EVALUATION OF THREE SELECTED THERAPEUTIC EXERCISE PROTOCOLS IN RETRACTIONOF ABDOMINAL MUSCLES AND RESOLUTION OF DIASTASIS RECTI ABDOMINIS IN POSTPARTUM WOMEN

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DEPARTMENT OF MEDICAL REHABILITATION

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A THESIS SUBMITTED TO THE DEPARTMENT OF MEDICAL REHABILITATION

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SUPERVISOR: PROF. G.C OKOYE

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APPROVAL

This is to certify that this work was carried out and concluded to the satisfaction of the department of Medical Rehabilitation, and External Examiner.

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TITLE OF THESIS: Evaluation of Three selected Therapeutic Exercise Protocols in Retractionof Abdominal Muscles and Resolution of Diastasis Recti Abdominis in Postpartum Women

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DEDICATION

This piece of work is dedicated to my lovely baby of the family, little Miss Jessie Kamsiyochukwu Oby Igwe who almost always stayed awake with me while this thesis was being put together.

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ABSTRACT

This study was undertaken to evaluate isotonic, isometric and isotonic/isometric combination exercises in the retraction of abdominal muscles,and to assess the effectiveness of isometric contraction in resolving diastasis recti abdominis in postpartum women. A total ofninetywomenof four to eight weeks postpartum who consented to the study were randomly selected. They comprised respectivelyof 29 (32.2%) primigravids and 61 (67.8%) multigravids with the mean age of 32.59±5.79 years.A batch of 60 women were grouped into four:group A, 15(Isotonic abdominal exercises), group B, 15 (Isometric abdominal exercises), group C, 15 (combination of isotonic and isometric exercises) and control group D, 15 who received no abdominal exercises for six weeks. Another batch of30 subjects for diastasis recti abdominis study were grouped into two: 23 (isometric group A) and 7 (control group B). For subjects in the first category, both initial and weekly abdominal girth were measured and recorded for six consecutive weeks, using a portable electronic myotape device, while category two subjects had initial and weekly inter-recti distance (IRD)measured at 2.5cm above and below the umbilicususing ultrasound imaging technique. The category one results showed no significant decrease ($p > 0.05$) in the mean abdominal girth at baseline, first week and second week across the groups. However, there was a significant decrease ($p < 0.05$) in the mean abdominal girth across the groups at the third to sixth weeks. The mean abdominal retraction value in the multigravid group (7.0 ± 1.8cm) was found to be higher than that of the primigravid group (6.2 ±1.9cm) and this was consistent through the periodsand statistically significant ($p < 0.05$). The mean abdominal retraction index (RI Ó 50%) was achieved by all groups except the control, at different periods. An overall view of category two results revealed statistically significant increase in closure of inter-recti distance of experimental group over the control, though not statistically significant ($p < 0.05$). There was significant relationship between closure at the upper and lower margins of the umbilicus($p < 0.05$), in favour of the former.Closure of inter-recti distance was alsosignificant ($p < 0.05$) at the fourth week when compared with the baseline. Result also showed that younger postpartum women achieved significantly better recovery from diastasis recti abdominis than their older counterparts. Thus these therapeutic exercise qualities should be recommended for the retraction of abdominal muscles as well as resolution of diastasis recti abdominis in postnatal women.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Pregnancy imposes significant morphological alteration on theabdominal muscles, with implications for the functional capacity of women during the postpartum period (Gilleard and Brown, 1996);Coldron *et al.*, 2008). In order to restore their figure and fitness during the postpartum period, many women continue, or begin abdominal strength exercise programmes.However, these prescribed abdominal exercise programmes in the postpartum period are not based on evidence and hardly adhere to the frequency, intensity, time and specificity(FITS) criteria of exercise prescription(Liaw *et al.*, 2011).

Nevertheless, abdominal muscle strengthening exercises continue to be recommended during the postpartum period (Benjamin *et al.*, 2013). Most postpartum women are encouraged to attend exercise programmes to restore their figure and fitness. The rationale behind abdominal strengthening programmes is the assumption that the contraction of all abdominal muscles will reduce the abdominal horizontal diameter in such a way that a horizontal force will be generated, which will in turn reduce the distance between abdominal muscles fibres (Liaw *et al.*, 2011). The horizontal force is the result of the overall action of the deep abdominal muscles (internal and external, oblique and transversus muscles) (Stoke *et al*., 2010).

However, there is no evidence that this horizontal tension will produce abdominal muscle fibres approximation (Pascoal *et al.*, 2014). Knowledge about the effects of specific exercise type and biochemical action on postpartum abdominal muscle morphological changes is required in order to develop specific abdominal strength exercise programmes for fitness, functional and morphological recovery in postpartum women.Accordingly there is paucity of literature about the effects of exercise on abdominal muscle morphology after pregnancy. To the authorôs knowledge, only scanty information exist in the literature about the effects of structured abdominal muscle exercises on the retraction of the abdominal muscle in postpartum women.

Closely associated with postpartum abdominal muscle weakness is a condition known as diastasis recti abdominis (DRA), which is defined as an increase in the inter-recti distance (IRD), or width of the linea alba. This condition is variously defined by different authors as separation of the recti bellies at the linea alba when the inter recti distance is greater than 1.5 cm (Gilleard and Brown, 1996); greater than 2 cm (Lo et al., 1999); greater than 2.5 cm (Candido et al., 2005); greater than 2 finger widths during a partial sit-up (Bursch, 1987; Sheppard, 1996). Inter recti distance in some cases is believed to resolve spontaneously (Liaw, 2011), but the extent to which this resolution occurs is uncertain.

The prevalence of IRD is essentially pronounced in multiparous women.Candidoet al., (2005)recorded 35% immediate occurence on postpartum women. In another work,(Boissonnault and Blaschak 1988) noted the existence of IRD in as much as 66% of third trimester women in a cross-sectional study.

The locations of IRD are mainly above and below the umbilicus. Rett et al., (2009)noted that the prevalence of DRA and mean DRA were greater above the umbilicus both among multiparae and primiparae. Below the umbilicus, the mean DRA was greater among multiparae.Boissonnault and Blaschak (1998) also recorded the greatest incidence of DRA around the umbilicus.

Methods of assessment of IRD includefingertip measurement,caliper measurement and ultrasound imaging (USI) (Chiarello et al., 2005).Reliability and validity of thesemethods are assessed according to their inter-rater or intra-rater qualities. While the fingertip measurement has inter-rater problems, it is intra-rater reliable as established by Bursch, (1987). Boxer, (1997) also found calipers to be sufficiently inter-rater reliable. On the other hand,Liaw et al., (2011), andMota et al., (2012) also found ultrasound imaging to be inter-rater reliable and valid compared to calipers and fingertips methods.Mendes et al.,(2007) supported the high validity of ultrasound imaging as a measurement instrument for DRA. The author maintained thatUSI is valid compared to measurements during surgery for DRA at and above umbilicus, but not below. In line with these clinical observations ultrasound imaging technique is considered a viable option in IRD measurement in this study

The main aim of this study was to determine the effects of different abdominal exercises on the abdominal diameter in postpartum women while exploring rates of exercise mediated abdominal muscle retraction. This study sought to work out a possible postnatal abdominal muscle retraction pattern using isotonic, isometric,and combinedmuscle works compared to a control group who received no abdominal muscle exercise. Alsoinfluence of gravid status and age on the retraction pattern were investigated. This research sought to determine the exercise dose (in terms of FITS) required to produce a retraction index, that is, 50 percent reduction in the difference between the girth of relaxed abdomen and a contracted one in the samewoman.

Finally the research sought to investigate exercise induced recovery of IRD as a pointer to abdominal muscle strength and endurance in postpartum women.The relationship between IRD resolution and time interval were also clinically examined.

1.2 **Statementof Problem**

Most physiological changes that occur during pregnancy gradually resolve during the 6 weeks to 8 weeks following delivery (Polden, 1985). This suggests that at the end of puerperium the mother should be back to her pre-pregnancy state. However the stretched abdominal muscles may become weak. The length of the abdominal muscles may increase by approximately two thirds in a primigravida while in multigravida this length may even double by term (Polden, 1985; Arena and Maffilli, 2004).

Diastasis recti abdominis is a common occurrence in postpartum women. Little information exists on the short- and long-term recovery of IRD and the relationship between changes in IRD and the functional performance of the abdominal muscles. (Liaw et al., 2011). A diastasis rectus abdominis can compromise mechanical trunk function in both genders (Chiarello and McAuley, 2013).

Therefore during the postpartum period, many women continue, or begin abdominal strengthening exercise programmes in order to restore their figure and fitness. However, prescription of these abdominal exercise programmes in the postpartum period is not based on evidence, and very little literature exists about the effects of exercise on abdominal muscle morphology during and after pregnancy (Pascoal *et al.,* 2014). It is unlikely that interventions will have expected effect in retracting the postpartum abdominal muscle. This renders a single summary statement of the effectiveness of exercise intervention on postpartum abdominal retraction invalid. Understanding of this will give a cue to a potential pathway to mechanism of postpartum abdominal muscle retraction hence best exercise protocol to further enhance it.

1.3 Objectivesof the Study

The objectives were to:

i. assess the effects of six weeks isotonic, isometric and mixed (Isotonic /Isometric) exercises on postpartum abdominal muscles,

ii. assess the differential effects of abdominal exercise protocols (isotonic, isometric and mixed) instituted six weeks postpartum on abdominal muscles retraction.

iii. evaluate the rate of abdominal muscles retraction within six weeks of different exercise protocols.

iv. determine a retraction index (RI) ï time dose of exercise at which the difference between the relaxed abdomen and the contracted abdomen is reduced by half using the different exercise protocols.

v. investigate the effects of isometric abdominal contraction in the reduction of inter-recti distance (IRD) in postpartum women.

vi. examine the relationship between IRD and abdominal muscles function.

vii. examine whether any relationship exists between exercise mediated recti diastasis recovery and age, as well as number of pregnancy in postpartum women.

1.4 Research questions

This study sought to give answers to the following questions:

i. Do exercises have effect on postpartum abdominal muscle retraction?

ii. Does different abdominal exercise protocols (isotonic, isometric and mixed) instituted six weeks postpartum have differential effects on postpartum abdominal muscle retraction?

iii. What are the rates of postpartum abdominal muscle retraction without specific exercise and with different exercise protocols?

iv. Using different therapeutic exercise regimen, what dose of exercise will achieve a retraction index ï time dose of exercise at which the difference between the relaxed abdomen and the contracted abdomen in the same person is reduced by half?

v. Using isometric abdominal muscle exercises, to what extent could IRD be reduced?

vi. How would multiparous women with recti diastasis respond to repeated bouts of abdominal isometric exercises?

vii. Would younger multiparous women with recti diastasis respond differently to isometric abdominal exercises from older ones?

1.5 Research Hypothesis

The broad research hypotheses of this study are:

1. Six weeks programmed exercise protocols of varying qualities are not likely to affect muscle contraction, sufficient to pull back postpartum abdominal muscles to pre-pregnancy state.
2. Under the same conditions, applied isotonic, isometric, and combined isotonic/isometric exercises will not have differential effects on the retraction quality of postpartum abdominal muscles.

3. Diastasis recti abdominis in postpartum women is not likely to respond to programmed abdominal isometric exercises.

These hypotheses were tested under the following sub-headings:

i. There will be no significant difference in abdominal muscle retraction across the groups at baseline.

ii. There will be no significant difference in abdominalmuscle retraction across the groups at week 1.

iii. There will be no significant difference in abdominalmuscle retraction across the groups at week 2.

iv. There will be no significant difference in abdominalmuscle retraction across the groups at week 3.

v. There will be no significant difference in abdominalmuscle retraction across the groups at week 4.

vi. There will be no significant difference in abdominalmuscle retraction across the groups at week 5.

vii. There will be no significant difference in abdominalmuscle retraction across the groups at week 6.

viii. There will be no significant difference in abdominalmuscle retraction for the isometric group across the time series.

ix. There will be no significant difference in abdominalmuscle retraction for the isotonic group across the time series.

x. There will be no significant difference in abdominalmuscle retraction for the mixed group across the time series.

xi. There will be no significant difference in abdominalmuscle retraction for the control group across the time series.

xii. There will be no significant difference in the closure of IRD between the effects ofexercise and spontaneous recovery.

1.6 Significanceof the Study

Post-delivery flabby abdominal muscles present undesirable clumsiness, weakness and compromised function, especially in the subsequent pregnancies. Postnatal period is a time characterized by excitement, especially with healthy baby and mother. Many women hope that their fitness will help them during labour and delivery and also expedite postnatal recovery. It has been found that women who continue to exercise during and after pregnancy had a lower incidence of abdominal and vaginal impairment during the next pregnancy and delivery (Clapp, 1990). It is generally accepted that physically fit women recover more quickly after birth (Polden and Mantle, 1990).

The results of this study is expected to provide testable clinical option for the postpartum abdominal muscle control, and to create a platform for cliniciansto make sound clinical decisions that are time based in the provision of maternal healthcare services.

1.7 Definition of terms

i. Isotonic contraction ï Muscle contraction against a constant load, with approximation of the ends of the muscle.
ii. Isometric contraction ï Muscle contraction involving shortening of contractile element without an appreciable decrease in the length of the whole muscle.
iii. Muscle contraction/relaxationï Mechanical action of a muscle involving shortening/lengthening of the contractile elements.
iv. Muscle retraction ï Muscular action involving itôs withdrawal to original state after mechanical stretch.
v. Primigravida ï A woman who has gone through the experience of one pregnancy.
vi. Multigravida ï A women who has gone through the experience of at least two pregnancies.
vii. Diastasis recti abdominis - An increase in the abdominal inter-recti distance, or width of the linea alba.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The childbearing year is both a season and a goal for which physical preparation and restoration are essential and rewarding. Extensive physical and physiological changes accompany pregnancy, and by extension, childbirth. Noble, (1994) suggests that flabby abdomen, pelvic organ support problems, and compromised urine control are some of the problems that may arise in connection with childbirth and these symptoms may be slow to develop and may subtly manifest themselves as fatigue, frustration, and unhappiness. The signs may be ignored initially, but with the passage of years, and perhaps subsequent pregnancies, surgical repair may be necessary.

Pregnancy creates a special need for exercise, and so is life after delivery. Postnatal period is a time characterized by excitement, especially with healthy baby and mother. Many women hope that their fitness will help them during labour and delivery and also expedite postnatal recovery. It has been found that women who continue to exercise during and after pregnancy had a lower incidence of abdominal and vaginal impairment during the next pregnancy and delivery (Clapp, 1990). Therefore it is generally accepted that physically fit women recover more quickly after the birth (Polden and Mantle, 1990).

During pregnancy, inevitable changes occur. These changes may include the stretching of muscles, softening of ligaments, and loosening of joints in order to make more room inside, mediated by the hormone relaxin.

There is also widespread fluid retention, which may cause localized oedema especially in the ankle, wrist and calf regions. Most of these changes are sustained even after delivery leading to various postpartum discomforts such as flabbiness and hence weakness of the abdominal muscles, and the pelvic floor muscles. Weak muscles are functionally deficient, and as a result would create functional difficulties in the subsequent pregnancies. Whether the external and internal structural supports of the body are adequate to meet and recover from these changes depends on the individual involved (Noble, 1994). The muscles supporting the backbone and those in front and beneath the pelvis are put under stress, which alters their function if care is not taken. So there lies the great need to exercise and maintain the voluntary muscles so as to maintain their functionality.

Accordingly, after delivery the uterus continues its involuntary contractions, and within six weeks it will return to its original state, leaving the individualȣs physical efforts to return the other muscles to their former size and function (Noble, 1994). Morkved and Bo (2000) in their extensive research relating to pelvic floor muscle training clearly show, on many occasions, that only those women who had continued input from the physiotherapist beyond the puerperium were able to maintain muscle strength in a one-year follow up. In their own study, Ostgaard and Anderson (1992) show that 37% of women still had back pain eighteen months post-delivery, thus reinforcing a true justification for physiotherapy not only during, but beyond the pregnancy year.

Traditionally, various methods of returning the overstretched abdominal muscles to size are practiced. These attempts ranged from tying a strip of cloth around the abdomen to regular prone lying.This method is passive in nature and has the potency of restricting the mobility of abdominal muscles which may reduce their active disposition towards activities of daily living. Muscle wastage may accompany other intrinsic muscle actions in response to reduced clearance to perform full range of motion. Apparent reduction in muscle girth may be observed which may be as a result of the wastage. It is known that muscle strength is better enhanced when subjected to active rather than passive life.It is common knowledge that muscle wastage generallyleads to itsweakness and impaired function. However, it is noteworthy that exercise regime exhibits the potency of activating metabolism in the muscles causing increased tone and muscle strength. This action in turn brings about approximation between the muscle fibres thereby pulling the stretched muscles back to their original functional positions.

Studies have shown that exercise effects are most pronounced when it involves multiple large muscle groups and is sufficiently prolonged and strenuous to induce metabolic and circulatory stress (Basmajian 1980; Polden and Mantle, (1991). In their work, Golnick *et al*., (1973) observed that endurance training has been shown to increase muscle glycogen storage and oxidative capacity following exercise.

2.2 Physiological Changes during Pregnancy

While most of the physiological changes occurring during pregnancy may resolve within 6-8 weeks, the musculoskeletal system can still manifest some effects as long as 6 months postpartum (Polden and Mantle, 1990). Brayshaw and Wright (1994) summarized the main physiological changes occurring immediately after childbirth as.

i. Involution of the uterus which immediately follows delivery, and should be complete after 6 weeks.

ii. Lactation, which occurs as a result of the action of prolactin initially secreted by the anterior pituitary gland.

iii. Physiological changes in other body systems, which return the body to its pre-pregnancy state.

However, prior to these changes, the preceding pregnant state has the potency of inducing elongation of the abdominal muscle fibres; the abdomen protrudes from 20 weeks to accommodate the growing fetus, the linear alba separates (diastasis). The resulting skin stretch according to Thomson *et al.*, (1991), may cause stretch marks (striae gravida) in the fairer, dryer skin types, as the elastic tissue tears. The skin pigmentation causes the nipples and areolas to darken and a fine brown line, the linear nigra, appears between the navel and pubis. The rib cage also widens to accommodate the uterus. There is also a 50% increase in blood plasma volume by the 34^{th} week (Thomson *et al.*, 1991). The red blood cells production and volume are adjusted to, and regulated by, the increased demand for oxygen transport. The concentration of red blood cells may fall because of the increased plasma volume; the total hemoglobin is raised. The white blood cell count is proportionally high to give protection potentially against infection. The blood flow through the skin and mucous membranes increase to 70% by 36 weeks and accounts for increased sweating, heat sensitivity and nasal congestion.

There are notable changes in posture and gait as weightincreases. As the pelvic joints relax,the center of gravity shifts forward resulting in strain on the lumbar spine as the abdominal muscles lengthen.

2.3 The Influence of Therapeutic Exercise

Therapeutic exercise is a motion of the body or its parts, to relieve symptoms or to improve function, (Licht, 1980). Such exercises enhance muscle strength and endurance, where strength is regarded as the maximum force which can be exerted against an immovable object (static or isometric strength);the heaviest weight which can be lifted or lowered against gravity (dynamic or isotonic strength); or the maximal torque which can be developed against a pre-set rate-limiting device (isokinetic) (De Lateur,1980). The dynamic contractions can be sub-divided into lengthening (eccentric) and shortening (concentric) contractions of varying velocities. Strengthening that arises from eccentric and concentric muscle work are not usually identical but bear a definite relationship to each other. As velocity of shortening increases, the maximal tension, which can be developed by the muscle, decreases. On the other hand an inverse relationship between velocity of contraction and maximal torque has also been found on the isokinetic rate-limiting device.

The absolute muscle strength is a term used to indicate the maximum tension developed by muscle per unit of physiological cross sectional area.

The endurance of a muscle may be defined as the ability of the muscle to continue a particular static or dynamic task. The extent to which muscle endurance is related to muscle strength, and the specificity of exercise programmes designed to improve one or the other are however, subjects of considerable controversy.

2.4 Evidence for the Benefit of Exercise during and after pregnancy

Studies suggest that women who began various forms of non-weight-bearing (free) exercises (cycling or swimming) in early pregnancy were able to maintain a high-intensity, moderate-duration regimen of exercise training throughout the third trimester (ACOG, 2000; Arena and Maffilli, 2004). Thus, the maternal adaptation to both physiologic and morphologic changes appears to favour non-weight bearing exercise over weight-bearing exercise during pregnancy.

Most of the guidelines for designing a general fitness programme in women outlined previously by the American College of Obstetricians and Gynecologists also apply to pregnant women (ACOG, 2002). An exercise prescription in pregnancy should be individualized and should include a health assessment. However, the physiologic changes occurring during pregnancy described here should lead obstetricians and pregnant women to consider several modifications of these general guidelines. It must be emphasized that none of these recommendations has a firm basis in prospective, randomized, clinical trials. These guidelines follow from a critical analysis of the available physiologic data regarding exercise and pregnancy and represent reasonable extrapolations from such knowledge.

2.5 Recommendations for Exercise in Pregnancy and Postpartum

There are no data in humans to indicate that pregnant women should limit exercise intensity and lower target heart rates because of potential adverse effects. For women who do not have any additional risk factors for adverse maternal or perinatal outcome, the following recommendations may be made:

During pregnancy, women can continue to exercise and derive health benefits even from mild-to-moderate exercise routines. Regular exercise (at least three times per week) is preferable to intermittent activity. Women should avoid exercise in the supine position after the first trimester. Such a position is associated with decreased cardiac output in most pregnant women; because the remaining cardiac output will be preferentially distributed away from splanchnic beds (including the uterus) during vigorous exercise; such regimens are best avoided during pregnancy.

Prolonged periods of motionless standing should also be avoided. Women should be aware of the decreased oxygen available for aerobic exercise during pregnancy. They should be encouraged to modify the intensity of their exercise according to maternal symptoms. Pregnant women should stop exercising when fatigued and not exercise to exhaustion. Weight bearing exercises may under some circumstances be continued at intensities similar to those prior to pregnancy throughout pregnancy. Non-weight-bearing exercises such as cycling or swimming will minimize the risk of injury and facilitate the continuation of exercise during pregnancy. Morphologic changes in pregnancy should serve as a relative contraindication to types of exercise in which loss of balance could be detrimental to maternal or fetal well-being, especially in the third trimester.

Further, any type of exercise involving the potential for even mild abdominal trauma should be avoided. Pregnancy requires an additional 300 kca in order to maintain metabolic homeostasis. Thus, women who exercise during pregnancy should be particularly careful to ensure an adequate diet. Pregnant women who exercise in the first trimester should augment heat dissipation by ensuring adequate hydration, appropriate clothing, and optimal environmental surroundings during exercise. Many of the physiologic and morphologic changes of pregnancy persist 4-6 weeks postpartum. Thus, prepregnancy exercise routines should be resumed gradually based on a womanĝs physical capability.

2.6 Brief Gross Anatomy of the Abdominal Muscles.

The anterolateral wall of the human abdomen is fortified by four large muscles. These muscles are external oblique, internal oblique, tranversus abdominis, and rectus abdominis. Two small muscles, the cremaster and pyramidalis are also present. The external oblique, internal oblique and transversus abdominis are larger flat muscles placed in the anteolateral aspect of the abdominal wall, each ending in an extensive aponeurosis that reaches the mid-line (Chaurasia, 2013). At the mid-line the aponeurosis of the right and left sides decussate to form a median band known as linea alba. The rectus abdominis runs vertically on each side of the linea alba and enclosed in a sheath formed by the aponeuroses of the external and internal oblique, and transversus abdominis.

(a) External Oblique Muscle

This muscle originates through fleshy slips from the shaft of the lower eight ribs; and terminates with aponeurosis at the midline (Fig. 1). The upper four slips interdigitate with those of serratus anterior, and the lower four with latissimus dorsi. At the level of navel the aponeurosis of the external oblique blends with that of the internal oblique proximal to the lateral border of the rectus abdominis. Above the pubic crest the aponeurosis of the external oblique has a triangular aperture referred to as superficial inguinal ring. Nerve supply is by lower six thoracic nerves.

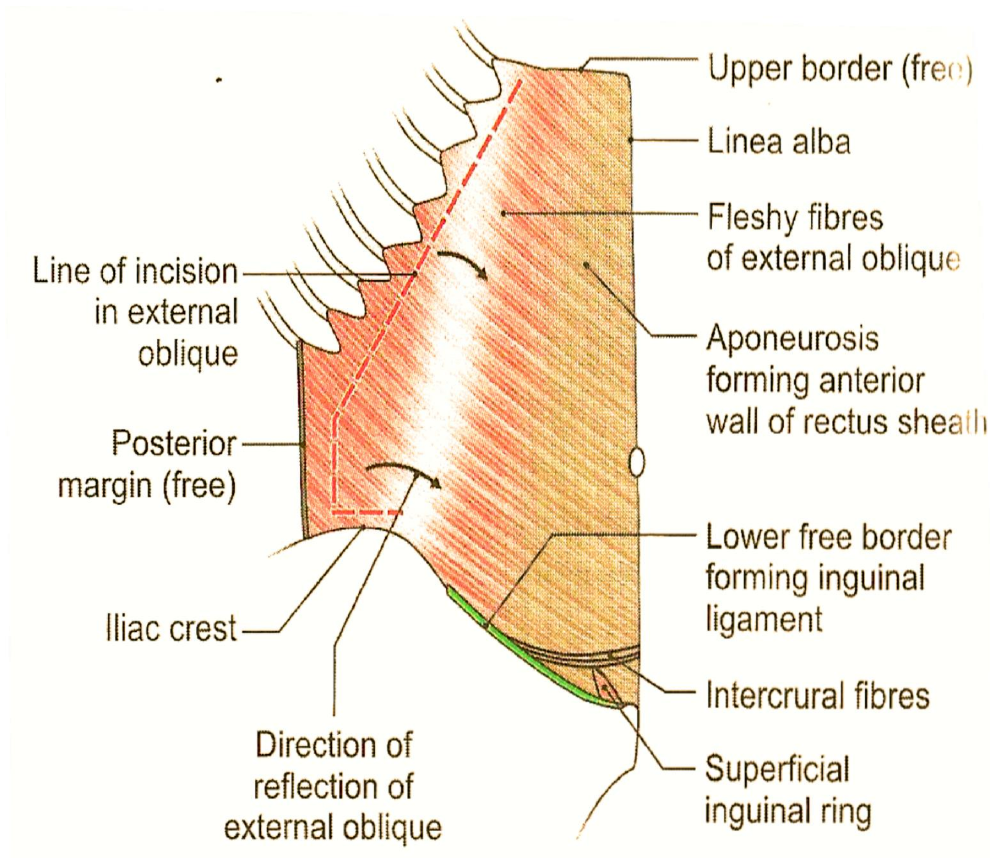


Fig. 1 Structure of the external oblique muscle (Adapted from Chaurasia, 2013)

(b) Internal oblique muscle

The muscle has three points of origin, the lateral two-thirds of the inguinal ligament, anterior two-thirds of intermediate area of the iliac crest and the thoracolumbar fascia. It then runs upwards, forwards and medially crossing the fibres of the external oblique muscle at right angles (chaurasia, 2013).

It also has two points of insertion- the uppermost fibres into the lower three or four ribs and their cartilages, while the greater part of the muscle ends in an aponeurosis and inserts into the seventh, eighth and ninth costal cartilages, the xiphoid process, linea alba, pubic crest and the pectineal line of the pubis (Fig. 2). Nerve supply is by the lower six thoracic nerves, and the first lumbar nerve. This muscle limits itself to the costal margin. The cremaster muscle is formed by fibre of the internal oblique muscle of the abdomen.

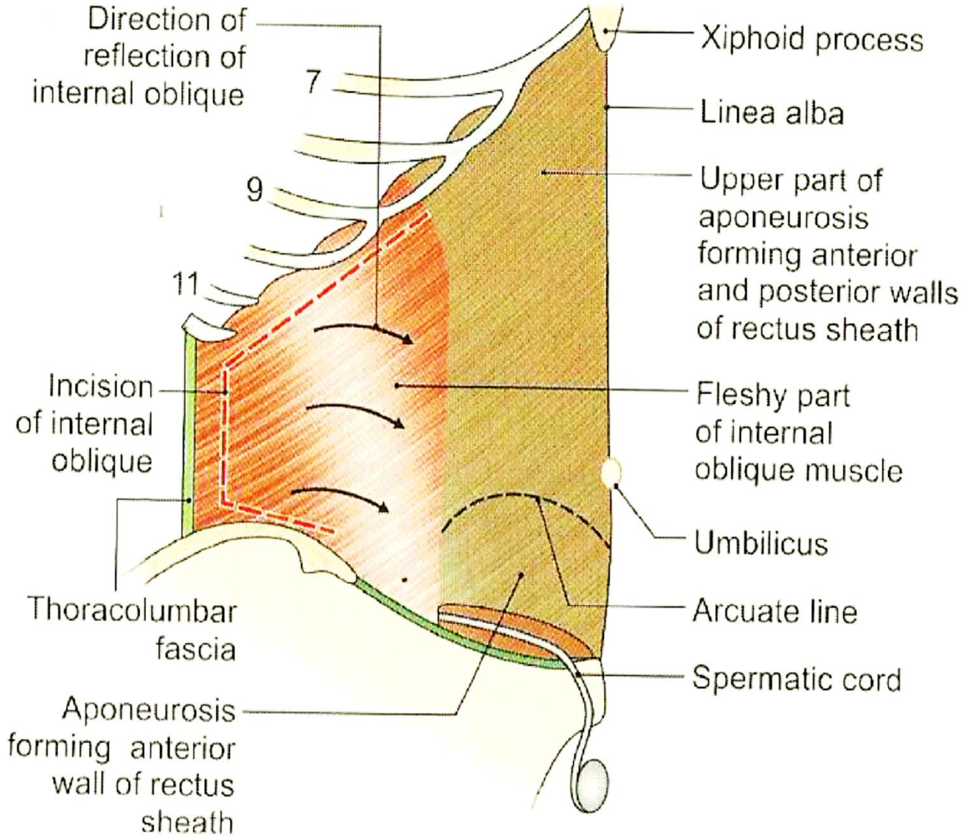


Fig. 2 Structure of the internal oblique muscle, (adapted from Chaurasia, 2013).

(c) Transversus abdominis muscle

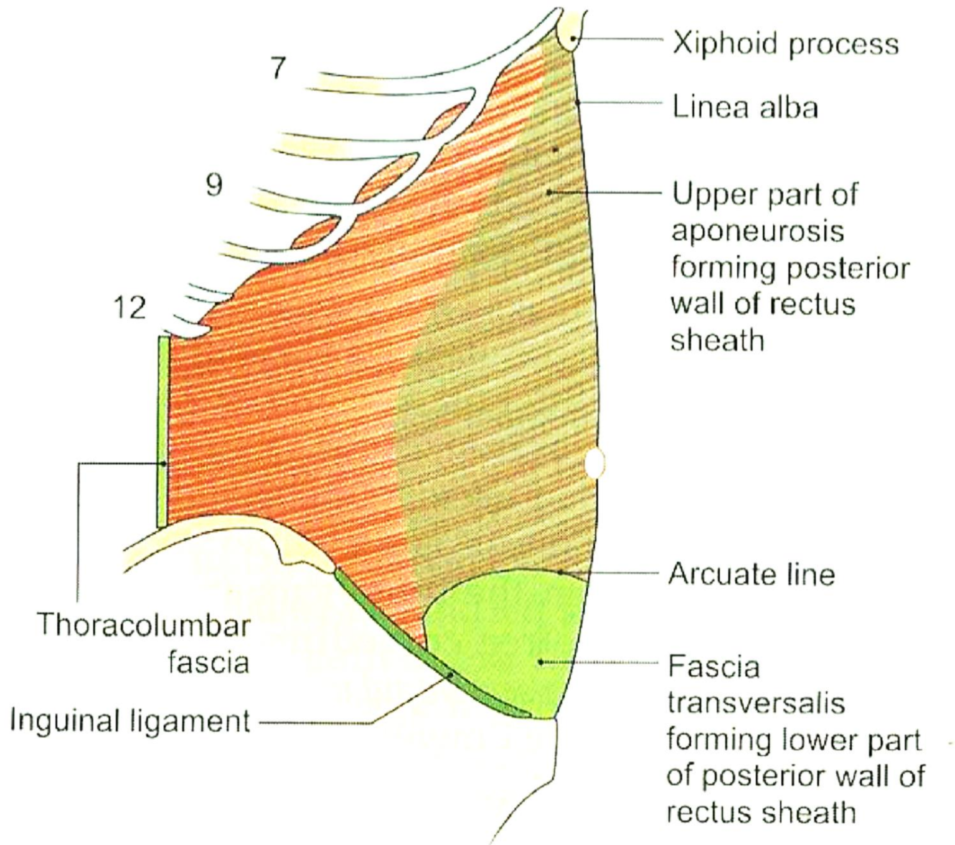


Fig. 3 Structure of the transversus abdominis muscle, (adapted from Chaurasia, 2013).

Transversus abdominis has four points of origin ï the lateral one ï third of the inguinal ligament, anterior two-thirds of inner lip of the iliac crest, thoracolumbar fascia and the inner surface of the lower six costal cartilages (fig.3).

Its insertion is through a broad aponeurosis formed by its fibres into ï the xiphoid process, the linea alba, the pubic crest and the pectineal line of the pubis. The lower fibres fuse with the first lumbar nerve. Like the other two flat muscles transversus abdominis seems to end in the liner alba.

(d) Rectus abdominis muscle.

This muscle originate through two tendinous heads. The lateral head arises from the lateral part of the pubic crest while the medial head from the anterior pubic ligament. It inserts on the front of the wall of the thorax, along a horizontal line passing laterally from the xiphoid process cutting the 7^{th}, 6^{th} and 5^{th} costal cartilages in that order (fig. 4). Its nerve supply is through the sixth and seventh thoracic nerves. It is enclosed in a sheaf formed mainly by the aponeurosis of the three flat muscles of the abdominal wall.

Rectus abdominis is three times as wide cranially, where it is fleshy, as it is caudally where it is tendinous. Its lateral border crosses the gall-bladder at the costal margin (Anderson, 1980).

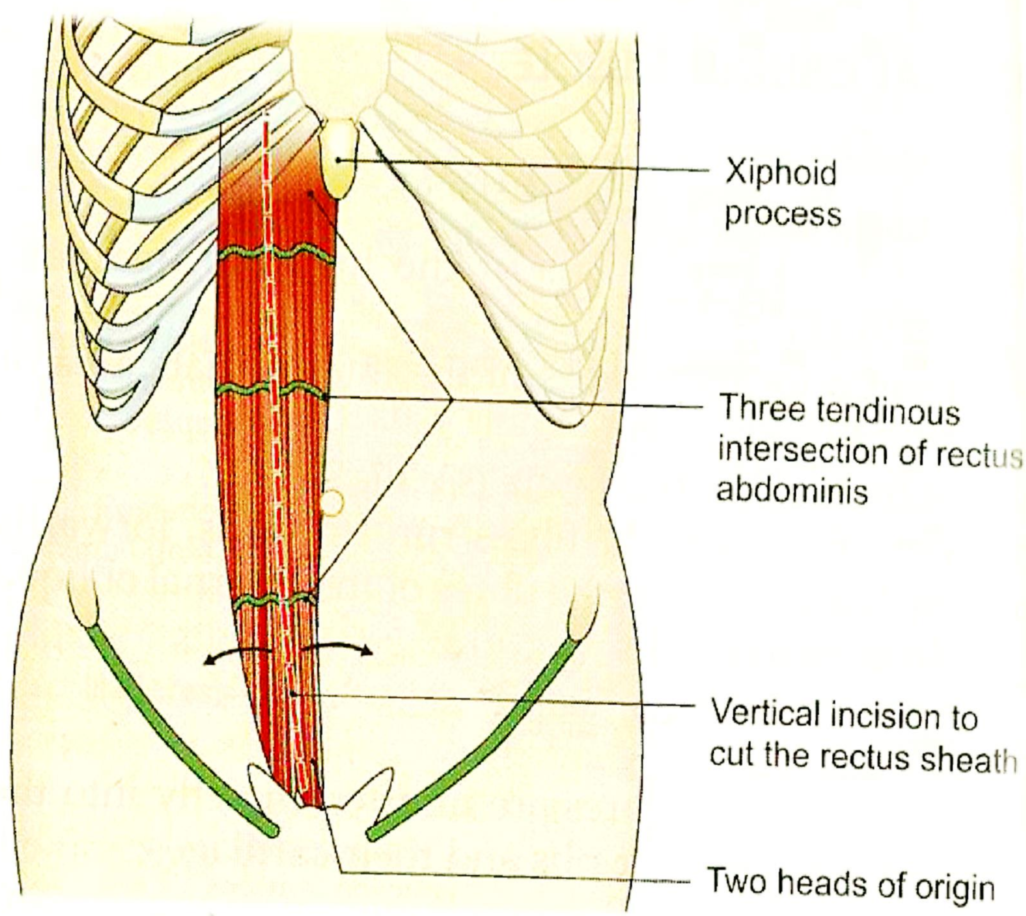


Fig. 4 Structure of the rectus abdominis muscle, (adapted from Chaurasia, 2013).

e) Blood supply and drainages of abdominal wall and muscles

Arterial blood supply of abdominal muscles are from inter-woven branches of arteries of the abdominal wall which include thesuperior epigastric, musculophrenic, posterior intercostal, inferior epigastric, deep circumflex iliac, superficial epigastric, superficial circumflex iliac andsuperficial external pudendal arteries

In the venous drainage system, the veins accompany corresponding arteries and eventually drain into the inferior vena cava. Above the level of umbilicus the lymphatics drain upwards into the axillary lymph nodes, while below the umbilicus they drain into the superficial inguinal lymph nodes

f) Major actions of Abdominal Muscles

1. The four main muscles of the anterior abdominal wall from four-way firm elastic support for the abdominal content. This action is mainly carried out by the oblique muscles especially the internal oblique by muscle tone.
2. Combined action of oblique and transversus abdominis muscles ensures expulsive acts like micturition, defecation vomiting etc, through compression of the abdominal viscera.
3. External oblique muscles contraction brings about forceful expiratory action like coughing, sneezing, blowing etc by compressing the lower part of the thorax.
4. Trunk movement function
    - Rectus abdominis is mainly responsible for the flexion of the trunk and lumbar spine

- Lateral rotation of the trunk is brought about by one sided contraction of the oblique muscles
- Combined action of the internal and external oblique muscles produce trunk rotation.

2.7 Functional Anatomy of Abdominal Muscles

The abdominal muscles (external oblique, internal oblique, transversus abdominisand rectus abdominis,) are arranged like an extensive four-way corset which span the front of the trunk from the breastbone and ribs to the public bones, and around the side of the pelvic ridge that can be felt at each hip. As shown in figure 5, their arrangement and attachments are quite complex, but can be compared to an elaborate corset. The extensive diagonal fabric around the sides of a corset or girdle is similar to the two oblique abdominal muscles that overlap in such a way that each layer pulls in the opposite direction. The vertical panel down the corsetõs center represents the straight abdominal muscles (which are actually two recti muscles joining in the midline, at the linea alba). An extensive horizontal waistband is formed by the transverse abdominal muscles.

Although each segment of the abdominal corset makes a key contribution, during exercises and activities the different parts are combined rather than isolated. For example, the top half of the corset is emphasized during movement with the upper trunk; the lower abdominals work to stabilize the pelvis when the legs are moved. According to Noble (2005), the functions of the abdominal muscles are varied and include to:

i. maintain the proper positions of the abdominal and pelvic organs (including the enlarging uterus in pregnancy).

ii. assist in deliberate breathing, singing, shouting, coughing, sneezing, vomiting, straining, elimination, and the second stage of labor.

iii. control the tilt of the pelvis. The downward pull of the buttock muscles, together with the upward pull of the abdominal, maintains the correct alignment of the pelvis in relation to the backbone. The sideways pelvis tilt ï hip hiking ï is also abdominal muscles action.

iv. flex the trunk to one side, which involve half of the muscles at a time.

v. raise the trunk upward from a back ï lying or semi-lying position. Commencing the movement is the most difficult part since the force of gravity must beovercome. Even just raising the head will cause the abdominal muscles to tighten.

vi. rotate the trunk; for example, bringing one shoulder toward the opposite hip, or moving the hips in relation to the chest.

vii. brace the body when it is under stress ï lifting, straining, or outside blows. This is a reflex protection during effort.

viii. stabilize the lower back during leg-raising, knee-rolling.

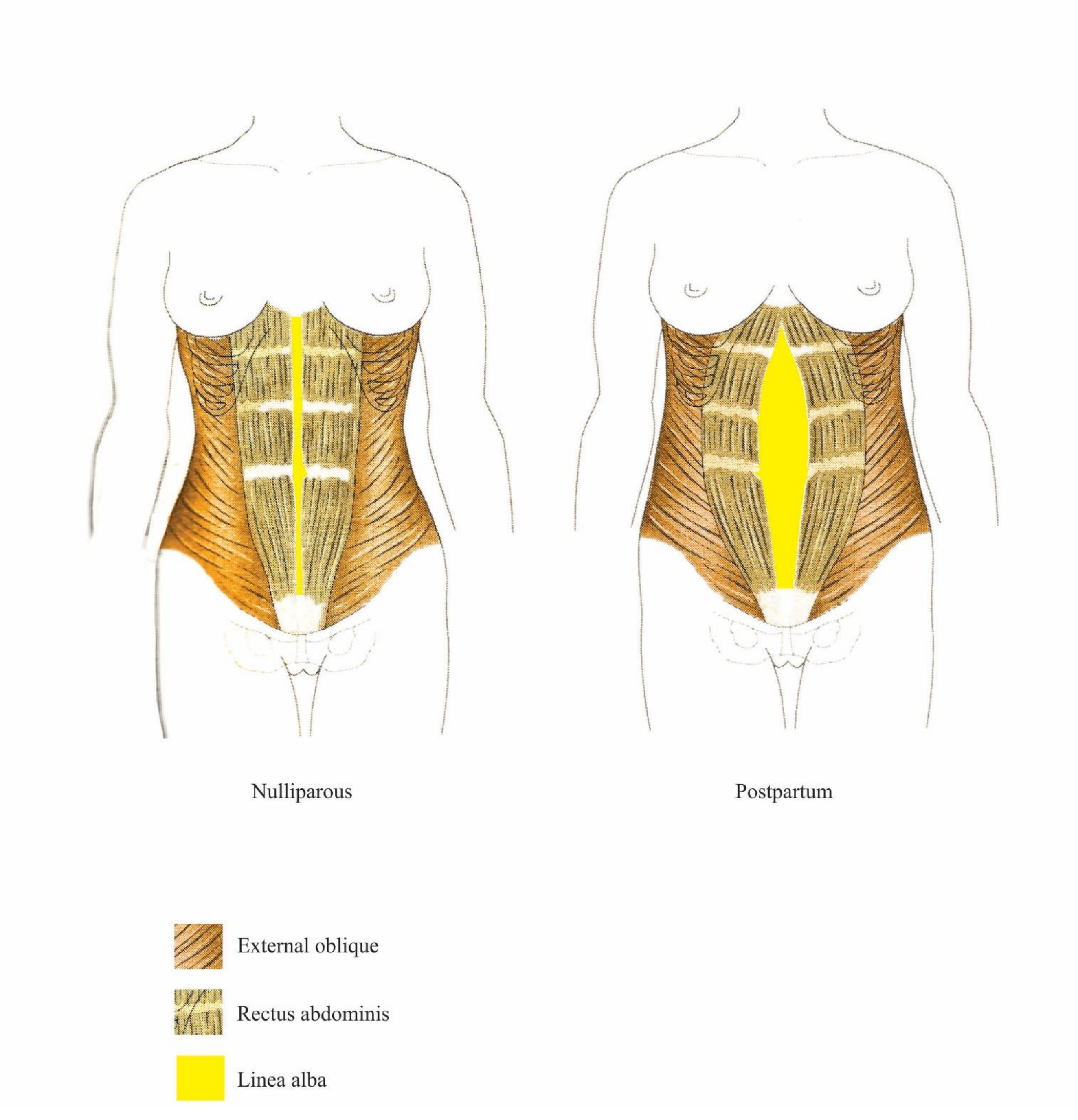


Fig. 5Structure of the Abdominal Muscles, in Nulliparous and Postpartum, (adapted from Mantle et al., 2004).

The habitual use of the standing and sitting positions during exercise provide little stimulus for the abdominal muscles, nor are these muscles exercised when we walk at a normal pace on level ground. Therefore, the abdominal muscles are usually the weakest group of muscles among the general population and their weakness is one of the most common causes of backache (Mantle *et al*., 2005; Noble, 2005). Their maximal exertion occurs only when they must perform against resistance, factors such as leverage and body weight, during trunk or leg-raising from the horizontal, and while running, lifting, and so on.

2.7.1 Abdominal Muscles during Pregnancy

In order to accommodate the increasing size of the uterus, the abdominal muscles permit an enormous degree of stretching. Evidence of this is also seen superficially by stretch marks, which indicate that the skin has reached the limit of its elasticity, and obliteration of the navel, which occurs around the seventh month. During pregnancy it is necessary to keep the muscles in good shape so that they can adequately support the load in front, which is placing increasing stress on the backbone. A correct pelvic tilt is the keystone. Without it, poor posture, muscle strain, and backache result. The abdominal muscles feel apparently fit during pregnancy because they are being continuously stretched over the enlarging uterus ï the resistance keeps them taut. Because they are stretched so tight, it is important to avoid any positions or exercises that cause further stretch, in order to prevent muscle weakness.

It is understandable that without special effort on the motherô s part after delivery, there will not be a complete return to former tone and length. The abdominal wall may still resemble a girdle, but appears worn out. Muscles, unlike girdles, do recover their inherent properties, and exercise during pregnancy will facilitate recovery afterward. Intact muscles, which have maintained their contractile ability and blood circulation as much as possible, will lengthen more easily and shorten more quickly afterward.

Many women are not interested in special exercises until they look and feel quite pregnant, then they are motivated to take action. There are few reasons that prenatal exercises receive little emphasis in most childbirth preparation classes. The number of students may be large, the schedule very tight, the focus usually on preparation for labor and delivery. And frequently the expectant mother seeking advice or instruction is well into the last trimester. While it would be unwise to begin progressive abdominal muscles exercises at this time, certainly the essential exercises can and should be done. These maintain existing strength and firm the muscles. Any position or exercise causing extremes of movement, muscles strain, or stress on the joints, which are vulnerable because of the slackened ligaments, is most definitely to be avoided. Such include full range trunk flexion in standing position and hip abduction exercises in any position.

2.7.2 Abdominal Muscles Postpartum

The abdominal muscles are very loose and stretched after delivery and provide inadequate support for the pelvis and lower back. At this time these joints are particularly at risk because of the hormonal changes in pregnancy, which softened their protective ligaments. It is essential now to avoid any strain on the backbone or any stretching of the abdominal muscles. Exercises, then, are performed in stable positions where support is maximal and unnecessary effort avoided. The ligaments will gradually tighten back to their former stage as the uterus returns to normal, due to the fact that physiological adjustments of the body during the former shape, size, and efficiency, on the contrary, require active input. Best results are achieved when exercises are commenced within twenty-four hours after delivery (Mantle *et al*., 2005; Noble, 2005), especially if necessary.

Initially, it is normal to engage in tensing, retracting, and pulling in the muscles to coax them back to their former length and tone. Since the abdominal muscles have been subjected to prolonged tension stress, it is important not to overwork them at first but to repeat the exercises a few at a time and often. The exercises are simple and completely safe; they are easy to do and can be performed on the bed. Strong exercises must not be attempted until there has been good recovery of the abdominal wall and pelvic floor. This will vary with each woman and relates to her physical condition before pregnancy, her labour and delivery, and the management in the immediate postpartum phase.

However, it is advisable that postpartum women should not perform strong abdominal muscles exercises until the correction of any lingering sphincter weakness is effected, or the state of the abdominal wall is checked.

2.8Neural Basis for Muscle facilitation and inhibition

The neurological basisfor certainmuscular facilitation and inhibition techniques used widely in both traditional and modern therapeutic exercises are traceable to Sherringtonôs findings from his investigations pertaining to spinal reflex physiology. Sherrington defined the concept of facilitation and inhibition in terms of how experimentally induced and naturally occurring inputs from peripheral nerves influenced the excitability (fig. 6), which is the tendency to discharge impulses of these neural elements (Patton, 1965).

It is pertinent to relate the therapistôs focus and understanding of the attitude of the skeletal muscles to stimulus to Sherringtonôs principles on muscle facilitation and inhibition as shown in figure 6. Historically, Patton (1965) maintained that the target of Sherringtonôs investigations is identical to what should be the therapistôs focus of attention, namely the delineation of modulating influences upon the activity of the spinal alpha motoneurons also referred to as the ventral horn cells that innervate voluntary musculature. He demonstrated the neurological facilitation and inhibition processes as follows (fig. 6)

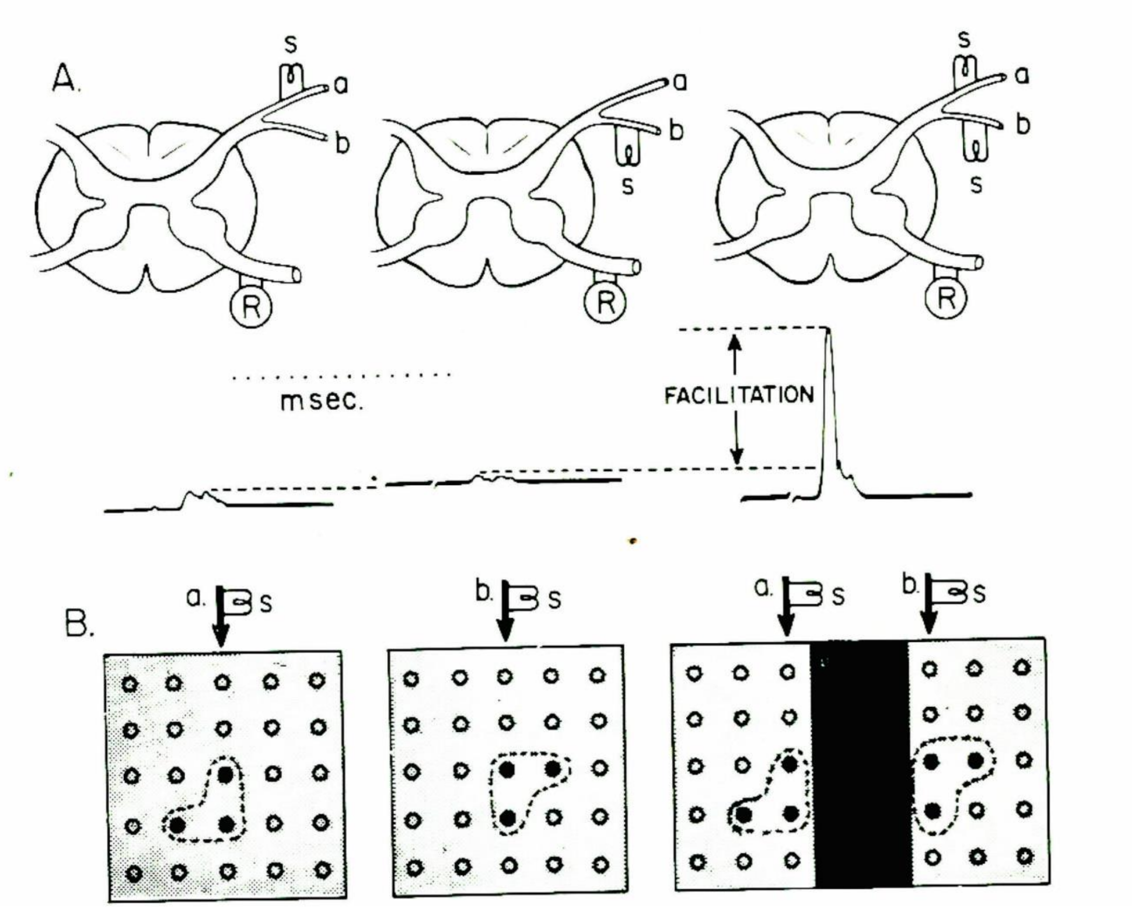


Fig. 6 (A) Demonstration of facilitation. (B) Mechanism of facilitation, (adapted from Patton,1965).

During facilitation (fig. 6 (A), weak stimulation of each two dorsal root strands, a and b, produces low-amplitude reflex responses shown in left and middle traces, respectively. Simultaneous stimulation of a and b elicited facilitated reflex discharge on the right, greater than the sum of the individual responses.

The mechanism of action (fig. 6(B) follows a consistent pathway. On the left and in the middle are represented the motoneurons pool served by afferent sources, a and b. input from each source discharges three motoneurons, and subliminally excites the remainder of the pool. The subliminal fringes of a and b partially overlap. Thus, when inputs a and b are provided simultaneously, additional neurons in the zone of overlap are brought to threshold, and eleven rather than six neurons fire. This action invariably excites the muscle fibres, initiating contraction.

Harris (1969) explained the spatiotemporal summation, which provides the basis for facilitation of voluntary activation of muscles, as well as the anatomical-physiological basis for facilitation techniques(Fig. 7).The author insisted that the convergence of peripheral and central excitatory influence on Ŭ motoneurons is the basis for facilitating discharge of the Ŭ motoneurons under volitional drive by ñputting inôô peripheral input such as muscles stretch (fig.7 (a). In figure 7(b),input A represents peripheral input to Ŭ motoneurons from stretch receptors; B represents descending input via the corticospinal tract and extrapyramidal routes. Both inputs converge upon common motoneurons.

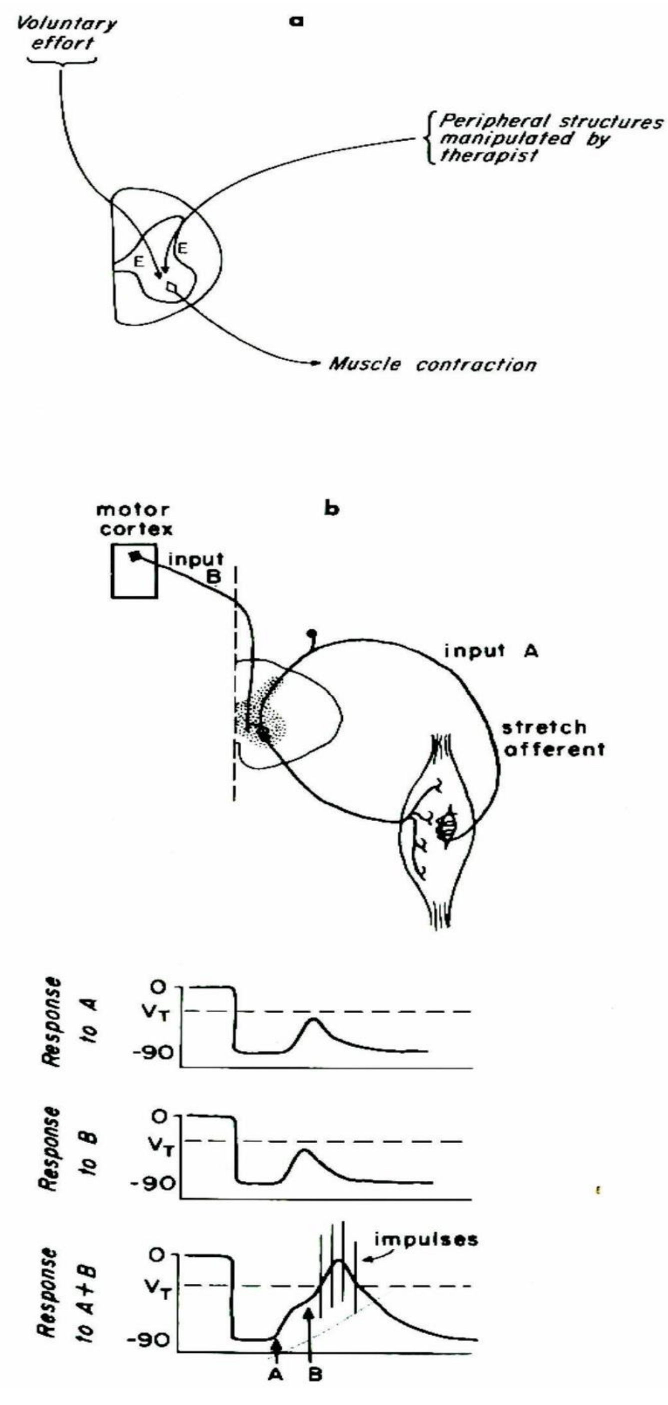


Fig. 7(a) Diagrammatic representation of spatiotemporal summation.
(b) Detailed representation of the anatomical-physiological basis for facilitation techniques, (adapted fromHarris, 1971).

Intracellularly recorded responses of a single motoneuron to A or B alone are subthreshold; no impulse discharge results from either input in isolation. When B (representing volitional activation) follows closely after A (representing peripheral input which the therapist sets up by quick stretch of the muscles to be facilitated), the two inputs summate to produce a suprathreshold depolarization leading to impulse discharge. The two inputs come from different regions and must occur more or less simultaneously in order for the depolarization they produce to add and thus exceed threshold, hence this process is referred to as spatiotemporal summation(Harris1969).

2.9 Essential Principles for Abdominal Muscle Exercises

Toward the end pregnancy and the early postpartum, the same essential exercises should be performed. It is logical that the muscles prepared are the ones that will be restored later and it is easy to remember the programme if it is earlier practiced in pregnancy. The starting positions and actions of the therapeutic exercises used in this study were chosen to prevent the strain of joints or muscles. Most of the exercises emphasize control of the pelvic tilt since this improves posture and relieves back strain. These movements require minimal exertion and help to maintain the condition of the muscles as they expand over the enlarging uterus. Some degree of progression is naturally provided since the muscles work harder as the weight of the uterus increases. However, stronger exercises which progress the abdominal muscles against the resistance of gravity are required to improve the condition and power of the muscular corset.

Abdominal muscle exercises using leverage and the force of gravity for resistance are typically activities which involve the raising and lowering of the trunk or the legs. Sit-ups emphasize action in the upper part of the abdominal corset as the muscles shorten to raise the trunk. Leg movements involve strong stabilizing work from the lower abdominal muscles to control the pelvic tilt. It is not easy to properly strengthen the abdominal muscles because their action is complicated by an associated group of muscles ï the hip flexors. Double-leg-raising and the conventional sit-ups with the legs out straight are commonly used to achieve this goal, but evidence shows that they are undesirable as well as often ineffective (Supper,1998). Many a person is proud of his or her ability to do a series of sit-ups or leg-raises; however these actions depend largely on the hip flexors and frequently give rise to back pain because they pull on joints of the lumbar spine.

The key to good abdominal exercises is to protect the lower back from the adverse pull of the hip flexors and to be in control of the leverage and resistance from gravity. The exercise of raising and lowering the outstretched legs, therefore, is potentially dangerous to the spinal joints. It should be modified so that the knees are bent and the heels can be rested on the surface at any time when the back threatens to arch.

2.10Muscle Morphology and Functional Basis of Therapeutic Exercise

Muscles are mainly formed by the union of extrafusal contractile elements which receive their innervations from axons that emerge from ventral roots of the spinal cord. The cell body or soma of the axon resides in the ventral horn as an alpha motoneuron. Each motor cell supplies varying numbers of muscle fibres by successive bifurcations of its axis cylinder. The motoneuron, its axon, and all the muscle fibres innervated by terminal aborizations of this nerve fibre are referred to as motor unit (Wolf, 1980). Human body movement mediated by this motor unit has a long history of importance. Sherrington in 1906 termed the outflow from alpha motoneurons as ‗the final common pathway' for it is through the expression of motor unit activity that movement occurs.

Since therapeutic exercise denotes a variety and orderly succession of procedures designed to restore function, it would appear that an awareness of motor unit properties could serve well as a basis for appropriate exercise treatment plans (Licht 2008). It becomes imperative therefore that the structural make-up of the muscle should be well assessed in order to understand the influence of therapeutic exercise on it.

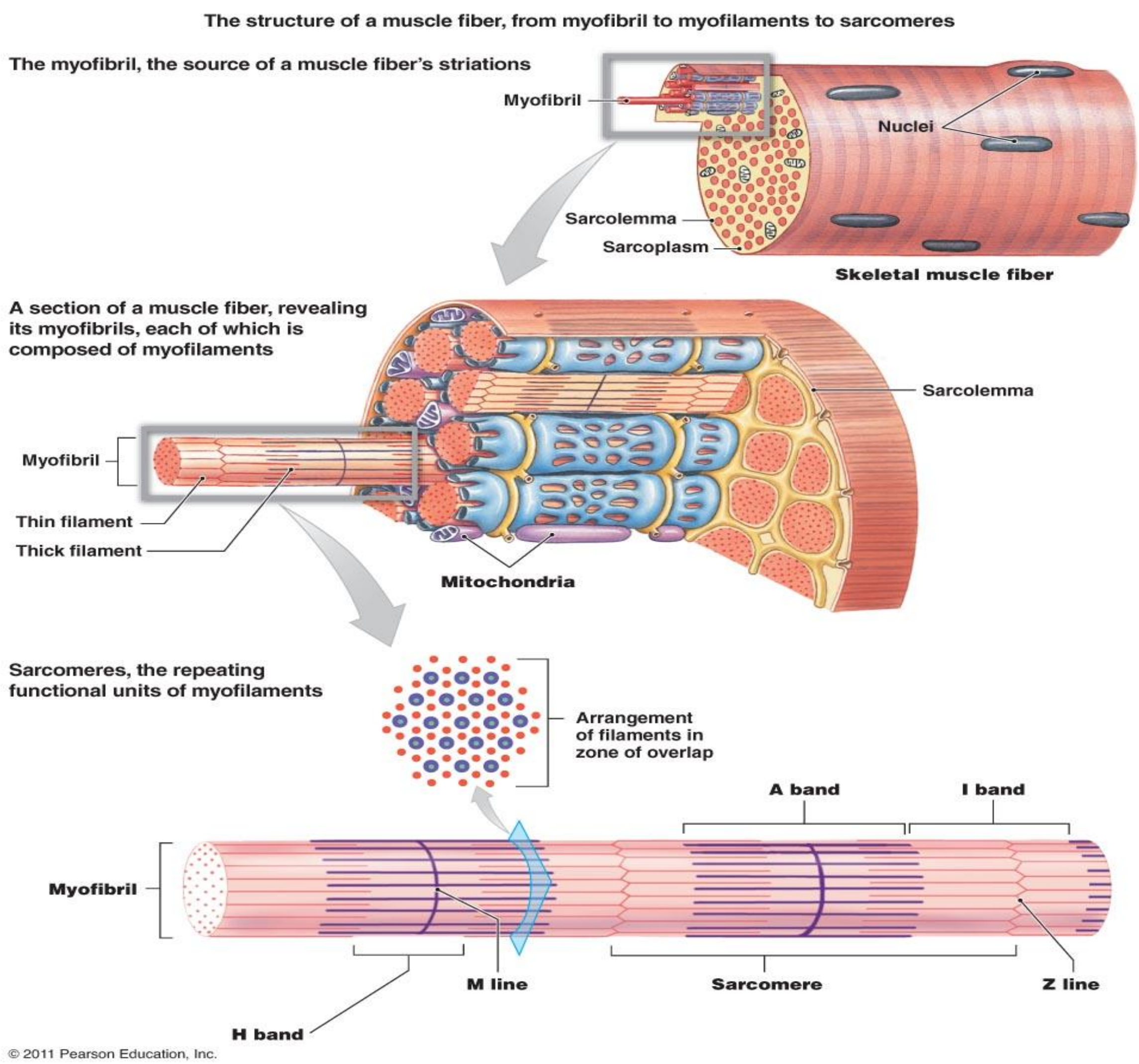


Fig.8. Stucture of Muscle fibre: from myofibril to myofilaments to sarcomere, (adapted from Volkers *et al*., 2013).

The muscle fibre is a large syncytial cell of variable width and length. Like other cells it is formed by protoplasm, the sarcoplasm which contain sarcrolemmal nuclei, and is limited by a cell membrane, the sarcolemma, as seen in figure 8. The myofibrils are cytoplasmic differentiation in relation to the contractile specialization of the cell. Accordingly, the sarcoplasm is the undifferentiated protoplasm in which myofibrils are embedded. It surrounds the sarcolemmal and end-plate nuclei and varies in amount from muscle to muscle. As a rule, muscle in constant activity like the ocular and respiratory muscles have the greatest amount of sarcoplasm, whereas muscles which contract quickly and fatigue readily contain the fewest (Licht, 1980).

The myofibril are the only contractile elements of the muscle fibre. Structurally they are oriented in a longitudinal direction, parallel to one another, and run the entire length of the fibre (fig.9).

The basic contractile unit of the skeletal muscle is the sarcomere (fig. 9).Sarcomere is defined as the structural and functional unit of a skeletal muscle. It gives skeletal and cardiac muscles their striated appearance. Each sarcomere extends between two ***'Z' line*** of myofibril. Thus, each myofibril contains many sarcomeres arranged in series throughout its length. When the muscle is in relaxed state, the average length of each sarcomere is 2 to 3 μ.

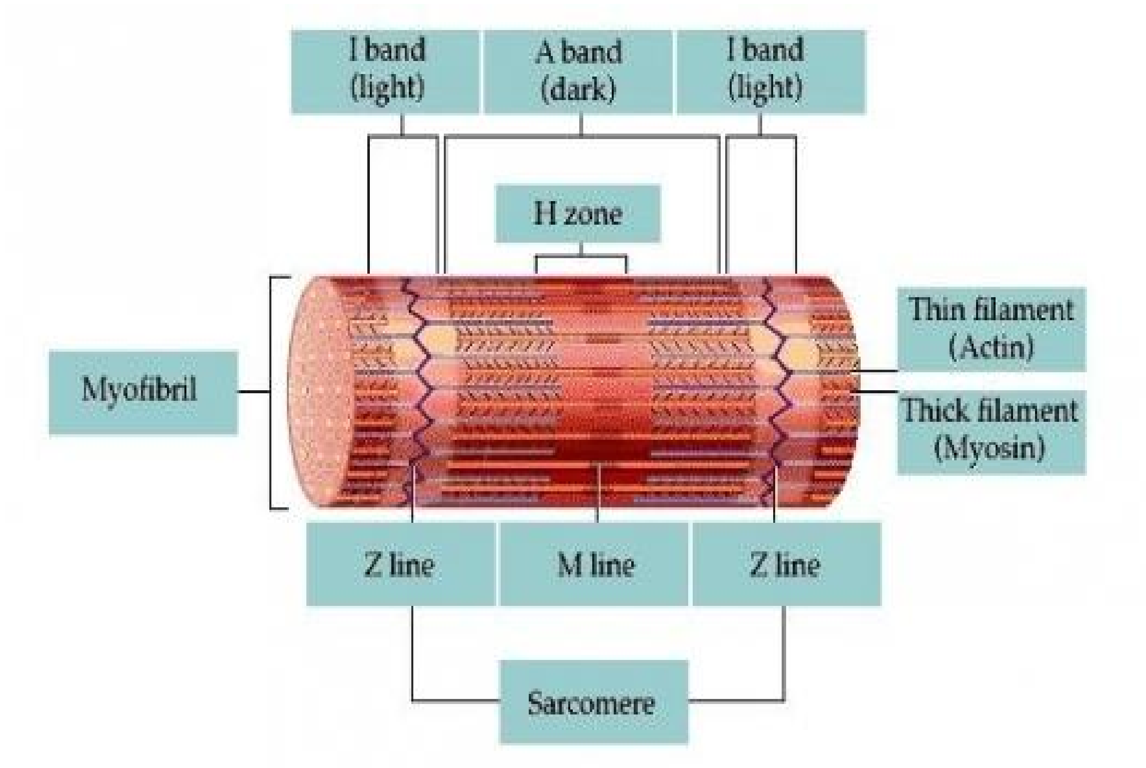


Fig. 9 Structure of the Sarcomere: Basic contractile unit of skeletal muscle It extends between two Z lines of the myofibril,(adapted from Volkers *et al*., 2013).

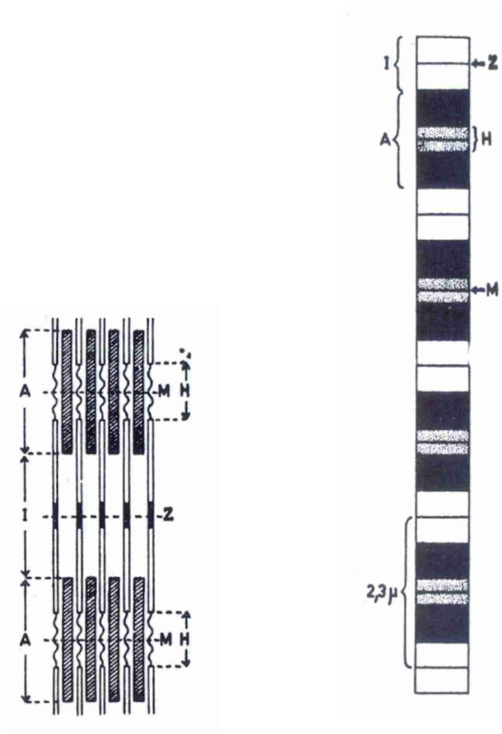
b  a

Fig. 10 Microscopic and ultramicroscopic structure of the myofibril

(a) Microscopic appearance of a myofibril in resting state.
(b) Schematic representation of the ultrastructure of a myofibril in longitudinal section.
Abbreviations: Z band; H zone; M, myosin; A, actin filaments(Adapted fromHanson and Huxley, 2005)

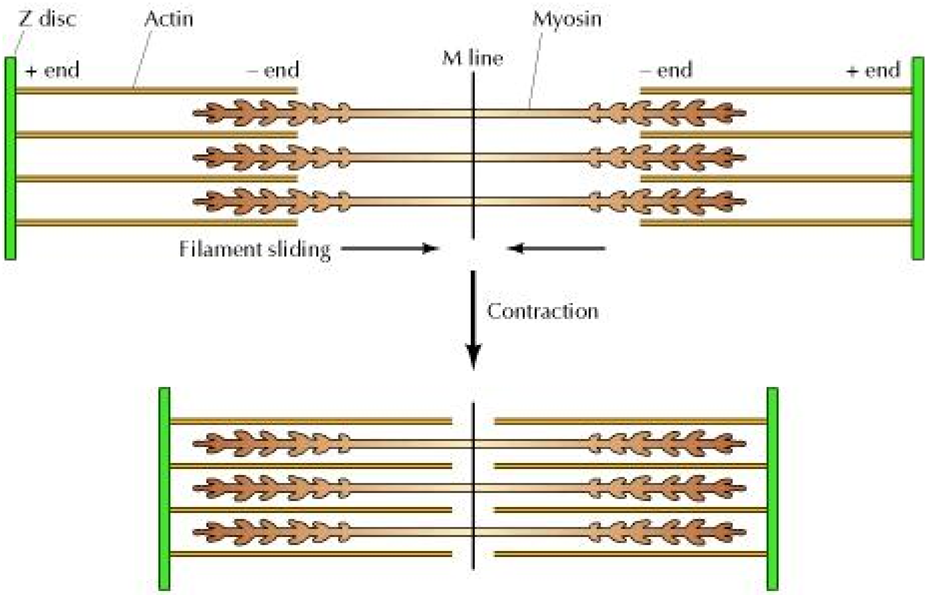
In transverse sections, the myofibrils tend to be grouped into bundles known as cohnheimôs fields. In longitudinal sections they have a periodic structure consisting of alternating bands of approximately equal length: dark óAô band (anisotropic), and light óIô band (Isotropic). These bands are not homogenous. Thus óAô contains in its mid part a clearer zone (H zone), in the middle of which may be found a dark line (M line). The óIô band is divided into two equal parts by the Z line, (fig.10 and 11). This line is probably a link between the myofibrils, whereas the other parts are independent. The dark band (óAô) of each myofibril in a single muscle fibre is normally opposite the dark band of all other fibrils. This arrangement is responsible for the cross-striation in the muscle. It is known that the contractile unit (sarcomere) is the portion of the myofibril included between two Z lines (fig.10)

Noteworthy is the fact that the óIô band is formed by actin filaments, inserted between filaments of myosin such that each is surrounded by six filaments of actin.

In a lateral view both actin and myosin filaments are seen to overlap the óAô band up to the level of óHô zone. Hanson and Huxley (2005) believe that they are linked together at the Z band and the H zone by a thin elastic thread.

During muscle exercise, actin and myosin filaments co-act so as to bring about contraction and relaxation. In passive muscle stretching, actin filaments slide along myosin molecules. During contraction, they slide in opposite direction and penetrate into the H zone, until they meet at the level of M, as shown in figure 11.

a



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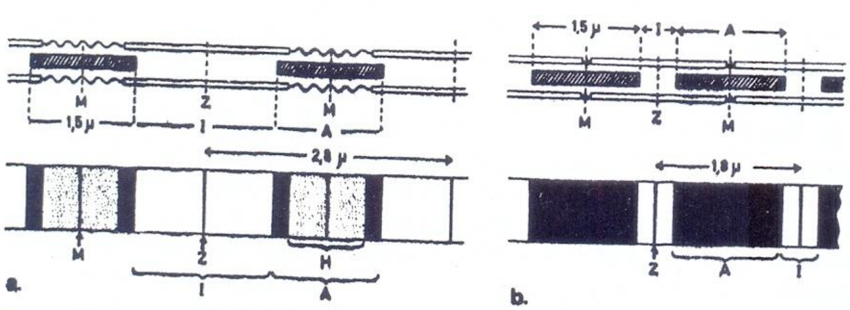


Fig 11. Structural changes in myofibrils
(a) During passive stretch, (b) During active contraction
(Adapted from Hanson and Huxley, 2005)

It is obvious that the contractile properties of the muscle fibre are activated by physical exercise. The rate and frequency of the response of each muscle group however, will depend on the nature and intrinsic behaviors of its neural innervations. Large diameter myelinated nerve fibres normally respond faster than the small diameter unmyelinated fibres.

Exercise therefore, potentiates muscle metabolism and by so doing increases tone, and facilitates muscle strength and endurance, since there exists cordial relationship between work load and muscle strength.

2.11Molecular Mechanism of Muscle Contraction

At the neuro-muscular junction, motor neuron releases a neurotransmitter acetylcholine (ACH) which in turn triggers off an action potential (AP). The action potential propagates across the sarcolemma and into the transverse tubules to initiate calcium ion (Ca^{2+}) release from the sarcoplasmic reticulum in the process known as excitationï contraction coupling. Ca^{2+} binding to regulatory proteins on the actin (thin) filament triggers the myosin (thick) crossï bridge cycle that produces muscle contraction (Fig.12).

In a resting muscle troponin I is tightly bound to the actin filament whereas tropomyosin covers the sites where myosin heads bind to actin. Therefore the troponin ï tropomyosin complex constitutes a órelaxing proteinô that inhibits the interaction between actin and myosin (Ganong, 1987). The immediate energy required for contraction is provided by adenosine triphosphate (ATP) which in muscle fibre is readily hydrolized to adenosine diphosphate (ADP), catalyzed by adenosine triphosphatase (ATPase).

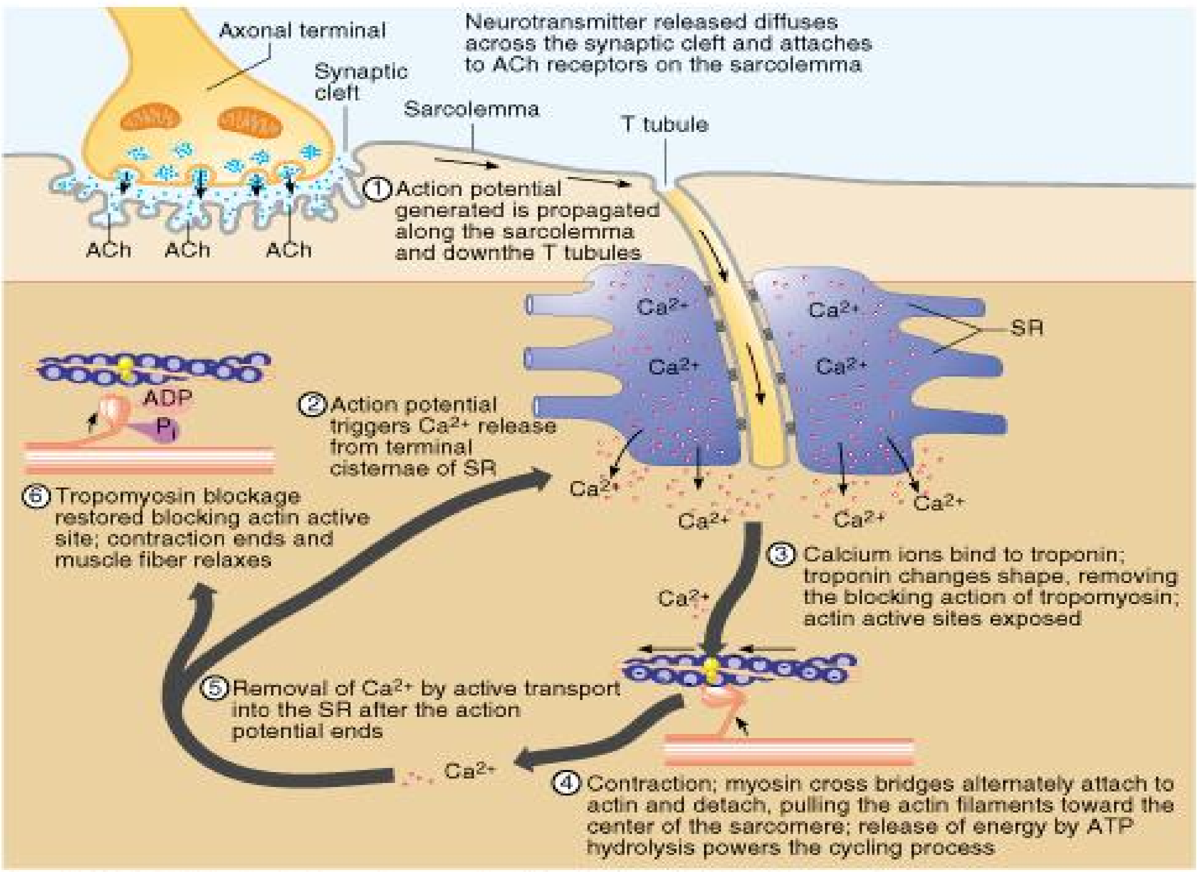


Fig. 12. Neuro-muscular junction (NMJ). Motor neurons release the neurotransmitter acetylcholine (Ach), which triggers an action potential. NMJ formation is also induced by motor neuron factors that signal muscle proteins,(adapted from Volkers *et al*., 2013).

When the Ca^{2+} released by the action potential (AP) binds to troponin C, the binding of troponin I to actin is presumably weakened, and this permits the tropomyosin to move laterally. This movement accordingly uncovers binding sites for the myosin heads, so that ATP is split and contraction occurs. Seven myosin binding sites are uncovered for each molecule of troponin that binds to calcium ion (Ganong, 1987).

ATP is generated both glycolytically and oxidatively in the muscle respectively from glucose and fatty acid. Muscle possesses intrinsic energyï sensing mechanism that permits adaptation of metabolic systems to changes in energy demand (Volkers et al., 2013)

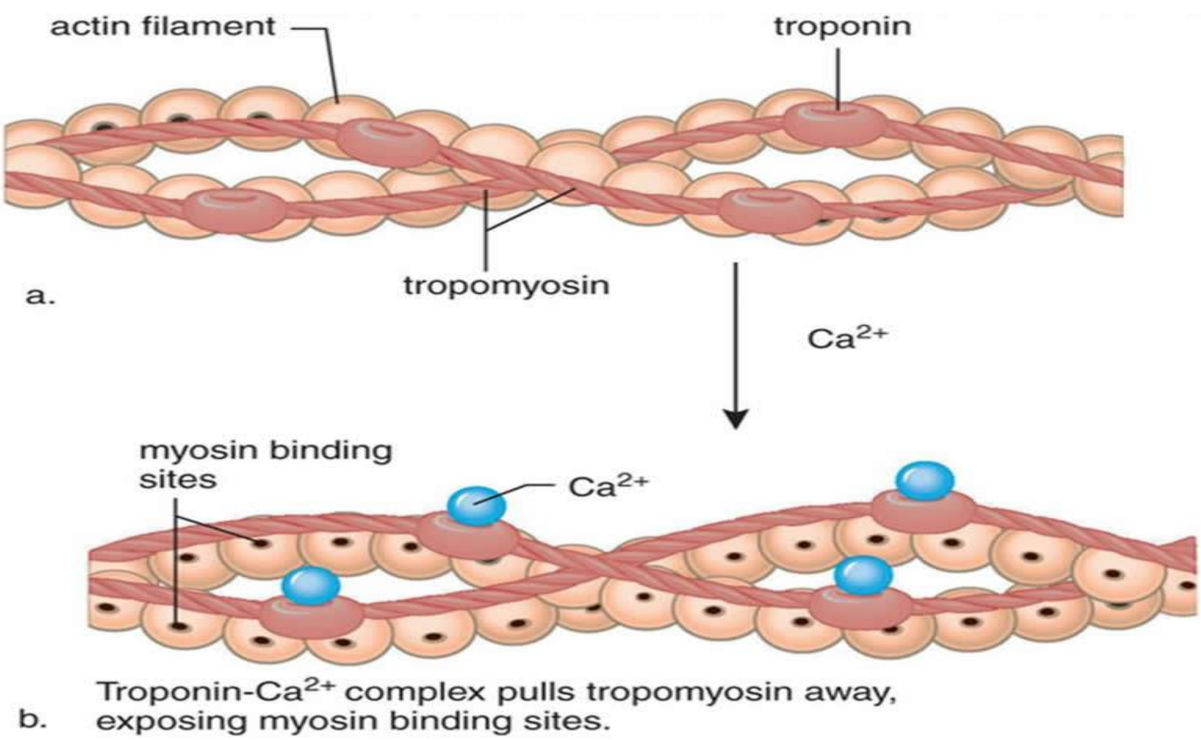


Fig. 13. Contraction Regulation by calcium ion, myosin and tropomyosin

- **a)** Resting position of actin and myosin filaments with troponin and tropomyosin covering their binding sites respectively.
- **b)** Troponin-Calcium ion complex pull away tropomyosin exposing myosin binding sites, enabling contraction by mutual sliding of the filaments

(Adapted from Volkers *et al*., 2013)

During muscle relaxation, calcium ion is pumped back into sarcoplasmic reticulum. Then Ca^{2+} is released from troponin C, and there is cessation of interaction between actin and myosin (fig. 13).

2.12Contraindications to Exercise

The aforementioned recommendations are intended for women who do not have any additional risk factors for adverse maternal or perinatal outcome. A number of medical or obstetric conditions may lead the obstetrician to recommend modifications of these principles. According to Artal and O'Toole, 2003, the following conditions should be considered contraindications to exercise during pregnancy:

i. Pregnancy-induced hypertension
ii. Preterm rupture of membranes
iii. Preterm labor during previous or current pregnancy or both
iv. Incompetent cervix/cerclage
v. Persistent second- or third-trimester bleeding
vi. Intrauterine growth retardation

In addition, women with certain other medical or obstetric conditions, including chronic hypertension or active thyroid, cardiac, vascular, or pulmonary disease, should be evaluated carefully in order to determine whether an exercise program is appropriate.

2.13 Exercise in the Postpartum Period

Many of the physiological and morphological changes of pregnancy persist for four to six weeks postpartum. Thus, exercise routines may be resumed only gradually after pregnancy and should be individualized. Physical activity can thus be resumed as soon as physically and medically safe. This will certainly vary from one woman to another, with some being capable of engaging in an exercise routine within days of delivery. There are no published studies to indicate that, in the absence of medical complications, rapid resumption of activities will result in adverse effects. Undoubtedly, having undergone detraining, resumption of activities should be gradual.

No known maternal complications are associated with resumption of training,Artal and O'Toole, 2003). Moderate weight reduction while nursing is safe and does not compromise neonatal weight gain,**(**ACOG, 2002)**.** Failure to gain weight is associated with decreased milk production, which may be secondary to inadequate fluid or nutritional intake to balance training induced outputs (Berk, 2004). Nursing women should consider feeding their infants before exercising in order to avoid the discomfort of engorged breasts. In addition, nursing before exercise avoids the potential problems associated with increased acidity of milk secondary to any buildup of lactic acid. Moreover, a return to physical activity after pregnancy has been associated with decreased postpartum depression, but only if the exercise is stress relieving and not stress provoking.

On the influence of exercises, abdominal exercises or more specific type of abdominal exercises (Isometric versus Isotonic) or combination of abdominal exercise on abdominal retraction following child delivery, there is no documented evidence. Research has shown that after child birth and within 6 week the abdominal visceral return to their or near to their pregestational state hence the abdominal muscle retraction, (Davies*etal.,* 2003). However, this is not complete and the abdomen continues to return and for some women the pregestational abdominal shape and circumference may not be returned. Because strengthening muscle work using isometric exercise is known to increase muscle tension and strength, these exercises have potential of influencing abdominal retraction or rate of retraction. These however need to be established in a randomized controlled trial.

2.14Effects of isotonic contraction of the abdominal muscles in postpartum

Importantly, the energy demand of the muscle during shortening (isotonic) contractions is higher than during isometric contractions (Potma and Stienen, 1996). However the energy expenditure causes firmer approximation of muscle fibres such that toning is grossly effected as a necessary end-product.

2.15Effects of isometric contraction of the abdominal muscles in postpartum

Search for literature on effect of isometric abdominal muscle contraction on postparturm abdominal muscle retraction rate yielded no result. However findings on the effect of postpaturm isometric exercises on some abdominal characteristics are available. For example, Pascoal *et al.,* (2014) determined the effect of isometric contraction of the abdominal muscles on inter-rectus distance in postpartum women in case control study of ten postpartum women {mean age 30,mean weight 58 (SD 7) kg; mean height 159 (SD 4) cm} and 10 nulliparous (control) women [mean age 28 (SD 2) years; mean weight 56 (SD 6) kg; mean height 160 (SD 6) cm] using ultrasound images recorded at rest (supine position) and during an abdominal isometric contraction, with the subject actively performing an abdominal crunch (crook lying position) from the anterior abdominal wall. Two-way analysis of variance was used to compare the inter-rectus distance between groups (postpartum vs control) and between levels of abdominal muscle activation (rest vs isometric contraction). The results showed that inter-rectus distance was significantly greater in the postpartum group compared with the control group [14.7 (SD 3.1) mm vs 9.6 (SD 2.8) mm; mean difference 5.1mm; 95% confidence interval (CI) 3.4 to 6.8). The inter-rectus distance was significantly lower during isometric contraction compared with rest (10.7 (SD 3.1) mm vs 13.4 (SD 3.1) mm; mean difference 2.8mm; 95% CI 1.2 to 4.5). No interaction was found between group and muscle contraction. They therefore concluded that inter-rectus distance was significantly higher in postpartum women compared with controls, and significantly lower during isometric contraction of the abdominal muscles (abdominal crunch) compared with rest.

2.16 Combining Isotonic and Isometric muscle work against doing each alone

There is no research that has considered the effects of combined Isotonic and Isometric postpartum abdominal muscle works versus either isometric or isotonic alone.

Research concerning the effects of combined isometric-isotonic training on various aspects of physical fitness is limited. Training with equipment designed to utilize both isometric and isotonic contractions has shown improvement in baseball velocity (Logan, 1966), body conditioning (Lewis, 1966), strength of professional football players (Friedman 1966, 16), pull-ups and dips (Alexander 1968), shot-put performance (Antone 1965), and certain physical fitness components (Retamess, 2012). Henriksen (1965) reported that a group training with both isometric and isotonic dead lifts recorded significant improvement in two static positions of the deadlift, but overall was not a significantly better training programme than isometric or isotonic programmes.

It has been reported (Vøllestad *et al.*, 1997) that muscular endurance is improved at approximately the same rate by both isometric and isotonic exercise programmes. "Push-ups" (or "press-ups") have been recognised as a suitable measure of muscular endurance (Clarke, 1959; Cureton 1945; Knowlton, 1957; Rallis, 1965). According to Cureton's validity and factor analysis of 28 muscular endurance items (Cureton 1945), the floor push-up ranked third as a predictor of all-round muscular endurance, with the mile run and chinning ranked first and second, respectively. Push-up performance has been improved by general endurance work (Knowlton, 1957), isometrics, weight-training, and regular physical education activities (Rallis, 1965), but no research has been reported which shows the effects of combined isometric-isotonic exercises upon push-up performance.

2.17Functional Physiological Consideration of the Action of Myogenic Satellite Cells

The human adult skeletal muscles need to adapt to various physical and pathological challenges available in their functional existence. Myogenic satellite cells are believed to play significant role in the repair of damaged muscles. By implication therefore, it may be largely responsible for the reduction of inter-recti distance (IRD) in recti diastasis condition in postpartum women. For skeletal muscle to function properly, coordinationamong multiple biological networks is required. Each network has critical components responsible for its function (Smith *et al*.,2013).The processes by which these adaptations

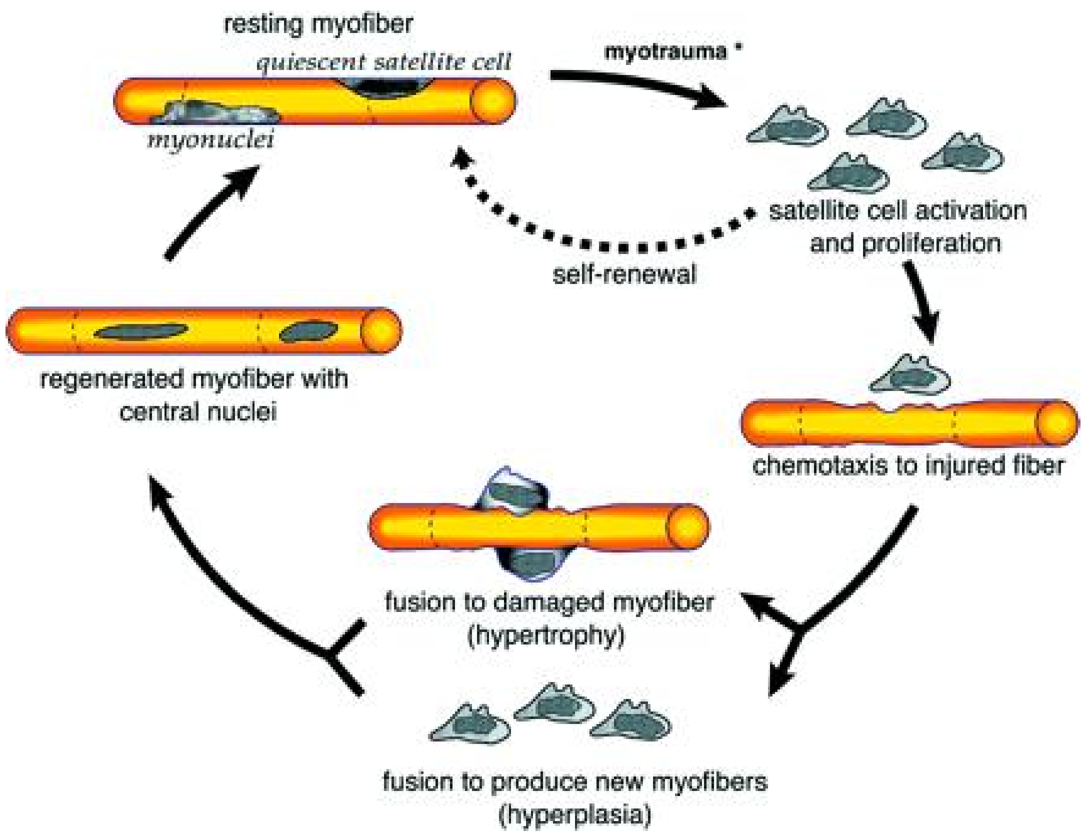


Fig. 14. Regenerative action of myogenic satellite cells, (adapted from Hawkeand Garry, 2001)

occur are largely attributed to a small population of cells that are resident in adult skeletal muscle and are referred to as satellite cells (Tatsumi*et al*., 1998). These cells were first identified in 1961 by Katz. Mauro (1961) alsodescribed a cell closely associated with the periphery of the frog myofiber and termed it a satellite cell based on its location. Quiescent satellite cells are physically distinct from the adult myofiber as they reside in indentations between the sarcolemma and the basal lamina (Muir*et al*., 1965). Adult skeletal muscle fibers are terminally differentiated such that muscle growth and regeneration are accomplished by satellite cells. As indicated in figure 14, in the unperturbed state, these cells remain in a nonproliferative, quiescent state. However, in response to stimuli such as myotrauma, satellite cells become activated, proliferate, and express myogenic markers (satellite cells expressing myogenic markers are also termed myoblasts). Ultimately, these cells fuse to existing muscle fibers or fuse together to form new myofibers during regeneration of damaged skeletal muscle (Bischoff, 1997; Schulz and McCormick, 1994). The satellite cells are therefore regarded as being regenerative in nature, and as such are mainly responsible for the growth, remodeling and repair of damaged skeletal muscles.

Consequently, several authorities (Lemischka, 1999; Megeney *et al*., 1996; Ordahl, 1999; Seale and Rudnicki, 2000; Seale *et al*., 2000) have proposed new paradigm regarding the regenerative capacity and plasticity of the myogenic satellite cell population. These paradigms suggest that the satellite cell population not only has a remarkable capacity for muscle regeneration but may also contribute to alternative muscle and non-muscle lineages and may have clinical applications in the treatment of devastating and deadly diseases such as muscular dystrophy.

In line with this understanding it may be inferred that these cells may have important role to play in the toning and strengthening of the abdominal muscles, mediated by exercises. This idea may lay credence to the fact that stretching of abdominal muscles during pregnancy may potent some level of microtrauma to the abdominal wall, which consequently presents the need for abdominal exercises. The quantity of cells generated by different exercise regimen, and the volume required and the process involved in effecting significant toning are therefore subjects for further research.

2.18Origin and Identification of Myogenic Satellite Cells

Myogenic Satellite Cells have both somitic and nonsomitic origin. Earlier studies support the hypothesis that muscle precursor cells, including the myogenic satellite cell population, originate from the multipotential mesodermal cells of the somite (Fischel, 1995; Ordahl *etal*., 2000; Schultz and McCormick, 1994). The support for this hypothesis is primarily derived from chimeric or interspecies grafting experiments that have been performed in avian models. These studies involved the transplantation (or exchange) of embryonic somites from donor quail embryos into host chick embryos (Christ *et al.*, 1974; Le Douarin and Barq, 1969). The transplanted quail cells have distinguishing morphological characteristics and were observed to migrate from the somite and contribute to both the limb muscles and the satellite cell population in postnatal chick skeletal muscle. Satellite cells have been isolated from the fetal skeletal muscle from an

E15 or older mouse embryo, suggesting that satellite cells populate the developing limb during the latter stages of embryogenesis (Cornelison and Wold, 1997; Cossu, 1997; Cossu and Mavilio, 2000). Whether the satellite cells migrate from the somite as a distinct lineage or whether they originate from a preexisting lineage (i.e., embryonic or fetal myoblasts) in the developing limb is unclear. Nevertheless, the underlying concept was that each of the myoblast precursor cells (i.e., embryonic myoblasts, fetal myoblasts, and satellite cells) was a derivative of the somite.

This postulation has however been challenged by recent studies. In their different studies, De Angelis *et al*., (1999) and Ordahl, (1999)have suggested that multipotential cells of nonsomitic origin may be the precursors of the satellite cell. De Angelis *et al*., (1999) reported that cells isolated from the embryonic dorsal aorta had a similar morphological appearance and a similar profile of gene expression to that of satellite cells. Furthermore, transplantation of the aorta-derived myogenic cells into newborn mice revealed that this cell population participated in postnatal muscle growth, regeneration, and fusion with resident satellite cells. The authors proposed that satellite cells may be derived from endothelial cells or a precursor common to both the satellite cell and the endothelial cell.

Resident within adult skeletal muscle is a pool of undifferentiated mononuclear cells termed satellite cells because of their anatomic location at the periphery of the mature, multinucleated myotube. The defining characteristic of the satellite cell is that the basal lamina that surrounds the satellite cell and the associated myofiber is continuous (Schultz and McCormick, 1994). The identification of this cell population has historically utilized ultrastructural techniques (Gibsonand Schultz,1983;SchmalbruchandHellhammer1977*)*.Other distinguishing morphological features of the satellite cell population include a relatively high nuclear-to-cytoplasmic ratio with few organelles, a smaller nuclear size compared with the adjacent nucleus of the myotube, and an increase in the amount of nuclear heterochromatin compared with that of the myonucleus (Schultz and McCormick, 1994). These morphological features are consistent with the finding that satellite cells are relatively quiescent and transcriptionally less active. These distinguishing features are absent following activation or proliferation of the satellite cells in response to growth, remodeling, or muscle injury. After activation, the satellite cells are more easily identified as they appear as a swelling on the myofiber with cytoplasmic processes that extend from one or both poles of the cell(Schultz and McCormick, 1994). Associated with the increase in mitotic activity, there is a reduction in heterochromatin, an increase in cytoplasmic-to-nuclear ratio, and an increase in the number of intracellular organelles (Schultz and McCormick, 1994).

2.19Closure of Recti Diastasis as an indicator for the presence of Myogenic Satellite Cells

Satellite cells, resident in myogenic stem cells foundbetween the basement membrane and the sarco-lemma in postnatal skeletal muscle (Mauro 1961), arenormally quiescent most of the time in adult skeletalmuscles. When muscle is injured, overused ormechanically stretched, these cells are activated toenter the cell cycle, divide, differentiate and fuse withmuscle fibers to repair damaged regions and toenhance hypertrophy of muscle fibers (Koishiet al, 1995; Marotoet al, 1997; Bischoff 1997).It has been well known that there are variations inpostnatal muscle growth and regeneration patternsamong skeletal muscles as well as animal breeds orstrains, and it could be related to differences in theability of their satellite cells to proliferate and/or differentiate(Mauro, 1961).

The closure of inter-recti distance in postpartum women may be viewed as a sign that myogenic satellite cells are produced during programmed abdominal exercises. Isometric abdominal contraction is thought to be efficacious in the reduction of inter-recti space. Isometric contraction is also believed to mobilize myogenic satellite cells necessary to bring about reduction in the inter-rectus distance in postpartum women (Paschal et al., 2014). It is common knowledge that stretching of the abdominal muscles during pregnancy represents a form of micro trauma. As such in postpartum stretched muscle fibres cause elongation and separation between the two recti abdominis muscles. This condition termed recti diastasis or divarification will almost certainly be apparent in any woman who was at term prior to labour (Mantle *et al*., 2004).

Recti diastasis can vary between a small vertical gap 2 ï 3cm wide and 12 ï 15cm long, to a space measuring 12 ï 20cm in width and extending nearly the whole length of the recti muscle (Mantle *et al*, 2004). As a result, the entire abdominal ócorsetô will be weakened with very little apparent mechanical control. Those whose pregnancies necessitated prolonged inactivity, or those who habitually take very little exercise, are mostly at risk of having very weak abdominal muscles. The combination of reduced mechanical control and increased elasticity of ligaments will render the back much more susceptible to injury. Those most at risk of developing a gross divarification are women with narrow pelvis, those who carried large babies, who had multiple birth, and multiparous women (Mantle et al., 2004).

2.20Clinical Response of Satellite Cells during Exercises

Exercise-induced muscle stretch initiates an immune response, resulting in the influx of macrophages into the damaged region. After the acute insult, macrophage infiltration peaks within 48 h (Vierck*et al*., 2000). Initially, the role of these blood-borne macrophages was believed to be limited to phagocytosis and the digestion of myonecrotic fibers. However, additional roles for macrophages during the early stages of muscle repair are emerging. Macrophages are essential in the orchestration of the repair process as they secrete a collection of cytokine factors that regulate the satellite cell pool (Nathan, 1987*)*. Importantly, in the absence of a macrophage response, muscle regeneration is absent; in the presence of an enhanced macrophage response, there is an increase in satellite cell proliferation and differentiation (Lescaudron *et al*.,1999).

In response to resistance training, muscle stretch results in the release of growth factors that will, in part, regulate the satellite cell population during regeneration. For example, immune factors such as macrophages and neutrophilsare upregulated in response to hypertrophic signals in skeletal muscle and promotes proliferation and fusion of the satellite cell pool (Adams*et al*., 1999;Chakravarthy*et al*., 2000; (Vierck*et al*., 2000). Growth factors and/or cytokines may play a role in the signaling or commissioning of the satellite cells to participate in the hypertrophic remodeling response. Although a number of questions remain regarding the role of the satellite cell in muscle remodeling, the primary physiological consequence of the hypertrophic response is to produce a muscle with a greater capacity for peak force generation (Hawke and Garry, 2001).

Atrophy of skeletal muscle results in a reduction in myonuclei number and can be induced by numerous factors including denervation, hindlimb suspension, and malnutrition (Grounds, 1999). Atrophy and remodeling that result from muscle disuse can be produced in laboratory rodents physiologically by tail/hindlimb suspension or immobilization of specific muscle groups in plaster casts or pathologically through denervation. The response of the satellite cells appears to be pleiotropic and dependent on the atrophic stimulus (Hawke and Garry, 2001).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Design

The study was a single blinded randomized control trial. A batch of sixty postpartum women (Ó4 weeks and < 8 weeks postpartum) were randomly allocated into four groups ï Group A received isometric exercise, group B isotonic exercise, group C mixed (both isotonic and isometric) exercises and group D received no abdominal exercises for six weeks. Another batch of thirty women of between four and eight weeks postpartum were randomly assigned into two groups. Group A (23 experimental participants) who served as their own control, and 8 of whom compared with a control group B received isometric exercise for four weeks.Group B (7 control participants) received no abdominal exercises for the same period of four weeks.The allocations were concealed such that assessor was blinded with respect to the treatment each group was receiving.

3.2 Participants

The women who participated in the research had healthy pregnancies and vaginal deliveries. Both the experimental and control participants were recruited from the Obstetrics and Gynecology clinic of Federal Teaching Hospital Abakaliki. Only women who were able to perform the abdominal crunch exercise were eligible for inclusion in the studies. Before participation, the researcher gave the subjects all the relevant research information (e.g. risks and benefits), orally and in written form, allowing them to make an informed decision about participation.

3.3 Inclusion Criteria

The following subjects were included in the study:

i. Subjects who have no history of caesarean section delivery.

ii. Subjects who have gone through a minimum of onepregnancy.

iii. No history of prolonged maternal illness

iv. Subjects who were not hypertensive.

v. women who were able to perform the abdominal crunch exercise.

vi. Women who had recti diastasis of at least 2.5cm wide (for IRD study only)

3.4 Exclusion Criteria

i. Subjects with diastases of rectus abdominis muscles, of more than two finger-breadths apart. (for muscle retraction study only)

ii. Subjects delivered through caesarean section.

iii. Subjects with postnatal uterine prolapse.

iv. Women with fresh surgery on the abdominal or thoracic region.

3.5 Ethical Issues

The studies were approved by the Ethics and Institution Review Committee of Federal Teaching Hospital Abakaliki. Only women who signed informed consent forms were included in the study.

3.6 Sample size calculation

According to Brookes et al., (2001), trials have the same power to detect a treatment effect that is half the size of the interaction effect. Therefore, to calculate the minimum sample size needed for the trial, the standard deviation (SD) estimates was adopted with a two-sided two-sample t-test, alpha level at 0.05, power of 0.80, possible loss of follow-up 10% and 5% expected treatment non-compliance. Sample size of 60(15 in each group) and 15 (8 in group A and 7 in group B) participants will allow detection of interaction size effect of 1.0SD and a treatment main effect of 0.5SD on the primary outcome measures of abdominal retraction and retraction rate, and IRD reduction respectively.

3.7 Procedures

Informed consent was obtained from each of the subjects prior to investigation. Sixty subjects in part one of this study were grouped into four of 15 participants each: Isotonic group(A), Isometric group(B),combined group (C) and Control group (D), prior to the assignment of therapeutic exercises.

In the second part of this work, thirty multiparous postpartum women with age range 29 ï 44 years, and mean age 36.7± 2.76 yearswho participated in the study were randomly assigned into two groups, group A(isometric) 23 in number, and group B(control) 7 in number. The 23 women in the experimental (isometric) group A also served as their own control while 8 of them compared with the control group. Initial IRD were measured for all participants using 7.5-MHz Linear diagnostic ultrasound transducer, model: NeuSonic Pi by NewTech Medical. Group A subjects were then placed on isometric abdominal muscle contraction, two sessions daily (morning and evening) at 30 minutes per session in three batches of 10minutes each, with 2minutes resting period between each batch for a period of four weeks. Weekly IRD for each subject in the group were measured and noted. The group B subjects were not given any abdominal exercises but were placed on routine 30 minutes morning jog for the same period of four weeks, with weekly IRD measurements.The avoidance of abdominal exercise in group B subjects was necessary so as to check for any possible spontaneous IRD resolution.

3.7.1 Inter-recti Distance Measurement Protocol

Each subject was asked to lie supine in a crook-lying position (knees bent, feet flat on the couch) with her arms at her side. The measurement sites on the abdomen were marked with a water-soluble pen at the superior and inferior borders of the umbilicus, 2.5 cm above the superior border of the umbilicus, and 2.5 cm below the inferior border of the umbilicus. These landmarks on the abdominal wall were regarded as typical locations for prevalent occurrence of DRA (Rett*et al*., 2009;Boissonnault and Blaschak, 1988). Next, the woman was asked to perform a modified curl-up. The examiner demonstrated one curl-up for the subject to show how high the curl-up should be (scapula about 10degrees off the couch, back supported with pillows). Ultrasound imaging transducer was then placed perpendicular to the linea alba on the marked points (2.5cm above and

2.5cmbelow the umbilicus) as proposed by Chiarello and McAuley, 2013 and measurement values recorded.

The transducer frequency of 7.5 MHz was chosen as it is considered appropriate in superficial and linear measurement of IRD both in females and males (Mendes*et al*., 2007)The sonographer was a specialist clinical radiographer and radiological scientist with sixteen years practical experience.

3.8 Therapeutic Exercise Regimes

A) Isotonic Group

Group A participants were placed on the following exercise therapy sessions according to laid down prescriptions (Thomson *et. al*., 1991; Downie, 1993; Brayshaw and Wright, 1994).

i. Supine lying, back flattened, curl-up and held to a count of 4, and slowly down followed by rest for about 10 seconds; repeat 30 times- progress to holding for a count of10, (see Plate 3).

ii. Crook lying, back flattened on the couch, head and shoulders lifted and turn left and right, and slowly back-repeat 30 times, (see Plates 5 and 6).

iii. Crook lying, tighten abdominal muscles, lift head and shoulders and lower slowly (this may be done with 3 pillows on one another under the head to start. These pillows are removed one at a time as the muscles become stronger). Repeat 30 times (see Plate 4)

iv. Sitting, trunk bending side by side. Repeat 20 times on each side.

These four exercise regimes were done twice daily ï morning and night, for a period of six consecutive weeks.

B) Isometric Group and IRD Group A

Subjects here were made to undertake static muscle (isometric) exercises as follows:

i. Supine lying- trunk raised to about 45 degrees from the couch and held to a slow count of 10, repeated to 10 times, with 30 seconds rest between each set, (see Plate 7).

ii. Progress to 20 counts in the same position.

iii. Crook lying- Both arms reaching for the knees and held for 15 slow counts, repeat 20 times, with in-between resting period of 45 seconds (Plate 8).

iv. Progress to 30 counts in the same position.

These exercise regimes were done twice daily ï morning and night, for a period of six andfour consecutive weeks, respectively for isometric and IRD (A) groups.

C) Combined Group

Subjects in group C were required to perform the combination of the therapeutic exercises in both groups A and B, with a 10minutes resting period between the two group exercises.

The combined exercise regimes were done twise daily ï morning and evening for the same period of six weeks.

D) Control Group and IRD Control Group B

Subjects in these groups were not subjected to any abdominal muscle exercise.

They were given palliative routine ankle dorsiflexion/plantaflexion exercisesin sitting position as well as mild jogging. However their abdominal circumferences and IRD performances were monitored at similar intervals as the other groups to check for possible intrinsic retraction, and spontaneous recovery of DRA.

In all cases in part one study, initial abdominal circumference in relaxed supine lying was measured (tip of the umblicus as the landmark) (Plates 1 and 9), with a portable electronic mayotape device and noted. Then each subject was asked to tighten (tense; pull-in) the abdominal muscles maximally while measurement was taken and noted (Plates 2 and 10). Weekly measurements for each subject in relaxed mode only, were noted for six consecutive weeks.Also noted were the ages of each subject, and number of pregnancies prior to study.

3.9 Measurement Instruments

1. Myotape Device

Retraction value (abdominal girth) measurements were done via a portable electronic myotape device model white BTM152 designed by Topend Sports. TheMyotape body measurement device is especially suitable for the assessment of girth or circumference measurements of any body part, including the arm, thigh, calf, chest, abdomen waist, and hips.This device is made of long lasting vinyl tape with lightweight white plastic body.

Ithas a push-button retraction and locking feature which ensures snug and accurate measurement, both in centimetres and inches (see plate 11).

2. Ultrasound Imaging machine (USI)

The ultrasound imaging (USI) unitwas used to measure the gap between the two rectus abdominis muscles (IRD) created by recti diastasis at the linear alba. This instrument has been validated. The inter-rater validation by several authorities (Bursch, (1987), Boxer, (1997),Liaw et al., (2011), Mota et al., (2012).Mendes et al., (2007) presents the instrument as a reliable source of measuring IRD with minimal error. The inter-rater reliability compared to caliper method is 0.79 - 0.71(Chiarello and McAuley 2013). The USI unit used in this study was 7.5-MHz Linear diagnostic ultrasound transducer, model: NeuSonic Pi by NewTech Medical. All measurement were in centimetres.

Plate 1
Subject with relaxed abdominal muscles
Position used for baseline abdominal girth measurement (relaxed mode).

Plate 2
Subject with actively contracted abdominal muscles
Position used for baseline abdominal girth measurement (tensed mode).

Plate 3
Curl-up exercise in supine lying for group A subjects
Isotonic abdominal exercise in supine lying, used for experimental group A in the abdominal retraction study (arrow indicates back and forth movement of the trunk).

Plate 4
Curl-up exercise in crook lying for group A subjects

Isotonic abdominal exercise in crook lying, used for experimental group A in the abdominal retraction study (arrow indicates back and forth movement of the trunk).

Plate 5
Group A subject lifts head and shoulders, and looks to the left

Isometric abdominal exercise in crook lying, used as accessory exercise for experimental group A in the diastasis recti abdominis study

Plate 6
Group A subject lifts head and shoulders, and looks to the right

Isometric abdominal exercise in crook lying, used as accessory exercise for experimental group A in the diastasis recti abdominis study

Plate 7
Group B subject raises trunk to about 45 degrees from the couch and held to a slow count of 10. This progresses with time to a count of 20.

Isometric abdominal exercise in supine lying, used for experimental group B in both abdominal retraction anddiastasis recti abdominis studies (pillows are removed one after the other as exercise progresses).

Plate 8
Group B subject in crook lying, both arms reach out for the knees and held for a slow count of 15.
This progresses with time to a slow count of 30.

Isometric abdominal exercise in crook lying, used for experimental group B in both abdominal retraction and diastasis recti abdominis studies (pillows are completely removed in this case).

Plate 9
Measurement of abdominal girth of subjects in a relaxed mood using portable electronic myotape device, for all groups.

Mean weekly results obtained in this process from both experimental and control groups in the abdominal retraction study (in relaxed state) are compared.

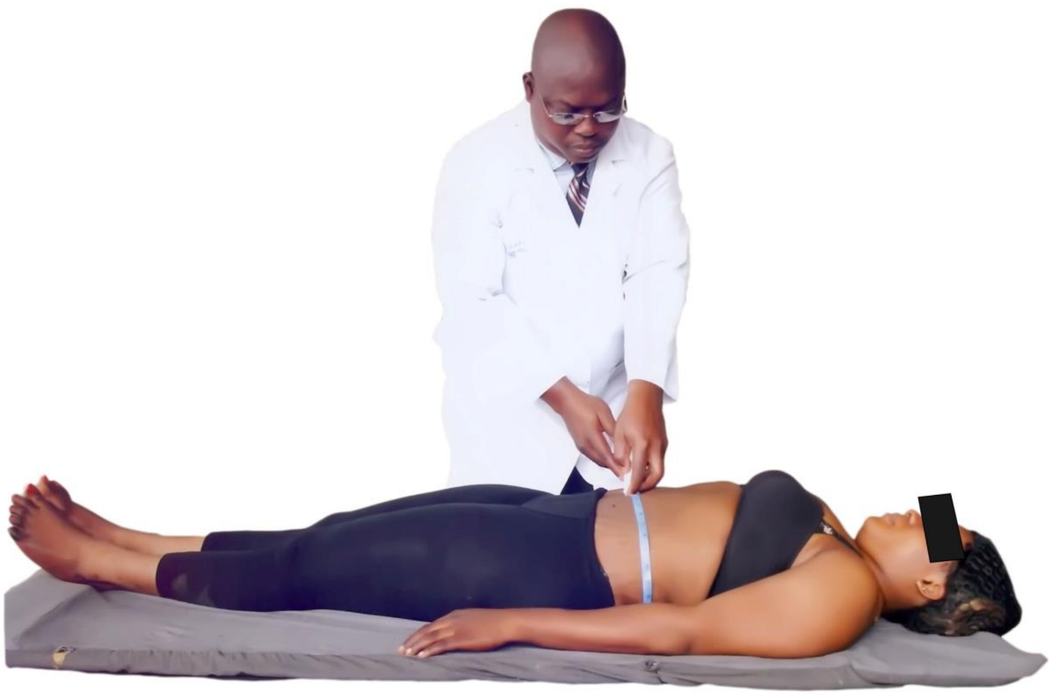


Plate 10
Measurement of abdominal girth of subjects in a tensed mood using portable electronic myotape device, for all groups.

Mean weekly results obtained in this process from both experimental and control groups in the abdominal retraction study (in tensed state) are compared.

Plate 11
A Myotape device, model white BTM152, designed by Topend Sports, used in the measurement of abdominal girth of subjects.

Plate 12

Ultrasound Imaging Unit (USI)**,**model: NeuSonic Pi with7.5-MHz Linear diagnostic transducer, by NewTech Medical.Instrument used in inter-recti distance (IRD) measurement.

A

B C

Plate 13

A) Placement of ultrasound imaging transducer on the subjectôs abdomen for the measurement of inter-recti distance: perpendicular on 2.5cm above the superior border of the umbilicus. Same was also done 2.5cm below the inferior border of the umbilicus.

B) Sample of sonographic image obtained 2.5 cm superior to the umbilicus.

C) Sample of sonographic image obtained 2.5 cm inferior to the umbilicus.

3.10 Duration of Study

This research was conducted between April, 2013 and January, 2014

3.11 Data Collection

3.11.1 Postpartum Abdominal Muscle Retraction

In the study, data were obtained through primary source. Individual initial and weekly measurement values of the abdominal circumference were recorded. In each subject a critical point at which the abdominal muscles achieve a half value of the difference between the initial relaxed and tensed abdominal circumference values were noted. Comparative data from within and between groups were noted.

Three Physiotherapy Research Assistants were involved to follow up the subjects in order to ensure that subjects maintained regular and correct exercise protocols. These physiotherapists were wellacquainted with thevarious group exercises prior to follow up. They also participated in data collection.

3.11.2 Postpartum Inter-Recti Distance Recovery

In this case, data were also obtained through primary source. Individual initial and weekly ultrasonography measurement values of the abdominal inter-recti distance obtained in relaxed crook lying from the 15 subjects were recorded. All measurements were done 2.5cm above and below the umbilical ring.

A Sonographer was employed in the study to assist in taking all measurements using a set of diagnostic ultrasound.

3.12 Data Analysis

Independent t test was utilized to draw comparison of baseline means of all four groups for all variables. Other comparisons were performed as Intent-to-Treat analyses. A Group by Time ANOVA with repeated measure on Time factor compared means of retraction scores. The Time simple effect within each group with Bonferroni Multiple-Comparison Test was made,andused for comparisons among the means at each time. All analyses and imputation procedures were done using SPSS software version 15. Statistical significance was set at $p < 0.05$ at 95% confidence interval. The obtained data were analyzed using the analysis of variance (ANOVA)

For the IRD, a 2-way mixed ANOVA was utilized to draw comparison of the mean value differencies both within and and between groups.All analyses and imputation procedures were done using SPSS software version 15. Statistical significance was set at $p < 0.05$ at 95% confidence interval.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Demographic Characteristics of Subjects in Part I of the Study

A total of 60 recently delivered mothers were recruited for the part I of this study. They comprised of 29(48.4%) primigravids and 31 (51.6%) multigravids, their distribution within each group is summarized in the 2x2 contingent table as shown in table 1. The participants were within the age range of 18 ï 48 years, with a mean age of 28.48 ± 5.79 years.

4.1.2 Mean Abdominal Retraction of Participants across the Periods

The mean abdominal retraction of the participants at baseline, 1st, 2nd, 3rd, 4th, 5th and 6th week for each of the groups (isometric, isotonic, combined (mixed) and control)(fig. 15), and gravid status (primigravids and multigravids)(fig. 16) are summarized in table 2. At baseline, the isotonic group had the highest mean abdominal retraction (16.7 ± 5.9cm) while the isometric group had the least mean abdominal retraction (12.8 ± 2.8cm). However these differences were not statistically significant ($p > 0.05$). At the first week, there was almost an even distribution of the abdominal retraction with the isometric group on the lead (13.0 ± 6.0cm) and the Control group with the least (11.5 ± 2.1cm). Across each group, there was consistent decrease in the mean abdominal retraction of participant down the time series except for the Isometric group that had a mild increase in mean abdominal retraction from baseline to first week (12.8 ± 2.8 ï 13.0 ± 6.0). Table 2 also shows the mean abdominal retraction of primigravid and multigravid participants.

There was also a consistent decrease in mean abdominal retraction valueall through the periods for both groups. However, the mean abdominal retraction value in the multigravid group was higher than that of the primigravid group and this was consistent down the periods and statistically significant ($p < 0.05$), as shown in table 2 and figure 15.It should be noted that abdominal retraction value necessarily has an inverse relationship with the corresponding retraction quality.

Table 1: A 2x2 Contingency Table describing the distribution of Primigravid and Multigravid Participants across the Groups.

		Gravidstatus		Total
		Primigravida	Multigravida	
Group	Isometric	7(46.7%)	8(53.3%)	15
	Isotonic	9(60.0%)	6(40.0%)	15
	Mixed	7(46.7%)	8(53.3%)	15
	Control	6(40.0%)	9(60.0%)	15
Total		29(48.4%)	31(51.6%)	60

Table 2: The mean Abdominal Retraction of the Participants across the periods (baseline, 1st, 2nd, 3rd, 4th, 5th and 6th week) for each of the groups

Particulars		Baseline DF	Wk1 DF	Wk2 DF	Wk3 DF	Wk4 DF	Wk5 DF	Wk6DF
Group								
Isometric	Mean	12.8	13.0	10.2	8.8	7.5	6.0	5.5
n = 15	S.D	2.8	6.0	2.3	2.1	1.6	1.6	1.6
Isotonic	Mean	16.7	13.6	10.8	9.7	7.2	6.0	5.9
n = 15	S.D	5.9	4.1	3.8	2.9	2.1	1.4	1.7
Mixed	Mean	14.9	12.7	9.8	7.3	6.9	6.7	6.6
n = 15	S.D	3.8	2.9	2.4	1.9	1.5	1.3	1.2
Control	Mean	13.3	11.5	10.8	9.3	9.5	8.5	8.5
n = 15	S.D	1.8	2.1	2.8	1.9	3.0	1.7	1.4
Total	Mean	14.4	12.7	10.4	8.8	7.8	6.8	6.6
N = 60	S.D	4.1	4.0	2.9	2.4	2.3	1.8	1.9
Gravidstatus								
Primigravida	Mean	13.6	11.6	9.8	8.2	7.2	6.4	6.2
n = 29	S.D	4.0	2.4	2.5	2.5	1.9	1.9	1.9
Multigravida	Mean	15.2	13.8	10.9	9.4	8.3	7.2	7.0
n = 31	S.D	4.0	4.9	3.1	2.1	2.5	1.6	1.8
Total	Mean	14.4	12.7	10.4	8.8	7.8	6.8	6.6
N = 60	S.D	4.1	4.0	2.9	2.4	2.3	1.8	1.9

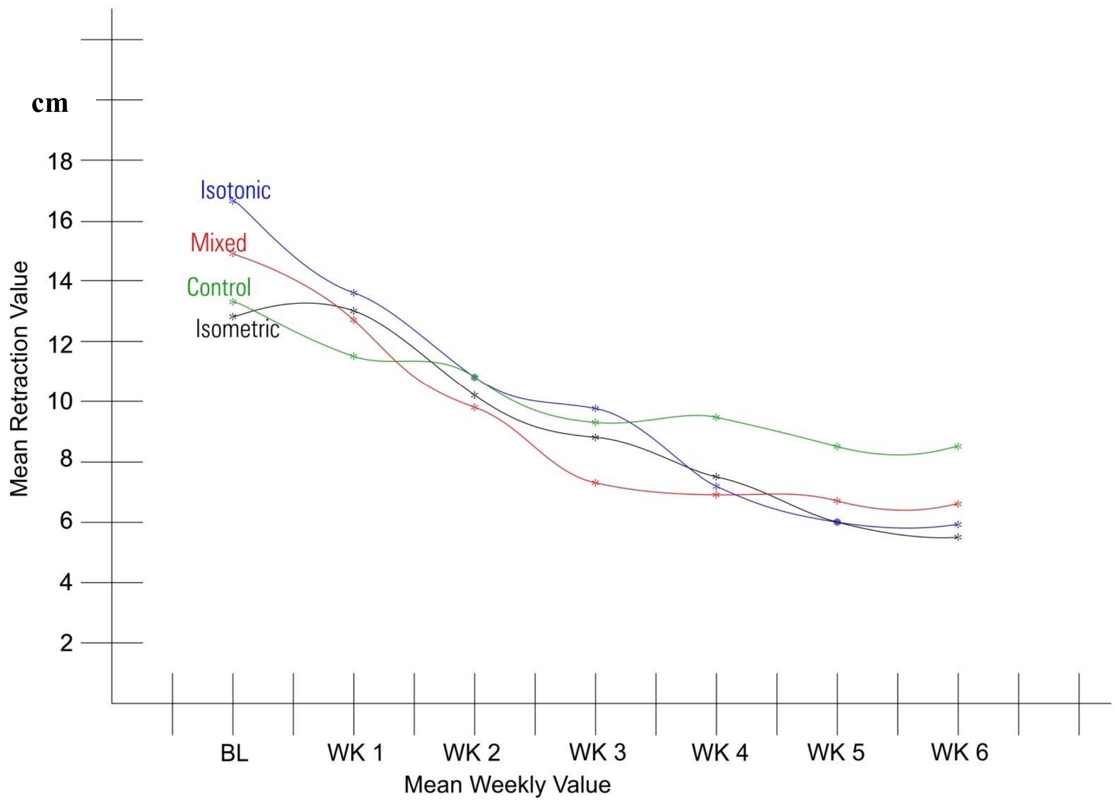


Fig. 15: Graphical Presentation of Abdominal Retraction Mean Values of Participants across the time series (baseline, 1st, 2nd, 3rd, 4th, 5th and 6th week) for each of the groups

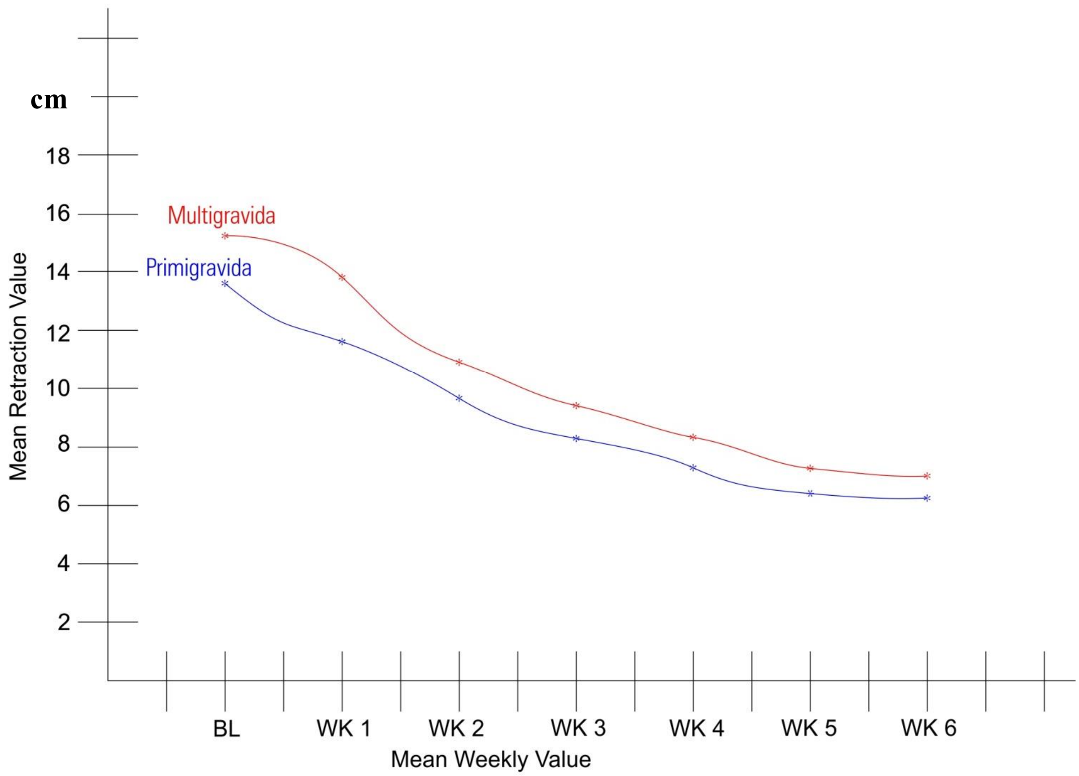


Fig. 16: Graphical Presentation of the Abdominal Retraction Mean Values of Participants across the time series (baseline, 1st, 2nd, 3rd, 4th, 5th and 6th week) for Primigravida and Multigravida

4.1.3 Abdominal Retraction Rate across the Group

With the exception of the isometric group at week1, there was a consistent positive increase in abdominal retraction rate within each group down the time series (Table 3). Comparing the rate of abdominal retraction among the groups for each time series, the Isotonic and mixed group consistently had higher rates of abdominal retraction than the control and Isometric group. While the mixed group attained the abdominal retraction index (ri =50%), at the third week, the isotonic and isometric groups attained theirs at the fourth and fifth weeks respectively. However, the control group never attained the abdominal retraction rate throughout the time series.

Table 3: Abdominal Retraction Rate of Participants (N = 60)

Particulars		Baseline	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6
Group								
Isometric	Mean	0.0	-1.2	2.6	4.0	5.3	6.8	7.3
n = 15	%	0.0	-9.4	20.3	31.3	41.4	**53.1***	57.0
Isotonic	Mean	0.0	3.1	5.9	7.0	9.5	10.7	10.8
n = 15	%	0.0	18.6	35.3	41.9	**56.9***	64.1	64.7
Mixed	Mean	0.0	2.2	5.1	7.6	8.0	8.2	8.3
n = 15	%	0.0	14.8	34.2	**51.0***	53.7	55.0	55.7
Control	Mean	0.0	1.8	2.5	4.0	3.8	4.8	4.8
n = 15	%	0.0	13.5	18.8	30.1	28.6	36.1	36.1

*Retraction index (RI Ó50%)

4.1.4 Comparison of Mean Abdominal Retraction across the Groups

Table 4 shows the comparison of the mean abdominal retraction across the groups (Isometric, Isotonic, Mixed and Control). There was no significant difference ($p > 0.05$) in the mean abdominal retraction at baseline ($F = 1.098$, $p = 0.358$), first week ($F = 0.699$, $p = 0.557$) and second week ($F = 0.395$, $p = 0.757$) across the groups. However, there was a significant difference ($p < 0.05$) in the mean abdominal retraction across the group at the third week ($F = 3.113$, $p = 0.033$), fourth week ($F = 4.646$, $p = 0.006$), fifth week ($F = 9.328$, $p = 0.000$) and sixth week ($F = 11.940$, $p = 0.000$). The post hoc (Bonferoni) analysis (table 5) shows that the significant difference observed at the third week occurred between the Isotonic versus Mixed group ($t = 2.327$, $p = 0.038$). At the fourth week, the significant difference in mean abdominal retraction was found to occur between the Control group versus the Isotonic groups ($t = 2.340$, $p = 0.024$) and the control group versus the mixed group ($t = 2.610$, $p = 0.009$). At the fifth week, the significant difference occurred between the Control versus the Isometric ($t = 2.467$, $p = 0.000$), Control versus Isotonic ($t = 2.507$, $p = 0.000$) and control versus mixed ($t = 1.827$, $p = 0.009$). At the sixth week, the significant difference also occurred between the Control versus Isometric ($t = 2.993$, $p = 0.000$), Control versus Isotonic ($t = 2.627$, $p = 0.000$) and Control versus Mixed ($t = 1.953$, $p = 0.004$).

Table 4: The comparison of the mean abdominal retraction across the groups using ANOVA

	Baseline	Wk1DF	Wk2DF	Wk3DF	Wk4DF	Wk5DF	Wk6DF
F	1.098	0.699	0.395	3.113	4.646	9.326	11.940
Sig	0.358	0.557	0.757	*0.033	*0.006	*0.000	*0.000

Table 5: Post Hoc (Bonferroni) Analysis for the comparison of the mean abdominal retraction across group for the baseline and weeks with significant difference.

Dependent Variable	**(I) Group**	**(J) Group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
BaselineDF	Mixed	Isometric	2.12667	1.41543	0.832	-1.7448	5.9982
		Isotonic	0.18000	1.41543	1.000	-3.6915	4.0515
		Control	1.60000	1.41543	1.000	-2.2715	5.4715
	Isotonic	Isometric	1.94667	1.41543	1.000	-1.9248	5.8182
		Control	1.42000	1.41543	1.000	-2.4515	5.2915
	Control	Isometric	0.52667	1.41543	1.000	-3.3448	4.3982
Wk3DF	Isotonic	Isometric	0.82600	0.81918	1.000	-1.4146	3.0666
		Mixed	2.32667*	0.81918	0.038	0.0860	4.5673
		Control	0.36667	0.81918	1.000	-1.8740	2.6073
	Control	Isometric	0.45933	0.81918	1.000	-1.7813	2.7000
		Mixed	1.96000	0.81918	0.121	-.2806	4.2006
	Isometric	Mixed	1.50067	0.81918	0.434	-0.7400	3.7413
Wk4DF	Control	Isometric	2.01333	0.77810	0.074	-0.1149	4.1416
		Isotonic	2.34000*	0.77810	0.024	0.2117	4.4683
		Mixed	2.61000*	0.77810	0.009	0.4817	4.7383
	Isometric	Isotonic	0.32667	0.77810	1.000	-1.8016	2.4549
		Mixed	0.59667	0.77810	1.000	-1.5316	2.7249
	Isotonic	Mixed	0.27000	0.77810	1.000	-1.8583	2.3983
Wk5DF	Control	Isometric	2.46667*	.54430	.000	0.9779	3.9554
		Isotonic	2.50667*	.54430	.000	1.0179	3.9954
		Mixed	1.82667*	.54430	.009	0.3379	3.3154
	Mixed	Isometric	0.64000	.54430	1.000	-0.8488	2.1288
		Isotonic	0.68000	.54430	1.000	-0.8088	2.1688
	Isometric	Isotonic	0.04000	.54430	1.000	-1.4488	1.5288
Wk6DF	Control	Isometric	2.99333*	.54583	.000	1.5004	4.4863
		Isotonic	2.62667*	.54583	.000	1.1337	4.1196
		Mixed	1.95333*	.54583	.004	0.4604	3.4463
	Mixed	Isometric	1.04000	.54583	.371	-0.4530	2.5330
		Isotonic	0.67333	.54583	1.000	-0.8196	2.1663
	Isotonic	Isometric	0.36667	.54583	1.000	-1.1263	1.8596

Key: WK = Week, DF = Difference, I = Group in the first order, J =Group in the second order

4.1.5 Comparison of Mean Abdominal Retraction across the Periods

Table 6 shows the comparison of the mean abdominal retraction for each group across the time series (Baseline, week1, week2, week3, week4, week5 and week6) using the Greenhouse Geisser Repeated Measure ANOVA. There were significant differences across the periods for all the groups: Isometric group ($F = 30.188$, $p = 0.001$), Isotonic group ($F = 27.419$, $p = 0.001$), Mixed group ($F = 15.921$, $p = 0.001$) and Control group ($F = 21.217$, $p = 0.001$). Therefore, there were significantly progressive increases in abdominal retraction in all groups compared to their respective baseline. The post hoc (Bonferroni) analysis for the isometric group shows that there was no significant difference between the mean abdominal retraction at baseline and week1 ($p> 0.05$). However, there was a significant difference in mean abdominal retraction between the baseline and the other periods (week2, week3, week4, week5 and week6),($p < 0.05$). There was no significant difference in the mean abdominal retraction between week 1 and each of week2 ($t = 2.793$, $p = 1.000$) and week3 ($t = 4.159$, $p = 0.189$),($p < 0.05$). However, there was significant difference between week 1 mean abdominal retraction and each of week 4 ($t = 5.507$, $p = 0.028$), week 5 ($t = 6.960$, $p = 0.004$) and week 6 ($F = 7.467$, $p = 0.002$). There was significant difference in mean abdominal retraction between week 2 and each of weeks 3, 4, 5 and 6 ($p = 0.001$). This means that abdominal retraction was greater in later weeks than in week 2. It was also significantly higher in weeks 4, 5 and 6, compared to week 3 ($p < 0.05$). Comparatively, weeks 5($t = 1.453$, $p = 0.001$) and 6($t = 1.960$, $p = 0.001$)had significantly greater mean abdominal muscle retraction than week 4, ($p < 0.05$). There was however, no significant difference between the mean abdominal retraction at week5 and week6 ($t = 0.507$, $p = 0.267$), ($p > 0.05$),(table 7).

The post hoc (Bonferroni) analysis for the isotonic group is shown in table 8. There was no significant difference in mean abdominal retraction between baseline and each of week1 ($t = 1.100$, $p = 1.000$) and week2 ($t = 3.933$, $p = 0.418$), ($p > 0.05$). However, there was a significant difference between the baseline and each of the other weeks ($p = 0.001$). There was a significant difference between week 1 and other weeks ahead ($p < 0.05$) except for group 2 ($t = 2.833$, $p = 1.000$). With the exception of week3 ($t = 1.133$, $p =1.000$), there was a significant difference between week2 and other weeks (4, 5 and 6) ($p < 0.05$). There was a significant difference between week 3 and each of other weeks (4, 5 and 6) ($p < 0.05$). While there was no significant difference in mean abdominal retraction between week4 and week5 ($t = 1.167$, $p = 0.364$), there was a significant difference between week4 and week6 ($t = 1.267$, $p = 0.022$). There was also, no significant difference in mean abdominal retraction between week5 and week6 ($t = 0.100$, $p = 1.000$).

Table 9 shows the post hoc (Bonferroni) analysis for the mixed group. There was a significant difference in mean abdominal retraction between baseline and other periods (weeks1, 2, 3, 4, 5 and 6) ($p < 0.005$). There was also a significant difference in mean abdominal retraction between week1 and other time series (weeks 2, 3, 4, 5 and 6) ($p = 0.001$). Similarly, there was a significant difference in mean abdominal retraction between week2 and other time series (weeks 3, 4, 5 and 6) ($p = 0.001$). However, there was no significant difference in mean abdominal retraction between week3 and other time series (weeks 4, 5 and 6) ($p = 1.000$). Also, there was no significant difference in mean abdominal retraction between week4 and other time series (weeks 5 and 6) ($p =$

1.000). Similarly, there was no significant difference in mean abdominal retraction between week5 and week6 (p = 1.000).

The post hoc (Bonferroni) analysis for the control group is shown in table 10. There was a significant difference in mean abdominal retraction between baseline and other time series (weeks 1, 2, 3, 4, 5 and 6) ($p < 0.005$). Except for week2 (p = 1.000) and week 4 (p = 0.138), there was a significant difference in mean abdominal retraction between week1 and other time series (weeks 3, 5 and 6) (p = 1.000). With the exception of week 5 (p = 0.042), there was no significant difference in mean abdominal retraction between week2 and other time series (weeks 3, 4 and 6) ($p > 0.05$). There was no significant difference in mean abdominal retraction between week3 and other time series (weeks 4,5 and 6) ($p > 0.05$). Also, there was no significant difference in mean abdominal retraction between week4 and other time series (weeks 5 and 6) (p = 1.000). Similarly, there was no significant difference in mean abdominal retraction between week5 and week6 (p = 1.000).

Table 6: comparison of the mean abdominal retraction for each group across the periodss (Baseline, week1, week2, week3, week4, week5 and week6) using Repeated Measure ANOVA

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Greenhouse-Geisser	Isometric group	821.307	1.344	611.278	30.188	0.000*	0.683
	Isotonic group	1148.467	2.229	515.296	27.419	0.000*	0.662
	Mixed group	1008.544	1.496	674.354	115.921	0.000*	0.892
	Control group	282.346	3.076	91.781	21.217	0.000*	0.602

*Statistically significant value

Table 7: Bonferroni (Post Hoc)Analysis of the Comparison of the Mean Abdominal Retraction for the Isometric Group across the Periods.

(I) Time	**(J) Time**	**Mean Difference (I-J)**	**Std. Error**	**Sig.(a)**	**95% Confidence Interval for Difference(a)**	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
0	1	-0.213	1.291	1.000	-4.990	4.564
	2	2.580(*)	0.277	0.000	1.557	3.603
	3	3.946(*)	0.356	0.000	2.631	5.261
	4	5.293(*)	0.447	0.000	3.641	6.946
	5	6.747(*)	0.338	0.000	5.497	7.997
	6	7.253(*)	0.398	0.000	5.783	8.724
1	2	2.793	1.388	1.000	-2.341	7.928
	3	4.159	1.373	0.189	-.919	9.237
	4	5.507(*)	1.378	0.028	0.408	10.606
	5	6.960(*)	1.374	0.004	1.877	12.043
	6	7.467(*)	1.357	0.002	2.447	12.487
2	3	1.366(*)	0.196	0.000	0.639	2.093
	4	2.713(*)	0.367	0.000	1.355	4.071
	5	4.167(*)	0.299	0.000	3.059	5.274
	6	4.673(*)	0.379	0.000	3.270	6.076
3	4	1.347(*)	0.291	0.008	0.269	2.425
	5	2.801(*)	0.283	0.000	1.753	3.848
	6	3.307(*)	0.376	0.000	1.917	4.698
4	5	1.453(*)	0.257	0.001	0.503	2.404
	6	1.960(*)	0.321	0.001	0.773	3.147
5	6	0.507	0.177	0.267	-0.150	1.163

Key: I = Baseline and weeks in the first order, J = Weeks in the second order,
*Statistically significant value

Table 8: Bonferroni (Post Hoc)Analysis of the Comparison of the Mean Abdominal Retraction for the Isotonic Group across the Periods.

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
0	1	1.100	1.014	1.000	-2.653	4.853
	2	3.933	1.498	0.418	-1.606	9.473
	3	5.067(*)	1.149	0.013	0.815	9.319
	4	7.567(*)	1.210	0.000	3.091	12.043
	5	8.733(*)	1.326	0.000	3.827	13.640
	6	8.833(*)	1.414	0.000	3.603	14.064
1	2	2.833	1.488	1.000	-2.670	8.337
	3	3.967(*)	0.952	0.020	0.446	7.487
	4	6.467(*)	0.837	0.000	3.369	9.564
	5	7.633(*)	1.045	0.000	3.768	11.498
	6	7.733(*)	1.014	0.000	3.982	11.484
2	3	1.133	0.720	1.000	-1.529	3.795
	4	3.633(*)	0.882	0.022	0.372	6.895
	5	4.800(*)	0.788	0.001	1.885	7.715
	6	4.900(*)	0.793	0.001	1.966	7.834
3	4	2.500(*)	0.447	0.001	0.846	4.154
	5	3.667(*)	0.618	0.001	1.379	5.955
	6	3.767(*)	0.603	0.000	1.535	5.998
4	5	1.167	0.364	0.134	-0.180	2.513
	6	1.267(*)	0.308	0.022	0.127	2.406
5	6	100	0.268	1.000	-0.892	1.092

I = Baseline and weeks in the first order, J = Weeks in the second order, *Statistically significant value

Table 9: Bonferroni (Post Hoc)Analysis of the Comparison of the Mean Abdominal Retraction for the combined Group across the Periods.

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
0	1	2.220(*)	0.388	0.001	0.784	3.656
	2	5.067(*)	0.404	0.000	3.572	6.561
	3	7.573(*)	0.562	0.000	5.495	9.652
	4	8.017(*)	0.653	0.000	5.600	10.434
	5	8.233(*)	0.721	0.000	5.567	10.900
	6	8.340(*)	0.775	0.000	5.474	11.206
1	2	2.847(*)	0.229	0.000	1.998	3.696
	3	5.353(*)	0.353	0.000	4.049	6.657
	4	5.797(*)	0.485	0.000	4.002	7.591
	5	6.013(*)	0.533	0.000	4.041	7.985
	6	6.120(*)	0.578	0.000	3.984	8.256
2	3	2.507(*)	0.205	0.000	1.747	3.266
	4	2.950(*)	0.336	0.000	1.707	4.193
	5	3.167(*)	0.378	0.000	1.768	4.565
	6	3.273(*)	0.428	0.000	1.689	4.858
3	4	0.443	0.301	1.000	-0.671	1.557
	5	0.660	0.313	1.000	-0.497	1.817
	6	0.767	0.360	1.000	-0.566	2.100
4	5	0.217	0.117	1.000	-0.216	0.649
	6	0.323	0.177	1.000	-0.331	0.977
5	6	0.107	0.094	1.000	-0.242	0.456

I = Baseline and weeks in the first order, J = Weeks in the second order, *Statistically significant value

Table 10: Bonferroni (Post Hoc)Analysis of the Comparison of the Mean Abdominal Retraction for the Control Group across the Periods.

(I) Time	**(J) Time**	**Mean Difference (I-J)**	**Std. Error**	**Sig.(a)**	**95% Confidence Interval for Difference(a)**	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
0	1	1.767(*)	0.222	0.000	0.945	2.588
	2	2.513(*)	0.667	0.043	0.047	4.979
	3	4.013(*)	0.387	0.000	2.580	5.446
	4	3.807(*)	0.614	0.000	1.536	6.078
	5	4.807(*)	0.486	0.000	3.010	6.603
	6	4.787(*)	0.404	0.000	3.293	6.280
1	2	0.747	0.635	1.000	-1.603	3.096
	3	2.247(*)	0.367	0.001	0.889	3.604
	4	2.040	0.640	0.138	-0.327	4.407
	5	3.040(*)	0.522	0.001	1.108	4.972
	6	3.020(*)	0.445	0.000	1.373	4.667
2	3	1.500	0.486	0.169	-0.297	3.297
	4	1.293	0.901	1.000	-2.040	4.626
	5	2.293(*)	0.605	0.042	0.056	4.531
	6	2.273	0.634	0.063	-0.073	4.619
3	4	-0.207	0.656	1.000	-2.633	2.220
	5	0.793	0.301	0.408	-0.318	1.905
	6	0.773	0.301	0.467	-0.340	1.886
4	5	1.000	0.658	1.000	-1.434	3.434
	6	0.980	0.665	1.000	-1.480	3.440
5	6	-.020	0.265	1.000	-1.000	0.960

I = Baseline and weeks in the first order, J = Weeks in the second order, *Statistically significant value

4.1.6 Demographic Characteristics of Subjects in Part II of the Study

A total of 30 women of 4 to 6 weeks postpartum participated in part II of this study. They were all multigravids who had two to five pregnancies, and were distributed as follows: eight experimental group A, seven control group B, and twenty three experimental group C (15 + 8 in group A) who also served as their own control. The participants were within the age range of 27 ï 44 years, with a mean age of 39.33 ± 2.71 years.

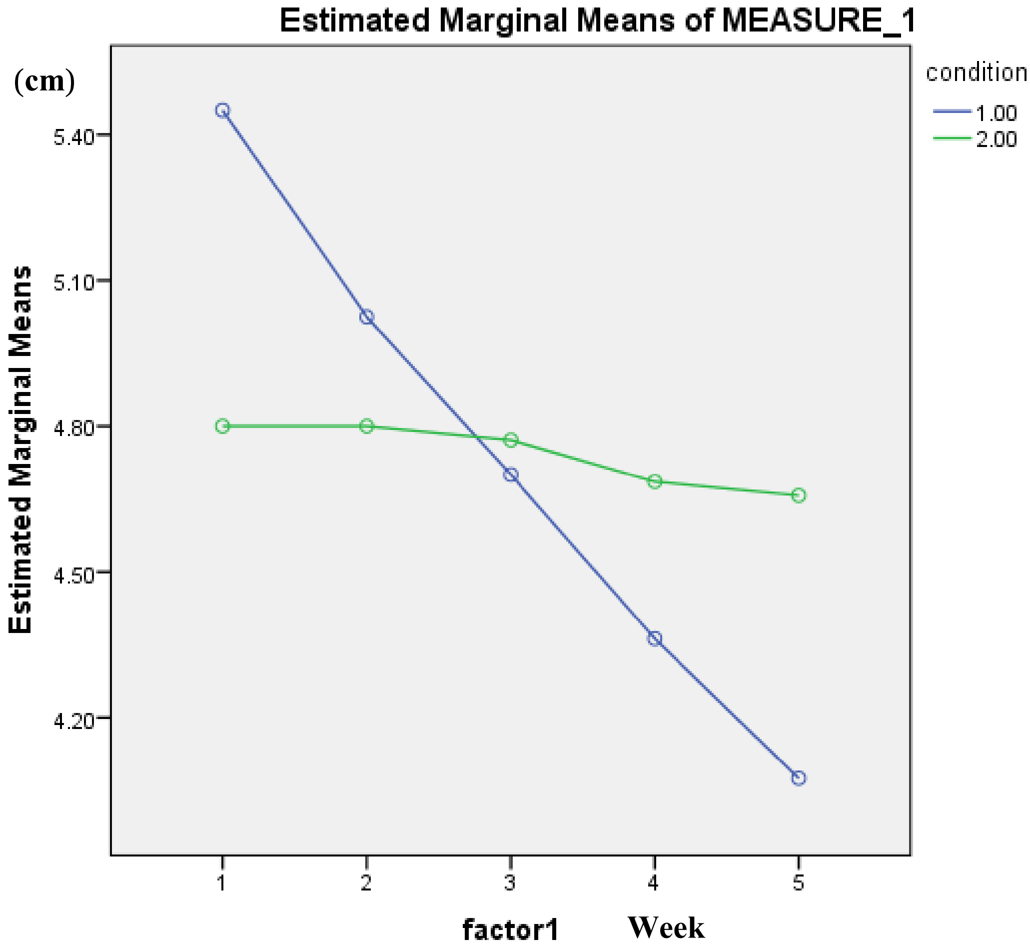
4.1.7 Comparison of Mean Inter-Recti Distance Reduction across the Periods

A 2ï way mixed ANOVA of the upper IRD closure performance in both experimental and control groups showed remarkable marginal difference in the mean values between the groups across time series, (Table 11; Fig 17). However, this difference is not statistically significant set at $p < 0.05$ and $f > 2.61$, the test within subject revealed significant difference in closure with time ($f = 32.35$ $p = 0.00$). The interaction effect between time and condition was also statistically significant ($f = 20.422$, $p = 0.00$), as shown in Table 12. This is an indication that upper inter-recti distance (IRD) closure is directly related to time.

When compared, the upper IRD closure ($f > 4.67$, $p < 0.05$) in both groups presented no significant difference ($f < 4.67$, $p > 0.05$) as indicated in Table 13. However, the marginal closure difference between the experimental and control groups was consistent down the time series.

Table 11: Descriptive Comparison of the closure of the upper Inter-recti Distance in experimental and control groups across the Periods.

Time	Group	mean	S.D	N
Baseline	Experimental	5.4500	1.87845	8
	Control	4.8000	2.04532	7
	Total	5.1467	1.91567	15
Week 1	Experimental	5.0250	1.93298	8
	Control	4.8000	2.04532	7
	Total	4.9200	1.91692	15
Week2	Experimental	4.7000	1.94275	8
	Control	4.7714	2.13675	7
	Total	4.7333	1.96093	15
Week3	Experimental	4.3625	1.91307	8
	Control	4.6857	2.09478	7
	Total	4.5133	1.93349	15
Week4	Experimental	4.0750	1.98692	8
	Control	4.6571	2.09432	7
	Total	4.3467	1.98597	15



Weeks

Condition**:1.00** ï Experimental group; **2.00** ï Control group

Fig. 17: Closure of the upper inter recti distance against time for both experimental and control groups, showing the pattern of resolution of the condition for each group.

Table 12: Test of within subject effect for upper and lower Inter-recti distance resolution.

Source	sum of square	df	mean square	F value	p value
Upper IRD					
Time (Weeks)	5.438	4	1.360	32.351	0.000*
Time*condtn.	3.433	4	0.858	20.422	0.000*
Error	2.185	52	0.042		
Lower IRD					
Time	6.592	4	1.648	26.263	0.000*
Time*condtn.	4.384	4	1.096	17.466	0.000*
Error(time)	3.263	52	0.063		

Key: IRD = Inter-recti distance.
Time = Inter-recti distance periodic closure effects in weeks.
Time*condtn. = Relationship between the initial status of inter-recti distance and its resolution effects through the weeks.
*Statistically significant value

Table 13: Test of between subject effects for upper and lower inter-recti distance resolution using 2-way mixed ANOVA.

Source	sum of square	df	mean square	F value	p value
Upper IRD					
Intercept	1672.402	1	1672.402	84.078	0.000*
Condition	0.008	1	0.008	0.985	0.000 *
Error	258.583	13	19.891		
Lower IRD					
Intercept	1608.162	1	1608.162	80.845	0.000*
Condition	0.213	1	0.213	0.011	0.919
Error	258.595	13	19.892		

Key: IRD = Inter-recti distance.*Statistically significant value.

Table 14: Descriptive statistics of the closure of the lower inter-recti distance in experimental and control groups across periods.

Time	group	mean	S.D	N
Baseline	Experimental	5.4000	1.78165	8
	Control	4.7714	2.09819	7
	Total	5.1067	1.89189	15
Week1	Experimental	4.9375	1.95224	8
	Control	4.7429	2.11619	7
	Total	4.8467	1.95845	15
Week2	experimental	4.5500	2.01494	8
	Control	4.6857	2.11773	7
	Total	4.6133	1.98921	15
Week3	Experimental	4.1625	1.88220	8
	Control	4.6429	2.05820	7
	Total	4.3867	1.91007	15
Week4	Experimental	3.8875	2.01667	8
	Control	4.6286	2.06778	7
	Total	4.2581	2.04221	15

4.1.8 Comparison of Mean Inter-recti distance Resolution between the Experimental and Control Groups at the Lower aspect of umbilicus

All through the four weeks marginal lower IRD closure mean difference occurred in favour of the experimental group. However this difference is not statistically significant (Table 14). Essentially, the marginal difference within time is consistent for both groups. The difference within the control group could be considered to represent the spontaneous resolution as described by Liaw et al., (2011) in a cohort study of 40 postpartum women. It is not clear however what is responsible for marginal mean difference observed between the upper and lower IRDs across the time series. Notably, the marginal mean change in closure of lower IRD for the subjects in the experimental group over time was greater than that of control group (Fig.17).

Test within subject effect for the low IRD closure (Table 12) at $p < 0.05$, $f > 2.61$ indicated statistical significance with time ($f = 26.263$, $p = 0.000$) showing that complete resolution of lower IRD could be achieved at longer time. The interaction effect between time and lower IRD closure was also statistically significant ($f = 17.466$, $p = 0.000$). Comparatively, lower IRD closure between subjects was found to be statistically significant ($f > 4.65$, $p < 0.05$), indicating relativity in closure among subjects in both groups, as shown in Table 13.

Table 15: Characteristic resolution of rectus abdominis separation in different weeks.

		Mean+ SD	95%Confidence Lower bound	Interval Upper bound	df	F	p-value
2cm above Umbilicus	Baseline	4.36+ 1.46	3.73	4.99	4	3.83	0.006*
	Week 1	4.02+ 1.42	3.40	4.63			
	Week 2	3.65+ 1.44	3.02	4.27			
	Week 3	3.25+ 1.43	2.63	3.87			
	Week 4	2.86+ 1.52	2.20	3.52			
2cm below Umbilicus	Baseline	4.23+ 1.41	3.64	4.36	4	3.61	0.008*
	Week 1	393+ 1.41	3.23	4.54			
	Week 2	3.62+ 1.42	3.00	4.23			
	Week 3	3.19+ 1.38	2.60	3.79			
	Week 4	2.84+1.49	2.20	3.49			

*Statistically significant value

4.1.9Characteristic resolution of rectus abdominis separation in different weeks.

There was notable resolution of recti diastasis 2.5cm above and below the umbilicus as the isometric exercises progresses through the four weeks duration. It was found out that there were progressively significant reduction of inter-recti distance above and below the umbilicus from baseline to fourth week($p< 0.05$).Characteristically, the resolution pattern indicates progressive approximation all through the four weeks in both the upper and lower aspects of the umbilicus. These closures are statistically significant in relation to the baseline in the two locations of the linea alba, 2cm above the umbilicus ($P=0.006$) and 2cm below the umbilicus ($P = 0.008$), as shown in table 15.

Though progressive in nature, this relativity in the resolution indicates that isometric abdominal exercises actually played strengthening role in the experimental group. When this toning effect was compared at the upper and lower aspects of the umbilicus, no significant difference was established between their extents of closure, though there was marginally higher improvement above than below the umbilicus. This finding means that exercise induced inter-recti distance resolution quality does not necessarily depend on location of occurrence of this separation.

Bonferroni post hoc comparison of inter-recti distance resolution among participants in the four weeks of isometric exercises shows statistical significance ($P < 0.05$) between the baseline and fourth week both 2.5cm above and below the umbilical margin, as show in table 16. However this was not the case with the first, second and third weeks.

Table 16: Bonferroni (post hoc) comparison of the separation resolution among the participants in the four weeks of isometric exercises

2cm above umbilicus	Baseline	Week 1	Week 2	Week 3	Week 4
Baseline	-	0.34 (1.000)	0.71(1.00)	1.11(0.113)	1.50 (0.007*)
Week 1		-	0.37(1.00)	0.77(0.78)	1.16(0.08)
Week 2			-	0.36(1.00)	0.79(0.701)
Week 3				-	0.39 (1.000)
Week 4					-
2cm below the umbilicus					
Baseline	-	031(1.00)	0.63 (1.00)	1.06(0.130)	1.40(0.011*)
Week 1		-	0.32 (1.00)	0.74 (0.79	1.09(0.104)
Week 2			-	0.43 (1.00)	0.41(0.672
Week 3				-	0.35 (1.000)
Week 4				-	

*Statistically significant value

Table 17: Number of Pregnancy differences ininter-recti distance closure during isometricexercise N=23

	Mean±SD	95% CI Lower bound	df upper bound	F		p-value
Measurement 2cm above umbilicus						
2	2.55±0.61	2.96	2.83			
3	3.09±1.06	2.79	3.40	3	19.285	0.000*
4	4.57±1.86	3.88	5.26			
5	3.63±1.52	4.42	5.50			
Measurement 2cm above umbilicus						
2	2.75±0.51	2.50	2.99			
3	3.06±1.10	2.74	3.37	3	13.203	0.000*
4	4.56±1.96	3.82	5.28			
5	4.40±0.79	3.29	4.84			

*Statistically significant value, CI = Confidence interval

4.1.10 Number of Pregnancy differences in inter-recti distance closure during isometric exercise

Results from this studyshowed that women with increasing parity had poorer resolution of inter-recti distance for the measurement 2.5cm above and below the umbilicus(table 17). These differences were between those with two births and four births, two births and five births, three births and four births and between three births and five births as seen in the post hoc analysis in table 18.

Post hoc comparison of number of pregnancy difference and mean recti diastasis resolution reveals variable relationship between different numbers of multiparity. While the resolution value between multiparity of two and three was not statistically significant ($p > 0.05$), two compared to four and five show significant resolution difference ($P < 0.05$) of varying degrees, at 2.5cm above the umbilical ring. Multiparty of four compared to five showed no statistical significance ($p > 0.05$).

On the other hand at 2.5cm below the umbilical ring multiparity of two compared with three was also not statically significant ($P > 0.05$) whereas two in relation to four and five were significant with the values of $F = -1.805$, $P = 0.00$ and $F = -1.476$, $P = 0.00$ respectively. Multigravid of three compared to four and five showed statistical significance ($P < 0.05$). Comparatively multiparity of four to five had no mean resolution significance ($P > 0.05$).

Table 18: Bonferroni post hoc test of number of pregnancy differences in relation to recti diastasisresolution

	Number of pregnancy	Mean difference (p-values)		
Measurement 2.5cm above umbilicus	2	3	4	5
2	-	-0.549(0.611)	2.005 (0.00*)	2.422 (0.000*)
3			-1.476(0.000*)	-1.873(0.000*)
4				-0.397(1.000)
5				-
Measurement 2.5cm below umbilicus				
2	-	-0.311(1.00)	-1.805 (0.000*)	1.655(0.002*)
3		-	-1.476(0.000*)	-1.344(0.004*)
4			-	0.150(1.000)
5				-

*Statistically significant value

4.1.11 Consideration of Age of subjects and Inter-recti distance resolution

The subjects mean ages were considered in relation torecti diastasis mean resolution at two points 2.5cm above and below the umbilical ring. The result indicated significant improvement in inter-recti distance resolution ($p < 0.05$) at both 2.5cm above and below the umbilicus, with time. Analysis of variance (ANOVA) test revealed that younger subjects fared significantly better ($p< 0.05$) in terms of reduction in their recti diastases than older counterparts. This finding is true for both points 2.5cm above and below the umbilical ring, (Table 19).

This result shows that age was negatively related with the inter-recti distance resolution.Bonferroni post hoc analysis also revealed that postpartum women in their twenties had better closure compared with those in their thirties and forties. However, there was no difference in the pattern and rate of resolution between women at thirties compared to those in their forties as seen in table 20.

Table 19: Age mediated differences in resolution of separation in 4 weeks of Isometric exercises, using analysis of variance (ANOVA)

		Mean ± SD	df	F	p-value
2cm above umbilicus					
	2	2.67± 0.78	2	9.542	0.000*
	3	4.07± 1.77			
	4	3.78± 1.20			
2cm below the umbilicus					
	2	2.65± 0.81			
	3	3.89± 1.75			
	4	3.88± 1.05	2	8.746	0.000*
	5	3.56± 1.48			

*Statistically significant value

Table 20: Bonferroni (post hoc) test of the difference in age in terms of the diastasis resolution

		means difference (p-value)	
Measurement 2cm above umbilicus	2	3	4
2	-	-1.397(0.000)	-1.110(0.010*)
3		-	0.287(1.00*)
4			-
Measurement 2cm below umbilicus	2	3	4
2	-	-1. 241(0.000)	-1.227(0.000*)
3		-	0.015(1.00)
4			

*Statistically significant value

4.1.12Null Hypothesis Testing for Abdominal Muscle Retraction

Hypothesis 1:

Statement: There will be no significant difference in abdominal retraction across the groups at baseline.

Alpha level: 0.05

Test Statistics: One way Analysis of Variance (ANOVA)

F = 1.098

p = 0.358

Decision: Since p > 0.05, the hypothesis was not rejected. It was concluded that there was no significant difference in abdominal retraction across the groups at baseline.

Hypothesis 2:

Statement: There will be no significant difference in abdominal retraction across the groups at week 1.

Alpha level: 0.05

Test Statistics: One way Analysis of Variance (ANOVA)

F = 0.699

p = 0.557

Decision: Since p > 0.05, the hypothesis was not rejected. It was concluded that there was no significant difference in abdominal retraction across the groups at week 1.

Hypothesis 3:

Statement: There will be no significant difference in abdominal retraction across the groups at week 2.

Alpha level: 0.05

Test Statistics: One way Analysis of Variance (ANOVA)

$F = 0.395$

$p = 0.757$

Decision: Since $p > 0.05$, the hypothesis was not rejected. It was concluded that there was no significant difference in abdominal retraction across the groups at week 2.

Hypothesis 4:

Statement: There will be no significant difference in abdominal retraction across the groups at week 3.

Alpha level: 0.05

Test Statistics: One way Analysis of Variance (ANOVA)

$F = 3.113$

$p = 0.033$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction across the groups at week 3.

Hypothesis 5:

Statement: There will be no significant difference in abdominal retraction across the groups at week 4.

Alpha level: 0.05

Test Statistics: One way Analysis of Variance (ANOVA)

$F = 4.646$

$p = 0.006$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction across the groups at week 4.

Hypothesis 6:

Statement: There will be no significant difference in abdominal retraction across the groups at week 5.

Alpha level: 0.05

Test Statistics: One way Analysis of Variance (ANOVA)

$F = 9.326$

$p = 0.000$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction across the groups at week 5.

Hypothesis 7:

Statement: There will be no significant difference in abdominal retraction across the groups at week 6.

Alpha level: 0.05

Test Statistics: One way Analysis of Variance (ANOVA)

$F = 11.940$

$p = 0.000$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction across the groups at week 6.

Hypothesis 8:

Statement: There will be no significant difference in abdominal retraction for the isometric group across the time series.

Alpha level: 0.05

Test Statistics: Repeated Measure Analysis of Variance

$F = 30.188$

$p = 0.000$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction for the isometric group across the time series.

Hypothesis 9:

Statement: There will be no significant difference in abdominal retraction for the isotonic group across the time series.

Alpha level: 0.05

Test Statistics: Repeated Measure Analysis of Variance

$F = 27.419$

$p = 0.000$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction for the isotonic group across the time series.

Hypothesis 10:

Statement: There will be no significant difference in abdominal retraction for the mixed group across the time series.

Alpha level: 0.05

Test Statistics: Repeated Measure Analysis of Variance

$F = 115.921$

$p = 0.000$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction for the mixed group across the time series.

Hypothesis 11:

Statement: There will be no significant difference in abdominal retraction for the control group across the time series.

Alpha level: 0.05

Test Statistics: Repeated Measure Analysis of Variance

$F = 21.217$

$p = 0.000$

Decision: Since $p < 0.05$, the hypothesis was rejected. It was concluded that there was a significant difference in abdominal retraction for the control group across the time series.

4.2 Discussion

4.2.1 Part I: Abdominal Muscle Retraction Index

An almost equal number of primigravid and multigravid mothers participated in this study. However, there were more primigravids than multigravids in the isotonic group and the reverse was the case in the control group. This was so because the random assignment did not take into consideration the demographic characteristics of the participants but to produce equal number of participants in each group. It has been argued that the goal of random assignment is to eliminate individual cofounding characteristics (Brookes et al., 2001).

There was a consistent decrease in abdominal retraction of the participants in all the groups across the time series. This may be indicative of diminishing returns in abdominal retraction with or without exercise. Exercise tones the abdominal muscles and burns the abdominal fat and this effect is expected to thin out with time. It may not be surprising to have found similar effect among the control group.This suggests that without exercise, the abdomen retracts on its own probably due to spontaneous retraction of the stretched muscles after being relieved of the stretching force (delivery) as well as the involuntary contraction of the uterus, an action that initiates its return to original state. This finding seems to conform with those of Mantle et al., 2005 where they predicated the spontaneous return of postpartum abdominal muscles on the tightening effects of ligaments in response to physiological adjustment of the tissues.

However, the true picture of the effects of exercise is better appreciated when the rate of abdominal contraction is considered. In this study, the control group never achieved the half initial retraction mark unlike the exercising group, rather there was a plateau at the fifth week. There has been no similar published study with which to compare these findings, it can however be deduced that exercise increases the rate of abdominal retraction as found among the participants of this study. While isotonic exercise retracts the abdominal muscles initially at the fastest rate, combined exercise achieves the 50 percent retraction rate fastest. Due to their vigorous nature, isotonic exercises are usually better at burning of calories whereas the primary benefit of isometric contractions is that they work muscle fibres that would otherwise remain idle (Aman et al., 2013). The initial effect of isotonic exercise on the abdominal retraction rate may therefore be attributed to burning of calories (adipose tissue) which invariably affects the abdominal volume and its retraction. The combination of burning of calories and general toning of muscle fibres is better appreciated in the combined exercise group and this may explain the fact that the mixed exercisers in this study achieved the 50 percent retraction rate fastest (at the third week).

In this study, there was a significant difference in the mean abdominal retraction across the group only at the third, fourth, fifth and six weeks. This implies that among the various groups (Isometric, Isotonic, Combined and Control groups), the mean abdominal retraction between any two of these groups differ significantly. Post hoc revealed that in the third week, the significant difference was found between the mean abdominal retraction of participants in isotonic group and those in the isometric group, with the former taking the lead. This indicates that the effect of isotonic exercise on abdominal retraction is significantly more than that of isometric exercise one week after exercise. This could be due to the fact that isotonic exercises burns out abdominal fat and improves the tone more than isometric exercise especially at the earlier part of an exercise training. This also has its clinical importance.Clinicians hoping to achieve earlier retraction of abdominal muscles may need to do more of isotonic exercise especially at the first week. Post hoc also showed significant difference between isotonic and control groups as well as between combined and control group at the fourth week. This implies that the effect of isotonic and combined exercise training is better felt at the fourth week. It is quite difficult explaining why there was no significant effect of isometric training but in isotonic and combined training. As explained earlier, isotonic exercise burns fat more and tones the muscle more. It is possible that the isotonic part of the combined exercise may have contributed to this significant effect in abdominal retraction. However, at fifth and sixth weeks, there was significant difference between each of isotonic, isometric and combined exercise groups and control. This implies that the effect of isometric exercise only becomes significant from the fifth week. It is worthy of note that it was also at this week that the fifty percent retraction rate was achieved for the isometric group. This therefore may imply that the effect of isometric exercise in toning muscles was strongly felt with time. This compares with Pascoal et al., (2014) who demonstrated the effect of isometric contractionof the abdominal muscles on inter-recti distance in a case controlled study of ten postpartum women where significant muscle contraction and strength were achieved.

Finally, the significant difference in abdominal retraction for all the groups across the time series indicates that with or without exercise, the abdominal volume retracts intrinsically. This may be due to the involuntary contraction of the uterus after delivery. Also, it is possible that the physical activities and other extraneous variables may serve as cofounder in this study because it is quite difficult to explain the significant difference seen in the control group. This therefore implies that the results should be interpreted with caution.

4.2.2 Diastasis Recti Abdominis (DRA)

In the study of diastasis recti abdominis, it is pertinent to note that isometric exercise played a leading role in approximation of the inter-recti distance both at the upper and lower abdomen. This may be attributed to the fact that the exercise type functions essentially in muscle toning and thus approximation of muscle fibres. This action is most likely responsible for the narrowing of the gap between the two recti muscles at the linea alba, above and below the umbilicus. Results from this study have shown a marginal difference in the reduction of inter-recti distance between the upper and lower margins of the umbilicus. This result seems to be in agreement with that of Liaw, et al., (2011) who recorded 1.80 ± 0.72 cm and 1.16 ± 0.58 cm respectively for upper and lower margins of the umbilical ring. However, it is not clear why this difference exists, and this provides justification for further research.

Significant mean differences in reduction of inter-recti distance also exist among experimental participants in the study. This could be as a result of individual intrinsic differences in muscle response to exercises. It could also represent level of accuracy in the exercise performance among subjects. Resolution of inter-recti distance was also progressive with time. This means that given a long time this effect could be greater, and may subsequently lead to complete resolution.

Comparatively, the mean difference in inter-recti distance closure between the experimental and control groups was only marginal in favour of the experimental group. However this difference was not statistically significant. It is possible that spontaneous recovery effect may have played a major role in the control group. The combination of this effect, with the effects of isometric exercise could have given the experimental group the lead. The difference within the control group could be considered to represent the spontaneous resolution as described by Liaw et al., (2011) in a cohort study of 40 postpartum women. It is not clear however what is responsible for marginal mean difference observed between the upper and lower inter-recti distances across the periods.

The results obtained in this study further revealed that there was no mean significant difference in the baseline IRD in the lower abdomen between experimental and control groups (5.400 ± 1.781cm and 4.771 ± 2.098 cm respectively). However the experimental (Isometric) group achieved progressive IRD resolution marginally greater than the control group down the time series. At the fourth week the mean IRD resolution relationship were 3.887 ± 2.061cm and 4.628 ± 2.067cm respectively for experimental and control groups. This increased inter-recti distance closure in the experimental group over the control group was found to be statistically significant. This implies that inter-recti gap reduced more readily in the experimental group than in the control group. The overall closure mean values showed 1.513 ± 1.90cm for experimental group and 0.14 ± 2.08cm for control group. This result seems to have similar closure pattern with those obtained by Pascoal et al., (2014) who recorded 1.07 ± 3.1cm and 1.34 ± 3.1cm respectively when they compared inter-recti distance resolution between postpartum women who had isometric contraction and others at rest. The upper inter-recti gap resolution pattern between the experimental and control groups followed an incremental order in favour of the former which was not essentially different from the lower abdominal values.

The approximation in the muscular myofibres which is largely responsible for the resolution of recti diastasis appears to be more marked during isometric contraction. It is therefore possible that some biochemical muscle markers that are naturally activated by damage or muscular exercise may play a role in reducing the gap created by recti diastasis. This assertion may be supported by the action of myogenic satellite cells seen in the works of Bischoff (1997) and Schulz and Mc Cormick (1994), where they found out that these cells though quiescent in unperturbed state are activated in response to myotrauma and vigorous muscular activities to proliferate and bring about regeneration of damaged skeletal muscles. This action is secondary to the fussion of these myogenic satellite cells to existing muscle fibres to form new myofibres. Mauro (1961) also factored in these cells as essential mediators in the toning of postnatal abdominal muscles, as well as their regeneration and growth. Though the action of these myogenic satellite cells were not studied in this work, their theoretical non-activation status in this case could explain why the poor resolution of the recti diastasis in the control group was observed, as the muscle fibres solely depended on intrinsic spontaneous input. In other words, these cells were not activated since the muscle fibres were devoid of mechanical stretch and contraction that accompany isometric exercises.

Characteristically, the inter-recti distance resolution pattern as obtained in this work indicates progressive approximation all through the four weeks in both the upper and lower aspects of the umbilicus. These closures are statistically significant in relation to the baseline in the two locations of the linea alba, 2cm above the umbilicus ($P=0.006$) and 2cm below the umbilicus ($P = 0.008$).

Though progressive in nature, this relativity in the recti diastasis resolution indicates that isometric abdominal exercises actually played muscle strengthening role in the experimental group. When this toning effect was compared at the upper and lower aspects of the umbilicus, only marginal difference in favour of the former was established between their extents of closure. This finding means that exercise induced inter-recti gap resolution quality does not necessarily depend on location of occurrence of this separation.

Comparison of recti diastasis resolution among participants in the four weeks of isometric exercises shows statistical significance ($P < 0.05$) between the baseline and fourth week both 2.5cm above and below the umbilical margin. However this was not the case with the first, second and third weeks.

This finding shows that given a longer period of isometric exercises, patients of recti diastasis could achieve full resolution. However, this chance of full recovery would be predicated on consolidated and accurate exercise performance. The outcome can be compared with high IRD recovery achieved by Liaw et al, (2001) in their longitudinal cohort study of forty postpartum women after 7 weeks of isometric exercises.

Comparison of number of pregnancy and mean inter-recti gap resolution reveals variable relationship between different numbers of multiparity. While the resolution value between multiparity of two and three was not statistically significant ($p > 0.05$), two compared to four and five show significant resolution difference ($P < 0.05$) of varying degrees, at 2.5cm above the umbilical ring. Multiparty of four compared to five showed no statistical significance ($p > 0.05$).

On the other hand the inter-recti gap closure at 2.5cm below the umbilical ring of multiparity of two previous pregnancies compared with those of three was also not statically significant ($P > 0.05$) whereas those of two in relation to four and five were significant with the values of $F = -1.805$, $P=0.00$ and $F = -1.476$, $P=0.00$ respectively. Multigravid of three compared to those of four and five showed statistical significance ($P < 0.05$). Comparatively multiparity of four to five had no mean resolution significance ($P > 0.05$).

These findings have shown indication that multiparous women with recti diastases achieve various degrees of recovery which may depend on individual multiparous condition. Therefore, women with fewer number of previous pregnancies were found to have higher closure of inter-recti gaps than their counterparts with records of numerous pregnancies. It was also not clear if there were relative differences in the degree of recti diastasis closure between the two spots of study (i.e. 2.5cm above and below the umbilical ring) when considering the number of previous pregnancies experienced by the subjects. Clinical investigation is therefore necessary in this regard so as to have a comparative knowledge of performance of various locations along the linea alba as caused by recti- diastasis and related to different levels of multiparity.

The subjects mean age was compared with the recti diastasis mean resolution at the two points 2.5cm above and below the umbilical ring. The result indicated significant closure at both 2.5 above and below the umbilicus for younger women over their older counterparts.

This result shows that age was negatively related with the recti diastasis resolution. Postpartum women in their twenties had better closure compared with those in their thirties and forties. However there was no difference in the pattern and rate of resolution between women at thirties compared to those in their forties.

It is pertinent to observe here that the younger the subject the faster the IRD resolution. This assertion is true for both locations of study along the linea alba. It is therefore possible to conclude that muscular prompt response to stimuli is favourable in younger women than the order ones. It could also be inferred that aging myofibres may not respond readily to toning forces of exercise sufficient to activate younger ones. Although no previous work was available with which to compare the IRD resolution with maternal age, Lo (1999) listed age above 34 years among the risk factors for the occurrence of recti diastasis. This means that child-bearing women within this age bracket are at risk of sustaining the ailment. The clinical implication of these findings is that clinicians handling cases of recti diastasis should be cautious when prognosticating treatment success and pay attention to age of clients. This action is necessary so as to enable individualized management protocol.

In considering the pattern of IRD resolution from baseline to the fourth week it was found that significant closure of inter-recti gap occurred at the fourth week for both upper and lower aspects of the umbilical ring. The result also revealed that though marginal resolution occurred between the baseline and week1 all through to week3, these differences were not statistically significant. Between week1 and week2, week2 and week3 and week4 marginal resolution pattern varied disproportionally but were progressive and quite visible. These results could point to the fact that isometric muscle work played remarkable role in the contractile quality of skeletal muscles, including abdominal muscles. It means that if this exercise quality is sustained for a longer period, it could solve the problem of recti separation as well as strengthen other weak muscles of the abdomen. This finding could be compared with the results obtained by Liaw et al., (2011) in which IRD resolution of thirty postpartum women were studied against time. They found out mean resolution difference between 7 weeks and 6 weeks postpartum to be 0.17 ± 0.35cm and 0.14 ± 0.40 respectively for 2.5cm above and below the umbilical ring. The difference at the 2.5cm above the umbilical ring was found to be statistically significant at $P < 0.05$.

The role of exercise in the resolution of inter-recti gap cannot be over emphasized. The exercise effect could be held responsible for most of the inter-recti distance approximation found in this work. Other factors like intrinsic muscular action and spontaneous resolution may be co-founders in this gap reduction outcome, though in a smaller scale. This is evident in the comparative differences seen between the experimental (exercise) and control (non-exercise) groups in this study. The finding corroborates those found by Chairello, (2005) in a quasi-experimental study carried out in eighteen prenatal women. In the work 90 minutes abdominal strengthening exercise classes were held six times with the experimental group of the subjects with various degrees of rectus abdominis separation. The outcome showed that the exercise group achieved significantly smaller separation when compared with the non-exercise group.

Though efficacious in strengthening of abdominal muscles and treatment of recti diastasis, exercise protocol as sole intervention has its own limitations. Patients who are subjected to this method are usually reluctant and unable to conform to the set exercise programmes. Others though willing, may carry out these exercises incorrectly or see it as recreational and should be done at their own discretion. It is also factual that high percentage of clients naturally perceive exercise as mere volitional activity rather than treatment strategy for ailment. It was also possible that some subjects in this study handled successive therapeutic exercise protocols with levity and so did not acquire sufficient benefit inherent in this method of intervention.The factors so enumerated may have adversely affected the outcome of this study.

Other proposed treatment modalities for recti diastasis such as the use of corsets (Colie and Harris (2004), Keeler et al., (2012) and taping (Keeler et al., (2012) could have been incorporated with exercise as this possibly could have ensured better outcome. Inability to include primiparous subjects in the IRD study also created a level of limitation to critical outcome and quality of this study. Inclusion of an appreciable number of primigravids would have created an additional insight into the pattern of closure of IRD in response to therapeutic exercise.

This study was not concluded without some notable limitations. These limiting factors though effectively managed posed remarkable challenges to the overall outcome of this work. The location of the study was quite a distance from the researcherôs base, with the implication of paucity of follow-up of subjects. Reluctance on the part of participants in carrying out exercise instructions in the absence of the researcher and presentation of self for routine sonography checks posed serious challenge to accurate data collection.Paucity of fund also contributed to some of the inadequacies and challenges experienced in this research.In all this study cannot be said to be exhaustive and so efforts should be made towardsengaging more number of subjects and exploring other useful methods in future.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

Pregnancy imposes significant morphological alteration on theabdominal muscles, with implications for the functional capacity of women during the postpartum period. One of such alterations is diastasis recti abdominis (DRA). In order to restore their figure and fitness during the postpartum period, many women continue, or begin abdominal strengthening exercise programmes. In the clinical setting, it appears that abdominal muscle strengthening exercises are recommended during the postpartum period usually as a matter of routine. Knowledge about the effects of specific exercise type on postpartum abdominal muscle morphological changes is required in order to develop specific abdominal strengthening exercise programmes for fitness, functional and morphological recovery in postpartum women. Most prescription of abdominal exercise programmes in the postpartum period especially in our environment appears not based on evidence buttressed on the fact that very little literature exists about the effects of exercise on abdominal muscle morphology during and after pregnancy. The studies were therefore conceived to assess the effects of these different therapeutic abdominal exercises (isotonic, isometric and combined) on the abdominal morphology of postpartum women using abdominal retraction and IRD closure as the primary outcome measures.

The literature review highlighted critical literatures on postpartum exercises. The physiological changes during pregnancy as well as the influence of therapeutic exerciseswere appraised. Evidences for the benefit of exercise during pregnancy were reviewed while throwing more lights on the recommendation of exercise in pregnancy and thereafter.

Muscle morphology and functional basis of therapeutic exercises were also reviewed. Important contraindications to exercise as well as forms of exercise in the postpartum period were also assessed. Finally, the effects of isotonic, isometric and combined (isotonic and isometric) contraction ofpostpartum abdominal muscles were equally evaluated.

The study used a single blindedrandomized control trial design. Ethical approval was sought and obtained from the Ethics and Institutional Review Committee of Federal Teaching Hospital Abakaliki before commencement of the study. Informed consent was obtained from each of the subjects prior to investigation. Simple random selection was used to select participants, who were subsequently randomly assigned to any of the four groups (isotonic, isometric, combined and control), as well as the two DRA experimental and control groups. The abdominal retraction and IRD closure were assessed pre and post treatment for the six and four consecutive weeks period of the trial. A total of 60 and 15 postpartum mothers, respectively of age range of 18 to 48 years and a mean age of 28.48 ± 5.79 years, and29 to 44 years, and mean age of 36.7 ± 2.76 participated in this study. Data was analysed using descriptive statistics as well as analysis of variance (ANOVA) andrepeated measure ANOVA. Post hoc bonferoni tests were used to determine points of difference between and within groups. Level of significance was set at $p < 0.05$, with 95% confidence interval.

A total of 60 recently delivered mothers were recruited for the part one of this study they comprised of 29(48.4%) primigravids and 31 (51.6%) multigravids. The participants were within the age range of 18 to 48 years, with a mean age of 28.48 ± 5.79 years. There was no significant difference ($p > 0.05$) in the mean abdominal retraction at baseline ($F = 1.098$, $p = 0.358$), first week ($F = 0.699$, $p = 0.557$) and second week ($F = 0.395$, $p = 0.757$) across the groups. However, there was a significant difference ($p < 0.05$) in the mean abdominal retraction across the groups at the third week ($F = 3.113$, $p = 0.033$), fourth week ($F = 4.646$, $p = 0.006$), fifth week ($F = 9.328$, $p = 0.000$) and sixth week ($F = 11.940$, $p = 0.000$). There were significant differences ($p < 0.05$) across the time series for all the groups: Isometric group ($F = 30.188$, $p = 0.001$), Isotonic group ($F = 27.419$, $p = 0.001$), combined group ($F = 15.921$, $p = 0.001$) and Control group ($F = 21.217$, $p = 0.001$).

In the second study, a total of 30 multigravid mothers of ages 29 to 44 years and mean age of 36.7 ± 2.76 were involved.The inter-recti distanceclosure performance with time was found to be statistically significant ($F > 2.61$, $p < 0.05$).Test of between subject effects for both upper and lower inter-recti distance was not significant and so was the difference in closure effect between the upper and lower margins of the umbilicus ($F < 4.68$, $p > 0.05$). Paired sample test between upper and lower IRDs also had no significant difference ($t < 2.145$,$p > 0.05$)

Comparison of variables in the experimental group showedno significant relationship between age and closure at the upper and lower abdomen ($r < 0.514$, $p > 0.05$). There was also no significant relationship between number of pregnancies and closure at the upper and lower abdomen ($r < 0.514$, $p > 0.05$).Significant relationship exists between closure at the upper abdomen and closure at the lower abdomen ($r > 0.514$, $p < 0.05$), closure of which higher at the upper than lower abdomen.There was statistical significance in the mean difference of inter-recti distance closure between experimental and control groups, which is in favour of the former.

Twenty three subjects who went through abdominal isometric exercises were considered in respect to their recti diastasis resolution scores from baseline through to fourth week of exercises. The result showed that significant resolution ($p< 0.05$)occurred when baseline was compared with the fourth week of exercise. However, only marginal differences occurred between baseline and first week, first week and second week, and second week and third week. There was no significant mean resolution difference ($p> 0.05$)between the baseline and any of the first to third week.

Gravid status was also found to have influence on recti diastasis closure using isometric abdominal exercises as method of intervention.While inter-recti distance resolution value between multiparity of wmen with two previous pregnancies and those of three was not statistically significant ($p> 0.05$), two compared to four and five show significant resolution difference ($P < 0.05$) of varying degrees, at 2.5cm above the umbilical ring. Multiparty of four compared to five showed no statistical significance ($p> 0.05$). At2.5cm below the umbilical ring multiparity of two compared with three was also not statistically significant ($P> 0.05$) whereas the resolution in multigravida of two in relation to four and five were significant ($p < 0.05$) In other words women with fewer number of previous pregnancies had higher inter-recti gap resolution than their counterparts who recorded numerous pregnancies.

Comparison of mean age of subjects in the exercise group with recti diastasis resolution also revealed significant inverse relationship. At the two points 2.5cm above and below the umbilical ring the outcome indicated significant relationship with age. This result shows that age was negatively related with inter-recti distance resolution. Postpartum women in their twenties had better closure compared with those in their thirties and forties. However there was no difference in the pattern and rate of resolution between women at thirties compared to those in their forties using post hoc analysis.

5.2 Conclusions

Based on the outcome of the studies, the following conclusions were drawn:

i. Isotonic abdominal strengthening exercises are more effective than the isometric type but less than the combined effects of both in achieving mean retraction index (RIÓ50%) of the abdominal muscle contractile status.

ii. Significant effects of abdominal strengthening exercises should be expected from the third week of the exercise protocol, especially when combined isotonic/isometric muscle exercises is the choice treatment.

iii. Primigravids respond more readily to abdominal strengthening exercises than the multigravid women.

iv. Isometric exercise can improve the recovery of diastasis recti abdominis, especially when sustained for a long period of time, and this can improve abdominal muscle strength and function.

v. Approximation of inter-recti distance under the influence of exercise protocol should be expected to commence at about the second week of the programme.

vi. Closure rate of inter-recti distance between the upper and lower margins of the umbilical ring follow similar pattern, but slightly higher in the upper margin.

vii. Age and number of previous pregnancies are important factors to consider when expecting timelyrecovery from diastasis recti abdominis in postpartum women.

5.3 Recommendations

Based on the findings from these studies, the following recommendations are made:

i. Clinicians should integrate combination of isometric and isotonic exercises with emphasis on the isotonic components in their exercise protocol involved in strengthening abdominal muscles during postnatal exercise classes.

ii. Clinicians may prognosticate therapeutic effects of abdominal strengthening exercises of postpartum mothers from third week. There is therefore need for the clients to be encouraged that expected effects may not be instantaneous.

iii. In order to achieve maximum benefit, it may also be pertinent to explore individualized exercise therapy programme for postpartum women since their abdominal muscle response to therapeutic exercises in time, may differ from person to person.

iv. Further randomized clinical trials utilizing additional outcome measures such as electromyography results of the abdominal muscles would give additional information.

v. Clinicians should integrate isometric exercises in the intervention plan for the management of diastasis recti abdominis, so as to facilitate timely reduction in size and eventual resolution of inter-recti distance in postpartum women.

vi. Treatment plan for diastasis recti abdominis should be assigned sufficient time in order to achieve maximum benefit of programmed exercises.

vii. It is necessary for care givers to consider the age and number of pregnancies of clients when planning therapeutic exercise programme as method of intervention for recti diastasis in postpartum women. This will ensure accurate application of modalities and resultant maximum benefit.

viii. Further research on diastasis recti abdominis management is essential to explore the efficacy of other available intervention methods, involving more subjects and extending the intervention time.

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Appendix I

Raw data of the inter-recti distance (IRD) Study
Experimental (Isometric) group

S/No	Subject	age Yrs.	No of Preg.	Initial measurement (cm.) UP /DN	Wk 1 (Cm) UP / DN	Wk 2 (Cm) UP /DN	Wk 3 UP /DN	Wk 4 (Cm) UP / DN
1.	OA	36	4	5.1/5.4	3.8/3.5	3.5/3.5	2.8/22.7	2.6/2.0
2.	TM	29	3	3.4/4.0	3.4/3.8	3.1/3.7	3.1/3.5	2.7/2.9
3.	MO	38	5	6.6/5.1	6.1/5.0	5.7/4.2	5.7/4.0	5.1/3.7
4.	AC	42	3	5.3/5.4	51/4.9	4.7/4.2	4.2/4.1	3.8/4.00

5.	JC	39	4	7/7	7/7	6.8/6.9	6.5/6.3	6.5/6.1
6.	SA	40	5	5.9/5.8	5.2/5.6	5.3/5.1	4.8/4.6	4.4/4.5
7.	TU	35	4	8.0/8.2	7.7/7.9	7.1/7.6	6.6/7.00	6.6/7.00
8.	OC	28	3	2.3/2.3	1.9/1.8	1.4/1.2	1.2/1.1	0.9/0.9
9.	KO	27	2	3.3/3.0	3.3/3.0	2.9/3.0	2.5/2.7	2.1/2.4
10.	RE	38	4	4.8/4.3	4/3.8	3.7/3.5	3.1/2.9	2.6/2.9
11.	MO2	41	2	2.6/3.4	2.6/3.2	2.0/3.1	2.0/2.5	1.6/2.0
12.	RO	27	3	4.0/3.6	3.7/3.1	3.2/2.9	3.0/2.2	2.7/1.9
13.	SA2	40	3	5.1/5.0	4.8/5.0	4.1/4.7	3.5/4.0	2.7/1.9
14.	KA	29	2	3.1/3.4	3.0/3.1	2.8/2.6	2.0/2.1	1.6/1.8
15.	TU2	44	5	4.6/4.1	4.5/4.0	4.0/3.8	3.6/3.4	3.0/3.1
16.	KAK	32	3	3.1/2.9	3.0/2.9	2.6/2.2	2.0/1.8	1.4/1.2
17.	MA	30	3	4.6/4.2	4.1/3.9	3.8/3.8	3.4/3.3	3.0/2.8
18.	UK	36	4	3.6/3.5	3.3/3.1	2.9/2.7	2.6/2.6	2.1/2.0
19.	MM	32	3	2.8/2.8	2.5/2.7	2.1/2.3	2.0/2.1	1.6/1.8
20.	AJ	29	2	3.6/3.4	3.2/3.1	2.7/2.9	2.2/2.2	1.8/2.0
21.	AT38		3	4.1/4.0	3.6/3.6	3.3/3.2	2.8/2.8	1.6/1.4
22.	MAC35		4	3.9/3.7	3.5/3.5	3.4/3.5	3.0/3.3	3.0/3.2
23.	EC	40	3	3.5/3.2	3.1/3.0	2.8/2.7	2.2/2.2	2.0/2.2

Appendix II

Raw data of the inter-recti distance (IRD) Study
Control group

S/No	Subject	Age Yrs.	No of Pregnancy	Initial (cm.) measurement UP / DN	Wk 1 (Cm) UP /DN	Wk 2 (Cm) UP /DN	Wk 3 (Cm) UP/ DN	Wk 4 (Cm)
1.	AC	36	4	3.3/3.2	3.3/3.2	3.3/3.2	3.2/3.2	3.2/3.2
2.	ME	44	5	8/3.1	8.1/8.1	8.1/8.1	8.00/7.9	8.0/7.9
3.	JU	40	6	6.8/6.8	6.8/6.8	6.8/6.5	6.6/6.5	6.6/6.5
4.	UM	29	3	3.3/3.7	3.8/3.5	3.6/3.5	3.5/3.5	3.5/3.4

5.	NO	32	4	4.1/4.0	4.2/4.0	4.1/4.0	4.1/4.0	4.0/4.0
6.	MC	43	4	5.4/5.4	5.5/5.4	5.5/5.5	5.4/5.4	5.3/5.4
7.	JU	39	5	2.2/2.2	2.1/2.2	2.0/2.0	2.0/2.0	2.0/2.0

APPENDIX III

INFORMED CONSENT FORM

Research Topic: Evaluation of Isotonic, Isometric and Combined Exercises in the Restoration of Abdominal Muscles Tone and the Implication of Isometric Contraction in the Reduction of Inter- Recti Distance in Postpartum Women at Abakaliki, Ebonyi State, Nigeria

Introduction: My name is Igwe Sylvester Emeka, an academic staff of the department of medical Rehabilitation Faculty of Health Sciences and Technology, College of Medicine, University of Nigeria, Enugu.

Nature of Research and Voluntary Participation: This is a Ph.D. research, meant for postnatal women who have gone through at least two pregnancies. Participation in the research is entirely voluntary. You have the right to withdraw consent and discontinue your participation at any given time without prejudice to your chance of participation in any future research.

Procedure: You will be required to make yourself available for and carry out structured abdominal exercises before and after which measurements are done with a myotape device or ultrasound imaging unit, depending on which group you may belong. This is to check how fast and to what extent your abdominal muscles could return back to shape and strength after delivery.

Risk: These exercise procedures and measurement techniques are non-invasive and present no harm or injury. However, you can become exhausted during an elongated exercise period, the reason for which there are resting intervals.

Confidentiality: Please note that your name will not be written on the data table, neither will it be used in connection with information obtained from you. This implies that strict confidentiality is observed.

Feedback: In case of any further clarification, feel free to contact me using the following media:Telephone: 0803706082, e-mail: esigwe1@yahoo.com.

Response: This research process has been well explained to me and the contents are fully understood. I am willing to participate in the study as described above.

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Participant **Researcher**

Name/Sign/Date Name/Sign/ Date

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Witness

Name/Sign/ Date