The Effects of an Exercise Program on Diastasis Recti Abdominis in Pregnant Women

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ABSTRACT

Background and Purpose: Diastasis recti abdominis (DRA) is a condition in which the two bellies of the rectus abdominis muscle separate along the linea alba. Existing literature has acknowledged the incidence, presence, and risk factors for DRA in pregnant women. Additional studies have examined the potential benefits and consequences of exercising during pregnancy, however, no research has specifically investigated the effects of exercise on DRA during pregnancy. The purpose of this study was to determine the effects of an abdominal-muscle strengthening program on the presence and the size of DRA in pregnant women. **Subjects and Methods:** Twenty-four pregnant women, 12 exercising and 12 non-exercising, were recruited to participate in this study. Of the 24 women, eight exercising and 10 non-exercising women met the inclusion criteria. A digital caliper was used to measure DRA at three marked sites along the midline of each subject's abdomen: 4.5cm above the umbilicus, at the umbilicus, and 4.5cm below the umbilicus. Measurements were taken by two investigators with a high inter-rater reliability of ICC (3,1) = 0.870 and high intra-rater reliabilities of ICC (3,1) = 0.997 and 0.995 respectively. Subjects were instructed to come up into a partial sit-up as the investigator measured DRA at each site. Two measurements were taken at each site and the average measurement for each site was used for statistical analysis. **Results:** DRA was found to be more common in the non-exercising women than in the exercising women, with a 90% and 12.5% presence respectively. DRA was also significantly larger in non-exercising women than in exercising women at each of the three measurement sites ($F_{(17,1)} = 13.54$, $p<0.05$, $F_{(17,1)} = 16.66$, $p=0.001$, $F_{(17,1)} = 13.13$, $p<0.05$). **Conclusion:** Exercise may be helpful in preventing or reducing the size of DRA in pregnant women. However, further investigation of the effect of exercise on DRA and the potential implications of DRA on functional activities is warranted.

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CHAPTER 1: INTRODUCTION

Research Statement

The purpose of this study is to examine the effects of an exercise program on diastasis recti abdominis in pregnant women.

Statement of Aims

1) To determine the presence and size of diastasis recti abdominis in pregnant women who are exercising.

2) To determine the presence and size of diastasis recti abdominis in pregnant women who are not exercising.

3) To determine if there is a difference in the presence and size of diastasis recti abdominis between exercising and non-exercising pregnant women.

Hypotheses

1) There will be a greater incidence of diastasis recti abdominis in non-exercising pregnant women as compared to exercising pregnant women.

2) There will be a larger diastasis recti abdominis at each of three measurement sites in non-exercising pregnant women as compared to exercising pregnant women

Operational Definitions

Exercising: Pregnant women enrolled in the Maternal Fitness Program who have been exercising for at least six weeks and are in Class B (see Appendix A).

Non-Exercising: Pregnant women who have not participated in any formal exercise program since the onset of their pregnancy.

Diastasis recti abdominis: A separation of the rectus abdominis muscles at the linea alba greater than 2 cm above the arcuate line and greater than 1 cm below the arcuate line.

Significance

The rectus abdominis muscle group runs longitudinally from the base of the sternum and mid-thoracic cavity to the symphysis pubis. The two bellies of the muscle are connected by a sheath of connective tissue called the linea alba. Diastasis recti abdominis (DRA) is a condition characterized by the separation of the rectus abdominis muscle at the linea alba most often related to pregnancy. Hormonal changes during pregnancy result in increased extensibility of connective tissue throughout the body, possibly affecting the linea alba. This increased extensibility, in addition to the mechanical stress exerted on the anterior abdominal wall by the growing fetus, can result in a DRA (Boissonnault, 1988).

As pregnancy advances, the rectus abdominis muscles become stretched and elongated around the enlarging uterus. This altered line of pull may compromise the optimal length-tension relationship of the muscle. Additionally, the prolonged stretch of the rectus abdominis muscles may lead to weakening of the musculature (Goldspink & Williams, 1978). The resultant insufficiency of the abdominal muscles can lead to functional implications for the pregnant woman. The rectus abdominis muscles, in addition to other trunk musculature, play a key role in posture, trunk stability, respiration, trunk flexion, rotation, sidebending, and vaginal delivery of a baby (Boissonnault, 1988). A weakened abdominal wall may also compromise simple activities of daily living such as rolling over, lifting items, and elimination (Boissonnault, 1988).

The incidence of DRA is much greater than once believed. Boissonnault et al. (1988) found that 66% of women in their third trimester of pregnancy presented with DRA. Another study examining post-partum women found that in women who had given birth less than four days prior, 62.5% presented with DRA (Bursch, 1987).

The American College of Obstetricians (ACOG) recommends exercise for pregnant women, stating its benefits as "maintaining muscle tone, strength, and endurance and protecting against low back pain" (Wilder, 1988). Research efforts examining the effects of exercise in pregnant women have largely focused on physiological responses of the fetus and birth outcomes after aerobic exercise. An exhaustive computerized literature search reveals a paucity of scientific studies on the effects of exercise on the health and function of the pregnant mother. Additionally, Gall and Kaufmann (1987) report that the effects of strengthening exercise on pregnant women have not been adequately studied in scientific literature. Literature specific to DRA to date has primarily focused on the incidence and risk factors for the condition. While current prenatal treatment DRA consists of preventing an already existing DRA from expanding and strengthening the abdominal muscles, the effects of exercise on DRA in pregnant women remain elusive (Boissonnault, 1988).

As exercise improves the tone and strength of the abdominal muscles, it is logical that strengthening the abdominal muscles during pregnancy may help to decrease the incidence and/or size of the DRA (Noble, 1982). While this theoretical framework is important, clinical studies on DRA as well as research comparing pregnant women who exercise with those who do not are needed to provide scientific evidence from which practitioners can base sound clinical decision-making.

Only recently are physicians and health care practitioners recognizing the potential functional limitations of DRA. As physical therapists are the primary health care professionals to treat musculoskeletal impairments and function, they will likely be faced with many patients suffering from this condition. Knowledge of the role of exercise in the resultant presence and size of DRA may help determine effective interventions for the prevention and treatment of the condition.

CHAPTER 2 : REVIEW OF LITERATURE

Existing literature has acknowledged the high incidence, presence, and risk factors for the condition diastasis recti abdominis (DRA) in pregnant women. Additional studies have examined the potential benefits and consequences of exercising during pregnancy, however, no research has specifically investigated the effects of such exercise on DRA. The aim of our study is to determine the effect of an abdominal-muscle strengthening program on the presence and size of DRA in pregnant women. In order to fully appreciate the potential effects of the exercise program on DRA, it is important to have a basic understanding of the structure and function of the abdominal muscles, possible implications and causes of DRA - including normal physiologic changes in the female body during pregnancy, potential effects of exercise during pregnancy, and the reliability of instruments used to quantify the size of DRA.

Abdominal Muscles

Before we can investigate what happens to the abdominal muscles during pregnancy, we must first describe them in the non-pregnant individual. By understanding the structure and function of the anterolateral abdominal wall we can attempt to investigate its role in the pregnant woman.

The anteriolateral abdominal wall functions to support and protect the contents of the abdominal cavity. It consists of fascial layers, four pairs of abdominal muscles, their aponeuroses, and the linea alba. The most superficial layer of the anterolateral abdominal wall contains two layers of fascia. The most superficial of these two layers is known as

Camper's fascia which contains varying amounts of fat. The deeper layer is known as Scarpa's fascia, which is more elastic and membranous than the superficial layer (Boissonnault & Kotarinos, 1988).

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Deep to these two layers of fascia are the aponeuroses of the three horizontal abdominal muscles, the transverse abdominis, the external oblique, and the internal oblique. Aponeuroses are defined as flat sheets of densely arranged collagen fibers usually containing several layers (Woodburne & Burkel, 1994). Rizk (1991) describes the aponeuroses of the abdominal muscles as being bilaminar. The collagen fibers within each layer are parallel, but are aligned in directions different from their adjacent layer. The fibrous bundles are also intertwined from layer to layer, giving the aponeuroses increased structural stability and elasticity (Woodburne & Burkel, 1994). Anteriorly, the aponeuroses of the three horizontal abdominal muscles join together to form the rectus sheath, which covers the fourth abdominal muscle, the rectus abdominis. Above the umbilicus, the aponeurosis of the internal oblique splits. The superficial layer runs with the aponeurosis of the external oblique anterior to the rectus abdominis muscle. The deep layer runs with the aponeurosis of the transverse abdominis muscle posterior to the rectus abdominis muscle. Below the umbilicus the aponeuroses of all three horizontal muscles run anterior to the rectus abdominis muscle. When the aponeuroses from the right and left horizontal abdominal muscles intertwine, they form a tendinous band extending from the ziphoid process to the pubic symphisis known as the linea alba. Below the umbilicus, the linea alba is a thin band allowing the two bellies of the rectus abdominis muscle to touch. Above the umbilicus, the linea alba forms a band approximately 2cm wide due to diverging muscle bellies (Woodburne & Burkel, 1994). The organization of the aponeurotic sheaths around the rectus abdominis muscle has been found to contribute to the increased elastic strength of the linea alba below the umbilicus in comparison to the above the umbilicus. Rath et al. (1996) did a biomechanical study of 40 cadaver abdominal walls and found that the sub-umbilical region of the rectus sheath exhibited a greater constraint than the supra-umbilical portion. The author defines constraint as the resistance of the tissue to linear traction. It can be inferred than that this greater constraint below the umbilicus could lead to less separation of the linea alba in sub-umbilical regions versus supra-umbilical portions.

The next component of the anterolateral abdominal wall includes four pairs of large flat muscles which function together for a variety of purposes. The deepest of these muscles is the transverse abdominis muscle (TrA). The TrA originates from the lower six ribs, the transverse processes of the first four or five lumbar vertebrae and the medial lip of the iliac crest. It's fibers run horizontally and attach anteriorly as an aponeurotic sheath (Lacote & Chevalier, 1987).

The next, more superficial layers of abdominal muscles are the oblique muscles. The external oblique originates from the external surface of ribs five through twelve with its fibers running inferomedially and attaching anteriorly as an aponeurotic sheath (Moore & Dalley, 1999). The inferior oblique originates from the thoracolumbar fascia, the iliac crest, and the inguinal ligament. It's fibers run horizontally at the level of the anterior inferior iliac spine (AIIS), obliquely upward superior to the AIIS and obliquely downward inferior to the AIIS. Its fibers also attach anteriorly as an aponeurotic sheath (Moore & Dalley, 1999).

The most superficial of the muscles of the anterolateral abdominal wall is the rectus abdominis. It originates from the costal cartilages of the fifth, sixth, and seventh ribs. It runs longitudinally along the anterior wall, inserting onto the pubic bone from the pubis symphysis to the pubic spine (Lacote & Chevalier, 1987). The muscle bellies from the right and left rectus muscles are connected longitudinally by the linea alba.

These four muscles of the anterolateral abdominal wall function both independently and as a group for several purposes. The three most important abdominal muscles to this study include: trunk flexion and rotation, maintaining postural stability, and increasing intra-abdominal pressure. The primary anatomical functions of the rectus abdominis muscle and the oblique muscles are to flex and rotate the trunk. Because of their longitudinal fibers, the rectus abdominis muscles approximate the ribs and the pelvis upon contraction (LaCote & Chevalier, 1987). The oblique muscles, which have fibers running obliquely, contract to assist with trunk flexion as well as trunk rotation. In the earliest known EMG study of the abdominal muscles, Floyd and Silver (1950) found that in the supine position, lifting the head against gravity elicited a strong contraction of the rectus abdominis muscles. Sheffield et al. (1962) went a little further to examine the role of the abdominal muscles during flexion of the entire trunk in the supine position. They found that when subjects raised their trunk to 90 degrees from the supine position with their hands behind their head, there was maximal contraction of the rectus abdominis muscle.

Partridge and Walters (1959) attempted to study the abdominal muscles during various everyday movements. They found that the rectus abdominis muscle was active during a trunk curl in the supine position and when the trunk curl was combined with rotation, the internal and external oblique muscles began firing to assist the rectus abdominis muscle. This study also found that the internal oblique muscle is the major contributor to hip rolling. Hip rolling is performed by bringing the knees to the chest then dropping them to the floor on one side and then to the other. This movement was done to simulate activities of daily living such as rolling side to side and getting out of bed.

In addition to flexing and rotating the trunk, the abdominal muscles play a key role in postural stability. The abdominal muscles along with the back extensors and the thoracolumbar fascia function to bring dynamic stability to the trunk. It has been postulated thought that rectus abdominis, as the most superficial abdominal muscle, had a large responsibility in maintaining a person's posture. DeTroyer et al. (1990) proved this with electromyography studies of the abdominal muscles. The authors found increased activity of rectus abdominis when patient's flexed their head against resistance with little contribution from the external oblique. Another EMG study done in 1994 showed that when a person was given both predicted and unpredicted perturbations in standing, all four abdominal muscles contracted to maintain the person in the upright position (Cresswell et al., 1994). It can be concluded, that the external oblique, internal oblique, and transverse abdominis act as accessory muscles when increased effort is required.

Perhaps the most important function of the abdominal muscles is to increase the intra-abdominal pressure (IAP). An increase in the IAP is necessary for such functions as defecation, urination, forced expiration, and parturition or childbirth (Wilder, 1988). With the glottis closed, the abdominal muscles contract to produce the force required for these straining activities (Moore & Dalley, 1999). Floyd and Silver (1950) found that when subjects were asked to close their glottis and bear down the external and internal oblique muscles contract in direct proportion to the amount of effort made. The rectus abdominis muscle was found to be active, but to a much lesser degree. The transverse abdominis was not tested because of its deep location within the abdominal cavity that was not accessible to surface electrodes.

A more recent study conducted by Cresswell et al. (1992) used needle electrodes to look at all four abdominal muscles, including the transverse abdominis. Their study found that an increase in IAP was consistently associated with high levels of transverse abdominis muscle activity. This increase in IAP was evident during both flexion and extension activities. While the authors were unsure what role an increase in IAP had with these two activities, they hypothesized that when the transverse abdominis contracted, it provided a general mechanism for trunk stabilization during maximal isometric contraction.

Given the knowledge that these four abdominal muscles are active during various exercises, it can be inferred that by repeating these exercises as in the Maternal Fitness program, strength and functional gains can be attained.

Musculoskeletal Changes During Pregnancy

During pregnancy the female body undergoes many physiologic changes. Among these changes are hormonal and anatomic alterations that play an important role in the expansion of the abdominal wall.

In order for the female body to accommodate for the growing fetus, the abdominal wall must expand in size. Relaxin, estrogen, and progesterone are three important hormones which contribute to abdominal expansion and to the soft tissue laxity that occurs throughout the body (Boissonnault, 1988; Wojtys et al., 1998; Samuel et al., 1996). Throughout the course of pregnancy each of these three hormones are released in increasing levels. However the proportionate increase of each hormone is disputed (Szlachter et al., 1982; Boissonnault, 1988).

Research has investigated these hormones in terms of the effects of relaxin, estrogen, and progesterone on connective tissue metabolism throughout the body. Relaxin, in high doses alone or in low doses when combined with estrogen, significantly reduces the collagen content in the rat pubic symphysis (Samuel et al., 1996). Estrogen alone has been shown to decrease the collagen content in rat tendon and fascia and enhance the effects of collagen remodeling by relaxin (Samuel et al., 1996; Dyer et al., 1980). Progesterone acts to counteract or regulate the combined effects of estrogen and relaxin by stimulating collagen synthesis (Samuel et al., 1996).

These findings are significant in providing an explanation for the possibility of abdominal expansion during pregnancy. The left and right rectus abdominis muscles have aponeuroses, or dense compacted collagen fibers, that come together at the midline of the anterior abdominal wall, forming the linea alba. The combined effects of relaxin, estrogen, and progesterone may actually target the linea alba and cause remodeling of the collagen fibers holding the rectus abdominis muscles together. Based on electron microscopy findings, Iverson (1966) suggested that under hormonal influence and during pregnancy, connective tissue fibrils are deposited in a looser, more diffuse network, resulting in wavy bundles of fibrils. Given these findings, the increased extensibility of the anterior abdominal wall may be afforded by the remodeling and straightening of these wavy fibrils.

To accommodate for the growth and development of the fetus, the uterus must also expand in size. During the course of pregnancy the uterus undergoes tremendous growth from approximately 6.5 cm long, 4 cm wide, and 2.5 cm deep to about 32 cm long, 24 cm wide, and 22 cm deep (Reeder et al, 1980). The weight of the uterus also increases from about 50 g before pregnancy to 1000 g by the end of gestation (Boissonnnault, 1988). At this point the uterus contains the fetus, placenta, and over 1000 ml of amniotic fluid (compared to a prepregnancy capacity of 2 cc), resulting in a total weight of about 12 lbs (Boissonnault, 1988; Reeder et al.,1980).

The remarkable size and weight of the uterus is important to consider as the uterus grows into the abdominal cavity. Between the 3rd and 4th month of pregnancy, the growing uterus stretches out of the pelvis and can be palpated above the pubic symphysis. By approximately the 6th month it will reach the umbilicus (Reeder et al., 1980). As the uterus continues to grow, it comes into contact with the anterior abdominal wall and displaces the abdominal organs laterally and the diaphragm superiorly until it has reached its highest point, at about the level of the xiphoid process, by the 9th month of gestation (Lerch et al., 1978; Reeder et al., 1980). To accommodate for the decrease in respiratory capacity caused by the upward displacement of the diaphragm, the lower ribs flare out and the antero-posterior and transverse diameter of the thoracic cage increases (Reeder et al., 1980; Lerch et al., 1978; Gilroy et al.,1988). The combined effects of the uterine expansion, organ displacement, and ribcage expansion places significant tension on the surrounding abdominal muscles and fascia.

Diastasis Recti Abdominis

Diastasis recti abdominis (DRA) is a painless condition characterized by a separation of the two bellies of the rectus abdominis muscles. While the incidence of the condition has been noted in people with obesity and those with chronic, obstructive lung disease (Boissonnault & Kotarinos, 1988), most cases are manifested in pregnant women.

The biomechanical properties of muscle and connective tissue in the human body dictate that continuous low loading over an extended amount of time will result in particular changes in the microstructure of the material, termed "creep" (Levangie & Norkin, 1992). Up to a certain length, connective tissue will retain its elastic properties and return to original length when the load is released. After continuous load (e.g. gravid uterus), connective tissue may reach the plastic phase, resulting in a permanent change in length. Stretching of the linea alba in pregnancy allows the rectus abdominis muscles to separate and move laterally along the abdominal wall (Blaschak & Boissonnault, 1988; Brown & Gilleard, 1996), but less is known about the effects of prolonged stretch in skeletal muscle tissue. Theoretically, an overstretched muscle loses its optimal length-tension relationship and is less able to produce normal muscle contraction, termed stretch weakness (Goldspink & Williams, 1978). Animal studies have shown, however, that muscles stretched over time will add sarcomeres to their length, in effect increasing the maximum tension developed in the muscle (Goldspink & Williams, 1978). Brown and Gilleard (1996) found a 115% increase in length of the rectus abdominis muscle in pregnant women, measured via anatomical landmarks and a direct linear transformation method for three-dimensional photography. If this additional length is accompanied by an increase in sarcomere length, potential weakness of the abdominal muscles in pregnant women may be due to the altered line of pull of the muscles (Brown & Gilleard, 1996), rather than a true stretch weakness. More research utilizing validated measures of abdominal muscle length are needed to investigate the effects of these biomechanial alterations in the abdominal muscles of pregnant women.

The location along the linea alba and the degree of separation of the rectus abdominis muscle have not been well defined. Brown and Gilleard (1996) found DRA to be largest above the umbilicus and smallest below the umbilicus. Additional scientific research examining these aspects is lacking, but a consideration of anatomy of the abdominal wall supports this finding (Rath, 1996). Currently, diagnosis of DRA is simply any separation greater than the normal width of the linea alba which is 2 cm wide above the umbilicus and 1 cm wide below the umbilicus (Noble, 1982).

Relatively few empirical studies with sound methodology address the incidence and implications of DRA. Boissonault and Blaschak (1988) investigated the incidence of the condition during various times throughout pregnancy in 81 women carrying and delivering their first child. They found DRA in 27% of women in their second trimester increasing to 66% in their third trimester. A study by Gilleard and Brown (1996) examined six pregnant women with DRA and assesses the functional capability of the rectus abdominal muscle to stabilize the pelvis against resistance. Using performance of a controlled curl-up and a validated abdominal muscle test (AMT) as criteria, they found decreases in abdominal muscle function with advancing pregnancy. Reduced strength in the abdominal muscles can have functional implications pre-natally, during the birthing process, and post-natally. Daily activities that recruit the abdominal muscles, such as lifting, rolling, and elimination may be impaired secondary to DRA (Wilder, 1988), although no empirical data exists investigating these functions. Weak abdominal muscles can prevent effective pushing during the second stage of labor (Boissonnault, 1988). DRA may also indirectly impair functional activities. The anterior abdominal wall aids in the maintenance of normal lumbar lordosis, thus muscle impairment may exacerbate lumbar lordosis (Hall, 1987). This may contribute to the low back pain common in pregnancy and in turn, limit a pregnant woman's tolerance of daily activity.

Monitoring the development of DRA in routine pre-natal checkups will enlighten the healthcare community about the incidence of DRA. Empirical evidence examining the biomechanical alterations of the abdominal muscles and subsequent implications on function is needed.

Exercise and Pregnancy

Research results regarding the effects of exercise on pregnancy, both on maternal and fetal health are equivocal. Earlier trends in research on exercise and pregnancy focused on exercise-induced effects on the developing fetus, not the effects on maternal health. Research efforts examined the theoretical effects of aerobic exercise on the developing fetus primarily utilizing animal models. These studies employed techniques involving exercising an animal to exhaustion followed by measurement of different parameters such as maternal body temperature, stress hormones, and visceral blood flow (Clapp, 2000; Sternfeld, 1997). These maternal changes were then analyzed in light of pregnancy outcomes, such as length of labor, mode of delivery, birth weight and Apgar scores (Bryan et al., 1982; Hall, 1987). Although theoretical risks to the fetus exist (Artal, 1992), most studies utilizing human subjects show few complications directly related to exercise during pregnancy (Hall, 1987; Clapp, 1990). In fact, many studies indicate that the fetus adapts well to maternal exercise without adverse effects. Kelderman and Johnson (1998) conducted a review of the literature on exercise and pregnancy and determined that only chronic exercise that exceeds the mother and fetus' ability to adapt to the cardiovascular and thermodynamic changes adversely affects the outcome of the pregnancy. They also found numerous other studies supporting the notion that conditioning the pregnant mother can actually help protect the fetus from such physiological stresses exposed to the mother.

The American College of Obstetrics and Gynecology (ACOG) recommends exercise for pregnant women, stating the benefits as "maintaining muscle tone, strength, and endurance and protecting against low back pain" (Wilder, 1988). The ACOG, however, also states that exercise standards for pregnant women have not been established; the ethical considerations in performing research on pregnant women may well explain the limited database of research that exists in this area. The ACOG guidelines delineate general criteria for safety and outline the absolute and relative contraindications to exercise, without focusing on specific exercise modalities. Sternfeld (1997) proffers that the goals of muscular conditioning for the pregnant woman are to "improve posture, provide support for breasts, strengthen muscles used during labor, and prevent urinary incontinence." Additional findings in the literature point out that physically fit women tend to better tolerate labor pain (Artel, 1992; Hall et al., 1987). Hall et al. (1987) hypothesized that improving maternal fitness would decrease biomechanical changes and subsequent prenatal discomfort and decrease complications at birth. Although no significant differences in labor times were found, exercising women reported a decrease in discomforts of pregnancy, an easier labor and delivery, and improved self-image.

The 1994 revised ACOG guidelines acknowledge the lack of experimental evidence that regular exercise improves the outcome of pregnancy as measured by labor, maternal, and fetal complications. Clapp (1990) suggests that the relationship between exercise and labor is difficult to assess purely due to multiple variables of exercise and other uterine, obstetric, and fetal factors that can influence labor. A common flaw of most research comparing pregnant women who exercise to women who do not, is that subjects were rarely randomly assigned to either the experimental or control groups. It is possible that women who exercise during pregnancy were already fit prior to initiating their maternal exercise program. Conclusions derived from studies with methodological flaws should be carefully scrutinized and not extrapolated to the non-exercising population.

Although no empirical evidence exists investigating the effects of abdominal strengthening in the pregnant population (Brown & Gilleard, 1996), it is well documented in exercise physiology literature that exercise improves the strength and endurance of skeletal muscle tissue. Logically, then, exercising the abdominal muscles could prevent potential weakness occurring in the abdominal muscles of pregnant women. If this were the case, functional activities requiring the use of the abdominal muscles during pregnancy, and certainly the vaginal birthing process, would be less impaired.

Failure to strengthen the rectus abdominis muscle during pregnancy can exacerbate lumbar lordosis and subsequent back pain (Hall, 1987). Strengthening earlier in pregnancy is preferable to later when the enlarged uterus and subsequent biomechanical alteration of the abdominal muscles may preclude effective strengthening (Gleeson, 1988). The ACOG guidelines for exercise during pregnancy state that pregnant women should not exercise in the supine position after the fourth month of pregnancy due to possible compression of the inferior vena cava (Wilder, 1988). As traditional abdominal exercises incorporate the supine position, this recommendation may explain the omission of abdominal strengthening exercises in many prenatal exercise regimens. The amount of time and mode of exercise contraindicated in this position, however, are unclear and many obstetricians believe that complications are uncommon and most women can continue to lie supine after the fourth month (Mellion, 1988). The ACOG states that pelvic tilts in the standing or sitting position which "strengthen abdominal musculature..." can be done throughout pregnancy, and pregnant women should be encouraged to perform as many as they can throughout the day. Noble states that pelvic tilts improve posture and relieve backache and stiffness. A review of the literature of physical therapy services by Gleeson and Pauls (1988) revealed the posterior pelvic tilt a the most widely chosen abdominal toning exercise for pregnant women. Interestingly, ar EMG study measuring abdominal muscle firing in both pregnant and non-pregnant populations showed little EMG activity during a supine pelvic tilt (Booth, 1980).

Pregnant women need safe and efficient ways to maintain and improve both cardiovascular and musculoskeletal conditioning throughout pregnancy (Hall, 1987). In addition to the health of the developing fetus, functional capabilities of the mother durin pregnancy are important consequences of her fitness. As DRA receives greater attention in both the medical and fitness communities as a true dysfunction, prevention and treatment of the condition must become a priority. Exercise recommendations should be backed by sound scientific evidence and further research investigating safe, effective exercises is clearly warranted.

Diastasis Recti Abdominis Measurement

Although the incidence of diastasis recti abdominis (DRA) is high and there are many implications, there has been little research done in this area to date. In fact, there is even less information available on the measurement of DRA. Until recently, physical therapists measured DRA using a finger width method. This method of measurement was researched by Bursch (1987) to determine its reliability. Each rater inserted the second, third, and fourth fingers of her right hand into the subject's abdomen to the level of the proximal interphalangeal joints. To standardize palpation, a Polyform device was used to guide palpation of the abdominal wall. The patient performed a partial curl-up three times during palpation by the rater. The number of fingers filling the space was recorded for each trial and averaged. Inter-rater reliability was assessed using an analysis of variance (ANOVA) for repeated measures. According to the ANOVA, there was a highly significant difference in measurement scores between raters ($F=6.30$, $df=3,117$; $p<.0005$). The conclusion was that this method of DRA measurement is unreliable for clinical assessment.

Intra-rater reliability of DRA measurement using dial calipers was also investigated (Boxer and Jones, 1997). Each subject was tested by a single investigator. Two measurements were taken on three different occasions: a resting measurement, where the rectus abdominis muscle was relaxed, and an active measurement, where the rectus abdominis muscle was contracted. To increase the reliability of this study, standardization techniques and blinding to measurements were employed. The digital caliper method of measuring DRA has been shown to have high intra-rater reliability for both resting (ICC=.93) and active measurements (ICC=.95) (Boxer and Jones, 1997).

Hitchman et al. (1997) investigated inter-rater reliability of DRA measurement using dial calipers. Each subject was measured by three different raters. Each rater measured the women in the resting and active position three times. The data concludes that the inter-rater reliability for the resting measurements was high (ICC=.84) and inter-rater reliability for the active measurements was moderate (ICC=.64).

Physical therapists need to have a reliable tool for assessing the size of the DRA. Although the traditional finger width method may be suitable to measure the progression of DRA in a single investigator, it was concluded to be unreliable due to variables such as differences in finger width as well as subjective interpretation of pressure. (Bursch, 1987) The most reliable tool for measuring DRA to date is the dial caliper. Since this method of measurement was demonstrated to have high intra-rater reliability and moderate to high inter-rater reliability, we will be employing this method in our study.

In recent years, research has led to theories on the role of hormones and musculoskeletal changes in the development of DRA in pregnant women. The literature demonstrates that during pregnancy, the abdominal muscles are stretched and placed at a mechanical disadvantage. This stretch weakness leads to an impairment in functional activities, such as rolling over, lifting items, elimination and childbirth itself. Strengthening the abdominal musculature may retard the capacity of the rectus abdominis muscle to separate, thus decreasing the incidence and/or size of DRA. Many maternal exercise programs incorporate some abdominal muscle training in their workouts (i.e. pelvic tilt), but the literature has not revealed how these exercises affect the development of the DRA condition. If abdominal muscle strengthening can benefit the non-pregnant individual, one can conclude that exercising the abdominal muscles during pregnancy would be beneficial. With the use of a reliable measuring instrument, we will be able to test how an exercise program has affected DRA development and size in pregnant women.

CHAPTER 3: METHODOLOGY

Venue

Data collection was conducted at the following two facilities:

Maternal Fitness

168 E. 16th St., 4th Floor

New York, NY 10003

Contact: Julie Tupler, R.N., President

212-353-1947

Bruno, Cohen, & Trufelli, M.D., P.C.

1300 Union Turnpike, Ste. 201

New Hyde Park, NY 10040

Contact: Charles A. Bruno, M.D.

516-354-2525

Letters of consent for use of clients and space to conduct this research are found in Appendix B and C.

Subjects

The sample consisted of 24 pregnant women, 12 who were participating in an exercise program and 12 who were not currently participating in an exercise program. Pregnant women who were currently participating in an exercise program were included in the study if they met the following criteria:

Inclusion criteria:

* They were enrolled in the Maternal Fitness program (class B).

* They were ages 20-40 years

* They were primigravid

* They were from 16-24 weeks of their pregnancy

Pregnant women who were currently participating in an exercise program were excluded in the study if they met the following criteria:

Exclusion criteria:

* They were carrying multiple fetuses

* They had high risk pregnancy including; hypertension, diabetes mellitus, heart conditions, alcohol and/or drug use

Pregnant women who were not currently participating in an exercise program were included in the study if they met the following criteria:

Inclusion criteria:

* They were ages 20-40 years

* They were primigravid

* They were from 16-24 weeks of their pregnancy

Pregnant women who were not currently participating in an exercise program were excluded in the study if they met the following criteria:

Exclusion criteria:

* They were carrying multiple fetuses

* They had high risk pregnancy including; hypertension, diabetes mellitus, heart conditions, alcohol and/or drug use

* They were taking part in regular exercise, i.e. aerobic conditioning or strengthening for a duration of greater than 20 minutes a week.

Method of Recruitment

Pregnant exercising women were recruited at the Maternal Fitness program in New York City. The co-investigators made arrangements with the President of Maternal Fitness, Julie Tupler, RN to make a 10-minute presentation to her clients and staff during a regularly scheduled class A session. Clients were informed that upon entry to the class B program they would be eligible for participation in our study, which would compare the size of diastasis recti abdominis in exercising and non-exercising pregnant women. Co-investigators explained the entire procedure to the women. Clients were told how they would be required to lie on their backs, expose their bellies and be palpated by one of the co-investigators, come into a partial curl-up so that their scapulae were off the mat, be marked with a water soluble pen, and be measured with the use of the nylon digital caliper. They were informed that the measurement would be taken two times at three different sites along the midline of their bellies. Subjects were informed that participating in this study would require only 25 minutes of their time. A flyer with general information about the study and phone numbers of two of the co-investigators were posted for interested clients. (Appendix D). Clients were informed that if they had questions or concerns that they could reach the co-investigators at the numbers listed on the flyer. Interested clients were asked to leave their phone numbers on a sign-up sheet so that the co-investigators could call them (Appendix E). Once phone contact was established, potential subjects were interviewed briefly to determine if they met any of the criteria for inclusion or exclusion for our study (Appendix F). If they were suitable for our study, an appointment was made for diastasis recti abdominis measurement. Subjects not meeting the criteria were thanked for their interest. Appointments were made immediately before or after a regularly scheduled class B session at the Maternal Fitness Program location.

Pregnant non-exercising women were recruited at the private obstetrics/gynecology office of Charles Bruno, MD. Arrangements were made by the co-investigators with Dr. Bruno to make a 10 minute presentation to his staff so that they would be able to refer questions to the co-investigators. A flyer with general information about the study and phone numbers of two of the co-investigators was posted at the front desk for interested clients (Appendix D). Clients were informed that if they had questions or concerns they could reach the co-investigators at the numbers listed on the flyer. Interested client also left their phone numbers on a sign-up sheet so the co-investigators could call them (Appendix E). Once phone contact was established, potential subjects were interviewed briefly to determine if they met any of the criteria for inclusion or exclusion for our study (Appendix F). If the client was suitable for our study, an appointment was made for diastasis recti abdominis measurement at the beginning or end of a regularly scheduled doctor's visit. Subjects not meeting the criteria were thanked for their interest.

Instrumentation

The traditional finger-width method of diastasis recti abdominis measurement in pregnant women has been shown to be unreliable for the clinical assessment of diastasis recti abdominis (Bursch, 1987). As such, a nylon digital caliper was chosen as a more reliable instrument to measure diastasis recti abdominis for the present study. Boxer and Jones (1997) had demonstrated a moderate inter-rater reliability (ICC=0.62) for the caliper in measuring diastasis recti and Hitchman et al.(1997) had shown the calipers to have a high intra-rater reliability for measuring diastasis recti abdominis (ICC=0.95).

Procedures

Prior to testing, the subjects were asked to read and sign a consent form (Appendix G). Questions regarding height, weight, age and week of pregnancy were asked and answers were placed on the data collection form (Appendix H). Upon completion, they were asked to lie on their back, with their hips and knees flexed and arms resting at their sides with one pillow placed under their head (Boxer, 1997). The subjects who were participating in the Maternal Fitness exercise program were asked to lie on a mat so the co-investigators could obtain the measurements. The subjects who were not participating in an exercise program were asked to lie on a flat examination table so the co-investigators could obtain the measurements.

Measurements were taken at three different sites as described by Boissonnault and Blaschak (1988): at the umbilicus, 4.5 cm above, and 4.5 cm below. Each site was marked with a water-soluble marker to ensure accuracy of repeated measurements. With the subject lying on their back, the examiner measured 4.5 cm from the superior border of the umbilicus with a flexible tape measurement and placed a mark level to the midpoint of the umbilicus. The examiner then measured 4.5 cm from the inferior border of the umbilicus and placed another mark level with the midpoint of the umbilicus. The third site at the umbilicus did not require a mark.

Once the marks were in place, the measurements were taken. One examiner was responsible for taking the measurements and a second examiner was present to provide manual assistance and support for the subject. The first measurement was taken at the mark 4.5cm above the umbilicus, the second measurement was taken at the umbilicus, and the third measurement was taken 4.5cm below the umbilicus. The subjects were asked to lift their head and shoulders off the mat, reaching towards their knees with outstretched arms until the spine of their scapulae cleared the mat. (Stephenson and O'Connor, 2000) This was verified by palpation of the scapulae by the examiner. The subjects were asked to maintain this position while the examiner palpated the rectus abdominis muscles. This took approximately 10-20 seconds. The subjects were allowed to rest if they became fatigued. The subjects then relaxed with the examiner's fingers remaining on the rectus abdominis muscles. The subjects were asked to repeat the activity and maintain the position while the examiner placed the measuring probes of the calipers against the medial borders of the rectus abdominis muscles. The calipers were placed so that the probes were perpendicular to the surface of the muscle (Boxer, 1997).

Two measurements were taken at each of the three different sites, with the subjects being allowed to rest in a side-lying position in between measurements. The average of the two measurements was calculated and all values were recorded on the patient's data collection sheet (Appendix H).

Time

The entire process, including signing the consent form, filling out the questionnaire, and taking the measurements took approximately 25 minutes per subject.

Space

The space required was approximately 15 ft. x 15 ft. or the size of a small examination room. Data collection took place at Maternal Fitness in New York City and the obstetrics/gynecology office of Bruno, Cohen and Truffelli, M.D., P.C., in New Hyde Park, New York (see Appendices B and C).

Equipment

The following equipment was needed for this study: an examination table or floor mat, a pillow, and digital calipers.

Cost

This study cost the examiners approximately $100 for transportation fees.

Data Analysis

This study was a two-group, between subjects, quasi experimental post-test design. Descriptive statistics were collected for all variables. Independent t-test were performed on each subject characteristic with a significant difference found between the two groups in respect to number of pregnancies. An analysis of covariance (ANCOVA) was run with number of previous pregnancies as the covariate.

Reliability

An initial study was conducted to establish inter- and intra-rater reliability for two examiners using the digital caliper. For inter-rater reliability, three pregnant women were recruited and measured independently by two examiners as described in the above protocol. Measurements made by one examiner were withheld from the other to ensure that the examiners remained unbiased. Investigators were found to be highly reliable with respect to inter-rater reliability, (ICC (3,1) = 0.87). Additional women were recruited to establish intra-rater reliability for both examiners. To eliminate potential biased measurements, values obtained were recorded by a separate examiner. An ICC (3,1) for the each examiner was determined to be 0.997 and 0.995 respectively, indicating high intra-rater reliability for each examiner.

CHAPTER 4: RESULTS

The sample for this study consisted of 24 pregnant women, 12 who were exercising, and 12 who were not. The original inclusion criteria for this study required that the women be primigravid and between 16-24 weeks pregnant. However, due to lack of response from women meeting these criteria, multigravid women up to their 35^{th} week of pregnancy were included in the sample. Of the original 24 women, 8 exercising women and 10 non-exercising women met the new criteria and agreed to participate in this study. All participating subjects were between 20-40 years old, carrying only one fetus, and were free from high risk categories including hypertension, diabetes mellitus, heart conditions, and alcohol or drug use. Women in the exercising group had all completed at least 6 weeks of a maternal fitness program with emphasis on abdominal strengthening. Women in the non-exercising group were not participating in any aerobic or strengthening exercise for more than 20 minutes a week. The sample size and subject characteristics of each group can be found in Table 1. As indicated in this table, an independent t-test demonstrated no significant difference between the two groups for sample size, age, height, weight, or number of weeks pregnant. There was however, a statistically significant difference between the number of pregnancies in each group, such that the non-exercising women had significantly more pregnancies than the exercising women.

Figure 1 illustrates the presence of DRA in the exercising and non-exercising sample in this study. DRA was found in only 1 of the 8 (12.5%) exercising women and in 9 of the 10 (90%) of the non-exercising women. Presence of DRA was based on Wilder's (1982) definition of DRA as being a separation of the rectus abdominis greater than 2 cm.

The mean and standard error for DRA measurements in exercising and non-exercising women are found in Table 2. As demonstrated in this table, the mean DRA measurements at each of the three sites were generally larger in the non-exercising women than in the exercising women.

To account for the statistically significant difference in number of pregnancies between each group, an Analysis of Covariance was computed for each measurement site with number of pregnancies as the covariant. As seen in table 3, DRA was significantly larger in the non-exercising group than in the exercising group at 4.5 cm above the umbilicus, regardless of number of pregnancies in each group ($F_{(17,1)}=13.54$, $p<0.05$). The non-exercising group had an average DRA of 30.12, mm greater than the exercising group when measured 4.5 cm above the umbilicus. The ANCOVA for that measurement site revealed that $R^2 = 0.56$, indicating that 56% of the difference in DRA between the two groups measured 4.5 cm above the umbilicus can be accounted for by exercising. As seen in table 4, there was also a significantly larger DRA in the non-exercising group than in the exercising group at the umbilicus, regardless of the number pregnancies ($F_{(17,1)}=16.66$, $p=0.001$). The non-exercising group had an average DRA of 48.12 mm greater than the exercising group when measured at the umbilicus. The ANCOVA for that measurement site revealed that $R^2 = 0.63$, indicating that 63% of the difference in DRA between the two groups measured at the umbilicus can be accounted for by exercising. As seen in table 5, there was also a significantly larger DRA in the non-exercising group than in the exercising group at 4.5 cm below the umbilicus, regardless of the number pregnancies ($F_{(17,1)}=13.13$, $p<0.05$). The non-exercising group had an average DRA of 53.24 mm greater than the exercising group when measured 4.5 cm below the umbilicus. The ANCOVA for that measurement site revealed that $R^2 = 0.59$, indicating that 59% of the difference in DRA between the two groups measured 4.5 cm below the umbilicus can be accounted for by exercising.

SUBJECT CHARACTERISTICS	EXERCISING	NON-EXERCISING	SIGNIFICANCE
NUMBER OF SUBJECTS	8	10	-
AGE	32 (0.78)	30.4 (1.25)	p>0.05
HEIGHT	66.38 (1.29)	65 (0.63)	p>0.05
WEIGHT	165.63 (15.37)	152.6 (5.42)	p>0.05
WEEKS OF PREGNANCY	25.5 (2.15)	25.6 (1.64)	p>0.05
NUMBER OF PREGNANCIES	1.25 (0.16)	2.3 (0.37)	p<0.05

Table 1. Subject Characteristics (mean (standard error)).

DRA MEASUREMENT SITE	EXERCISING	NON-EXERCISING	SIGNIFICANCE
4.5 cm ABOVE UMBILICUS	9.68 (2.31)	39.80 (5.63)	p<0.05
AT UMBILICUS	11.43 (3.12)	59.55 (7.87)	p<0.05
4.5 cm BELOW UMBILICUS	8.22 (2.63)	60.46 (9.65)	p<0.05

Table 2. Mean (standard error) of DRA measurements of exercising and non-exercising pregnant women at three measurement sites (mm).

SOURCE	DF	MEAN SQUARE	F-VALUE	P-VALUE
MODEL	2	2018.51	9.62	0.002
ERROR	15	209.81	-	-
CORRECTED TOTAL	17	-	-	-
EXERCISE	1	2840.59	13.54	0.002
NUMBER OF PREGNANCY	1	4.96	0.02	0.879

Table 3. Analysis of Covariance for DRA at 4.5 cm above the umbilicus in exercising and non-exercising pregnant women, with number of pregnancies as the covariant.

SOURCE	DF	MEAN SQUARE	F-VALUE	P-VALUE
MODEL	2	5199.09	12.97	.0005
ERROR	15	400.91	-	-
CORRECTED TOTAL	17	-	-	-
EXERCISE	1	6678.25	16.66	0.001
NUMBER OF PREGNANCY	1	104.78	0.26	0.617

Table 4. Analysis of Covariance for DRA at the umbilicus in exercising and non-exercising pregnant women, with number of pregnancies as the covariant.

SOURCE	DF	MEAN SQUARE	F-VALUE	P-VALUE
MODEL	2	6184.52	10.87	0.001
ERROR	15	568.81	-	-
CORRECTED TOTAL	17	-	-	-
EXERCISE	1	7467.90	13.13	0.003
NUMBER OF PREGNANCY	1	241.82	0.43	0.525

Table 5. Analysis of Covariance for DRA 4.5 cm below the umbilicus in exercising and non-exercising pregnant women, with number of pregnancies as the covariant.

CHAPTER 5:DISCUSSION

Diastasis Recti Abdominis (DRA) is a condition within the pregnant population that has received little attention in the past. Previous studies have attempted to examine the incidence and prevalence of DRA, but no studies to date have addressed the possible functional limitations of this condition. Studies have also failed to examine potential prevention and/or treatment strategies to address possible functional limitations. As physical therapists are the primary providers of musculoskeletal rehabilitation, it is important to have these tools available to them. The intent of this study was to examine the effects of an exercise program on DRA in pregnant women.

The initial inclusion criteria were formulated in order to avoid the potential confounds of these risk factors. However, most available subjects did not fit the original criteria necessitating the inclusion of multigravid women and women past 24 weeks of pregnancy. Statistically, this had no effect on our results.

The primary aim of this study was to determine if there was a difference in the presence and/or size of DRA between pregnant women who were exercising and those who were not exercising. The first hypothesis of the study predicted a greater incidence of DRA in non-exercising pregnant women as compared to exercising pregnant women. Our results support this hypothesis as there was a 90% presence in the non-exercising group as compared to a 12.5% incidence in the exercising group. Although Boissonnault and Blaschak (1987) reported the incidence of DRA to be as high as 66%, there are no studies to date that differentiate between exercising and non-exercising women when reporting DRA measurements. Our study thus provides additional evidence that DRA is prevalent among the pregnant population. Moreover, our results shed light on the relationship between abdominal exercise and DRA in the pregnant population.

Our second hypothesis predicted a larger DRA at each of the three measurement sites in non-exercising pregnant women as compared to exercising pregnant women. This hypothesis was also supported statistically, as shown in Tables 3, 4, and 5 using an Analysis of Covariance (ANCOVA), which demonstrated that the non-exercising group had significantly larger diastases than the exercising group. The ANCOVA also revealed that 56-63% of the variation between the two groups was directly attributed to exercise. As regular exercise improves the strength and tone of the abdominal muscles, it can be inferred that abdominal exercise may help to prevent or decrease the size of DRA. Our results, along with scientific literature on abdominal anatomy and exercise physiology strongly support this notion. Notably, no previous studies have examined the relationship between exercise and DRA.

Although our finding were significant, broad applications of these results to the general pregnant population should be avoided due to several important methodological limitations. The relatively small sample size consisting of eight exercising and 10 non-exercising women preclude the assumption that they are representative of all pregnant women. Additionally, most of the subjects were Caucasian and living in large urban or suburban areas. Subjects were also of high enough socioeconomic status to be seeing a private practice physician or participating in a non-community based maternal fitness exercise program. The applicability of findings to pregnant women with different demographic characteristics should be viewed with caution.

Difficulties in the measurement of DRA presented another limitation to our study.

While the two measurers in the present study attempted to employ the same methodology, problems were encountered in the actual execution. Both examiners found that measuring a small separation with the caliper was difficult. Also, a greater amount of tissue between the skin and abdominal muscles in certain subjects obscured definitive palpation of the two bellies of the rectus abdominis muscle. Despite these barriers, reliability measurements remained high as compared to the finger width method used in prior studies. Future research utilizing a digital caliper is warranted to determine the most effective way to measure DRA in a pregnant population of diverse body types.

Certain risk factors for developing DRA are noted in the literature and include obesity, multigravidy, and position in the childbearing year. Our study examined pregnant women covering a broad range of gestational weeks. Future studies limiting the number of weeks of pregnancy to a particular trimester may help to decrease variability of findings. Additionally, because obesity is a stated risk factor, it is logical that it should also be measured in any study looking at the incidence of DRA. However the common measurement of obesity includes the calculation of body mass index (BMI) which may not be a valid measurement in pregnant women whose weight is abnormally high secondary to normal pregnancy weight gain. Employing another method of measuring obesity, such as pre-pregnancy weight, would allow researchers to account for this confound.

Although it is plausible that women in the exercise group demonstrated an absent or smaller DRA due to abdominal exercise, other factors must be considered. Prior level of fitness was not assessed in either subject group. The possibility thus exists that women who participated in a diligent exercise regimen including abdominal strengthening prior to becoming pregnant may have been less likely to develop DRA during pregnancy. By the same token, women who were sedentary prior to becoming pregnant may be more deconditioned and prone to developing a DRA.

Further empirical examination on DRA is clearly indicated and due to the paucity of research on DRA, a multitude of possibilities exists for future studies. Perhaps most importantly, future researchers should investigate negative implications DRA can have on functional activities and its potential contribution to back pain. Results of these studies may provide convincing evidence that DRA is a musculoskeletal condition deserving attention from healthcare providers. While present anatomical and physiological considerations strongly implicate DRA, additional scientific evidence is clearly warranted before such claims are made.

Clinical ramifications of these results are widespread. If the incidence of DRA is as prevalent as the present data suggests, physicians who care for pregnant women should consider monitoring DRA in their standard prenatal care. If exercise can help reduce or even prevent a DRA, appropriate referral to a physical therapist for treatment can be made. Physical therapists should be knowledgeable about DRA and in the prescription of appropriate abdominal exercises that will help prevent or decrease DRA in their pregnant patients.

CHAPTER 6: CONCLUSION

This study investigated the effect of an exercise program on diastasis recti abdominis (DRA) in pregnant women. The investigators demonstrated high inter- and intra-rater reliability with the use of digital calipers for measurement of DRA. We found that non-exercising pregnant women had a greater presence of DRA at all three measurement sites when compared to exercising pregnant women. Non-exercising pregnant women also had a larger DRA at all three sites than exercising pregnant women. This is clinically important for physical therapists in the treatment of DRA. By prescribing abdominal exercises, they can help to prevent or decrease the DRA in their pregnant patients. Further research is warranted to examine the functional limitations of DRA as well as looking at the effect of exercise through the natural course of DRA during pregnancy.

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Maternal Fitness: Class B Abdominal Exercises

1) Transverse Abdominis: Tupler Technique

Purpose: To strengthen the transverse muscle for the act of pushing and to shorten the recti from the middle of the muscle.

Starting position: Sit with one hand resting on upper abdominals and one hand resting on lower abdominals. Have back supported and shoulders lined up with hips.

Contracting: Contract the transverse abdominis muscle by pulling the belly button back to the spine from point 5 to point 6. Nothing should move except the belly button. Count out loud as you squeeze the belly button back toward the spine. Hold, release, and repeat. 1 set = 100. Do 10 sets a day.

Practicing for Pushing: Practice while having a bowel movement. Sit with feet elevated. First expand the belly. Then bring the transverse to point 5 and then out the back to point 6 as you push ,or have a bowel movement. Pelvic floor muscles are open and relaxed. Pushing should be a backward movement, not downward.

2) Rectus Abdominis:

Purpose: To strengthen the recti from the top of the muscle by lifting head off of mat, from the bottom of the muscle by doing a pelvic tilt, and from middle of the muscle by bringing the transverse back to the spine. Remember, the transverse muscle is affected by gravity, the starting position of muscle, the way you lift your head and how high.

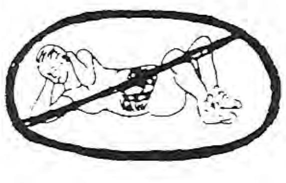
Starting Position: Lay on your back with both knees bent.

Pelvic Tilt: First, contract the transverse abdominis muscle (pull belly button back to spine). Then, tilt top of pelvis backward toward the mat in order to flatten the low back.

Head lift: First, contract the transverse abdominis muscle (pull belly button back to spine). Then, lift head off of mat just slightly, so that shoulders still remain on mat.

Head Lifts with Splint (for diastasis rectus abdominis): Perform supported head lifts with splint ONLY after transverse abdominis muscle is strengthened (10 sets of 100 daily) and mastery of pelvic tilt on back is achieved. Start by lying on your back with a towel or sheet wrapped around your back, holding one end of the towel in each hand. Contract the transverse abdominis muscle first. While holding this contraction, pull both ends of the sheet towards each other and across the stomach so that the rectus abdominis muscles are pulled together. Slowly lift head off mat (See head lift above).

3) **Obliques:** Squatting and sidelying exercises only Crossover exercises are discouraged.



MaternalFitness®

Thursday, July 27, 2000

Dear Columbia Presbyterian Medical Center IRB:

This letter is to verify that I have read the proposal of the students Kristen Ulery, Mita Patel, Kristin McCaslin and Laura Falzone and I am in full agreement with it. I am thus giving my permission to use my facility and my clients for their research thesis. If you have any questions or need any more information please feel free to call me at 212-353-1947.

Sincerely,

Julie Tupler, R.N.

Julie Tupler, R.N.
President

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August 12, 2000

Dear Members of Columbia Presbyterian Medical Center IRB:

This letter is to verify that I have read the proposal of Principal Investigator Cynthia Chiarello, PT, Ph.D., and of co-investigators Kristen Ulery, Mita Patel, Kristin McCaslin and Laura Falzone and I am in full agreement with it. I am thus giving my permission to use my facility and my clients for their research thesis. If you have any questions or need any more information, please feel free to call me.

Sincerely,

Charles A. Bruno, M.D.



RESEARCH STUDY

Conducted by Columbia University
Physical Therapy Graduate Students

We are conducting a study to see how exercise affects the abdominal muscles during pregnancy.

The study will require at most 25 minutes of your time and consists of performing a partial sit up while measurements are taken.

If you are interested or to find out more information, please contact:

Kristin McCaslin (212) 304-5776

or

Mita Patel (212) 304-5830

Solicitation of subjects into this study has been approved by the CPMC IRB # 9906

Appendix E

Columbia University Research Project Sign Up Sheet

	NAME	PHONE NUMBER	BEST TIME TO BE REACHED
1)			
2)			
3)			
4)			
5)			
6)			
7)			
8)			
9)			
10)			
11)			
12)			
13)			
14)			
15)			
16)			
17)			
18)			
19)			
20)			
21)			
22)			
23)			
24)			
25)			

ANY QUESTIONS, PLEASE CALL: KRISTIN MCCASLIN at (212) 304-5776
or
MITA PATEL at (212) 304-5830

Appendix F

Personal Data Questionnaire

Date: ____________________

Examiner: __________________________________

What is your age? ____________

Is this your first pregnancy? _____ (yes/no)

What week of pregnancy are you in? _____ week(s)

Are you carrying one child? _____ (yes/no)

Do you take part in a regular exercise program, i.e. aerobic conditioning or strengthening for a duration of greater than 20 minutes a week? _____ (yes/no)

Do you have any pre-existing medical conditions? ? (i.e. High Blood Pressure, Diabetes , Heart conditions)

Are you having any complications with your pregnancy?

Are you using any kind of medication or alcohol?

Are you currently participating in a research study? _____ (yes/no)

Have you ever participated in a research study? _____ (yes/no)

Telephone Number (H)____________(W)______________
Appointment Time_____________________
Site ________________________________
Subject #___________________________

Columbia Presbyterian Medical Center
Consent to Participate in a Research Study

IRB Approval Date: 9/20/00
Approval Expiration Date: 9/19/01
IRB Study Number: # 9906

The purpose of this consent form is to provide you with the information you need to consider in deciding whether to participate in the research study.

Study Title: The effect of an exercise program on diastasis recti abdominis and low back pain in pregnant women.

Study Purpose:

You are invited to participate in a research study of diastasis recti abdominis, which is a separation of the abdominal muscles, and low back pain. The study is designed to measure the width of this separation at three different sites and low back pain in both pregnant exercising women and pregnant non-exercising women.

Research indicates that exercise helps to improve the tone and strength of abdominal muscles. This study expects to find that there will be an increase in the presence and size of diastasis rectus abdominis and an increase in low back pain in non-exercising pregnant women as compared to exercising pregnant women.

You qualify as a possible participant in this study because you are pregnant for the first time, between the ages of 20-40, and are from 16-24 weeks of pregnancy. You are enrolled in the Maternal Fitness Program (class B). For pregnant non-exercising women, you are not taking part in regular exercise, i.e. aerobic conditioning or strengthening for a duration of greater than 20 minutes a week.

Study Procedures:

If you decide to participate you will be given an interview via telephone by one of the investigators to determine if you will be eligible for our study. The data collection will take place at the beginning or the end of your regularly scheduled exercise session or doctor's appointment. The investigators will notify you of the scheduled date and time. You will be asked to complete a questionnaire about low back pain. You will then be asked to lie on your back, with your arms resting at their sides. One pillow will be placed under your head.

One examiner will be responsible for taking the measurements and a second examiner will be present to provide manual assistance for your comfort and support. The investigator will measure the different landmarks with a flexible tape measure and mark your skin with a water-soluble marker. Then you will be asked to lift your head and shoulders off the mat, reaching toward your knees with outstretched arms until your shoulder blades clear the surface. You will be asked to hold this position while the investigator feels the anterior stomach muscles. You will then relax with the investigator's fingers remaining on the abdominal muscles. You will be asked to repeat the activity and maintain the position while the investigator measures the separation. Two measurements will be made at each of the three sites (4.5cm above the navel, at the navel, 4.5 cm below the navel). You will be allowed to rest in a side-lying position between measurements. The subject will perform this activity a total of nine repetitions, three repetitions at each of the three sites.

Your anticipated length of participation is one session of twenty-five minutes. The interview given prior to participation will take 5 minutes in duration.

Study Risks

Your participation in this study involves a minimal risk of temporary skin discomfort while the investigators take the measurements. This discomfort should dissipate moments after the caliper is removed from the skin.

Study Benefits

You may or may not benefit personally from this study. Benefits to you may include the awareness of whether or not you have a diastasis recti abdominis. Benefits to society may include satisfaction of helping other women and in the role you will play in promoting scientific research about this condition.

Alternatives

The alternative is simply not to participate

Costs

You will incur no cost as a participant in this study

Compensation

You will receive no monetary compensation for your participation in this study.

Confidentiality

Any information obtained during the study and identified with you will remain confidential. Your name will not appear on the data collection or the personal data questionnaire. You will be given a unique code number which will appear on the data collection sheet and the personal data questionnaire. To ensure confidentiality all data collection sheets and questionnaires will be kept in a locked file cabinet, accessible only to the investigators.

Participation is Voluntary

Your participation in this study is completely voluntary. You can refuse to participate, or withdraw from the study at any time, and such a decision will not affect your medical care at Columbia-Presbyterian Medical Center, now or in the future. Signing this form does not waive any of your legal rights.

Questions

If you have any questions, please ask, and we will do our best to answer them. If you have additional questions in the future you can reach Dr. Cynthia Chiarello at (212) 305-1650.

If you have any questions on your rights as a research subject, you can call the Institutional Review Board at (212) 305-5883 for information.

Statement of Consent

I have discussed this study with Laura Falzone and/or Kristin McCaslin and/or Mita Patel and/or Kristen Ulery to my satisfaction. I understand that my participation is voluntary and that I can withdraw from the study at any time without prejudice. I have read the above and agree to enter this research study. Signing this form does not waive any of my legal rights.

I have been informed that if I believe that I have sustained injury as a result of participating in a research study, I may contact the Principal Investigator, Dr. Cynthia Chiarello at (212) 305-1650, or the Institutional Review Board at (212) 305-5883, so that I can review the matter and identify the medical resources which may be available to me.

I understand that:

a) The Presbyterian Hospital will furnish that emergency medical care determined to be necessary by the medical staff of this hospital;

b) I will be responsible for the cost of such care, either personally or through my medical insurance or other form of medical coverage;

c) No monetary compensation for wages lost as a result of injury will be paid to me by the Columbia-Presbyterian Medical Center, and;

d) I will receive a copy of this consent form.

Signatures:

____

Participant Date

____

Investigator Eliciting Consent Date

The solicitation of subjects into this study has been approved by the Columbia-Presbyterian Medical Center Institutional Review Board

Appendix H

Data Collection sheet:

Subject #	Date:
Site:	Examiner:

Age:	Height:
Week of Pregnancy:	Weight:

Diastasis Recti Abdominis Measurement

4.5cm above umbilicus _______mm _______mm

at umbilicus _______mm _______ mm

4.5cm below umbilicus_______ mm _______mm

Additional Comments: ____

____

____

____

COLUMBIA UNIVERSITY
COLLEGE OF PHYSICIANS & SURGEONS

COLUMBIA PRESBYTERIAN MEDICAL CENTER INSTITUTIONAL REVIEW BOARD
CPMC IRB

September 20, 2000

Cynthia Chiarello, PT PhD
Department of Physical Therapy
NI 8th Floor

RE: IRB #9906; "THE EFFECT OF AN EXERCISE PROGRAM ON DIASTASIS RECTI ABDOMINIS AND LOW BACK PAIN IN PREGNANT WOMEN"

Dear Dr. Chiarello:

This study, which involves only interviews, questionnaire, and research involving non-invasive procedures, namely, measurement for diastasis recti abdominis, qualifies for an expedited review and approval. I am enclosing a signed copy of the approved protocol for your files.

The study has been approved for 12 months. The next renewal application (IRB Form C) will be due in August, 2001.

Any change in study procedures or recruitment procedures must be submitted for IRB review before implementation, unless it is needed for the safety of a study participant.

As with all research protocols, any adverse events must be reported at the time of their occurrence.

Sincerely,

Donald S. Kornfeld, M.D.
Chairman, CPMC IRB

DSK/bd

cc: Debra Krasinski, PhD

630 West 168th Street P&S 3-460 New York NY 10032 212 305 5883 Fax 212 305 1316

Columbia-Presbyterian Medical Center
Institutional Review Board

IRB Form A
(Rev 8/97)

Application for Approval of a Research Proposal Involving Human Subjects

Please TYPE ALL INFORMATION and complete both sides

IRB number: 9906
New study:
5 Year Renewal:

Title: The Effect of an Exercise Program on Diastasis Recti Abdominis and [illegible] Back Pain in Pregnant Women.

Investigator Information

Principal Investigator *(Must have Columbia rank of Assistant Professor or Associate Research Scientist or above)*:

Cynthia M. Chiarello, PT PhD — Physical Therapy — [signature]
Name — Department — Signature

710 West [illegible] — 305-1650 — 305-4569
Mailing address — Telephone number — Fax number

Cynthia M. Chiarello — 710 West 168 St. — 305-1650 — 305-[illegible]
Name of contact person — Mailing address — Telephone number — Fax number

Co-Investigators:

Laura Falzone — 188 Sherman St., Lynbrook, NY 11563 — (516)887-2618 — P.T.
Name — Mailing address — Telephone number — Department

Kristin McCaslin — 50 Haven Ave., Box G-19, New York, NY 10032 — (212)304-5[illegible] — [illegible]
Name — Mailing address — Telephone number — Department

Mita Patel — 50 Haven Ave., Box G-125, New York, NY 10032 — (212)304-58[illegible] — P.T.
Name — Mailing address — Telephone number — Department

Kristen Ulery — 50 Haven Ave., Box G-116, New York, NY 10032 — (212)304-5922 — P.T.

Departmental Approvals

Debra Krasnick [signature] — Aug. 28, 00
Chair, Department Committee on Human Investigation — Date

[signature] — August 28 2000
Department Chair or Institute or Center Director — Date

IRB Approval

(Leave this blank. After the study has been reviewed and approved this will be signed by the Chairman of the IRB)

[signature]
Chairman, Institutional Review Board — Date

RECEIVED
SEP 7 - 2000
By ______

Approvals of Participating Departments

Department | Department Chair | Committee Chair

Department | Department Chair | Committee Chair

Does this study involve the use of any of the following facilities, beyond that which would be necessary for routine clinical care? *(If so, appropriate approvals may be required.)*

- ☐ Radiologic/MRI Imaging
- ☐ Pathological Specimens
- ☐ Blood Bank (apheresis, transfusion, etc)
- ☐ Clinical Laboratories
- ☐ Radioactive Substances

If any of the following are involved, additional approvals and/or information may be required:

☐ **Minors (up to the age of 18)**
Approval is required from the Department of Pediatrics. Contact Dr. John Nicholson, 6-6244

Chair, Department of Pediatrics | Chair, Committee on Human Investigation

☒ **Pregnant women**
Approval is required from the Dept. of Obstetrics & Gynecology. Contact Dr. Stephen Brown, 6-6742

Chair, Department of Obstetrics & Gynecology | Chair, Committee on Human Investigation

☐ **An investigational drug or device**
(Please provide the IND/IDE number) ____________

☐ **Radiation exposure beyond that required for clinical purposes**
Approval is required from the Joint Radiation Safety Committee. For information, contact Dr. Eric Hall's office, 6-5660

☐ **Cancer Research**
Approval is required from the Cancer Protocol Review Committee ***before*** *the IRB can review the study. For information, call 6-8615*

☐ **Is this a commercially sponsored study?**
(If so, it must be submitted to the Office of Clinical Trials for review. That office is located at PH 15-1540, Phone #6-5063)

☐ **Is this study part of a grant application?**
(If so, please include the Methods and Human Subjects sections of the grant application, and complete the following information, so that IRB approval can be forwarded to the funding agency in a timely fashion.)

Agency | Application due date | IRB approval needed by

P.I. listed on grant | Application ID number (if known)