA participation, and determine factors related to participation in vigorous PA by race/ethnicity among women (Evenson et al., 2002). A questionnaire was used to assess the women's vigorous activity behavior at ages 18, 35, 50 years. The results showed that prevalence of vigorous activity declined with age, with the largest decrease occurring after age 50 for all ethnicities. Current vigorous activity was higher among women with lower body mass indices, non-smoking, in excellent general health, and of higher socioeconomic status across ethnic groups. Based on the results, the authors suggest lower prevalence of vigorous PA in the postmenopausal period may indicate a complex of health-related attitudes and behaviors beyond race/ethnicity. The authors also stated that the pre-menopausal period may be a critical time to target interventions to help women achieve and maintain their PA into the postmenopausal period (Evenson et al., 2002).

In 2004 Bowles et al. determined the construct validity of self-reported walking, running, and jogging activity on the basis of data from the Aerobics Center Longitudinal Study (Bowles et al., 2004). Approximately 5,000 men and women underwent one or more medical examination between 1976 and 1985 and completed a follow-up questionnaire in 1986. The follow-up questionnaire assessed walking, jogging, and running along with other strenuous activities for each year from 1976 through 1985. The results indicated significant correlations between recalled walking, jogging, and running and treadmill times for each year through out the ten-year period. Engaging sufficient historical PA for health benefits was associated with higher treadmill times and lower BMIs for men and women and lower triglyceride levels for men (Bowles et al., 2004).

The establishment of certain historical recall tools has expanded the time frames from which physical activity data can be gathered. Many tools used have been created for specific populations and time periods, as suggested by Washburn and Montoye, and others. What is not known is whether there is a specific format or framework that can allow a researcher to target specific populations and time periods of interest, but work from an established base.

The Modifiable Activity Questionnaire

The Modifiable Activity Questionnaire (MAQ) is an historical physical activity recall tool designed for easy modification to maximize the investigator's ability to assess PA in a variety of populations (Kriska and Bennett, 1997). Historical PA is activity engaged in more than one-year prior to the time of assessment. The questionnaire can assess past-year and past-week occupational and leisure activities, as well as extreme levels of inactivity due to disability. The original version of the questionnaire also assessed historical activity, which was used for retrospective studies of diabetes risk.

In 1990, the MAQ was used to examine the relationship of PA and diabetes in Pima Indians (Kriska et al., 1990). The questionnaire was used to assess both historical (lifetime PA) and more current (past-week, past-year) leisure and occupational PA. The questionnaire was interviewer-administered, and included components that were deemed necessary for comprehensive PA assessment of diabetes research in Native Americans. Reproducibility of the past-year LTPA estimate was determined in 69 participants aged 10-59 years. The data were found to be reliable in all age groups with exception to the 10-14 year olds (Kriska et al., 1990). Validity of the current-activity question section was determined via comparison with activity monitors. The authors concluded that the questionnaire was found to be both reliable and feasible to use in the Pima Indian population (Kriska et al., 1990).

In 1995, the MAQ was used further to examine the associate between glucose tolerance and physical activity, but this time in middle-aged non-diabetic, multiethnic residents of Mauritius (Pereira et al., 1995). Mauritius is an island located in the southwest Indian Ocean, and it's inhabitants have a high prevalence of non-insulin dependent diabetes mellitus (NIDDM). The survey was modified for this study by expanding the occupational and leisure time activities to include popular options specific to the Mauritius population. Results showed total PA to be an independent predictor of 2-hour post-load glucose concentration after controlling for body mass, waist-hip ratio, age, and family history of NIDDM. The authors stated that the data were supportive of a potentially important role of PA in prevention of NIDDM in middle-aged inhabitants of Mauritius (Pereira et al. 1995).

Recently, the MAQ has been used as a self-administered questionnaire to assess past-year PA and compared to the interview-administered version and doubly-labeled water (Vuillemin et al., 1999). Eighty-four subjects enrolled in an ongoing prospective study completed both the self and interviewer-administered versions of the MAQ. Excellent agreement was found between the self- and interview-administered mode of the questionnaires, Spearman rank order correlations were r=0.88 and 0.92 for leisure activity. Even though agreement between the two modes of questionnaire administration was strong, the authors noted that presence of an interviewer may provide the individual with a more structured framework for his/her response and may help the subject give more information (Vuillemin et al., 1999).

Summary

Overall, the literature has shown that PA can affect cardiovascular disease risk positively, and that it is an important health related factor to measure. PA measurement has improved over the years, and the recall of current PA by different PAR questionnaires has been shown to be accurate. The ability to assess historical PA, ranging from past week to 10 years or more, may allow researchers to assess the affects of distant past and lifetime PA on disease risk and mortality. Some historical recall tools have been validated using different populations and time periods of interest.

Based on the established reliability and validity of the MAQ and the adaptability of the questionnaire format for different populations and designs, we chose to use it as a PAR tool for women five to six years postpartum. The tool has been modified to fit specific time frames of interest, second and third trimester of a pregnancy approximately six years ago, as well as twelve weeks postpartum. The instrument was modified to be used as an interview tool, not self-administered. It is believed the tool can be easily modified for the pregnant population and show similar validity results as found in previous research using different populations.

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CHAPTER 3
Validation of a historical physical activity recall tool

Introduction

Background

Physical activity (PA) is important in the prevention of chronic disease and an integral part of healthy lifestyles. Epidemiological studies have shown that PA plays a role in chronic disease prevention (Paffenbarger et al., 1986; Powell and Paffenbarger, 1987). Healthy people 2010, a comprehensive set of disease and health promotion objectives, considers PA as an integral part of chronic disease prevention and has placed it as one of the major health issues for the nation (http://www.healthypeople.gov).

PA measurement is a process that should be performed with as much precision and accuracy as possible. Many tools are available to estimate PA on a daily, weekly, or yearly basis (Kriska et al., 1988). Choice of instrument is a function of research questions, study sample, funding, and other factors (Haskell and Kiernan, 2000). Instruments such as accelerometers and heart rate monitors can be worn and data are collected as the PA is performed. From these measures, caloric expenditure can be estimated. While fairly precise, these techniques are not generally used on large samples where recall surveys are more practical and cost effective (Haskell and Kiernan, 2000). Physical activity recall (PAR) relies on subject self-report from which caloric expenditure can be estimated. Recall surveys have been used for a variety of time frames and, depending on the questions asked, can gather either precise details about physical activity or general estimates of usual or typical PA participation (Haskell and Kiernan, 2000).

Most PAR tools have been validated using other direct measurement techniques. Stein et al. (2003) utilized accelerometry, HR monitoring and PAR and evaluated their reliability and agreement during pregnancy and the postpartum period. The authors found that the instruments were very reliable and showed good agreement on the group level.

Many PAR tools have been validated for use with different populations for assessing PA. The Modifiable Assessment Questionnaire (MAQ) is a tool that was developed to address physical activity and diabetes risk in Pima Indians, but it has since been validated with other populations (Kriska et al., 1990; Vuillemin et al., 2000). The strength of the MAQ is that it can be modified for population to be studies and time period. Physical activity can be recalled from the last week, to last year, to a specific time period in a person's life (Kriska, 1997). Modifiability will make this tool most useful in evaluating historical PA during a specific past event, such as pregnancy.

Significance of the problem

Historical PAR research has grown in recent years. Studies have focused on adults' abilities to recall PA and sport experiences from their youth, as well as occupational activity and relate those to present health status and disease risk (Chasen-Taber et al., 2002; Torgen et al., 1997). Validity of such a tool is difficult and limited by access to accurate historical data. A longitudinal prospective study with previously recorded activity levels is needed to validate an historical recall tool. Also, the validity of the MAQ for a past pregnancy is unknown. If it is determined that this tool is valid with the postpartum population, information regarding past pregnancy PA can be collected retrospectively and assist in determining the relationship of previous physical activity and chronic disease risk of both mother and offspring.

Purpose of the study

In this study, the historical data measured during a pregnancy that occurred six years ago will be compared to the subjects' physical activity recall, allowing for the validation of the MAQ for historical PA assessment. The purpose of this study is to evaluate the ability of women to recall their PA during three time points previously assessed (20 weeks gestation, 32 weeks gestation, 12 weeks postpartum) during a pregnancy that occurred six years ago. The research questions are as follows.

1. How accurately can women recall physical activity performed during a pregnancy that occurred six years ago?
2. Is a woman's ability to recall physical activity performed during a pregnancy that occurred six years ago related to current physical activity?

Methods

Participants

56 women participated in a study designed to determine the reliability and validity of three commonly used physical activity measurement modalities from 1997-2000 (Pivarnik et al., 2002; Stein et al., 2003). Study participants were recruited from obstetrical care clinics in the Mid-Michigan area. All participants delivered healthy, singleton infants. The original MAMA study involved the collection of heart rate telemetry, accelerometry, and a PAR over two consecutive days at 20 and 32 weeks gestation, and 12 weeks postpartum. The researcher reviewed the two-day PAR data with participants during each visit to the lab. When the women were recruited they were informed that the investigators may wish to obtain some follow-up measures (on them and/or their offspring) at a later time. Thus, participants were then contacted to participate in the current study. Email, telephone calls, and letters were used to contact

the 41 of the original 56 participants believed to still live in the area. After many phone calls, thirty women were located and agreed to participate, with only one refusal.

Instrumentation

The Modifiable Activity Questionnaire (MAQ) is a PAR instrument designed for easy modification to maximize the investigator's ability to assess PA levels in different populations (Kriska et al., 1990; Kriska, 1997). This questionnaire was used to assess historical PA levels at time points from a pregnancy that occurred six years ago. Those time points included 20 weeks and 32 weeks gestation, and 12 weeks postpartum.

Sample size, power analysis

Due to the follow-up design of this study, we could not increase sample size to enhance statistical power. Therefore, correlation values needed to achieve meaningful relationships and significance in line with previous reports were calculated using the available sample of 30 women. A review of other PAR tools and MAQ studies assisted in the determination of correlation significance.

Agreement between measured PA and self-reported PA via PAR tools for the same time periods have been established in studies comparing direct measurement techniques such as Vitalog and Caltrac accelerometers, to exercise logs and recall (Stein et al., 2003; Taylor et al., 1984). Correlations have ranged from 0.28 to 0.90 in studies that have assessed the validity and reliability of PAR tools (Kriska, 1997; Norman et al., 2001; Vuillemin et al., 2000; Wareham et al., 2002). In studies that have measured lifetime or historical leisure time physical activity levels, correlations have ranged from r=0.33 to 0.70 (Chasen-Taber et al. 2002; Torgen et al., 1997). Based on our sample size of 30, conversion tables indicated that an $r=0.36$ would be significant for an alpha level of $P<0.05$, while an $r=0.46$ would significant for an alpha level of $P<0.01$.

Data Collection Procedures

In the original MAMA study, actual PA data for all the three previously mentioned time points were collected using a two-day exercise PAR. During those two days, women wore watches with alarms that sounded on the hour. This alarm served as a reminder that they should record any activity performed within the previous hour. In addition, upon arrival to the lab, the study coordinator debriefed each participant to be sure that she recalled her previous day's activities as accurately as possible (Stein et al., 2003). During the follow-up visit, participants came to the Human Energy Research Lab at Michigan State University for one 45-60 minute visit. Upon arrival the participant was reminded of the study aims and protocols, after which written informed consent was obtained. Next, physical activity measures for 20 and 32 weeks gestation, 12 weeks postpartum, and current (last week) were collected. The historical recall portion of this study involved the repeated use of The Modifiable Activity Questionnaire (MAQ). Each participant was administered the MAQ for each time period in the order of most distant past (20 weeks gestation) to most current (last week).

Participants were asked to recall their PA levels during a usual week for 20 weeks gestation (the most historical time period of interest), then 32 weeks gestation, 12 weeks postpartum of a pregnancy that occurred six years ago, and finally current (last week). In order to assess past and current PA using the MAQ, participants were asked to circle all activities (from a pre-determined list generated from pilot studies) they had participated in during the time period of interest. Appendix B shows examples of the MAQ activity list. The circled activities were then listed in the "activity" box of the questionnaire. The frequencies, in days per week, and duration, in hours per bout, were established for each chosen activity. Hours per week for all activities chosen were calculated by multiplying frequency by duration. The MET value for all listed activities was determined using the compendium for physical activities developed by Ainsworth et al. (2000). Estimated energy expenditure for each activity was calculated and multiplied by the hours per week in order to calculate a weekly value, for example Kcal/week, (MET*WT)(dur/60)*freq=Kcal/wk (Kriska, 1997). The estimated costs of each activity were derived from the most recent compendium of physical activities (Ainsworth et al., 2000). After the average weekly energy expenditure values were calculated, those data were divided by seven to derive daily energy expenditure, then divided by the maternal body weights for each study period in order to obtain energy expenditure relative to weight ([Kcal/day]/kg=Kcal/day/kg). Please refer to appendix A for the energy expenditure equations used with the MAQ described in this section.

Data analysis

In the original MAMA study, actual PA data for 20 and 32 weeks gestation and 12 weeks postpartum were collected using a two-day exercise PAR. Leisure time energy expenditure values (kcal/day/kg) calculated from the PAR used in the original study and those from the MAQ used in the follow up study were analyzed based on the research questions for this dissertation. Statistical significance for all analytical procedures was set at an alpha level of $P=\leq 0.05$. The statistical program of JMP version 4 was used for all statistical procedures (Sall, Lehman, and Creighton, 2001). During the data analysis process it was discovered that there were two participants whose PA at all time periods was 2-3 standard deviations above the sample norm. Further inspection showed the women, though more active than the rest of the sample, to be with in the regression line and therefore, remained part of the analyses. Some analyses also involve comparisons based on current PA levels. Therefore the participants were separated into two groups based on those who met the current CDC/ACSM PA recommendations of 20 MET/wk or more, and those who did not.

Research Question One: How accurately can a woman recall physical activity performed during a pregnancy from six years ago?

Data analysis included calculation of Pearson correlations for the measured leisure time energy expenditure values (kcal/day/kg) of each time period (20 and 32 weeks gestation and 12 weeks postpartum) and the recalled values for those same time periods.

Research Question Two: Is a woman's ability to recall the physical activity performed during a pregnancy from six years ago related to current physical activity?

Data analysis included a one-way ANOVA to compare difference between measured and recalled past energy expenditure values at the different time periods (20 and 32 weeks gestation and 12 weeks postpartum), between subjects meeting CDC/ACSM PA guidelines (≥20 MET/wk), and those who did not.

Results

Descriptive characteristics and other select physiological measures of the entire sample can be found in Table 1. The averages for the sample included age 36.2 (±5.0) years, weight 65.5 kg (±12.9), height 165.9 cm (±6.9), and parity 2.5 children (±0.94). Sixty percent of the sample met the CDC/ACSM guidelines for current PA (≥20

MET/wk). Refer to Table 2 for the average PA in MET/wk at all time periods of interest (20 and 32 weeks gestation, 12 weeks postpartum and current). The results for Part I of this dissertation are organized by research question.

Research question one stated: *How accurately can a woman recall physical activity performed during a pregnancy from six years ago?* Results of the Pearson correlations on the entire subject population for the MAQ recalled and PAR measured leisure time energy expenditures (kcal/day/kg) were at 20 weeks gestation ($r=0.57$; $P<0.01$), at 32 weeks gestation ($r=0.85$; $P<0.01$), and at 12 weeks postpartum ($r=0.86$; $P< 0.01$). Refer to Figures 1-3 for results.

Research question two stated: *Is a woman's ability to recall the physical activity performed during a pregnancy from six years ago related to current physical activity?* Results showed that differences between recalled (MAQ) and measured (PAR) leisure time energy expenditure (kcal/day/kg) did not differ between women who exceeded or did not exceed CDC/ACSM recommended twenty METs per week. Differences in recall ability, or recalled (MAQ) minus measured (PAR) energy expenditure were small. Refer to Table 3 for results.

Discussion

The purpose of this study was to evaluate the ability of women to recall their PA during three time points previously assessed (20 weeks gestation, 32 weeks gestation, 12 weeks postpartum) during a pregnancy that occurred six years ago. Based on this purpose, the research questions included: how accurately can women recall physical activity performed during a pregnancy that occurred six years ago; and, was a woman's ability to recall physical activity performed during a pregnancy that occurred six years ago related to current physical activity?

The results regarding the ability of a woman to recall her past pregnancy PA showed the MAQ energy expenditure values to be significantly related to the original PAR energy expenditure values at all time periods of interest (20 and 32 weeks gestation and 12 weeks postpartum; Figures 1-3). The correlations from this MAMA follow-up are similar (r=0.57-0.86), if not stronger, to those found in previous PAR tool validation studies, as well as MAQ validation studies.

When Blair et al. (1991) evaluated the reliability of long-term recall of participation in PA by middle-aged men and women, correlations ranged from r=0.20-0.50. The Blair et al. sample included 451 participants, but we have no knowledge whether any of the women were pregnant. The length of recall for the Blair et al. study was greater (ten years) than that for this study (six years), which may have lessened their reliability estimates.

In a study similar to that of Blair et al., Bowles et al. (2004) assessed construct validity of self-reported historical physical activity. The results showed significant correlations between recalled walking, running, jogging, and treadmill times each year throughout a 10 year period (Bowles et al., 2004). The correlations ranged from r=0.40-0.61, very similar to those found in this study. The sample size was again much larger (n=5,063) and included both genders. The time for follow-up varied in the Bowles et al study, ranging from 1 to 10 years. The strong correlations between original and recalled energy expenditure found in the MAMA follow-up compare well with those from other long-term recall studies and would suggest the MAQ to be a valid tool to assess past pregnancy PA.

Chasen-Taber et al. (2002) examined the reproducibility of a self-administered historical PAR with adult females. The age of the study sample ranged from 39-65 years, and though it was not mentioned, some women may have been pregnant during at least one of the time periods assessed (menarche to 21, 22-34, 35-50, and 51-65). Correlation coefficients for reproducibility ranged from r=0.70-0.87. These are similar to the MAMA follow-up correlations found between actual and recalled PA for 32 weeks gestation and 12 weeks postpartum six years ago. The correlations for the Chasen-Taber et al. study are very high for the recall of PA from over 10-20 years ago.

Results from the present study can also be compared to those found in other investigations that have used the MAQ to assess past PA. Kriska et al. (1990) examined the relationship of PA and diabetes in Pima Indians, comparing the MAQ to values gathered via the Caltrac activity monitor (Kriska et al., 1990). The correlation between the two tools was relatively strong ($r=0.62$, $P \leq 0.05$) with a sample size of 17. Despite the difference in culture between the two populations, sample size was similar to this study as are the correlations at all time periods. In 1995, Pereira et al. (1995) used the MAQ to assess the relationship between physical inactivity and glucose intolerance on Mauritius adults. The MAQ was compared to a seven-point categorical activity scale (CAS) to establish internal validity. Though correlations were not reported, the MAQ and CAS PA measures were in agreement ($P \leq 0.001$) for both males and females, and PA differed among the three activity categories (inactive, moderate, and high). Sample size, culture, and gender of the Mauritius study (n=2790) differed from out investigation.

Even with these differences, it appears that the MAQ correlates well with different PAR tools and populations.

While our study showed women are able to recall their PA during a pregnancy some six years ago, present physical activity level does not appear to influence this ability. Because we are the first to perform this analysis during pregnancy, direct comparisons with similar previous studies are not possible. Norman et al. (2000) assessed the validity and reliability of self-reported total PA in 286 males, and examined differences by relative weight. The results showed the PAR tool correlated well with seven-day activity records ($r=0.56$). In addition, the authors found that the participants with a BMI ≤ 26.0 kg-m^2, were better able to recall their physical activity levels compared to heavier subjects. Also, the lighter subjects performed the greatest about of physical activity. The Normal et al. study did not assess historical PA, but the resulting differences in self-reported PA by relative weight may indicate the same trend.

Limitations

Limitations of the present study include small sample size and a homogeneous sample in terms of physical activity. Therefore, the range of activities and recall would be restricted, compared to a more diverse group, lowering statistical associations between our participants' current PA levels and ability to recall past pregnancy PA. Even with the limitations noted, MAQ recall correlations compared favorably to those reported in previous historical recall validation studies. Therefore, it appears the MAQ, used in this MAMA follow-up is an appropriate tool to assess past PA in postpartum women, six years after delivery, regardless of their current activity participation levels.

Future Directions

Based on the results of this validation study, we recommend that the MAQ be used in future long-term past pregnancy PA recall studies. Even with studies that did not originally measure PA during a past pregnancy, investigators can retrospectively assess PA and have reasonable confidence in the accuracy of their data. New findings may add to our knowledge of the relationship between PA during pregnancy and long-term body weight changes or other chronic disease risk issues. The MAQ should also be used with larger, more heterogeneous samples to determine it's validity with different ethnic and cultural groups. The MAQ should also be used in studies that include longer follow-up (ten years or greater) to determine it's accuracy at recalling PA in the more distant past.

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CHAPTER 4
The effects of past pregnancy physical activity on current physical activity, barriers to physical activity, and body size.

Historical Background

Information regarding what activities a pregnant women should and should not participate in has been available since the late 1700's (Artal, Drinkwater, and Wisewell, 1991). In the 1920's and 30's some restrictions for maternal exercise were published, but were based on social and cultural biases of the time, rather than empirical evidence (Artal, Drinkwater, and Wisewell, 1991). In the 1920's and into the 40's prenatal exercise programs were developed. Books directed toward self-powered, natural birthings are considered the basis for current prenatal exercise (Fairbairn, 1924; Fairbairn, 1926; Randell, 1945). In 1949 the United States Children's Bureau published an article which included physical activity recommendations (Children's Bureau Publication, 1949). The recommendations stated that moderate physical activity was good for a pregnant woman who was without illness or complication, and that she could continue housework, gardening, daily walks, and swim occasionally (Children's Bureau Publication, 1949).

During the 1970's women of child-bearing age became more active (largely due to increased sports opportunities for high school girls and collegiate women) and concerns about vigorous physical activity during pregnancy arose. It was not well-understood how a woman's physiological responses to physical activity would affect the maternal-fetal unit, so evidence based recommendations were not available. Physicians and other health care professionals had strong concerns about the effects of physical activity on maternal weight gain, blood pressure, glucose tolerance and insulin function, and temperature regulation.

Early Animal Studies

The first studies designed to systematically examine the maternal and fetal responses to physical activity during pregnancy primarily used animals as subjects (Clapp, 1980; Bagnall et al., 1983; Lotering, Gilbert, and Longo, 1983). In 1980, Clapp found that strenuous exercise with near-term ewes resulted in a rapid increase in maternal temperature, and decreased rate of blood flow to the placenta and fetus by more that 50% (Clapp, 1980). Despite this severe exercise challenge, the fetal lambs showed no signs of stress after an hour of continuous maternal exercise, indicating the placenta was able to compensate for the demanding cardiovascular responses.

A few years later, Bagnall, Mottola, and McFadden examined the effects of strenuous exercise on maternal rats and their developing fetuses. Twenty female rats were mated and divided into exercise and control groups after 19 days of treadmill running acclimatization (Bagnall et al., 1983). The exercising rats continued to run throughout gestation, while the controls did not. The rats were weighed daily, including the day following birth. Offspring numbers and weights were recorded. Results showed the fetuses were spared from any major effects of maternal exercise, with average birth weight and litter size being unaffected. There was a significant maternal weight difference between the exercise and control group mother rats at the end of gestation. The control group was 36 grams heavier at the end of gestation and lost weight after delivery, but remained to 14.6 grams heavier than the exercise group. The authors suggested the data reflect a decreased amount of amniotic fluid and maternal body fat in the exercising group (Bagnall et al., 1983).

To study whether maternal exercise causes fetal hypoxia, Lotgering, Gilbert, and Longo measured maternal and fetal temperatures and blood gases, then calculated uterine oxygen consumption of pregnant sheep in response to different treadmill exercise regimens (Lotgering, Gilbert, and Longo1983). The results showed that total uterine oxygen consumption was maintained during exercise, despite the reduction in uterine blood flow. The authors believed hemoconcentration and increase oxygen extraction helped maintain uterine oxygen consumption and suggested maternal exercise did not represent a major stressful or hypoxic event to the fetus (Lotgering, Gilbert, Longo, 1983).

Reviews published in 1985 and 1987 summarized the information generated by the animal studies of the 1980's (Clapp, 1987; Lotgering, Gilbert, and Longo, 1985). The authors reached three main conclusions 1) acute exercise during pregnancy had significant effects of maternal physiology without detrimental effect on the fetus in late pregnancy, 2) little was understood about the maternal-fetal effects of exercise during pregnancy with humans, 3) even with the reassuring information about exercise during late pregnancy in large animals, human studies would be needed to answer the many questions about the safety of exercise during pregnancy (Clapp, 1987; Lotgering, Gilbert, and Longo, 1985). Major findings from animal studies conducted to this point in time showed that despite some strong physiological responses of pregnant animals to exercise, the maternal-fetal unit remains unharmed. Whether these results could be generalized to humans had not yet been confirmed. However, the animal studies provided important insight into maternal-fetal adaptations to maternal exercise that proved valuable for future research on humans.

Early Human Studies

The first few human studies of exercise during pregnancy were designed to evaluate both maternal and fetal effects. In 1974, Knuttgen and Emerson assessed physiological responses to pregnancy at rest and during exercise. Thirteen women with normal pregnancies participated in this study and were tested at four-week intervals throughout gestation as well as six-weeks postpartum. Both steady state treadmill walking (4.5km/hr at 4% grade) and cycling (60 W) were performed. Oxygen consumption, heart rate, and ventilation were evaluated. Prepartum and postpartum values were also compared based on exercise mode, treadmill (weight bearing) or cycle ergometer (non-weight bearing) (Knuttgen and Emerson, 1974). The results showed pulmonary hyperventilation developed early in pregnancy and persisted at rest as well as during both exercise modes. Oxygen consumption and body weight showed consistent increases during pregnancy. Resting heart rate was more variable during pregnancy, and a consistent increase was observed in six of the thirteen subjects. Results also showed an increase in oxygen cost of treadmill walking, but not in cycle ergometry during pregnancy. It is likely that the decreased exercise economy that occurred was a result of pregnancy related weight gain (Knuttgen and Emerson, 1974).

Also in the 1970's, Pomerance, Gluck, and Lynch sought to determine if the fetus benefited from maternal physical fitness (Pomerance et al., 1974). The researchers investigated whether length of gestation, length of labor, birth weight, length, head circumference, and one-minute APGAR scores would differ based on maternal physical fitness levels. Study participants included forty-one women who delivered at a naval hospital in California (Pomerance et al., 1974). Cycle ergometry was used to assess maternal physical fitness. Aerobic capacity was estimated using a submaximal protocol (Astrand and Rodahl, 1970). The women were followed throughout the pregnancy and delivery. The results showed an inverse relationship between physical fitness scores and pre-pregnancy weight, with lighter women being more physically fit. Although physically fit multiparas tended to have shorter labors than primiparas, fitness was not significantly related to infant birth weight, length, head circumference, or one-minute APGAR scores (Pomerance et al., 1974).

In 1981, Artal et al. assessed maternal cardiovascular and metabolic responses to normal pregnancy. Study volunteers included twenty-three healthy pregnant women in their third trimesters. Cardiovascular and metabolic measurements were recorded during and after 15-minutes of light (2.3 METS) treadmill exercise (Artal et al., 1981). Although exercise induced a significant increase in maternal heart rate and a shortening of the R to R intervals on EKG, both returned to baseline by 30-minutes of recovery. Exercise also induced significant transitory increases in glucagon, norepinephrine, and epinephrine concentrations, all of which were reversed during recovery. The light exercise did not result in a change in glucose or cortisol concentrations. The authors concluded that light exercise for a brief duration elicited appropriate and transitory cardiovascular and metabolic responses during normal pregnancy (Artal et al., 1981).

Even as the amount of research regarding the physiological and maternal-fetal effects of exercise during pregnancy increased, concerns still existed. A major concern was the risk of physical activity causing a decrease in birth weight or shortened gestation, predisposing the infant to preterm delivery and subsequent health problems. In 1983, Berkowitz et al. examined the effects of physical activity on spontaneous preterm delivery. The authors found that women who exercised were half as likely as non-exercisers to deliver prematurely and found no evidence that physical activity was related to an increase the incidence of either smaller than average babies or premature labor (Berkowitz et al., 1983). However, it still remained unclear whether physical activity during pregnancy would limit calories available to the fetus, resulting in growth retardation, and/or cause uterine contractions leading to preterm deliveries. There was a great need for more human physical activity and pregnancy studies involving prospective cohort designs.

As a result of these few early human studies, the American College of Obstetricians and Gynecologists (ACOG) published the first guidelines regarding exercise during pregnancy in 1985 (ACOG, 1985). Based on the limited research available at the time, the recommendations were cautious. Concern for maternal-fetal temperature regulation and the effect of exercise increasing the risk of preterm birth and low birth weight (LBW) guided the recommendations. The authors indicated that maternal heart rates should not exceed 140 beats per minute and vigorous exercise should be limited to no more than 15 minutes per bout (ACOG, 1985).

After the publication of these ACOG guidelines, research regarding pregnancy and physical activity increased significantly with more than 500 papers being published between 1985 and 1994. Many of the outcomes reflected the results of previous studies showing no evidence that recreational exercise increases the risk of LBW or premature labor, and may decrease the incidence of both (Klebanoff, Shiono, and Carey 1990, Rabkin et al 1990). Studies showed that maternal physical activity actually increased placental growth and functional capacity, possibly providing a mechanism to positively affect birth weight (Clapp and Rizk, 1992; Jackson et al., 1995).

More recent human studies

Lokey et al. published a meta-analysis of the effects of physical exercise on pregnancy outcomes in 1991. Eighteen studies were included in this analysis. All studies were written in English, included women who exercised during pregnancy, and quantified outcome variables. Results showed that women who exercised during their pregnancies did not differ from sedentary women for any of the measured outcome variables; including maternal weight gain, infant birth weight, length of gestation, length of labor, and APGAR scores. Many exercise programs exceeded the suggested 1985 ACOG limitations, without apparent adverse effects. The authors concluded that overall, aerobic exercise performed for an average of forty-three minutes per day, three days per week, at a heart rate up to 144 beats per minute, did not appear to be related to adverse maternal or fetal effects in a healthy normal pregnancy (Lokey et al., 1991).

Based on encouraging results of studies performed after the 1985 guidelines, ACOG published a revised, updated version in 1994 (ACOG 1994). New evidence had failed to support concerns about harmful maternal-fetal effects from exercise performed during a normal healthy pregnancy. To the contrary, reviews analyzing the more recent studies indicated that maintaining a physically active lifestyle during pregnancy could enhance maternal health and improve the delivery process (Clapp, 1994; Crowell, 1995). The updated 1994 recommendations no longer included heart rate or vigorous exercise duration limitations for healthy mothers. Continuing aerobic exercise throughout pregnancy was encouraged for mothers who were active before pregnancy. In addition, individual health and exercise screenings and prescriptions were suggested for all pregnant women (ACOG, 1994).

Many studies performed after the 1994 ACOG guidelines were prospective and the majority supported the less stringent revised guidelines (Sternfeld et al., 1995; Kardel and Kase, 1998; Hatch et al., 1998). In 1995, Sternfeld et al conducted an investigation of the effects of participation in aerobic exercise on pregnancy outcome (Sternfeld et al., 1995). Study participants included 388 women followed from approximately sixteen weeks gestation through delivery. Frequency, duration, and type of exercise prior to and during the first trimester of pregnancy were collected by an in-person interview. Telephone interviews were used during the second and third trimesters (Sternfeld et al., 1995). Based on information collected, the women were grouped into different activity levels for each time period of interest. The levels included; level I= aerobic exercise (excluding walking) for 20-minutes at least 3 times per week, level II= aerobic exercise for 20 minutes at least 3 times per week, if and only if vigorous walking was included, level III= aerobic exercise for 20-minutes less than 3 times per week, level IV= aerobic exercise less that once per week. Results showed mean birth weight was unrelated to physical activity performed, either prior to, or during pregnancy. Gestational age and weight gain were also unrelated to maternal physical activity level. Pregnancy related symptoms, however, were inversely related to physical activity with women who exercised in greater amounts earlier in pregnancy reported fewer discomforts in later gestation. The authors concluded that aerobic exercise performed during pregnancy at levels great enough to produce or maintain exercise-training effects did not adversely affect birth weight or other maternal or fetal outcomes, but may be associated with fewer perceived pregnancy-related discomforts (Sternfeld et al., 1995).

Sternfeld et al. (1995) were able to examine different activity levels at specific time periods throughout gestation and assess relationships between those activity levels and pregnancy outcomes. A similar prospective study was conducted in Oslo, Norway in 1998. Women were given the choice to follow either a high or medium intensity exercise program through pregnancy up to six-weeks postpartum (Kardel and Kase, 1998). Results showed no differences between program intensity and duration of labor, birth weight, or APGAR scores at delivery. The authors concluded that healthy and well-conditioned women may exercise during pregnancy without compromising fetal growth or development (Kardel and Kase, 1998). Hatch et al. (1998) examining maternal leisure time activity and timely delivery, also found no adverse effect of maternal exercise during pregnancy on gestational length. In fact, women performing relatively high levels of activity (greater than 1000 kcal per week) appeared to be at reduced risk of spontaneous preterm birth (Hatch et al., 1998).

The previous studies involved women who were active before pregnancy, but questions remained about the effects of starting an exercise program during pregnancy on maternal-fetal health and birth outcome. A study evaluating the initiation of regular exercise in early pregnancy was conducted by Clapp et al. in 2000. The women were divided into two groups, exercise and controls. The exercising women participated in 20 minutes of weight-bearing activity (treadmill, step aerobics, or stair stepper) three to five times a week at 55% to 60% of preconception aerobic capacity (Clapp et al., 2000). The authors found that beginning a moderate physical activity regimen of weight bearing exercise in early pregnancy results in enhanced fetoplacental growth. The offspring of the exercising women were significantly longer and heavier than those born to control women (Clapp et al., 2000). The authors believed that this amount of exercise could easily be performed by most women during a normal, low-risk pregnancy.

Not all studies conducted after the 1994 ACOG guidelines showed that maternal exercise enhanced fetal growth and birth weight. In 1995, Bell, Palma, and Lumley assessed the effect of continuing a vigorous exercise program into late pregnancy on birth weight (Bell, Palma, and Lumley, 1995). Study participants were women who had participated in vigorous physical activity prior to pregnancy. A control group consisted of healthy pregnant women who did not participate in regular vigorous exercise. Seven-day food records and exercise diaries were kept at one time point during each trimester. The results showed women who continued to participate in 30 minutes of vigorous exercise more than four times a week at twenty-five weeks gestation gave birth to infants 315 grams lighter than those born to controls (Bell, Palma, and Lomley, 1995). The authors did not discuss any possible confounders regarding birth weight, such as pregravid weight and gestational weight gain. Also, even if babies born to vigorous exercisers were lighter, there was no mention of an increased risk of low birth weight. The decrease in mean birth weight may have indicated the exercising women gave birth to babies who were leaner, but no less healthy than those born to controls.

In two separate studies, Clapp et al. found that exercising women delivered lighter infants with less fat mass compared to babies born to controls (Clapp et al., 1999; Clapp et al. 2002). The authors found although gestational age at delivery, axial length, and head circumference were similar, the exercise group offspring were lighter and leaner than those of the control group (Clapp et al., 1999). Clapp et al. (2002) also examined the effects of exercise volume at different times during pregnancy. Currently exercising women were randomly assigned to one of three groups after eight weeks gestation (Clapp et al., 2002). One group performed moderate exercise throughout pregnancy, another group decreased volume of activity, and the third group increased exercise volume in mid to late pregnancy. Results showed that a high volume of moderate-intensity exercise performed in mid and late pregnancy reduced fetoplacental growth symmetrically, whereas reduction in exercise volume resulted in greater increase in fat mass and heavier babies (Clapp et al., 2002). Although birth weight was lower as exercise volume increased, there was no indication of increase risk of delivering a low birth weight infant.

In a review paper published in 1997, Sternfeld assessed the relationship between physical activity and pregnancy outcome (Sternfeld, 1997). Proposed risks of redistribution of uterine blood flow, fetal hypoxia, hyperthermia and teratogenic effects, and increase risk of pre-term labor were addressed based on the dual stresses of pregnancy and physical activity. Even after considering these potential risks, Sternfeld stated that the literature generally shows neutral or somewhat positive effects of physical activity on pregnancy outcome. Based on lack of evidence for harmful effects for healthy well-nourished women, Sternfeld suggested exercise during pregnancy appears to be safe and subject to few restrictions. This finding supports the overall tone of the revised 1994 ACOG recommendations (Sternfeld, 1997). A 1998 review by Pivarnik also stated that the evidence at that time appeared to indicate participation in moderate to vigorous activity throughout pregnancy may enhance birth weight, while more severe regimens may result in light offspring (Pivarnik, 1998). In addition, Pivarnik indicated most studies that had shown unfavorable birth outcomes had not addressed some important potential confounders of birth weight (such as SES) and that physical activity had not been well quantified throughout gestation. The author suggested that future studies included randomized trials in which women with out a history of chronic physical activity are assigned to an exercise or physical activity or control group (Pivarnik, 1998). Two additional reviews regarding the effects of physical activity on birth weight stated that the research has been inconclusive, primarily because many studies have examined different types, timing, durations, and intensities of activity (Larsen-Meyer, 2002; Johnston, 1991).

Based on knowledge gained from studies conducted after the 1994 recommendations, ACOG revised their physical activity guidelines again in 2002 (ACOG 2002). The main recommendation states that in the absence of either medical or obstetric complications, 30 minutes or more of moderate physical activity a day on most, if not all, days of the week is recommended for pregnant women (ACOG, 2002). These guidelines follow the physical activity recommendations for healthy adults put forth jointly by the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) (Pate et al., 1995). The guidelines also address concerns for competitive athletes and suggest regular exercise during pregnancy may provide additional benefits to women with gestational diabetes (ACOG, 2002).

The newest ACOG guidelines suggest pregnant women participate in "moderate physical activity", a term that has been difficult to define and separate from "exercise". Physical activity is defined as any bodily movement produced by skeletal muscle that results in energy expenditure (Casperson et al., 1985). Physical activity is performed to sustain life, but the amount is subject to personal choice and varies greatly from person to person and over time. Exercise is a subcategory of physical activity because it is planned, structured, repetitive, and purposeful in nature (Casperson et al., 1985). The CDC/ACSM and ACOG guidelines may be easier for most pregnant women to meet due to the fact that they recommend physical activity rather than structured exercise programs, allowing more options.

In 2003, the Canadian Clinical Practice Obstetrics Committee and the Canadian Society for Exercise Physiology Board of Directors created a Clinical Practice Guideline for exercise in pregnancy and the postpartum period (Davies et al., 2003). The objective was to design guidelines advising obstetric care providers of the maternal, fetal, and neonatal implications of aerobic and strength conditioning exercises in pregnancy. The authors completed a MEDLINE search from 1966-2002 for articles related to studies of maternal aerobic and strength conditioning in previously sedentary populations as well as in previously active populations, the impact of aerobic and strength conditioning on early and late pregnancy outcomes, and neonatal outcomes (Davies et al., 2003). After reviewing the literature six main recommendations were created 1) all women without contraindications should be encouraged to participate in aerobic and strength conditioning exercise as a part of a healthy lifestyle during pregnancy; 2) reasonable goals of aerobic conditioning in pregnancy should be to maintain a good fitness level without trying to reach peak fitness or train for an athletic competition; 3) women should chose activities that will minimize the risk of loss of balance and fetal trauma; 4) women should be advised that adverse pregnancy or neonatal outcomes are not increased by exercise; 5) initiation of pelvic floor exercises in the immediate postpartum period may reduce the risk of future urinary incontinence; 6) women should be advised that moderate exercise during lactation does not affect the quantity or composition of breast milk or impact infant growth (Davies et al., 2003). These guidelines are similar to those written by ACOG in 2002, recommending physical activity during pregnancy while providing more detailed suggestions directed toward the health care community rather than the pregnant woman.

Postpartum Weight Retention (PPWR) Reviews

Now that ACOG guidelines indicate a healthy pregnant woman can and should be physically active during pregnancy, there has been a gradual shift in research to focus on potential benefits of exercise during pregnancy beyond the perinatal period. For example, long-term effects of pregnancy on a woman's body size and lifestyle have yet to be determined. Some research has shown weight gained and retained after one pregnancy can increase with successive pregnancies (Rookus et al., 1987; Rooney and Schauberger, 2002; Greene et al., 1988). As weight increases a woman may become at risk for overweight or obesity after her childbearing years. Assessing the effects of the many variables that may play a role in postpartum weight retention may be difficult. There have been at least 31 factors identified in the relationship between pregnancy and weight retention. Examples include parity, pre-gravid weight, maternal pregnancy related weight gain, age, race, lactation, and physical activity (Johnson, 1991; Linne, Barkeling, and Rossner, 2004). Including all relevant factors in a study warrants a complex design. In addition different measurement tools may be used for the same variables (e.g., physical activity and lactation) leading to mixed and/or incomparable results.

In a 1991 review by Johnston, the author discussed trends in gestational weight gain since the 1980's, methodological problems in the assessment of weight changes in pregnancy, the proposed factors involved with gestational weight gain and retention, and weight changes in the postpartum period (Johnston, 1991). This detailed review included information from 204 published studies. The author concluded that reports on weight loss during the postpartum period indicate a large degree of variability in total weight change. Overall, the evidence suggested each successive birth adds approximately one kg of body weight above that normally gained with age (Johnston, 1991).

In 1995, Crowell reviewed approximately 37 studies on weight change in the postpartum period. Study topics ranged from weight gain and fetal growth, to factors affecting postpartum weight loss. The purpose of this review was to assemble the literature so a nurse-midwife could provide sound, clinical advice to pregnant women at risk for postpartum weight retention (Crowell, 1995). The main conclusions were that a woman needs six months to remove her pregnancy related weight gain and that women with average weight gain during pregnancy retain one kg after each child. The same average weight retention was also noted in the Johnston review and both values are above the 0.2 kg gained per year due to age. In addition, postpartum weight loss occurs earlier and to a greater degree in women of lower parity, age, and pre-pregnancy weight (Crowell, 1995). Both the Johnston and Crowell reviews state that an average amount of pregnancy related weight retention is one kg, but the variation among women may range from -12. to +26.5 kg (Ohlin and Rossner, 1990). Other studies have also shown a similar average in weight retention, along with a similarly wide variation. A study by

Ohlin and Rossner (1990) showed average weight retention to be 0.5 kg, though 14% of the sample retained 5 kg or more (Ohlin and Rossner, 1990).

Larson-Meyer reviewed studies that examined the effect of postpartum exercise on mothers and their offspring (Larson-Meyer, 2002). The studies were grouped into categories of those addressing the effect of postpartum exercise on changes in body weight, body composition, and energy balance (n=6) and those addressing the influence of maximal and submaximal exercise on human-milk lactic acid concentration (n=9) (Larsen-Meyer, 2002). Most studies included 25 or fewer subjects who were followed for six months or less. The main findings were that postpartum exercise can improve a woman's aerobic fitness, insulin sensitivity, high-density lipoprotein-cholesterol level, and psychological well-being. It was not clear whether postpartum exercise enhances body weight or fat loss. As for lactating women, regular exercise had not been shown to promote great weight loss, though a number of studies suggested exercise has no adverse effects on milk production (Larsen-Meyer, 2002).

Postpartum Weight Retention Studies

McKeown and Record (1957) published one of the first papers that evaluated pregnancy and postpartum weight development. The authors conducted a prospective study following women's weight changes from 3-24 months postpartum. Mean weights were plotted for age and parity showing three consistent trends; an increase in weight with age, an increase in weight increment with age, and an increase in weight increment with parity. The authors hypothesized a biological origin where increases in weight of women who have their first child after 35 years of age may be due to an association between obesity and low fertility (McKeown and Record, 1957). Since the McKeown and Record study, many others have determined the strongest indicator of weight retention after a pregnancy is the amount of weight gained during that pregnancy (Rooney and Schauberger, 2002; Ohlin and Rossner, 1995; Schauberger et al., 1992; Ohlin and Rossner, 1990; Greene et al., 1988; Muscati et al., 1995; Linne and Rossner, 2003).

Using a prospective design, Greene et al. analyzed interpregnancy weight change and found that the mean weight gain between pregnancies was 0.9 kg and on average women retained 0.9-2.3 kg between pregnancies after accounting for age related weight gain (Greene et al., 1988). Study subjects were women who had participated in the Collaborative Perinatal study in the United States from 1959-1965. From the original 58,760 women, the sample was restricted to 7,116 who had enrolled for more than one pregnancy and had singleton births. The study confirmed previous findings that women retain some of their pregnancy related weight gain. Half the participants retained two pounds in the two years between the beginning of one pregnancy and the beginning of another (Greene et al., 1988). The authors also found that at least one in ten women retained 15 pounds or more associated with pregnancy, and pregnancy weight gains of 20 pounds or more were associated with postpartum weight retentions (Greene et al., 1988).

PPWR, Gestational Weight Gain, and Race

Many studies have shown that postpartum weight retention is related to gestational weight gain, those that gain more often retain more (Ohlin and Rossner, 1990, 1994, Greene et al., 1988, Rooney and Schauberger, 2002). Past and current guidelines have reflected the tension between recommending the appropriate amount of weight gain for fetal development, without resulting in significant postpartum weight retention. Prior to the 1960's, average recommended weight gain during pregnancy was between 8-9 kg (Crowell, 1995). In 1970, the Committee on Maternal Nutrition recommended a higher gestational weight gain (10.9 kg) based on evidence that maternal weight restriction had negative effects on infant morbidity and mortality rates (Ohlin and Rossner, 1999). In 1990, the Institute of Medicine (IOM) created new recommendations based on a woman's pre-pregnancy BMI (IOM, 1990). The BMI groups and weight ranges include; low pregravid weight (BMI <19.8; 12.5-18.0 kg), normal pregravid weight (BMI 19.8-26.0; 11.5-16.0 kg), high pregravid weight (BMI >26.0-29.0; 7.0-11.5 kg), and very high pregravid weight (BMI >29.0; ~ 6.8 kg).

Johnston believed that the newest IOM recommendations are based on optimal infant outcomes rather than maternal health considerations (Johnston, 1991). Lederman investigated the outcomes of studies analyzing the effects of the IOM weight gain recommendations on postpartum weight retention and birth weight (Lederman, 2001). She concluded that weight gains above recommended levels were associated with increased maternal fat and pregnancy complications. The author suggested that health care providers can help reduce obesity risk by monitoring maternal weight; promoting healthy pre-pregnancy weight, pregnancy weight gain and postpartum weight loss; and encouraging the maintenance of an active postpartum lifestyle (Lederman, 2001). The question remains whether the recommendations work for all populations. It is unclear whether all races would benefit from following the IOM guidelines for gestational weight gain, or whether cultural differences play a role. It should be noted that the current 1990 IOM guidelines suggest that adolescents and Black women should strive to gain weight at the upper end of the recommended range.

In 1995, Boardley et al. investigated the relationship between maternal factors (including diet and physical activity), and postpartum weight change by race. Study participants were Black and White women seven to twelve months postpartum, who attended special supplemental food programs for Women, Infant, and Children (WIC) nutrition. The results showed Black women retained more postpartum weight than Whites. The overall sample showed breast-feeding was not related to postpartum weight change, but significant differences in breastfeeding were found, between the races. Other cultural or lifestyle differences were found, including time to return to work, marital status, and smoking. Black women also had lowered physical activity scores than Whites (Boardley et al., 1995). These race related differences are supported by other studies also assessing the IOM guidelines and their effect of postpartum weight retention (Parker and Abrams, 1993; Keppell and Taffel, 1993; Schieve et al., 1998). Taken together, results of these studies suggest lifestyle factors related to race have a significant impact on postpartum weight retention beyond gestational weight gain.

PPWR and lactation

The effect of lactation on postpartum weight retention has been investigated because of its role on maternal caloric expenditure and subsequent energy intake. The average woman utilizes an additional 300 calories a day when breastfeeding, but whether that extra caloric expenditure results in greater weight loss has not been clearly established (Brewer et al., 1989; Dewey et al., 1993). Lactation data from the McKeown and Record study showed consistent, but not large differences in weight based on duration of exclusive breast-feeding. Between months 3-12, weight loss increased slightly as lactation duration increased in the women who breastfed for 3 months or greater, but this effect was almost eliminated by 24 months (McKeown and Record 1957).

Rookus et al. (1987) investigated the effect of pregnancy and lactation on body mass index (BMI) nine months postpartum using a case-control design. Changes in BMI of 49 women (from pre-partum through nine months postpartum) were compared with BMI changes over the same period of time in a control group of 400 non-pregnant women. Lactation results showed that women who breastfed for more than two months gained 0.6 kg-m^2 more weight than the non pregnant women, whereas women who used bromocriptine to stop lactation lost body mass (Rookus et al., 1987). The results suggested that maternal obesity may be associated with breastfeeding for long periods of time. The authors proposed that women who breastfeed may increase dietary intake beyond what is needed to provide sufficient energy to sustain breastfeeding, thus nullifying the effect of lactation on weight loss (Rookus et al., 1987). Use of a nonpregnant control group was different from most previous studies, and the lactating comparison sample of 49 women was not large. Most previous studies have included at least 100 to 200 subjects (Haiek et al., 2001; Walker and Graves, 1997; Brewer et al., 1989).

Haiek et al. (2001) assessed the rate of a nine-month postpartum weight loss differences in 236 women, according to infant feeding method. Infant feeding methods included exclusive breast-feeding, mixed feeding, and predominantly bottle-feeding. The objective of the study was to clarify whether women from various socioeconomic and ethnic backgrounds lose weight at different rates as a function of lactation status. Most participants lost weight, but at 182 days postpartum, 31 of 181 weighed more than immediately after delivery (Haiek et al., 2001). Results also showed infant feeding method did not affect rate of postpartum weight loss. These results supported those of Rookus et al. (1987), and the authors suggested that breast-feeding women might eat more, and therefore lose weight more slowly. The authors also suggested that breast-feeding mothers may differ from bottle-feeding mothers in important attitudinal aspects (Haiek et al., 2001).

The results of Haiek et al. (2001) are supported by another study examining bottle vs. breast-feeding women. Walker and Graves explored the relationship between lifestyle variables with postpartum weight gain and body image attitudes of bottle- and breast-feeding women (Walker and Graves, 1997). A mail survey was sent to 513 women whose names were obtained from newspaper birth announcements, and participants were eligible if they resided in Austin, Texas, had a singleton birth, and a published mailing address. Of the 513 surveys mailed, 245 were returned and 207 met the exclusion criteria. Items collected from the survey included anthropometric, reproductive, and sociodemographic variables (Walker and Graves, 1997). No significant differences were found between breast and bottle-feeding groups for pre-pregnancy body mass index, gestational weight gain, time since delivery, or social variables. Breastfeeding women were more educated and more likely to be living with the infant's fathers. The results showed feeding method was not associated with postpartum weight gain in the sample as a whole. Bottle-feeding women with higher PPWR exercised less, had higher fat intakes, and were more dissatisfied with body image than mothers with lower gains. Breast-feeding mothers with high or low PPWR did not differ on any lifestyle factors (Walker and Graves, 1997). This study was a retrospective cross sectional design (four months postpartum) that relied on self-reported data.

Brewer et al. (1989) conducted a study analyzing postpartum changes in maternal weight and body fat depots in lactating versus non-lactating women. No significant differences were found between the groups at three months postpartum. The authors suggested that greater insulin sensitivity in lactating women may enable them to better conserve energy for use in milk production. The authors also stated that three months may be the turning point in metabolic efficiency (insulin sensitivity and energy conservation for milk production) for lactating as well as non-lactating women. This supports the finding of Rooney and Schauberger (2002) suggesting that women who breastfeed for more than 12 weeks may have less long-term weight retention or gain. The authors suggest lactation plays a role in postpartum weight and body fat loss, but that current RDA values for total calories may be too high to permit such losses (Brewer et al., 1989).

Though most results show no significant weight loss change with breast-feeding women, some investigators have found effects of lactation on postpartum weight loss. Dewey et al. (1993) examined maternal weight loss patterns during prolonged lactation. Subjects included mothers participating in the DARLING study, a longitudinal comparison of growth, nutrient intake, and morbidity of matched cohorts of breast-fed and formula-fed infants (Dewey et al., 1993). The women were divided into groups based on breast-feeding practices. The breast-feeding group consisted of 46 mothers whose infants received less than 120 ml of other milks until 12 months of age. The formula-feeding group consisted of 39 mothers whose infants were weaned completely to formula by three months. Weight and body fat were monitored through 24 months in both groups. The results showed no difference in weight loss at 1-3 months postpartum, but breast-feeding women showed a significant difference in weight loss from 3-6 months, suggesting women should breastfeed for six months or greater if they expect lactation to enhance weight loss. The authors suggested that their study results indicate lactation promotes weight loss during the first year postpartum and that the differences found in other studies maybe a function of inadequate study design (Dewey et al., 1993).

In 1997, Janney et al. performed a longitudinal study examining lactation and weight retention between infant feeding methods through 18 months postpartum. One hundred ten 20-40 year-old women were recruited during their third trimesters from birthing education and obstetric practices in Ann Arbor, Michigan (Janney et al., 1997). Weight was evaluated at two-weeks, two-months, four-months, six-months, and 12 and 18 months postpartum. Information about feeding practices, reproductive history, diet, and physical activity were collected at each visit. Regardless of infant feeding method, all participants lost weight from two-weeks to 18-months postpartum, with slower rates of weight loss occurring after 12-months. Overall, less weight was retained by the lactating women than their non-lactating counterparts. Even women who breast-fed for less than four months retained less weight than women who bottled-fed their infants. Once lactation was discontinued, the rate of weight loss slowed. The breast-feeding women achieved their pre-pregnancy weights approximately six months before those who bottle-fed their infants (Janney et al., 1997).

PPWR and physical activity

Physical activity is another lifestyle factor that may play a role in PPWR. The effects of physical activity on PPWR appear mixed, but differences in study design, measurement tools, and outcome measures may explain those results. Larson-Meyer (2002) reviewed approximately 60 cross-sectional and randomized control trials from the past 12 years, addressing the effect of postpartum exercise on weight loss and or energy balance in women, most of whom were lactating (Larson-Meyer, 2002). Overall, the studies suggest that moderate exercise without calorie restriction does not promote greater weight or fat loss. The author speculated that exercise may promote greater caloric intake and or reduced energy expenditure from non-physical activities, preventing a negative energy balance. Larson-Meyer concluded that benefits of exercise during the postpartum period are important it is not clear whether the physical activity promotes greater body-weight or body-fat loss after childbirth (Larson-Meyer, 2002). This review only included studies evaluating postpartum exercise, not exercise during pregnancy, and its effect on PPWR. Since the early 1990's there have been more studies with prospective and longitudinal designs assessing the relationship between physical activity during and after pregnancy on PPWR.

In 1994, Ohlin and Rossner assessed trends in eating patterns, physical activity, and sociodemographic factors in relation to postpartum body weight development. This prospective investigation was part of the Stockholm Pregnancy and Weight Development Study, where 1493 women were followed from the beginning of one pregnancy to 1 year postpartum. The study was designed to identify risk factors for postpartum weight retention using data collected from routine pregnancy records and questionnaires at six and twelve months postpartum (Ohlin and Rossner, 1994). Mean weight retention was

0.5kg above pre-pregnancy weight, while 14% of the sample retained 5 kg or more. The authors found that weight retention one year postpartum was greater in women who a) increased their energy intake during and after pregnancy, b) increased their snack eating after pregnancy, c) decreased their lunch frequency during and after pregnancy. Women who retained greater or equal to 5 kg at one year postpartum were less physically active in their leisure time when compared with women with lower postpartum weight gains (Ohlin and Rossner, 1994). Of the women who gained the most weight (>10 kg), 23% were inactive in their leisure time throughout all study time periods, compared with 4% of those with lower weight gains. The results indicated that nutrition habits and physical activity during the one-year postpartum follow-up were important for facilitating weight loss. The authors also believed that the degree of leisure time activity might, in addition to affecting energy expenditure, also reflect a greater health consciousness (Ohlin and Rossner, 1994).

Harris et al. (1997) examined the impact of pregnancy on long-term weight gain of primiparas in England and identified potential risk factors for maternal obesity. The study design was retrospective involving a repeat-pregnancy and examination of change in maternal body weight from the beginning of one pregnancy to the beginning of a second. Two hundred forty-three women with singleton births participated in the study. The results showed no significant long-term increase in mean maternal body weight following the first pregnancy, and while most mothers retained 1.0kg or less, 24.7 % retained 1.54 kg or more. Mothers with higher BMIs at the beginning of the first pregnancy, who gained more weight during pregnancy, gained significantly more weight from one pregnancy to the next (Harris et al., 1997). The same mothers also gave birth to heavier babies and had longer intervals between pregnancies. The authors concluded that pregnancy may be associated with a permanent increase in maternal body weight simply because it is a time of positive energy balance when some women gain excessive weight. The authors did not speculate as to the cause, but stated that other factors (such as pre-pregnant BMI) determine whether long-term weight gain actually occurs. The authors also suggested that higher weight gains of some women may have been the result of fundamental differences in physiology and or lifestyle that put them at higher risk for excessive weight gain, irrespective of pregnancy (Harris et al., 1997).

Sampselle et al. (1999) studied the role of exercise and postpartum well-being by evaluating reported patterns of postpartum physical activity and identifying benefits or risks associated with that activity at six weeks after delivery (Sampselle et al., 1999). Approximately 1000 women completed a questionnaire at a six week clinic visit. Body weight measured at the clinic was then compared to reported pre-pregnancy weight. The results showed women with higher physical activity levels retained less weight than their less active counterparts. Participation in vigorous exercise at six weeks postpartum was significantly associated with psychosocial well-being. The authors stated that although the outcomes of physical activity have been positive in the general population, exercise has rarely been an element of the postpartum care plans (Sampselle et al., 1999). This study was part of a large longitudinal study, which suggests results might be more generalizable compared to those obtained from cross-sectional design.

In 2002, Rooney and Schauberger investigated the relationship between excess pregnancy weight gain and long-term obesity, a decade after delivery. The original study was conducted in Wisconsin from 1989-1990. Seven hundred, ninety-five women were observed through pregnancy and six months postpartum to examine factors that affect weight loss. The women completed surveys at 2, 4, 6, 8, 12 and 24 weeks postpartum on breastfeeding, use of tobacco or alcohol, sexual activity, return to work, and frequency of exercise. In 1999, a follow-up was conducted and weights were obtained through medical record review (Rooney and Schauberger, 2002). The average weight change from pre-pregnancy to follow-up was a gain of 6.3 kg. Pre-pregnancy weight gain did not influence weight gain, but there was a trend of increased weight retention based on pregnancy-related weight gain. The results also showed women who breastfed and participated in aerobic exercise had significantly lower weight gains 8-10 years postpartum. The authors concluded that breast-feeding and exercise may be beneficial to control long-term weight (Rooney and Schauberger, 2002).

The Stockholm Pregnancy and Women's Nutrition (SPAWN) study is the longest prospective examination of the relationship between weight gain and retention after pregnancy (Linne and Rossner, 2003). Five hundred sixty-three of the original 1463 women participated in the study follow-up. Participants filled out questionnaires and anthropometric data were collected. The sample was divided into four groups based on factors such as number of years between pregnancies, pre-pregnancy BMI, weight gain during pregnancy, and weight change one year postpartum (Linne and Rossner, 2003). The results showed no differences between weight gain during pregnancy and retention in women who had more than two years between their first and second pregnancies. Overweight women (BMI > 25.0) did not gain more weight during pregnancy or retain more weight at one-year after the first and second pregnancy than women with lower BMIs. Women who were high pregnancy weight gainers (14 kg or more) and retainers

(1.8 kg or more) gained more weight during the first pregnancy and retained that weight into the second pregnancy. The same held true for those women for weight gain and retention after the second pregnancy (Linne and Rossner, 2003). Overall, women who were overweight before pregnancy did not have higher risk of postpartum weight retention than normal weight women. Weight gain during pregnancy and weight retention up to one year after delivery was predictive for weight development in the second pregnancy, but the correlation was not extremely high (Linne and Rossner, 2003).

Based on the same SPAWN data, Linne et al. (2004) evaluated how well pre-pregnancy BMI, gestational weight gain, and postpartum weight retention predict retention of weight after 15 years. Results showed overweight women did not gain more weight than normal weight women at one-year follow-up. High weight gainers during pregnancy retained more weight at the one and 15-year follow-ups. 56% of the high weight gainers during pregnancy ended up in the high weight retainers group. Overall, the data showed that weight retention at the end of the postpartum year predicts future overweight 15 years later. The authors suggested that since the women who had not lost the weight by one year postpartum were also those who retained weight at 15-years after delivery, one-year postpartum represented a suitable time period for intervention. The authors noted that small changes in everyday lifestyle are important determinants of long-term weight gain and the effects of those changes may be too small to measure by questionnaire. In addition, lack of measurement of such factors as consumption of alcohol, sweets, etc was a methodological weakness (Linne et al., 2004). The idea that pregnancy-related lifestyle changes are important is supported by a Rossner and Ohlin study of the factors that may link pregnancy to long-term weight retention and obesity.

This study was also based on SPAWN data and suggested that body weight changes, measured one year after delivery, depend more on lifestyle changes during and after pregnancy than by maternal body weight before conception (Rossner, and Ohlin, 1995).

Pregnancy and Postpartum Effects on Lifestyle Behaviors

Investigators can suggest that lifestyle factors such as nutrition, physical activity, and alcohol consumption play a role in long-term weight change, but they also need to evaluate what those lifestyle factors are, and what physiological effects they might have on future weight development. Information from the Australian Longitudinal Study of Women's Health indicates that young women with children are particularly unlikely to be "adequately active", which the authors considered defined as at least once a week. Less than half as many women with children engaged in adequate physical activity compared to women without children (Brown et al., 2000). These trends have also been demonstrated in Canadian studies which revealed that mothers with young children are the least likely population group to exercise (Brown et al., 2000).

Harris, Ellison, and Clement (1999) designed a longitudinal study to determine the psychosocial and behavioral changes resulting from motherhood and their effects on long-term weight gain (Harris, Ellison, and Clement, 1999). Seventy-four women participated in this study (Antenatal Care Project) which was a follow-up of an original randomized control study of antenatal care in south London, England. The researchers collected body weight data at the beginning of pregnancy, lifestyle and behavior variables during pregnancy, antenatal and obstetric care history, postpartum measures of postnatal depression, and measures of parenting stress. Postpartum height, weight and other lifestyle change information were gathered 30 months postpartum (Harris, Ellison, and Clement, 1999).

Results showed that weight gains consisted of weight gained during pregnancy and 2-3 years postpartum. The results showed lifestyle changes that accompany pregnancy and motherhood increase some women's vulnerability to eating disorder psychopathology. Women who felt they did less exercise after pregnancy than before were at a greater risk of long-term weight gain, as were those with few supportive individuals (Harris, Ellison, and Clement, 1999).

In 2002, Miller et al. examined the mediators of physical activity behavior change among women with small children. The investigators used an intervention trial with a control group, a group given print information about overcoming barriers of physical activity, and a group that was also invited to discuss development of local area strategies for the promotion of physical activity among mothers with young children (Miller et al., 2002). After controlling for baseline physical activity, residualized changes in self-efficacy and partner support significantly predicted whether a woman would meet physical activity guidelines. The researchers concluded that partner support and self-efficacy may be mediators of physical activity behavior change (Miller et al., 2002).

Self-efficacy and Physical Activity Behaviors

Self-efficacy is one of the most frequently identified psychological determinants of adherence to physical activity (McAuley and Mihalko, 1998). Self-efficacy beliefs are defined as peoples' judgments concerning their abilities to perform specific tasks successfully in the face of specific obstacles to obtain specific outcomes. These judgments are influenced by diverse sources of efficacy information (Bandura, 1977).

Self-efficacy is a dynamic construct that can be influenced by cognitive, physiological, behavioral, and social information (McAuley and Mihalko, 1998). Exercise efficacy refers to measures directed at the assessment of beliefs regarding individuals' capabilities to engage successfully in incremental bouts of physical activity. Self-efficacy beliefs for exercise are important because they are thought to play a significant role in an individual's decision, effort, and persistence to continue to exercise (Feltz, 1988).

DuCharme and Brawley (1995) examined the influence of various aspects of self-efficacy on the exercise attendance of novice participants. Study participants were sixty-three healthy adult females who enrolled for the first time at a large women's fitness club. Barrier self-efficacy, percent confidence, scheduling self-efficacy, behavioral intention, and exercise behavior were assessed during weeks one and nine of a 16-week exercise program (DuCharme and Brawley, 1995). Results indicated that both barrier and scheduling self-efficacy significantly predicted behavioral intention throughout the exercise program. The results of this study support Bandura's self-efficacy theory in that efficacy predicted attendance behavior of adherent novice exercisers (DuCharme and Brawley, 1995).

Self-efficacy and Physical Activity Behaviors During and After Pregnancy

It is not known whether pregnancy alters the role of self-efficacy in a woman's exercise behaviors. In 1989, Godin, Vezina, and Leclerc conducted a study to identify the factors that may influence a pregnant woman's decision to exercise after delivery (Godin, Vezina, and LeClerc, 1989). Ninety-eight pregnant women completed a questionnaire regarding attitudes, social norms, perceived barriers to exercise, and intentions to exercise after delivery. Differences were found in intentions to exercise between nulliparous and pluriparous pregnant women. The pluriparous women were more realistic in defining their intentions to exercise after delivery, emphasizing the importance of barriers to exercise based on past postpartum experiences (Godin, Vezina, and LeClerc, 1989). The investigator did not follow the participants after delivery to analyze the actual behaviors produced by the intentions.

In 2001, Beilock, Feltz, and Pivarnik studied psychosocial variables related to postpartum exercise behavior in female athletes. Athletes' (N=26) training patterns before, during, and after pregnancy were examined. The authors used a recall survey to examine exercise patterns and psychological variables mediating a return to training and competition after pregnancy (Beilock et al., 2001). Potential study subjects had to have at least four years of competitive athletic experience prior to a pregnancy that occurred within the past ten years. The questionnaires included the Training Patterns Questionnaire, a perceived barriers questionnaire, the Social Provisions Scale, and a follow-up telephone interview examining the types of social support needed during the postpartum period. The number of participants who continued to train during pregnancy decreased overtime from the first to the third trimester, while even fewer competed postpartum (Beilock et al. 2001). Lack of energy was reported as a primary barrier to training both during pregnancy and postpartum. Lack of time was perceived as the most significant barrier to training in the postpartum. Overall, the list of perceived barriers to training postpartum included lack of time, energy, interest, motivation, as well as breastfeeding (sensitive breasts), weight gain, and worry about returning to training too soon. Participants indicated overwhelmingly that childcare was the form of social support most needed (Beilock et al., 2001).

In 2004, Downs and Hausenblaus performed a retrospective examination of exercise beliefs and behaviors during pregnancy and postpartum. Women who were one-year postpartum were recruited from a private practice office in New Britain, Connecticut (Downs and Hausenblaus, 2004). Leisure time activity and exercise beliefs were collected from 74 women ranging from six days to five months postpartum. The most common beliefs during pregnancy were that exercise improves mood, and physical limitations (e.g. nausea) obstructed exercise participation. The most common beliefs during the postpartum period were that exercise controlled weight gain and a lack of time obstructed exercise participation (Downs and Hausenblaus, 2004).

The role of self-efficacy on exercise behavior is an important factor that plays a significant role in a woman's choice to participate in physical activity. Perceived barriers to exercise may influence her intentions to as well as actual participation in physical activity. The question remains of whether this relationship holds for pregnant women and those who have recently given birth. It is not known whether women who are active before pregnancy are more likely to remain active during pregnancy and through the postpartum period or whether activity affects long-term weight changes. More studies are needed to establish a clear role of self-efficacy and a woman's belief to overcome barriers to physical activity in actual activity participation beyond gestation.

Summary

Major points of emphasis for this literature review are that physical activity is safe, beneficial for both mother and fetus, and recommended for women with healthy, normal, singleton pregnancies. Early animal and human studies focused on the physiological effects of physical activity on the maternal-fetal unit. Most study findings suggest that a woman's physiology adapts during pregnancy in order to better dissipate heat, handle the stress of physical activity, and improve fetoplacental function. As the amount of research increased regarding the risks of physical activity during pregnancy, the ACOG has adapted their guidelines to reflect current knowledge. Current recommendations for a woman with a normal, healthy, uncomplicated singleton pregnancy strongly encourage moderate physical activity for 30 minutes most days of the week. This recommendation is similar to that proposed for the general population.

It has been shown that on average a woman will retain 1 kg, beyond weight gained due to age, for each pregnancy. However, the range is wide and can exceed 20kg in some women. The relationship between physical activity during pregnancy and postpartum weight change has been difficult to establish. Factors such as race, lactation, and weight gain during pregnancy have also been found to effect postpartum weight retention. Differences in study design, population, measurement of physical activity and lactation, and postpartum follow-up period have made clear relationships hard to define. Some long-term studies, including 10 years or more of follow-up, have shown that certain lifestyle factors, such as physical activity have played a role in weight gain and retention after delivery. Psychosocial factors regarding physical activity and pregnancy may also play a role in postpartum weight retention. A woman's self-efficacy has been shown to effect exercise participation and the ability to overcome barriers that arise during the postpartum period. The need exists to further assess these relationships between such lifestyle factors and weight retention. A long-term follow-up that includes original physical activity, lactation, and other lifestyle data may be able to add to the current knowledge base. Learning about the barriers to physical activity for postpartum women may also increase our ability to create programs and interventions to increase, if not maintain physical activity participation.

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CHAPTER 5
The effects of past pregnancy physical activity participation on current physical activity, barriers to physical activity, and current body size

Introduction

Background

In 1985, the American College of Obstetricians and Gynecologists published its first recommendations for exercise during pregnancy (ACOG, 1985). Based on limited research at that time, the recommendations were conservative. Major concerns included maternal temperature regulation issues, as well as exercise increasing the risk of preterm birth and low birth weight. Recommendations indicated that maternal heart rates should not exceed 140 beats per minute and vigorous exercise was to be limited to no more than 15 minutes per bout.

In 1994, the ACOG recommendations were revised to include and address research findings that had been performed in the nine years following the original guidelines (Clapp, 2000; Crowell, 1995; Johnston, 1991; Larson-Myer, 2002). Based on more recent data, many studies indicated that maintaining a physically active lifestyle during pregnancy could actually enhance the mother's health and improve the delivery process (Clapp, 2000; Crowell, 1995). As a result, new recommendations no longer included heart rate or duration restrictions for healthy mothers. Continuing aerobic exercise throughout pregnancy was encouraged for mothers who were active before pregnancy, and individual health and exercise screenings and prescriptions were suggested for all pregnant women (ACOG, 1994). However, the effects of sedentary women starting an exercise program during pregnancy and possible detrimental effects of resistance training throughout gestation had not yet been examined thoroughly.

Postpartum women were advised to undertake a slow progression of activity back to pre-pregnancy levels after the 6-week postpartum check up and medical permission. However, few details were provided.

In 2002, ACOG released its most recent list of recommendations for exercise during pregnancy. These follow the current CDC/ ACSM guidelines for the general population, suggesting that in the absence of medical or obstetric complications, 30 minutes or more of moderate exercise a day on most, if not all, days of the week is recommended for pregnant women (ACOG, 2002). The benefits of exercise for obese pregnant women and the possible prevention of gestational diabetes are discussed as well benefits of exercise for previously inactive women, or those with medical complications. The guidelines suggest elite and recreational athletes remain active, modifying exercise volume and intensity as medically indicated (ACOG, 2002). Even with additional research focusing on the postpartum period, the recommendations for exercise soon after delivery still suggested the gradual resumption of activities. Although few details are provided, the newest guidelines suggest that postpartum PA has been associated with decreased incidence of postpartum depression (ACOG, 2002).

Postpartum body weight changes and physical activity

Postpartum weight retention (PPWR) is the pregnancy related weight retained after delivery. Some research shows the risks of weight gain, weight retention, and subsequent obesity are increased during the childbearing years due to pregnancy-related weight gain (Greene et al., 1988; Harris et al., 1997; Rooney and Schauberger, 2002). Although most studies show that weight retention is common during the postpartum period, there is no consensus on the amount of weight typically retained. According to a review by Linne et al. (2002), mean weight increases after pregnancy, but individual variations are wide. The Stockholm Pregnancy and Women's Nutrition (SPAWN) studies report mean weight increases induced by pregnancy to be 0.5 kg in addition to age-related weight gain, but with a wide individual range (Linne et al., 2002). In 1988, Greene et al attempted to study the effect of pregnancy on body weight by assessing interpregnancy weight changes. Average weight gain between pregnancies was 0.9 kg, while one in ten women retained excessive weight of 7 kg or more associated with pregnancy (Greene et al., 1988).

The Institute of Medicine (IOM) has published guidelines for weight gain during pregnancy based on pregravid body size. Specifically, underweight women should gain between 12.5-18 kg, normal weight women should gain between 11.5-16 kg, overweight women should gain 7-11.5 kg, and obese women should gain approximately 6 kg (IOM, 1990). Several studies have been conducted to evaluate the effects of women of different ages, races, and pre-pregnancy weight following these guidelines on PPWR and infant birth weight (Keppel and Taffel, 1993; Schieve et al., 1998). Results have shown that IOM recommendations preserve healthy birth weight and limit PPWR in Caucasian women of normal pre-pregnancy weight, but may not positively affect BW for African American women (Keppel and Taffel, 1993; Schieve et al., 1998).

Many variables have been examined as potential predictors of PPWR. They include pre-pregnancy weight or body mass index (BMI), pregnancy-related weight gain, smoking, lactation, socioeconomic status (SES), marital status, parity, age, and PA (Ohlin and Rossner, 1989; Harris et al, 1997; Johnston, 1991). The relationship between these variables and PPWR has yet to be clearly established. Some studies have shown both positive and negative effects of these variables on PPWR, and the fact that they are intercorrelated makes study design and data collection method extremely important. Differences in outcome variables have often made it difficult to compare the results of one study to another. In almost all research, the strongest predictor of postpartum weight retention is gestational weight gain (Linne et al., 2004). However, it should be noted most studies have included short durations or follow-up periods and have been retrospective in design.

Results from the few research studies on the effects of PA on PPWR are varied, possibly due to differences in study design and PA measurement. Studies have followed women through 6 to 12 weeks postpartum (Muscati et al., 1996; Sampselle et al., 1999), with some continuing for 6-9 months (Boardley and Sargent, 1995; Brewer et al., 1989; Haiek et al., 2001; Keppel and Taffel, 1993; Rookus et al., 1987; Soltani and Fraser, 2000). A few studies have involved long term follow-up with information collected on lifestyle changes due to pregnancy and motherhood. In 2002, Rooney and Schauberger conducted an 8-10 year follow-up study to estimate the impact of excess pregnancy weight gain and failure to lose that weight on excess weight later on in life. They found that excessive weight gain and weight retention were important predictors of long-term weight changes and high BMI later in life (Rooney and Schauberger, 2002).

The arrival of a child can cause maternal lifestyle changes that may affect physical activity behaviors. In a prospective study of body weight changes in women, postpartum weight retention was more affected by lifestyle changes during and after pregnancy than by antenatal factors (Ohlin and Rossner, 1996). In 1992, Brown et al. assessed lifetime parity and weight of Iowa women who were part of a longitudinal cohort study examining body mass and cancer risk. Data collection included a mailed questionnaire requiring recall of pregnancy history and weights at ages 18, 30, 40, and 50 years (Brown et al., 1992). BMI for each age was calculated and parity was defined as the lifetime number of self-reported live births. The researchers found body weight and BMI increased with age and parity was associated with an increase in body weight of 0.55kg per live birth (Brown et al., 1992). At every age, women with a lifetime parity of 1-2 live births had lower mean body weights and BMI values than women with no live births or more than three. The authors stated that weight gain with age most likely results from lifestyle factors that institute a positive caloric balance during the adult years (Brown et al, 1992). They also stated that the results of this study reinforced the need to identify modifiable factors related to weight gain with age in women, so that appropriate interventions could be implemented.

The Australian Longitudinal Study of Women's Health indicated that 18-22 year old women with children are likely to be sedentary or participate in less than one physical activity bout per week (Brown et al., 2000). Less than half of this group of women participated in adequate PA compared with more than half of women without children (Brown et al., 2000). In a study by Miller et al. (2002), three groups of women, with pre-school aged children, were separated into different intervention groups to assess mediators of PA behavior change. A significant intervention effect was found indicating partner support and self-efficacy appeared to be mediators of PA behavior change (Miller et al. 2002). Lifestyle changes, especially the increase in sedentary behavior caused by the arrival of a new child can have a negative effect on a woman's PA level that in turn could affect weight retention, mental well-being, and overall health (Miller et al., 2002).

Self-efficacy and barriers to physical activity

Self-efficacy (SE) is a person's belief in his/her ability to succeed in tasks that occur in his/her life to obtain a specific outcome (Bandura, 1977). A woman's SE toward PA can affect her PA level. The strength of an individual's personal efficacy will determine what tasks are attempted, how much effort will be expended, and how long a person will persist in the face of adversity (McAuley and Mihalko, 1998).

Barrier efficacy involves a person's belief in his/her ability to overcome barriers that inhibit participation in certain aspects of his/her life (McAuley, 1992). Investigators who have focused on barriers have demonstrated this form of efficacy to be consistent with the prediction of exercise behavior (McAuley and Mihalko, 1998). Barriers to tasks or participation in PA can be measured by listing a reasonable number of barriers and assessing one's confidence in overcoming a barrier by using a 0-100% confidence scale (McAuley and Mihalko, 1998).

The establishment of certain barriers as important factors inhibiting PA behaviors in women with children could assist with the creation of intervention programs targeting increases in PA along with the prevention of PPWR. Beilock et al (2001) surveyed past athletes about the effects of pregnancy on training and return to competition. A list of common barriers to exercise was compiled and then participants indicated their degree of confidence from 0-100 in their ability to continue participation in training at least three times a week (Beilock et al, 2001). Participants indicated overwhelmingly that childcare was the biggest barrier to training in the postpartum period. Determining common barriers to exercise could help with the creation of new interventions for PA participation that target mothers with children.

Significance of the problem

According to a review by Mottola (2002), potential benefits of exercise during the postpartum period may include improved cardiovascular fitness, facilitated weight loss, increased energy, improved psychosocial well-being, decreased urinary stress incontinence, and decreased lactation-induced bone loss. While some research has shown the tendency for the childbearing years to be periods of decreased PA, few studies have examined the role of PA during pregnancy and the postpartum period to explain the variance in individual PPWR (Linne et al, 2002).

Due to lifestyle changes that occur because of pregnancy, factors related to the arrival of a new born may affect a woman's ability to exercise during the postpartum period, therefore affecting PPWR. Determining these factors or barriers can assist the fitness and PA community in increasing accessibility and motivation to become or remain physically active after pregnancy.

Few prospective longitudinal studies have been undertaken to examine PPWR and the lifestyle factors that change with motherhood (Linne et al, 2004; Rooney and Schauberger, 2002). In two noteworthy long-term studies, possible effects of PA during pregnancy on weight retention were not directly addressed though both noted that exercise participation after pregnancy may improve long-term weight control (Linne, et al., 2004; Rooney and Schauberger, 2002). There is a need for longitudinal prospective studies that address the long-term effects of PA during pregnancy and the postpartum period on weight as well as the barriers to PA that change lifestyle behaviors after pregnancy.

Purpose of the study

Due to gaps in current knowledge there is a need for a longitudinal study to assess long-term effects of PA participation on PPWR, and lifestyle changes on PA participation. This dissertation will follow a cohort of women (previously studied during pregnancy) to assess lifestyle factors, such as PA and barriers to exercise on current anthropometrics. The purpose of this study is to examine PA participation during a past pregnancy, current weight, anthropometrics, current PA levels, and barriers to exercise of women who are six years postpartum. Based on this purpose, the research questions are as follows.

1. Is current physical activity related to current body size?
2. Is physical activity performed during a pregnancy that occurred six years ago related to current physical activity?
3. What are the current barriers to exercise and what is the average percent confidence score?
4. Is a woman's percent confidence to overcome current barriers to exercise related to past pregnancy physical activity participation?

Limitations of the study

The study participants were obtained from a homogeneous convenience sample with respect to age, race, and socioeconomic status. Generalizability of study results to more diverse groups of previously pregnant women should be applied with caution. Breast-feeding data in the original study were collected at 12 weeks postpartum. The women will be asked as to recall duration of breastfeeding for that pregnancy, and their responses may be susceptible to recall bias. Recalled pre-pregnancy weight for the pregnancy six years ago will be a surrogate for pre-pregnancy weight, which was not available. Finally, some study participants may have had additional pregnancies since the original study.

Methods

Participants

56 women participated in a study designed to determine the reliability and validity of three commonly used physical activity measurement modalities from 1997-2000 (Pivarnik et al., 2002; Stein et al., 2003). Study participants were recruited from obstetrical care clinics in the Mid-Michigan area. All participants delivered healthy, singleton infants. The original MAMA study involved the collection of heart rate telemetry, accelerometry, and a PAR over two consecutive days at 20 and 32 weeks gestation, and 12 weeks postpartum. The researcher reviewed the two-day PAR data with participants during each visit to the lab. When the women were recruited they were informed that the investigators may wish to obtain some follow-up measures (on them and/or their offspring) at a later time. Thus, participants were then contacted to participate in the current study. Email, telephone calls, and letters were used to contact the 41 of the original 56 participants believed to still live in the area. After many phone calls, thirty women were located and agreed to participate, with only one refusal.

Instrumentation

A stadiometer was used to measure participant height in centimeters. A beam balance scale was used to measure participant weight in kilograms. Bioelectrical Impedance Analysis (BIA) was used to measure fat free mass (FFM). BIA involves the passing of a small current through the body (using either hand/foot electrodes or a scale) measuring the resulting tissue resistance and reactance values (Lohman, 1992). Percent body fat is calculated using FFM and measured weight.

The Modifiable Activity Questionnaire (MAQ) was used to recall PA from a past pregnancy. The MAQ is a PAR questionnaire designed for easy modification to maximize the ability to assess PA levels in different populations (Kriska et al, 1990: Kriska, 1997). This questionnaire has been used to assess historical as well as past week PA levels. The MAQ collects information regarding mode, intensity, duration, and frequency of PA as well as occupational activity values. The compendium of physical activities can then be used to calculate MET hours and Kcal expenditure for different activities and time periods (Ainsworth et al., 2000). The MAQ was created initially as an interviewer administered tool and was validated in two studies assessing PA levels and their effect on diabetes risk in Pima Indians. The MAQ PA data were compared with Caltrac activity counts using Spearman rank-order correlations, r=0.62. Test-retest correlations ranged from r=0.88-0.92. The MAQ has also been used to assess the effects of PA on female adult bone parameters, and glucose tolerance of Mauritius citizens. A copy of the questionnaire to be used with this study can be found in appendix B.

A Perceived Barriers Efficacy Questionnaire (PBEQ) was used to assess current barriers to PA (Beilock et al., 2001). The PBEQ requires participants to list their own perceived barriers to current exercise. Each participant is then asked to assign a percent confidence in overcoming each barrier. Percent confidence is a percentile that can range from 0-100, 0 meaning no confidence and 100 meaning total confidence in overcoming a chosen barrier. After a percent confidence score is given to each listed barrier, the top three barriers are ranked from first, meaning most, to third, meaning least important barrier. A percent confidence score is then calculated for each participant by averaging the scores of the top three ranked barriers. This questionnaire was pilot tested in another group (N=6) of postpartum women and is based on a similar tool used to assess barriers to exercise in athletic women returning to sport after delivery (Beilock et al., 2001). A copy of this questionnaire can be found in appendix C.

Sample size, power analysis

Due to the follow-up design of this study, we could not increase sample size to enhance statistical power. Therefore, correlation values needed to achieve meaningful relationships and significance in line with previous reports were calculated using the available sample of 30 women. A review of other PAR tools and MAQ studies assisted in the determination of correlation significance.

Agreement between measured PA and self-reported PA via PAR tools for the same time periods have been established in studies comparing direct measurement techniques such as Vitalog and Caltrac accelerometers, to exercise logs and recall (Stein et al., 2003; Taylor et al., 1984). Correlations have ranged from 0.28 to 0.90 in studies assessing the validity and reliability of PAR tools (Kriska, 1997; Norman et al., 2001; Vuillemin et al., 2000; Wareham et al., 2002). Based on our sample size of 30, conversion tables indicated that an $r=0.36$ would be significant for an alpha level of $P<0.05$, while an $r=0.46$ would significant for an alpha level of $P<0.01$.

Data Collection Procedures

In the original MAMA study, actual PA data for all the three previously mentioned time points were collected using a two-day exercise PAR. During those two days, women wore watches with alarms that sounded on the hour. This alarm served as a reminder that they should record any activity performed within the previous hour. In addition, the study coordinator debriefed each participant to be sure that she recalled her previous day's activities as accurately as possible (Stein et al., 2003). During the follow-up study participants came to the Human Energy Research Lab at Michigan State University for one 45-60 minute follow-up visit. Upon arrival the participant was reminded of the study aims and protocols, after which written informed consent forms were completed.

Anthropometrics

Height was measured to the nearest in 0.1 cm by using a stadiometer. Body weight was measured to the nearest 0.1 kg on a beam-balance. Both instruments were calibrated with known standards before use. FFM was estimated by BIA, and % fat was calculated from FFM and total body weight measurements. A single trained investigator performed these measures. Appendix 1 shows the anthropometric equations used in this study.

Surveys

The first questionnaire collected demographic information including age, parity, time back to work from pregnancy, smoking, marital status, and race. The MAQ assessed current PA and the PBQ assessed current barriers to PA. The previous sample was very homogeneous(predominantly Caucasian, college educated, and married), therefore, SES and education were not addressed specifically.

The MAQ was used to assess PA, at 20 weeks and 32 weeks gestation and 12 weeks postpartum during a pregnancy six years ago, and last week. The details for administering the MAQ were discussed previously in chapter 3 of this dissertation.

Overall, for each time period of interest, participants were asked to circle all activities (from a pre-determined list generated from pilot studies) in which they had participated. Refer to appendix B for examples of this activity list for the MAQ. The frequencies, in days per week, and duration, in hours per bout, were established for each chosen activity. The MET value for all listed activities was determined using the compendium for physical activities developed by Ainsworth et al. (2000). Estimated energy expenditure for each activity was calculated and multiplied by the hours per week in order to calculate a weekly value, for example Kcal/week, (MET*WT)(dur/60)*freq=Kcal/wk (Kriska, 1997). The estimated energy costs of each activity were derived from the most recent compendium of physical activities (Ainsworth et al., 2000). After the average weekly energy expenditure values were calculated, those data were divided by seven to derive daily energy expenditure, then divided by the maternal body weights for each study period in order to obtain energy expenditure relative to weight ([Kcal/day]/kg=Kcal/day/kg). Please refer to appendix A for the energy expenditure equations used with the MAQ described in this section.

Current barriers to PA were then assessed via the PBEQ. The participants were asked to list their perceived barriers to PA, rank order the top 3 barriers and indicate percent confidence in overcoming the listed barriers to physical activity on a scale of 0-100%. An overall confidence score was then calculated by averaging the scores of the top 3 barriers.

Data Analysis

Descriptive characteristics and selected physiological measures were calculated and presented in tabular form. Measures included participants' current age, parity, weight, height, and body composition. PPWR was calculated by subtracting previously determined pre-pregnancy weights from current measured weights. In the original MAMA study breast-feeding data were collected at 12 weeks postpartum only. In the current study we queried the participants about how many weeks they breast fed exclusively. Based on the updated breastfeeding data, the median value of both exclusive and total breastfeeding were noted. Women were then grouped by whether they breastfed less or equal to or greater than the median for exclusive breastfeeding (24 weeks).

Statistical significance for all analytical procedures was set at an alpha level of $P=\leq 0.05$. The statistical program of JMP version 4 was used for all statistical procedures (Sall, Lehman, and Creighton, 2001). During the data analysis process it was discovered that there were two participants whose PA at all time periods was 2-3 standard deviations above the sample norm. Closer inspection of the data showed the women, though more active than the rest, had values within the regression line and therefore, remained part of the analyses. Some analyses also involved comparisons based on current PA levels. Therefore the participants were separated into two groups based on those who met the current CDC/ACSM PA recommendations of 20 MET/wk or more, and those who did not.

Research Question One: Is current physical activity related to current body size?

Data analysis included Pearson correlations between current leisure time PA measures (kcal/day/kg) and the body size measures of BMI and % fat.

Research Question Two: Is physical activity that was performed during a pregnancy six years ago related to current physical activity?

Data analysis included Pearson correlations between the current leisure time PA measure (kcal/day/kg) and the previously recorded data from the three past time periods of interest (20 and 32 weeks gestation and 12 weeks postpartum).

Research Question Three: What are the current barriers to exercise and what is the average percent confidence score?

Data analysis included the frequencies of all barriers listed in tabular form with the top three barriers to exercise for all participants noted as such. The average percent confidence score for all study participants was also calculated along with standard deviations.

Research Question Four: Is a woman's percent confidence in overcoming current barriers to exercise related to past leisure time physical activity levels during a pregnancy six years ago?

Data analysis included Pearson correlations between the percent confidence scores and energy expenditure data (kcal/day/kg) from all time periods of interest (20 and 32 weeks gestation, 12 weeks postpartum). Both previously measured (via PAR) and historically recalled (via MAQ) PA during pregnancy were compared with percent confidence scores.

Results

Descriptive characteristics and other select physiological measures of the entire sample can be found in Table 1. The average BMI for the sample is considered normal and the % fat is between the 10^{th} ad 20^{th} percentile according to the ACSM Guidelines for Testing and Prescription. Anthropometric and descriptive data were grouped by current PA levels (≥20 MET/wk, or not) and can also be found in Table 1. Nine women had no further children after the one in the MAMA study, while one woman had three. The median for exclusive breastfeeding was 24 weeks with a range from 0-104 weeks. The median value for total breastfeeding with the entire sample was 52 weeks with a range from 3-182 weeks. As previously described in the data analysis section, the women were grouped by exclusive breastfeeding duration. One-way ANOVAs were run comparing the means between the breast feeding groups for current weight (1.07, P=0.30), PPWR (1.10, P=0.29), and percent confidence score (2.47, P=0.12). There were no significant differences found.

When the anthropometric data were separated into current PA level groups (women meeting or exceeding 20 MET/wk of activity), the more active women were the same age, height, and had the same number of children as the less active women. One-way ANOVAs were run and found mean differences based on current PA. At a significance of $P \leq 0.05$, the women who met or exceeded the CDC/ACSM recommendations for PA showed lower values for weight, BMI, %fat, and PPWR than those who did not. The median value for PPWR was 2.8 kg with the highest value being 14.9 kg and the lowest of -8.4kg. Ten of the thirty participants were at or below their pre-pregnancy weight of six years ago. Correlations were run to determine the relationships between PPWR and age (r=0.02), number of children (r=0.02), and energy expenditures [20 (r=0.02) and 32 weeks gestation (r=0.04), 12 weeks postpartum (r=0.1), and current (r=0.16)]. No significant relationships were found. The rest of the results for Part II of this dissertation are organized by research question.

Research question one stated: *Is current physical activity related to current body size?* Results of Pearson correlations showed that current leisure time energy expenditure (kcal/day/kg) were inversely related to BMI ($r=-0.55$; $P<0.01$) and % body fat ($r=-0.70$; $P<0.01$) for the entire sample. Further analysis also showed past pregnancy PA, both measured and recalled, inversely related to BMI and % body fat. Figures 4-15 contain the correlation data for past pregnancy PA and body size.

Research question two stated: *Is physical activity that was performed during a pregnancy six years ago related to current physical activity?* Results of Pearson correlations showed that current leisure time energy expenditure (kcal/day/kg) for all subjects was related to measured leisure time energy expenditure at 20 weeks gestation ($r=0.49$; $P< 0.01$), 32 weeks gestation ($r=0.71$; $P<0.01$), and 12 weeks postpartum ($r=0.73$; $P<0.01$). Pearson correlations were also run between the recalled (MAQ) past pregnancy PA and current PA with the following outcomes: at 20 weeks gestation ($r=0.85$; $P<0.01$), 32 weeks gestation ($r=0.85$; $P<0.01$), and 12 weeks postpartum ($r=0.80$; $P<0.01$). Table 4 contains the correlation data for research question 2.

Research question three stated: *What are the current barriers to exercise and what is the average percent confidence score?* The results of all of the frequencies for all listed barriers to exercise are displayed in Table 5. The top three barriers, with subsequent frequencies are as follows: The number one barrier was time (22), second was motivation (7), and third was childcare (6). The average percent confidence score was 65.6 % (±24.5). Further analysis showed that percent confidence score was positively correlated with current PA ($r=0.53$; $P<0.01$).

Research question four stated: *Is a woman's percent confidence to overcome current barriers to exercise related to past physical activity levels during a pregnancy six years ago?* Results of Pearson correlations on the entire sample showed the percent confidence scores were related to measured (PAR) leisure time energy expenditure at only 12weeks postpartum ($r=0.42$; $P<0.05$) when the original PAR leisure time energy expenditure data were used. In contrast, significant relationships were found at all study times when the MAQ recalled leisure time energy expenditure values were used. Specifically, significant correlations were found at 20 weeks ($r=0.51$; $P<0.01$), 32 weeks gestation ($r= 0.49$; $P<0.01$) and 12 weeks postpartum ($r=0.52$; $P<0.01$). Table 6 and Figures 16-18 consist of research question 4 correlation results.

Discussion

The purpose of this study was to examine PA participation during a past pregnancy, current weight, anthropometrics, current PA levels, and barriers to exercise of women who were six years postpartum. Based on this purpose, research questions included: was current physical activity related to current body size; was physical activity performed during a pregnancy that occurred six years ago related to current physical activity; what were the current barriers to exercise and what was the average percent confidence score; and was a woman's percent confidence to overcome current barriers to exercise related to past pregnancy physical activity participation.

The overall descriptive results of this study showed a mean PPWR of 2.8 kg (±5.2 kg), while values ranged from -8.4 to 14.9 kg. The mean PPWR in this sample is higher than that found by other studies (0.9kg, Greene et al., 1988; and 1.51 kg, Ohlin and Rossner, 1990). The range of PPWR is wide, but is similar to the range found by a similar study (-12.3 to 26.5 kg, Ohlin and Rossner, 1990). Differences in pre-pregnancy weight measurement are common in PPWR studies. Whether medical records or subject recall are used, the PPWR value will differ. Also, differences in duration of follow-up, number of pregnancies between weight measurements, and cultural differences between sample populations may cause variations in PPWR.

The results of the MAMA follow-up showed a significant inverse relationship between current PA levels and current body size values (BMI and % fat). This infers that current activity impacts postpartum body weight and fatness. Though no previous study examined this relationship specifically, Ohlin and Rossner (1994) indicated that physical activity was related to postpartum body weight. Their results showed that women who retained $\geq$5 kg at 1 year postpartum were seldom physically active (as defined by performing ~ 4-6 hours of light activity/week) in their leisure time (Ohlin and Rossner, 1994).

A statistically significant relationship was also found between past pregnancy PA and current PA, all time periods of interest (20 and 32 weeks gestation and 12 weeks postpartum) were significant at $P \leq 0.05$. Refer to Table 4 for these data.

Based on these analyses, past pregnancy PA is correlated with current PA, which is inversely related to current body size. When correlations were run between past PA (at all time periods of interest) and current body size, significance was found. This indicates that past pregnancy PA was inversely correlated with current body size variables. In order to establish how this relationship may work, further analyses were conducted to determine if current PA is a confounder, mediator, or modifier with in the past pregnancy PA and current body size relationship. When current PA was added into the model, the relationship between past pregnancy PA and current body size was erased, indicating that current PA is the proximate cause of current body size. Research has shown that past performance or PA participation is related to current PA participation, which the results of this study also support. So, current PA is the main predictor of current body size, past pregnancy PA behavior may have a direct relationship to current PA. Refer to Figure 19 for a visual representation of these relationships.

The current barriers to PA found in this study are displayed in Table 5. Those listed in this study are similar to those found by Beilock et al. (2001). The top barrier response for both studies was lack of time, and showed much higher frequencies that any other barriers listed. Other barriers such as lack of energy and motivation were also mentioned in both studies. The Beilock et al. participants were all former athletes who were asked to list barriers to training for competition during the postpartum period, while we queried our participants about current barriers to physical activity in general, not competition. Though a few participants in the present study may compete from time to time in road races, a majority of the sample was not competitive. Also, unlike the longitudinal design of this study, the Beilock et al. study was retrospective, asking for the recollection of barriers to training postpartum within 10 years past (Beilock et al., 2001). Unlike the current study, the Beilock et al. study did not assess current percent confidence in overcoming barriers to PA; therefore direct comparison with the present study is not possible. Beilock et al. found that postpartum PA was more predictive of current PA. The present study also found a significant correlation between measured past pregnancy PA at 12 weeks postpartum and percent confidence, possibly supporting the theory that postpartum activity and is more predictive of current activity and self-regulatory measures that activity during pregnancy.

Based on the idea of self-regulatory beliefs effecting PA behavior, we investigated current percent confidence score as an effect modifier in the past pregnancy

PA and current PA relationship. A stepwise analysis of past pregnancy and current PA, adding percent confidence as an interaction term, showed a significant ($P \leq 0.01$) increase in regression coefficient when the percent confidence was added as an interaction term. Specifically r^2 values increased from 0.24 to 0.64 (at 20 weeks gestation), 0.48 to 0.64 (at 32 weeks gestation), and 0.53 to 0.64 (at 12 weeks postpartum). This infers that high current confidence to overcome barriers to PA enhances the effect of past exercise on current activity behavior. The average percent confidence score in this study was 65.5 %, which infers a high confidence in overcoming current barriers to PA with this particular study population. This is supported by a 60% current PA participation rate, showing high PA participation and high percent confidence in overcoming current barrier to PA participation.

The connection between percent confidence score and past pregnancy PA was analyzed using original and recalled past pregnancy PA values. The only significant relationship between percent confidence scores and the original PA values occurred at 12 weeks postpartum, although the value at 32 weeks gestation approached significance ($r=0.30$). It is interesting that recalled PA was significantly correlated with percent confidence at all time points (20 and 32 weeks gestation and 12 weeks postpartum). This may be due to that fact that both measurements, recalled PA and percent confidence, were personal perceptions. The percent confidence score was a perception of how confident the subject was in overcoming barriers to current PA and the recalled PA value was their perception of how much activity they participated in during a past pregnancy. Therefore, a woman's perception (rather than reality) of past physical activity history is more meaningful in determining her confidence in overcoming barriers to being active.

We found no studies that compared both actual and recalled PA with current barriers to physical activity. However, Godin, Vezina, and Leclerc (1989) investigated the factors influencing intentions of pregnant women to exercise after giving birth. Their results showed that intention to exercise was strongly correlated with attitude towards the act, exercise habit, and perceived barriers to exercise (Godin, Vezina, and Leclerc, 1989).

An individuals' perception of ability to perform certain physical activities has been investigated using male post myocardial infarction patients. Ewart et al. (1983) discussed the relationships between pre-exercise testing self-efficacy and treadmill performance as well as the effect of post-test self-efficacy on subsequent PA participation in a normal environment (Ewart et al., 1983). Results showed that a patient's perception of his physical activity capacity and actual patterns of subsequent physical activity is influenced by early treadmill testing performance. The authors believed self-efficacy judgment to be an important link between functional status and physical performance (Ewart et al., 1983). Ewart et al. (1986) evaluated a similar population of men with coronary artery disease, to examine the relationship between self-efficacy and strength gains during a circuit weight training program (Ewart et al., 1986). Results stated that pre-training self-efficacy judgments predicted post-test strength gains (Ewart et al., 1986). These two papers support the notion that one's self-efficacy, or belief in ability to perform a task, can affect performance. The present study did not examine this relationship specifically, but linked perceived confidence with recalled physical activity. A common thread between the Ewart et al. papers and the present study is that an individual's self-perception and confidence can affect his/her ability to perform a task and/or overcome a barrier, whether it be physical activity participation, exercise testing, or the recall of past pregnancy PA.

Limitations

Limitations of this longitudinal study include the small sample size and homogeneous participant population. Many discrepancies found between the outcomes from this and other studies may be due to the noted study limitations. Study designs and measurement of PA and barriers also differed, lending to some of the discrepancies in the findings.

Even with the acknowledged study limitations, results of this MAMA follow-up showed, similar to other prominent PPWR studies, most women will retain weight during the postpartum period. Women who were active within the current recommended CDC/ACSM PA guidelines retained less weight six years postpartum than those who were not. Therefore, PA during a pregnancy and the postpartum period could help decrease PPWR and long-term weight retention. This MAMA follow-up also showed a possible relationship between past pregnancy physical activity and current body size. The existence of this relationship could greatly add to validity of promoting PA during pregnancy. Long-term weight management may be aided if women remain, or become, physically active during pregnancy and the postpartum.

Future Directions

Based on the results of this and other long-term postpartum weight retention studies, more research with large, heterogeneous samples are needed to further establish the role of pregnancy related PA on PPWR. Investigators should attempt to gather accurate objective pregnancy PA and energy expenditure values at study onset using measurement tools that have already been examined and found to be reliable and valid, in order to compare outcomes with other studies. If possible, duration of follow-up should include, but not end at, one year postpartum. Five to ten years should be the follow-up goal in order to assess long-term effects of PA during pregnancy.

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Table 1: Descriptive Statistics (M±SD) of total sample, and grouped by current physical activity (≥20 MET/wk)

	Age (yrs)	Ht (cm)	Wt (kg)	Parity (#kids)	BMI (kg-m^2)	FFM (kg)	%fat	PPWR (kg)
Total sample n=30	36.2 (5.0)	165.9 (6.9)	65.5 (12.9)	2.5 (0.94)	23.8 (4.2)	44.4 (4.6)	31.5 (8.9)	2.8 (5.2)
≥20 MET/wk n=18	36.9 (4.9)	166.4 (7.0)	**60.8* (11.0)**	2.5 (0.84)	**21.9* (3.8)**	43.2 (3.7)	**27.8* (9.1)**	**0.71* (4.6)**
≤20 MET/wk n=12	35.3 (5.1)	165.3 (8.4)	**72.5* (13.4)**	2.6 (0.80)	**26.5* (3.8)**	46.2 (4.5)	**37.2* (5.6)**	**6.2* (3.6)**

* Indicates significant values at P ≤0.05

Table 2: Average physical activity values (M±SD) at all time periods of interest (20 and 32 weeks gestation, 12 weeks postpartum, and current)

	20 weeks (MET/wk)	32 weeks (MET/wk)	12 weeks (MET/wk)	Current PA (MET/wk)
Total sample n=30	24.9 (37.1)	17.3 (22.8)	21.6 (25.6)	35.6 (35.1)
≥20 MET/wk	53.4 (45.6)	48.6 (23.0)	49.8 (26.2)	54.4 (33.6)
≤20 MET/wk	5.9 (7.1)	6.0 (6.1)	7.5 (7.0)	7.4 (7.6)

Table 3: One-way ANOVA of recall ability (MAQ-PAR) (M±SD) at the past pregnancy time points of interest (20 and 32 weeks gestations and 12 weeks postpartum) by current PA group (≥20 MET/wk)

	Recall Ability (kcal/kg/day)	F-ratio	P-value
20 weeks	0.10 (2.9)	3.00	0.09
32 weeks	0.02 (1.5)	0.87	0.36
12 weeks	-0.47 (2.0)	0.03	0.87

None of the values were significant.

Table 4: Correlations between measured (PAR) and recalled (MAQ) past pregnancy PA and current PA at all three time periods of interest (20 and 32 weeks gestation and 12 weeks postpartum)

	Current PA and PAR (kcal/kg/day)	Current PA and MAQ (kcal/kg/day)
20 weeks (kcal/kg/day)	**0.49***	**0.85***
32 weeks (kcal/kg/day)	**0.71***	**0.85***
12 weeks (Kcal/kg/day)	**0.73***	**0.80***

*Denotes significance at P-value of ≤0.05

Table 5: Listed current barriers to exercise in rank order.

Top Barriers	Frequency
Time	22
Motivation	7
Childcare	6
Weather	4
Work/worktime	4
Scheduling	4
Tiredness	3
Wanting to spend time with children	3
Injury	2
Lack of sleep	2
Kid prep time	2
Laziness/excuses	2
Lack of alone time	2
Family demands/housework	2
Illness	1
Accessibility	1
Money	1
Boredom	1
Guilt	1
Apathy/lethargy	1
Energy	1

Table 6: Correlations between percent confidence scores and MAQ (recalled) energy expenditures at time periods of interest (20 and 32 weeks gestation and 12 weeks postpartum).

	% confidence score and PAR (measured)	% confidence score and MAQ (recalled)
20 wk PA (kcal/kg/day)	0.16	**0.51***
32 wk PA (kcal/kg/day)	0.30	**0.49***
12 pp PA (kcal/kg/day)	**0.42***	**0.52***

*Indicates significant values at $p \leq 0.05$

Figure 1: Correlations (r) between past measured (PAR) and recalled (MAQ) physical activity at 20 weeks gestation

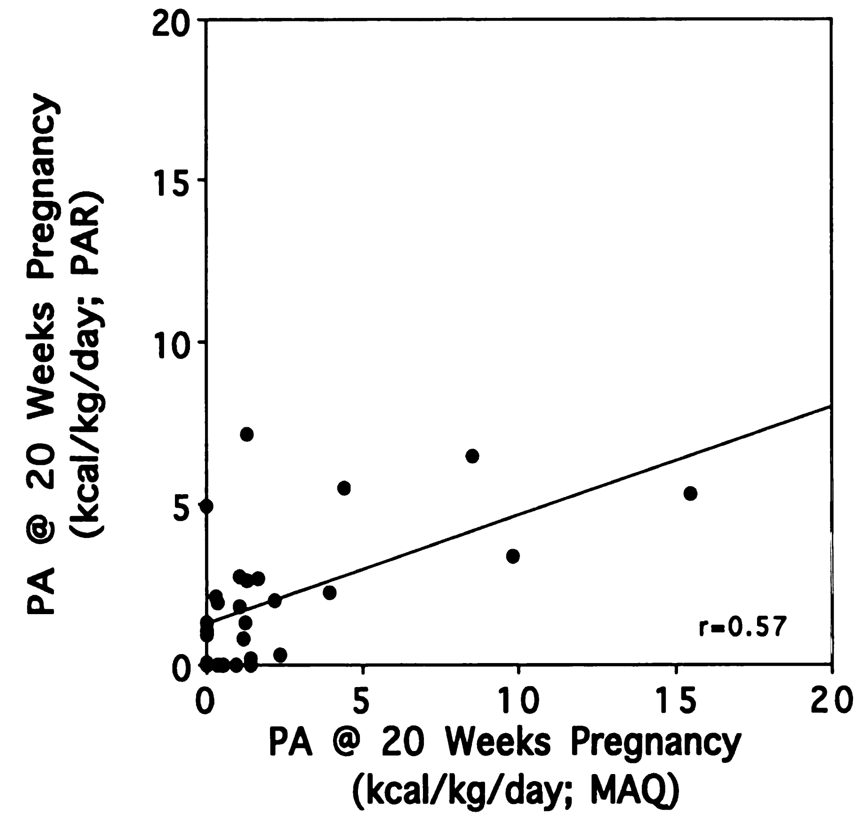

Figure 2: Correlations (r) between past measured (PAR) and recalled (MAQ) physical activity at 32 weeks gestation

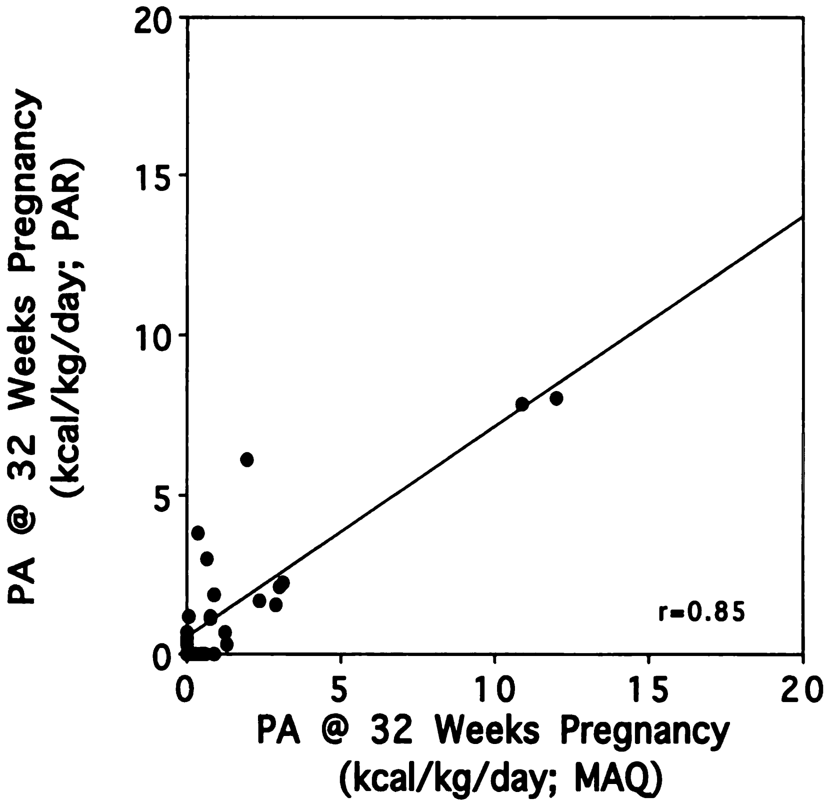

Figure 3: Correlations (r) between past measured (PAR) and recalled (MAQ) physical activity at 12 weeks postpartum

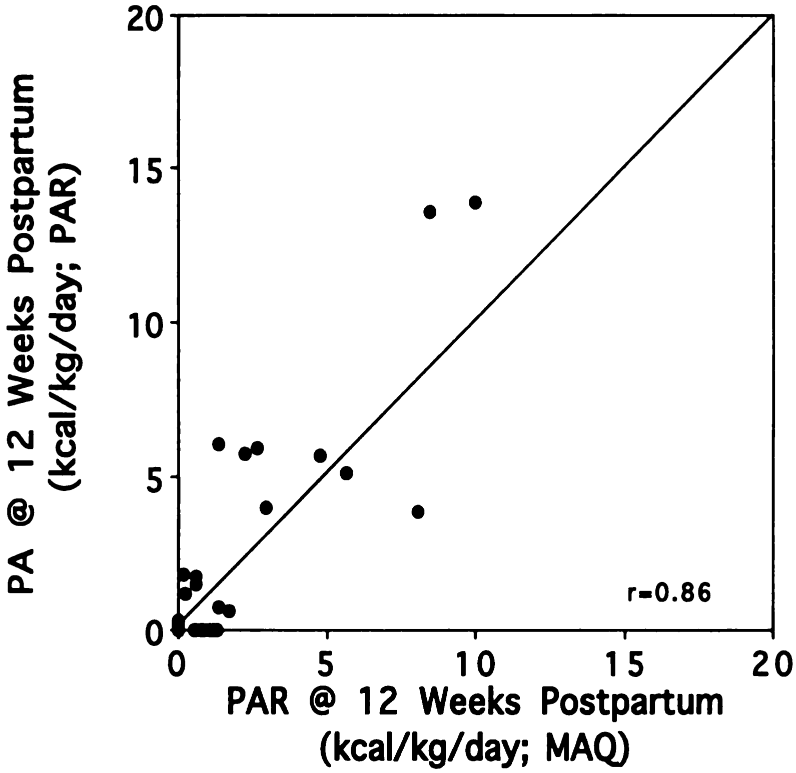

Figure 4: Correlations (r) between past measured (PAR) physical activity and BMI at 20 weeks gestation

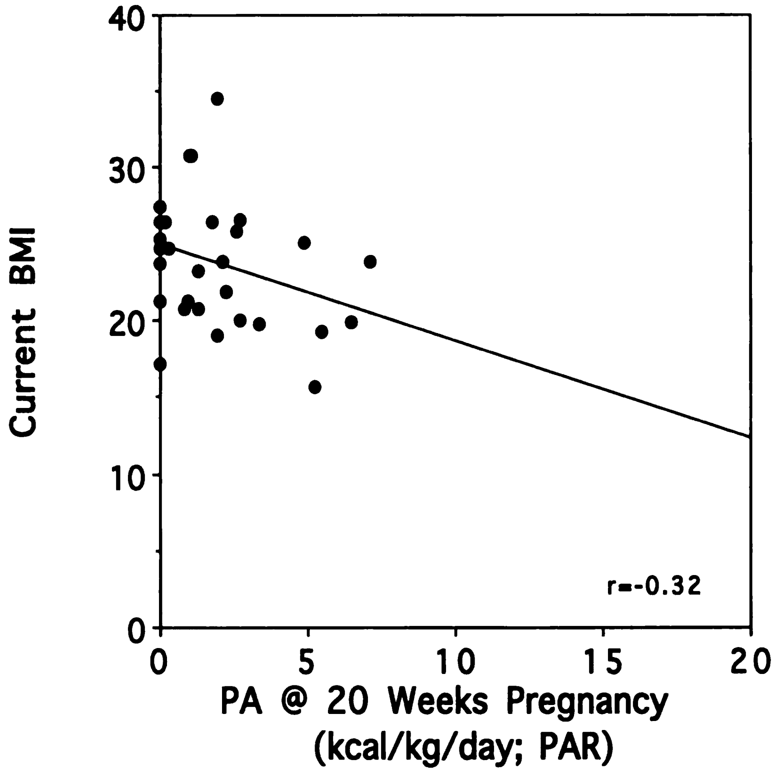

Figure 5: Correlations (r) between past measured (PAR) physical activity and BMI at 32 weeks gestation

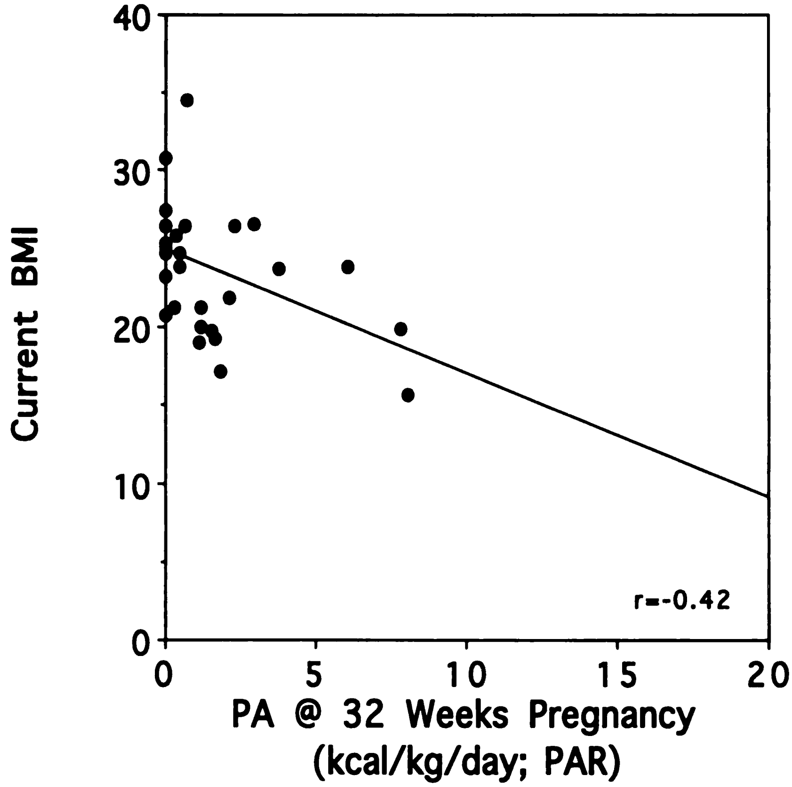

Figure 6: Correlations (r) between past measured (PAR) physical activity and BMI at 12 weeks postpartum.

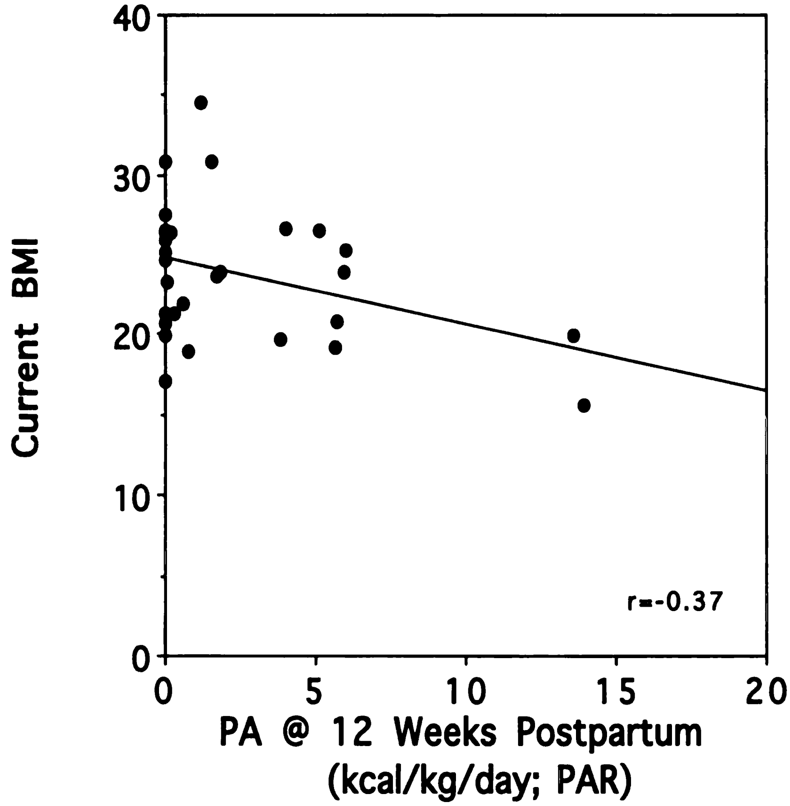

Figure 7: Correlations (r) between past measured (PAR) physical activity and percent body fat at 20 weeks gestation

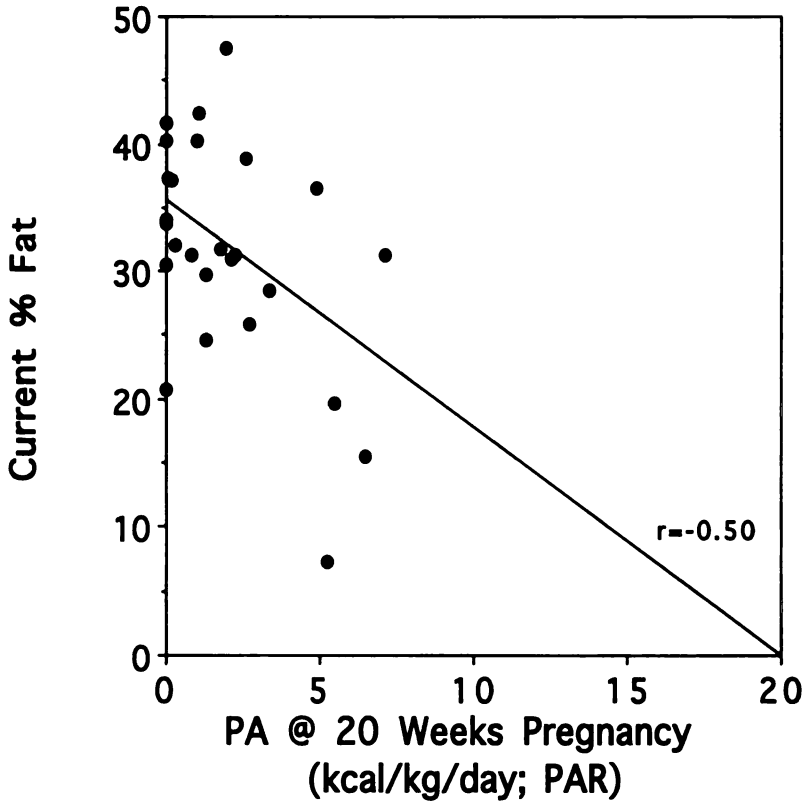

Figure 8: Correlations (r) between past measured (PAR) physical activity and percent body fat at 32 weeks gestation

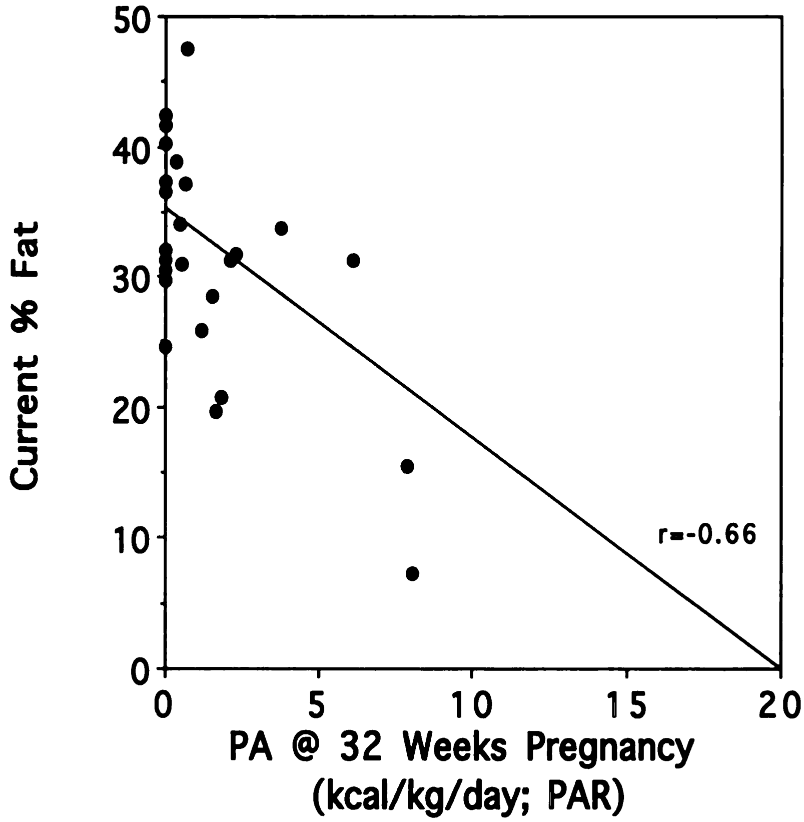

Figure 9: Correlations (r) between past measured (PAR) physical activity and percent body fat at 12 weeks postpartum

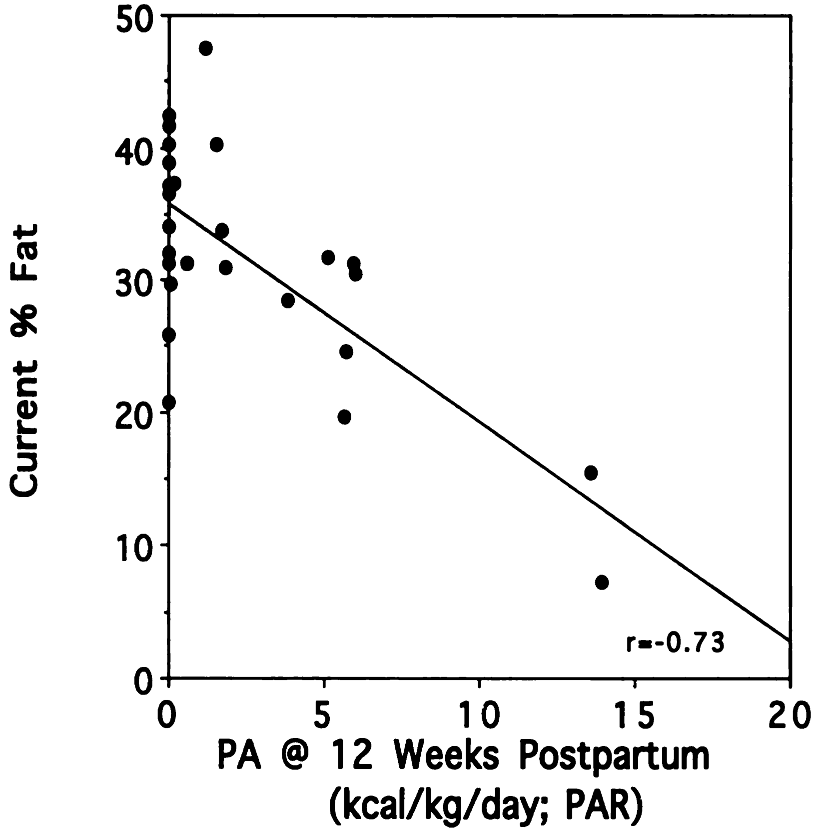

Figure 10: Correlations (r) between past recalled (MAQ) physical activity and BMI at 20 weeks gestation

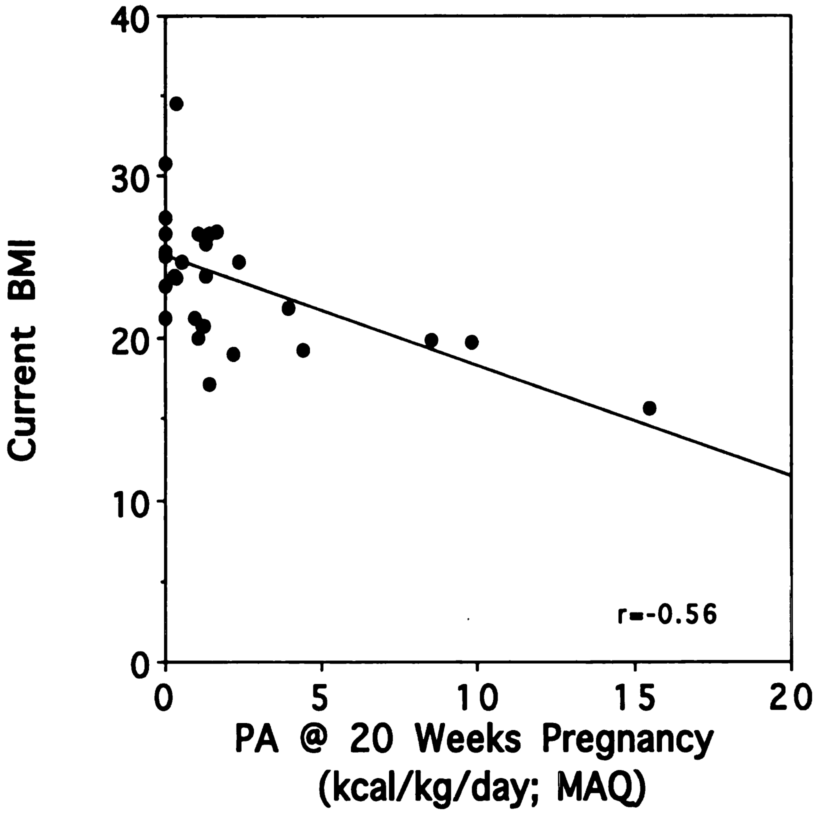

Figure 11: Correlations (r) between past recalled (MAQ) physical activity and BMI at 32 weeks gestation

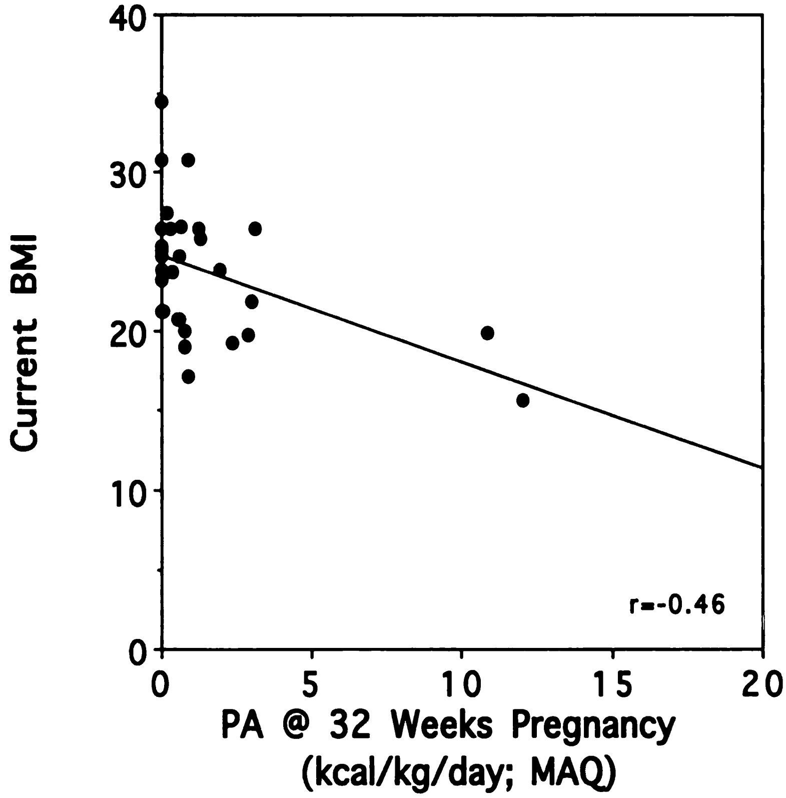

Figure 12: Correlations (r) between past recalled (MAQ) physical activity and BMI at 12 weeks postpartum

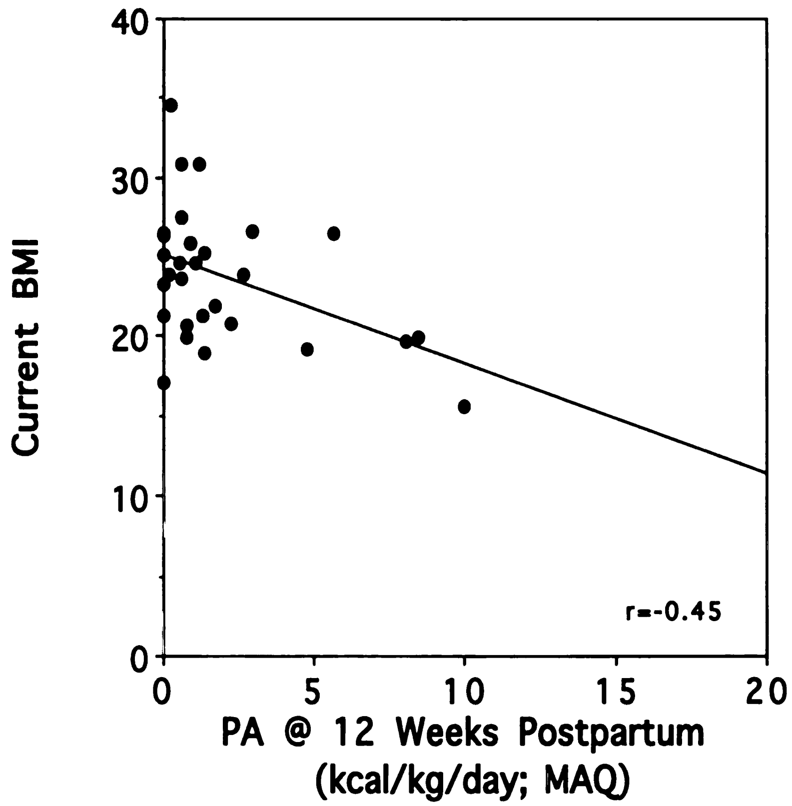

Figure 13: Correlations (r) between past recalled (MAQ) physical activity and percent fat at 20 weeks gestation

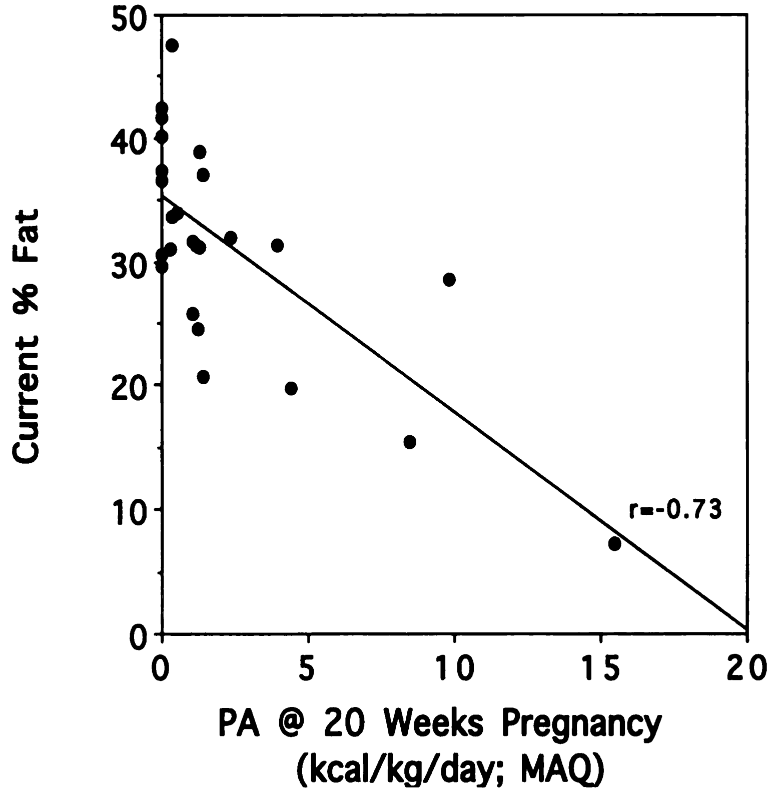

Figure 14: Correlations (r) between past recalled (MAQ) physical activity and percent fat at 32 weeks gestation

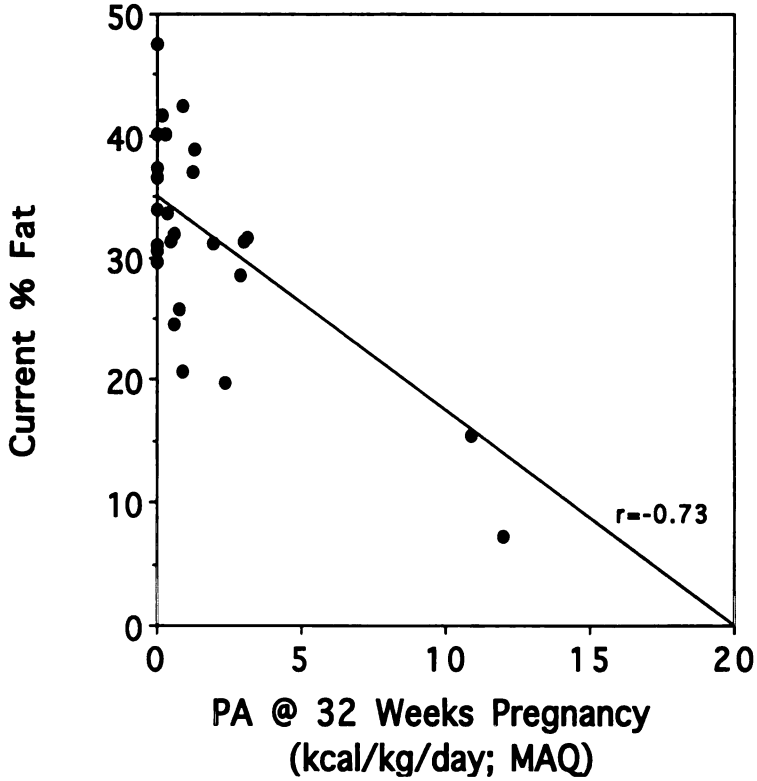

Figure 15: Correlations (r) between past recalled (MAQ) physical activity and percent fat at 12 weeks postpartum

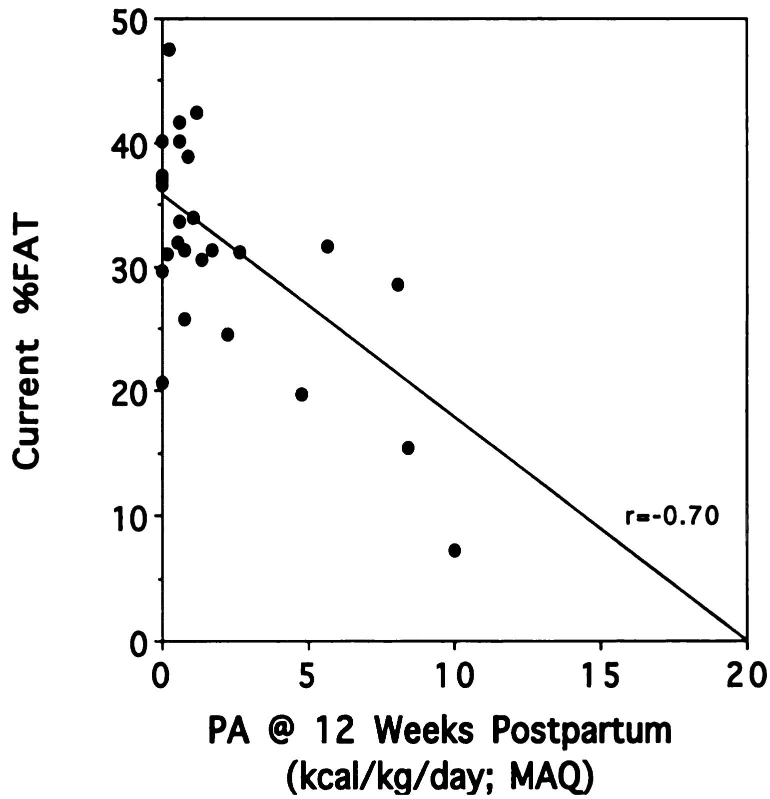

Figure 16: Correlations (r) between percent confidence and past physical activity, both measured (PAR) and recalled (MAQ) at 20 weeks gestation

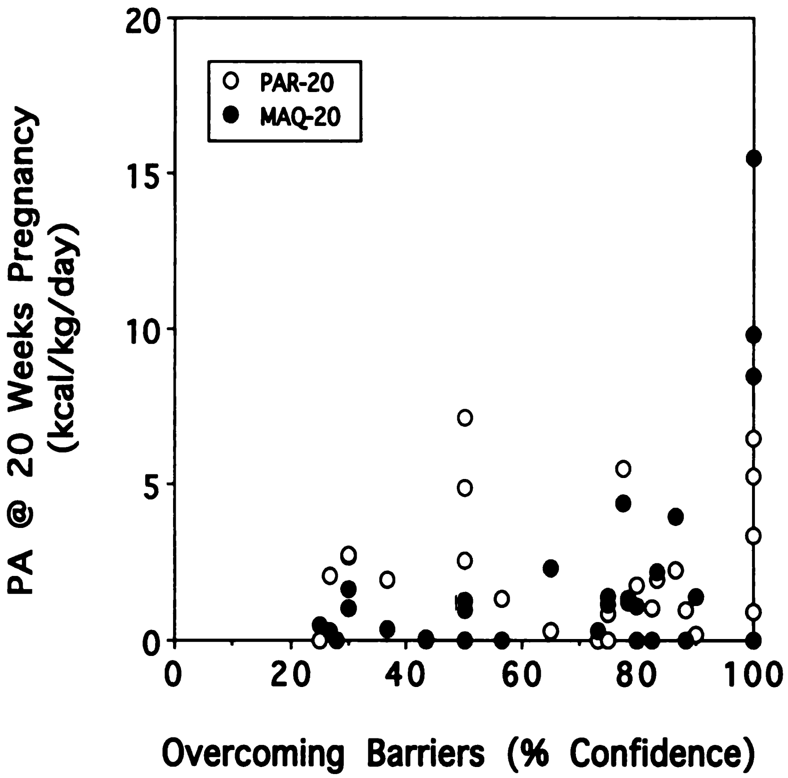

Figure 17: Correlations (r) between percent confidence and past physical activity, both measured (PAR) and recalled (MAQ) at 32 weeks gestation

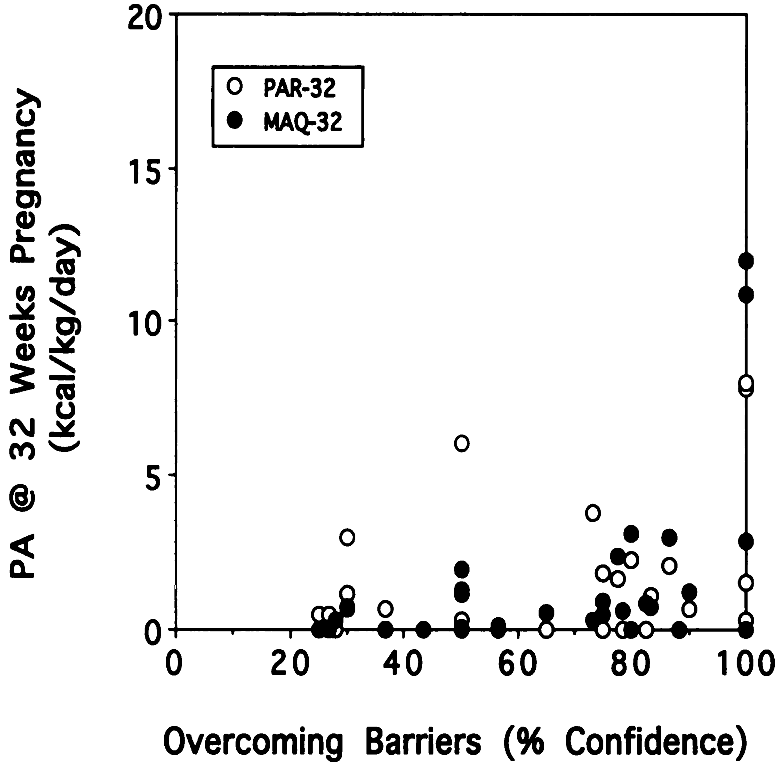

Figure 18: Correlations (r) between percent confidence and past physical activity, both measured (PAR) and recalled (MAQ) at 12 weeks postpartum

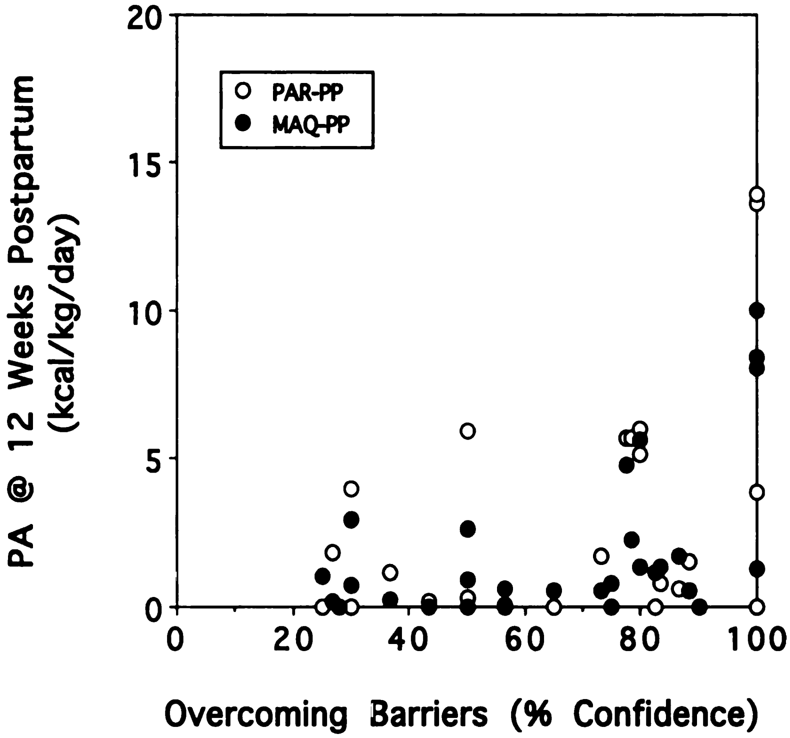

Figure 19: Visual representation of the past physical activity and current body size relationship

Current PA $\longrightarrow$ Current Body Size

Past Pregnancy PA $\longrightarrow$ Current PA

Past Pregnancy PA $\longrightarrow$ Current Body Size

How does current PA fit into this relationship?

$$\begin{tikzcd}
\text{Past Pregnancy PA} \arrow[rr] & & \text{Current PA} \arrow[rr] & & \text{Current Body Size} \\
& \text{Behavior influence} \arrow[u] & & \text{Proximate cause} \arrow[u] &
\end{tikzcd}$$

Appendix A

Anthropometric Equations

BMI (Body Mass Index)

BMI=kg-m^2

BIA (Bioelectrical Impedance)

FFM (kg)= 0.493 (HT2/R)+0.141 (BW)+11.59 (Lohman, 1992)

% Body Fat

FM= BW-FFM
%BF= (FM/BW) X 100

*Equations were obtained from *Applied Body composition Assessment* by Heyward and Stolarczyk

MAQ Leisure Time Energy Expenditure Equations

Kcal/wk

(MET*WT)(dur/60)*freq=Kcal/wk

Kcal/day/kg

(Kcal/wk)/7=Kcal/day
(Kcal/day)/kg=Kcal/day/kg

*Equation obtained from Ainsworth et al, Compendium of Physical Activities, 1993

Equation Key

FFM= fat free mass (kg)
HT= height (cm)
R= resistance (ohms)

BW=body weight (kg)
FM= fat mass (kg)

MET= metabolic equivalent
WT= weight of the subject (kg)
Dur= duration of the activity bout (min)
Freq= frequency of activity each week (days/wk)

Appendix B

Subject ID#: ________________

Modifiable Activity Questionnaire

Please circle all activities listed below that you have ever participated in more than 10 times in your life:

Jogging (outdoor, treadmill)	1	Football/Soccer	14	Stair Master	27
Swimming (laps, snorkeling)	2	Racquetball/Handball/Squash	15	Fencing	28
Bicycling (indoor, outdoor)	3	Horseback riding	16	Hiking	29
Softball/Baseball	4	Hunting	17	Tennis	30
Volleyball	5	Fishing	18	Golf	31
Bowling	6	Aerobic Dance/Step Aerobic	19	Canoeing/Rowing/Kayaking	32
Basketball	7	Water Aerobics	20	Water skiing	33
Skating (roller, ice, blading)	8	Dancing (Square,Line,Ballrm)	21	Jumping rope	34
Martial Arts (karate, judo)	9	Gardening or Yardwork	22	Snow skiing (X-C/Nordic trk)	35
Tai Chi	10	Badminton	23	Snow skiing (downhill)	36
Calisthenics/Toning exercises	11	Strength/Weight training	24	Snow shoeing	37
Wood Chopping	12	Rock climbing	25	Yoga	38
Water/coal hauling	13	Scuba Diving	26	Other	39
Walking for exercise	40				

Please list the names of the activities chosen below:

________________ ________________

________________ ________________

________________ ________________

________________ ________________

________________ ________________

________________ ________________

________________ ________________

________________ ________________

List each activity from those circled, that you participated in during the fall before you became pregnant five years ago. What was the frequency, duration, and intensity of each activity listed?

Activity	Frequency	Duration	Intensity

______ MET/wk ______ KCAL/wk

List each activity from those circled, that you participated in during the second trimester of your pregnancy five years ago. What was the frequency, duration, and intensity of each activity listed?

Activity	Frequency	Duration	Intensity

______ MET/wk ______ KCAL/wk

List each activity from those circled, that you participated in during the third trimester of your pregnancy five years ago. What was the frequency, duration, and intensity of each activity listed?

Activity	Frequency	Duration	Intensity

_______ MET/wk _______ KCAL/wk

List each activity from those circled, that you participated in at 12 weeks postpartum from your pregnancy five years ago. What was the frequency, duration, and intensity of each activity listed?

Activity	Frequency	Duration	Intensity

_______ MET/wk _______ KCAL/wk

List each activity from those circled, that you currently participate in during a typical week. What was the frequency, duration, and intensity of each activity listed?

Activity	Frequency	Duration	Intensity

_______ MET/wk _______ KCAL/wk

In general, how many HOURS each NIGHT do you sleep? ________

In general, how many HOURS per DAY do you usually spend watching television/using the computer? ______

Did you ever compete in an individual or team sport (not including any time spent in sports performed during school physical education classes)?

Yes/No

If yes, how many total years did you participate in competitive sports? ________

Appendix C

Perceived Barriers Efficacy Questionnaire

DIRECTIONS: List at least **THREE** barriers that you think interfere with your ability to participate in regular physical activity for the next three months. Next to each barrier, indicate the level of confidence (ranging from 0% to 100%) that you could overcome that barrier if it was present. Rank each barrier, 1 is perceived to be the hardest, 2 not as hard, and so on down the list. Please feel free to elaborate on why you chose the barriers in the space provided below.

Barriers	**% Confidence**	**Rank**
1.________________________	__________	____
2.________________________	__________	____
3.________________________	__________	____
4.________________________	__________	____
5.________________________	__________	____
6.________________________	__________	____

Elaborate:

Appendix D

The Effect of Physical Activity During a Past Pregnancy on Current Physical Activity, Barriers to Physical Activity, and Body Size; and Validation of a Historical Recall Tool

Statement of Informed Consent

Participant's Name:___________________________________

Purpose of the Study:
The purpose of this follow-up study is to assess current body size, physical activity levels, and barriers to physical activity, as well as to validate a historical physical activity recall tool.

Your participation in this study is voluntary. You may decline to participate in given activities if you so choose, refuse to answer specific survey questions, or withdraw from the study at any time without penalty.

Description of the Study:
You are invited to participate in this follow-up project which involves coming into the Human Energy Research lab (HERL) at Michigan State University (MSU) for one, two hour follow-up visit approximately five years after the pregnancy which was examined in the previous Maternal Activity Measurement and Assessment (MAMA) study. The one visit will consist of body size measurement and data collection via survey instruments. The details about the measurement and data collection are listed below.

Anthropometrics (body size measurements)
You will arrive at the HERL (Human Energy Research Lab) at Michigan State University in comfortable clothing meant for movement. You will have your height and weight measured, then we will measure your bioelectrical impedance (BIA) while you lay down with electrodes on your hands and ankles. BIA will measure your fat free mass by sending a small current through you body. BIA is based on the fact that water and muscle conduct currents while fat tissue does not. Current body composition will then be calculated from the measured fat free mass value and we will compare these values to those collected in the study 5 years ago.

Data Collection
After the anthropometric data is collected, we will administer surveys to assess current and past physical activity as well as current barriers to physical activity. Past physical activity will consist of you remembering how active you were before, at 20 weeks, 32 weeks gestation, and 12 weeks postpartum for the pregnancy that was examined 5 years ago. Current physical activity will be assessed by asking you to describe your activity for the past week. The barriers to physical activity will be assessed by asking you to list your current perceived barriers to physical activity participation, having your rank at least the

top three barriers chosen then have you determine your percent confidence for overcoming the listed barriers.

In addition to the data collection mentioned above, your medical records may be examined for information regarding infant birth weight, initial pregnancy visit weight, and gestational age.

Side Effects and Risks:
There are no physical risks involved in this study, therefore there should be no physical side effects involved in study participation.

Benefits:
For your participation you will receive a monetary award of $25. You will also learn your current weight and body composition. Also, the information obtained in this research will help future studies dealing with women, especially pregnant and postpartum women and how their bodies change for the long-term after a pregnancy.

Confidentiality:
All of your records from this study will be considered confidential and your name will not be identified in any publication or report from this study. Your privacy will be protected to the maximum extent allowable by law.

Cost:
Your participation in this research study will not involve any additional costs to you or your health care insurer.

Your signature below acknowledges your voluntary participation in this research study. Such participation does not release the investigators, institutions, sponsor, or granting agency from their professional and ethical responsibility to you. If you have any questions about the study, please contact the investigator Jim Pivarnik Ph.D. by phone: (517) 353-3520, by email: jimpiv@msu.edu, or regular mail: room 3 IM Sport Circle, East Lansing, MI 48824. If you have questions or concerns regarding your rights as a human subject, or are dissatisfied at any time with any aspect of the study, you may contact, anonymously, if you wish, Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517) 355-2180, fax: (517) 432-4503, email: ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

______________________________ ______________
Signature of Study Participant Date

____

______________________________ ______ ______
Address Home Work

____
Signature of Investigator