Musculoskeletal Health in Women: Impact of Stress, Aging, and Pregnancy

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Presentation Overview

- History & Definitions
- Sex Differences in Muscle Function
  - Impact of stress on sex differences
  - Impact of Aging on sex differences
  - Discussion of Clinical Importance
- Pregnancy & Postpartum
  - Physiological Changes
  - Common PT related issues
  - Clinical Assessment of pregnancy related PGP
  - Abdominal Muscle Function & Pain Perception after Pregnancy
  - Discussion of Clinical Importance

History

- Women have historically been excluded from clinical research due to “greater biological complexity”
- Many health care findings from research conducted on men have been generalized to be applicable to women
- 1990: NIH established a policy stating that women should “commonly” be part of medical and behavioral research
- 2012: The journal Endocrinology mandated that methods sections must disclose the sex of subjects studied (whether human, animal or cell cultures) (Blaustein Endocrinology, June 2012, 153(6):2539–2540)
- 2015: NIH issued the announcement “Consideration of Sex as a Biological Variable in NIH-funded Research”
“Sex” vs. “Gender”

• Sex: biological differences (reproductive organs, chromosomes)

• Gender: a “complex psychological, environmental, sociocultural, and political framework that encompasses the characteristics ascribed to each sex that are generally accepted and influenced by society.” (M. Racine et al 2012)

Skeletal Muscle Strength

• Voluntary activation: ability of the nervous system to drive the muscle

• Muscle cross-sectional area: number of muscle fibers and sarcomeres in parallel

Muscle Strength and Fatigue

An acute, exercise-induced reduction in the force or power of a muscle (Gandevia, 2001; Enoka and Duchateau 2008).
**Muscle Function:**

Strength, Fatigability and Steadiness

- **Strength:**
- Muscle Fatigue: reduction in strength and time to task failure
- Steadiness: force fluctuations

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**Sex Differences in Research of Muscle Function and Fatigability**

Disproportionate testing of men compared with women or the under-reporting of sex effects can mask an understanding of relevant sex differences in fatigability and performance.

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Sex Differences in Skeletal Muscle Function

- Muscle Mass & Strength
  - Men have more muscle mass than women, thus are usually stronger
  - When strength is normalized to muscle mass, the sex difference in strength is negligible
  - Greater muscle mass and higher force levels are usually associated with greater fatigability during sustained isometric contractions
    - Greater compressive force generated by larger muscle mass can impair muscle perfusion and clearance of metabolic byproducts

Hunter SK Acta Physiologica 2014
Sex Differences in Fatigability

Static Contractions

- Adductor Pollicis
- Finger Flexors
- Elbow Flexors
- Elbow Extensors
- Neck Muscles
- Back Extensors
- Knee Extensors
- Ankle Dorsiflexors

Women more fatigue resistant than men

>55 studies

Adductor Pollicis
Finger Flexors
Elbow Flexors
Elbow Extensors
Neck Muscles
Back Extensors
Knee Extensors
Ankle Dorsiflexors

Slide courtesy of Dr. Sandra Hunter, PhD

Hunter SK. Acta Physiologica 2014

Fatigability of the elbow flexor muscles for a sustained submaximal contraction is similar in men and women matched for strength.

Men: 803 g ± 306 s
Women: 664 g ± 391 s

P > 0.05

Men are more fatigable than strength-matched women when performing intermittent submaximal contractions.
Association Between Trunk Flexor Strength and Trunk Flexor Fatigability

Impact of Stress on Fatigability
Sex Differences in Muscular Response to Unloading

- Women have greater loss of total volume of muscle and fiber area, especially for type II fibers.
- For 30 days of unloading, women demonstrate more significant decline in strength as compared to men.
- With short term unloading, women show more dysfunction in neural activation.
- Women may require greater recovery time than men following unloading.

Summary of Sex Differences

- Women are often weaker and less fatigable
  - Results are task- and muscle-dependent!
- Women show greater decline in time to task failure with cognitive stress
- Women demonstrate greater deterioration of control of force with cognitive stress
- Women are more susceptible to disuse impairments (atrophy, neural activation deficits) and require greater recovery time
Possible Mechanisms for Sex Differences

Contractile Properties

- Women have slower muscle
- Women tend to have more Type I muscle fibers than men
- Women have slower SR Ca2+ kinetics
  - ATPase activity
  - Uptake into SR
Muscle Metabolism

- High force isometric contractions: men demonstrate greater glycolysis
- High intensity sprint exercise: women have lower accumulation of lactate, greater preservation of ATP
- Moderate/high intensity exercise (whole body): women oxidize more fat and less CHO
  - Muscle lipoprotein lipase, membrane fatty acid transport protein-1, FAT/CD36 protein, and citrate synthase levels are higher in women
  - Not dependent on level of training or age
  - Capacity for fat metabolism is associated with estrogen

Sex Hormones

- Conflicting evidence regarding influence of menstrual cycle on skeletal muscle performance
  - Strength and fatigability of isometric contractions do not appear to be altered by day of menstrual cycle
  - Birth control/menstrual cycle can impact metabolism, to a small degree, during long duration exercise
    - Impact is more profound when climate is hot/humid

CNS Function

- Women demonstrate higher activation of the cortex (IL & B) during finger tapping or when preparing to reach, while men demonstrate higher activity in subcortical areas (ex: basal ganglia)
"Normal" Aging

- Loss of muscle mass
  - Selective atrophy of Type II fibers
  - Loss of alpha motor neurons
  - Collateral sprouting
  - Instability of neuromuscular junction
  - Infiltrated by fat and fibrotic tissue
- More susceptible to negative effects of inflammation (Gheller et al. 2016)
- Greater variability in motor performance
- Decreased strength and power
- Altered fatigability
  - <75 years old typically LESS fatigable for isometric contractions
  - >75 years old typically MORE fatigable for isometric contractions
  - Old and very old MORE fatigable with high velocity dynamic contractions

Hunter, Pereira, Keenan 2016
Sex Differences with Age

- Women lose skeletal muscle mass at a slower rate than men (Gheller et al. 2016)
- Women have a 2.5x more fatty infiltrate in quads (Ponseti et al. 1991)
- Women have lesser loss of strength than men (~50%) (Gheller et al. 2016)
- Likely due to men having greater strength than women
- Old women have less loss of strength during eccentric muscle activations than old men.
  - Function of "slower cross-bridge kinetics, an increased proportion of weakly-bound compared with strongly-bound cross-bridges, and a stiffer musculotendinous complex" (Hunter, Pereira, Keenan 2016)
- Old women demonstrate greater fatigability with both low and high cognitive demand (Pereira 2015)
  - Mechanisms not fully understood at this time
Discussion

• Why is fatigability important?
• Why are sex differences important?
• Clinical implications of impact of stress on performance?
• Clinical implications of impact of aging on performance?
• Other clinical insights from the group?

References

• Blaustein JD. Animals Have a Sex, and so Should Titles and Methods Sections of Articles in Endocrinology. Anatomy & Endocrinology 2012; June, 153(6): 2539-2540.
• Hunter et al. Men are more fatigable than strength-matched women when performing intermittent submaximal contractions. J Appl Physiol 2009; 106: 2125-2132.

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Pregnancy & Postpartum

http://www.xsight.com.au
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Hormonal Changes

- Estrogens
  - Levels increase
    - Estradiol, estrone, estriol
  - Facilitate growth of the uterine muscle
  - Cause the ligaments of the pelvis and the pubic symphysis to become softer and more lax
  - Contribute to growth of milk ducts
  - Boost release of prolactin from mother’s pituitary gland
  - Increases creation of progesterone
  
  Chearskul 2006

Hormonal Changes

- Progesterone
  - Increases
  - Necessary for implantation and successful maintenance of pregnancy
  - Maintains lining of the uterus and facilitates production of nutrients to sustain zygote early in pregnancy
  - Triggers production of prolactin
  - Used by fetal adrenal gland to produce cortisol and aldosterone
  - Decreases uterine muscle excitability
  - Increases mother’s respiratory rate to offset increased CO₂ produced by heightened metabolic demand

Chearskul 2006
Hormonal Changes

• **Relaxin**
  - Increases
  - “decreases uterine muscle contractility by reducing the activity of uterine myosin kinase”
  - Softens the cervix and causes pelvic joint laxity
  - Boosts activity of collagenase enzyme
  - May also have renal effects
    - “renal vasodilation, hyperfiltration, and reduced myogenic activity of small renal arteries”

Chearskul 2006

Hormonal Changes

• **Insulin**
  - 1st half of pregnancy: Mom has greater sensitivity to insulin
  - 2nd half of pregnancy: Mom is in state of insulin resistance
  - Shift to fat metabolism for Mom
  - More plasma glucose and AA which facilitates uptake by the placenta to fetus
  - Estrogens, progesterone, placental growth hormone, and cortisol also influence insulin resistance
  - Gestational Diabetes occurs in ~4% of pregnancies

Hormonal Changes

• **Prolactin**
  - Progressive increase throughout pregnancy
  - Regulates fat metabolism

• **Renin Angiotensin System**
  - Increased Na+ retention
  - Contributing factor to development of preeclampsia

Chearskul 2006

Hormonal Changes

• **Elevated cortisol**
  - Facilitates fat storage in Mom
  - Stimulates development of mammary glands
  - Increased thyroid hormones and ACTH from pituitary

Chearskul 2006
Stretch of the Abdominal Wall

- Growing fetus = growing uterus = abdominal wall expansion
- Hypertrophy of type I fibers & increased proportion of type I fibers shown in animal studies (Lalatta Costerbosa et al 1988)

Physical Activity

- ACOG guidelines
  - Advocate the CDC recommendation of “150 minutes of moderate-intensity aerobic activity every week”.
  - Contraindications to exercise
    - “Certain types of heart and lung diseases”
    - Incompetent cervix
    - Multiple gestation
    - Risk factors for preterm labor
    - Placenta previa (after 20 weeks)
    - Preterm labor/rupture of membranes
    - Preeclampsia
    - Severe anemia

- Benefits of Exercise
  - Decreased back pain
  - Combats constipation
  - “May decrease risk of gestational diabetes, preeclampsia, and cesarean delivery”
  - Maintain healthy weight
  - General cardiovascular benefits
  - “Helps you lose the baby weight after your baby is born”
  - Advocate continued exercise after delivery to decrease risk of DVT and to manage weight

http://www.acog.org/Patients/FAQs/Exercise-During-Pregnancy

The Physical Activity Problem

- 68% of pregnant women report decreased physical activity
- 80% of postpartum women report significant decline in physical activity level

[Image of woman exercising]

[Image of baby in stroller]

(Cottle 2011)
Big Picture Impact on the Musculoskeletal System

- Ligamentous laxity
  - Pelvis
  - Wrists
- Decreased fascial integrity
  - DRA
  - Impaired force transfer
    - Brown & McGill study
    - Gracovetsky 2008
- Fiber type shift?
  - Animal studies

Definition of Pelvic Girdle Pain

- Location: between posterior iliac crest and gluteal fold
  - SIJ
  - Pubic symphysis
  - Posterior thigh
- Symptoms: decreased tolerance of sitting, standing, walking
- Confirmed by:
  - Ruling out lumbar spine as pain generator
  - Reproduction of symptoms with the following tests:
    - Posterior Pelvic Pain Provocation test (P²)
    - Patrick’s FABER
    - Palpation of long dorsal ligament
    - Gaenslen’s Test
    - Modified Trendelenburg Test
    - Palpation of pubic symphysis
    - Active Straight Leg Raise (ASLR) Test

Prevalence & Impact of PGP

- Prevalence in pregnant women: 20-23% (Albert 2000)
  - 50-75% if include LBP (Wu 2004, Wang 2004, Kristiansson 1996)
- Long term concerns:
  - 25% of pregnant women with PGP will continue to have pain in the postpartum period (Ostgaard et al 1996, Albert et al 2001, Wu et al 2004)
  - 20% of women will avoid a future pregnancy due to severe PGP (Brynhildsen 1998)
  - Worldwide, 1 in 4 women have chronic pelvic pain (Nygaard et al 2008)
Clinical Assessment of PGP in Pregnancy

- Posterior Pelvic Pain Provocation test (P4)
- Patrick’s FABER
- Palpation of long dorsal ligament
- Gaenslens Test
  - Modified Trendelenburg Test
  - Palpation of pubic symphysis
  - Active Straight Leg Raise (ASLR) Test

Posterior Pelvic Pain Provocation (P4)

- Patient supine on plinth
- Hip flexed to 90 degrees, knee relaxed
- Stabilize CL pelvis
- Downward pressure through long axis of femur
- Positive test: reproduction/exacerbation of posterior pelvic pain
  - 0 = no pain
  - 1 (mild) = complaint of pain without physical manifestation of pain
  - 2 (moderate) = complaint of pain with physical manifestation of pain
  - 3 (unbearable) = unable to complete test due to patient withdrawal

Patrick’s FABER

- Patient supine on plinth
- Leg brought into Flexion, Abduction, External Rotation
- Gentle overpressure applied at end-range ("forced FABER")
- Positive Test: reproduction/exacerbation of posterior pelvic pain (SII) or pubic symphysis
Palpation of long dorsal SIJ ligament

- Patient in sidelying with slight hip and knee flexion
- Position in prone for postpartum women
- Palpate along length of the ligament
- Positive test: Provocation/exacerbation of pain
  - 0 = no pain
  - 1 (mild) = complaint of pain without physical manifestation of pain
  - 2 (moderate) = complaint of pain with physical manifestation of pain
  - 3 (unbearable) = unable to complete test due to patient withdrawal

Gaenslens Test

- Two options for positioning (modify for pregnancy)
- One leg in flexion, CL leg brought into extension, mild overpressure on both legs
- Positive test: reproduction/exacerbation of posterior pelvic pain (especially SIJ) on side of extended leg

Modified Trendelenburg Test

- Patient in standing
  - PT stands behind patient
- One leg brought into flexion
- Positive test: pain in pubic symphysis.
  - Drop of pelvis CL to stance leg (functional hip weakness)
Palpation of Pubic Symphysis

- Patient can be in supine, semi-reclined, sidelying
- Clinician palpates pubic symphysis
- Positive test: Reproduction/exacerbation of pain at pubic symphysis

Albert et al. 2000

Active Straight Leg Raise (ASLR) Test

- Patient supine on plinth with legs extended
- Raise one leg at a time (heel height of 20 cm)
- Patient rates difficulty
  - 0 = not difficult at all
  - 1 = minimal difficulty
  - 2 = somewhat difficult
  - 3 = fairly difficult
  - 4 = very difficult
  - 5 = unable to lift leg off plinth
- If difficulty is rated above a zero, therapist provides manual compression to the pelvis and the test is repeated
- Positive Test: Decrease in reported difficulty with manual pelvic compression

Mensa 2012

Treatment

- We recommend individualized exercises in pregnancy.
- We recommend an individualized treatment program, focusing specifically on stabilizing exercises for control and stability, as part of a multifactorial treatment postpartum.
- We recommend intra-articular SIJ injections (under imaging guidance) for anklyosing spondylitis.
- Prescribe medication, if necessary, for pain relief (excluding pregnant women) preferably to be taken at regular intervals; first choice paracetamol, second choice NSAIDs.
- Give adequate information and reassure the patient as part of a multifactorial treatment
Abdominal Muscle Function in Postpartum Women

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The Abdominal Muscles Are Essential

- Synergists of Pelvic Floor Muscles
- Assist with breathing
- Regulate Intra-Abdominal Pressure
- Essential for lumbopelvic stability
“The Core”
- Middle of the kinetic chain
- Link between the upper and lower extremities
- Transfer of energy from upper to lower extremities (Kibbler 1998)

Labor and Delivery: Core Disruption
- Vaginal delivery
- Cesarean delivery

Traditional Postpartum Visit in the US
- Pelvic Exam
- Assessment of uterine involution
- Assessment of soft tissue healing
  - Perineum
  - Surgical site
- Pap Smear
- Discussion regarding birth control

6 Weeks Postpartum
Abdominal dysfunction has not been well quantified

- Not much research on effects of pregnancy has been done on human subjects
- Strength/force testing that has been done on humans is not very objective
- Most abundant abdominal muscle research focuses on presence and degree of Diastasis Recti Abdominis (DRA)

"Common" is often dismissed as "normal"

Research Questions

- Does function of the abdominal muscles change after pregnancy?
  - Force production
    - Trunk flexion
    - Torque-Angle Curve
  - Fatigability

- What factors contribute to function of the abdominal muscles after pregnancy?
  - Mode of delivery
  - DRA
  - Activity level
  - Pain
  - Body composition
  - Muscle thickness
  - Muscle activation
  - Time since delivery
Hypotheses

- In comparison to controls, postpartum women will:
  - Demonstrate decreased strength during a maximal voluntary isometric trunk flexion contraction
  - Be more fatigable, as evidenced by a shorter time to task failure
  - Have thinner rectus abdominis muscles
  - Report decreased physical activity
- Over the course of 16 weeks:
  - Postpartum women will demonstrate an improvement in strength and fatigability, but will remain weaker and more fatigable than control women

Protocol: Laboratory Measures of Strength and Fatigability

Protocol: Clinical Measures of Strength and Fatigability
Protocol: Laboratory Measure of Muscle Thickness

RESULTS

Initial Time Point (8-10 weeks postpartum): 15 Control (25.3 ± 5.2 years), 29 Postpartum (31.4 ± 5.2 years) women
Follow Up Time Point (24-26 weeks postpartum): 14 Control (25.4 ± 5.8 years), 28 Postpartum (32.0 ± 5.1 years) women

Postpartum Women (8-10 Weeks PP): 18 vaginal delivery, 11 Cesarean Delivery
Postpartum Women (24-26 Weeks PP): 17 vaginal delivery, 11 Cesarean Delivery

Body Composition
Physical Activity
Inter-Recti Distance
**Inter-Recti Distance Measured with Ultrasound**

- **Position (relative to umbilicus):**
  - 4 cm above
  - 2.5 cm above
  - 2.5 cm below
  - 4 cm below

<table>
<thead>
<tr>
<th>Distance (cm)</th>
<th>Control</th>
<th>Postpartum</th>
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<tbody>
<tr>
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<td>3.5</td>
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</table>

- **Control n=16, Postpartum n=19**
- **Position p<0.001**
- **Position x Group p=0.025**
- **Group p<0.001**

**Pain Testing**

- **Pressure Pain Threshold**
  - Nailbed of Left Middle Finger
  - **Postpartum Control**
    - Threshold (KPa)
      - 0
      - 50
      - 100
      - 150
      - 200
      - 250
      - 300

- **Lower Abdomen (Site of Pfannenstiel Incision)**
  - **Postpartum Control**
    - Threshold (KPa)
      - 0
      - 50
      - 100
      - 150
      - 200
      - 250
      - 300

**INITIAL**

- Pain Testing

**FOLLOW UP**

- Pain Testing

- **Pressure Pain Threshold**
  - Nailbed of Left Middle Finger
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      - 50
      - 100
      - 150
      - 200
      - 250
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      - 50
      - 100
      - 150
      - 200
      - 250
      - 300
Functional Tests

**Change in Pressure Pain Threshold From Before to After Exercise**

**Upper Abdominal Site**

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<th>PreEx</th>
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<tr>
<td>Group p=0.005</td>
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**Six Minute Walk Test Performance**

**Initial**

- Postpartum: [Data]
- Control: [Data]

**Follow Up**

- Postpartum: [Data]
- Control: [Data]
Strength

Hand Grip Strength

Grip Strength (lbs)

Right Left

0 20 40 60 80 100

Postpartum

Control

INITIAL

FOLLOW UP

Trunk Flexor Strength

Maximum Voluntary Isometric Contraction

Pre-Fatiguing Exercise

Torque (Nm)

0 10 20 30 40 50 60

Manual Muscle Testing Strength Grade

Strength Grade

0 1 2 3 4 5

Postpartum

Control

* **
Torque Angle Curve

Torque-Angle Curve of the Trunk Flexor Muscles

Position (degrees) -50 -40 -30 -20 -10 0 10 20 30

Torque (Nm) 0 20 40 60 80 100

Postpartum

INITIAL Control n=13, Postpartum n=28
Position p<0.001
Position x Group p=0.927
Group p=0.003

Fatigue Task

FOLLOW UP
Control n=16, Postpartum n=25
Position p<0.001
Position x Group p=0.909
Group p=0.003

Torque-Angle Curve of the Trunk Flexor Muscles

Position (degrees) -50 -40 -30 -20 -10 0 10 20 30

Torque (Nm) 0 20 40 60 80 100
Fatigability of the Trunk Flexor Muscles

Impact of Method of Delivery

Recovery of MVC Torque After Fatiguing Exercise
**Impact of Method of Delivery**

Trunk Flexion MVC Recovery
Vaginal vs Cesarean Delivery

6 Months Postpartum

<table>
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<tr>
<th>Time (Minutes)</th>
<th>Task Failure</th>
<th>MVC Torque (% Baseline MVC)</th>
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Cesarean Delivery
Vaginal Delivery

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<th>Time (Minutes)</th>
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<th>MVC Torque (% Baseline MVC)</th>
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**Recovery of MVC Torque After Fatiguing Exercise**

Task Failure r10 r20 Baseline

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</table>

Control n=15, Postpartum n=26
Time p<0.001
Time x Group p<0.001
Group p=0.001

**Recovery of MVC Torque After Fatiguing Exercise**

FOLLOW UP

<table>
<thead>
<tr>
<th>MVC Torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
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<tr>
<td>30</td>
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<tr>
<td>40</td>
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<tr>
<td>50</td>
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<tr>
<td>60</td>
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</tbody>
</table>

Control n=13, Postpartum n=27
Time p<0.001
Time x Group p=0.248
Group p<0.001

**Steadiness of contraction**
Correlations

Association Between Maximal Strength and Fatigability of the Trunk Flexor Muscles

INITIAL

FOLLOW UP

N=44

N=42

r=0.602
p<0.001

r=0.415
p=0.006
Association Between Trunk Flexor Fatigability and Body Fat Percentage (DXA)

**INITIAL**

- Time to Task Failure (s)
- Body Fat (%)
- $r = -0.342$
- $p = 0.023$
- $N = 44$

**FOLLOW UP**

- Time to Task Failure (s)
- Body Fat (%)
- $r = -0.402$
- $p = 0.008$
- $N = 42$

Association Between Trunk Flexor Fatigability and Inter-Recti Distance at 4 cm Below the Umbilicus (Measured with Ultrasound)

**INITIAL**

- Time to Task Failure (s)
- Inter-Recti Distance (cm)
- $r = -0.346$
- $p = 0.031$
- $N = 39$

**FOLLOW UP**

- Time to Task Failure (s)
- Inter-Recti Distance (cm)
- $r = -0.405$
- $p = 0.011$
- $N = 40$

Association Between Trunk Flexor Maximal Strength and Thickness of Right Rectus Abdominis Muscle at 2.5 cm Above the Umbilicus (Measured with Ultrasound)

- Maximal Strength (Nm)
- Muscle Thickness (cm)
- $r = 0.311$
- $p = 0.040$
- $N = 44$

- Maximal Strength (Nm)
- Muscle Thickness (cm)
- $r = 0.388$
- $p = 0.012$
- $N = 41$
Association Between Trunk Flexor Maximal Strength and Clinical Assessment of Abdominal Muscle Strength (Manual Muscle Testing)

MVC Strength (Nm)

0 20 40 60 80 100 120

MMT Strength Grade

0 1 2 3 4 5

r=0.532
p<0.001
N=43

Association Between Trunk Flexor Maximal Strength and Clinical Assessment of Abdominal Muscle Strength (Manual Muscle Testing)

MVC Strength (Nm)

0 10 20 30 40 50 60 70 80

MMT Strength Grade

0 1 2 3 4 5

r=0.621
p<0.001
N=38

Discussion

• Clinical implications of pregnancy & postpartum?
• Other clinical insights

References

References


