THE ROLE OF BREAST SIZE DURING PROLONGED STANDING: AN EVALUATION OF BIOMECHANICAL, PAIN DEVELOPMENT, AND PSYCHOSOCIAL FACTORS

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Abstract

Women with larger breasts have been found to have greater kyphosis and lordosis angles than women with smaller breasts. The purpose of this study was to investigate whether breast size is related to muscle activation, posture and pain development over a 2-hour prolonged standing exposure and psychosocial metrics.

Twenty-one university aged females with various breast sizes (B-E cup) completed the study. Mean muscle activation, spine angles, pain scores and psychosocial related questionnaire data were collected. Breast size was not found to affect mean muscle activation and spine angles. However, a greater number of larger sized group developed clinical levels of pain than smaller breasted women. Larger breasted women also develop pain earlier than smaller breasted women in the upper and mid back and showed a strong correlation between psychosocial factors and increasing breast size.

This work highlighted the importance of considering breast size, biomechanics and psychosocial measures together.

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List of Abbreviations

3D:	Three dimensional
AHAbd:	Active Hip Abduction
ANOVA:	Analysis of Variance
BMI:	Body Mass Index
BSQ:	Body Shape Questionnaire
EMG:	Electromyography
EO:	External Oblique Muscle (R/L ahead of abbreviation depicts left or right)
GM:	Gluteus Medius Muscle (R/L ahead of abbreviation depicts left or right)
IO:	Internal Oblique Muscle (R/L ahead of abbreviation depicts left or right)
IRED:	Infrared Emitting Diode
LBP:	Low Back Pain
LD:	Latissimus Dorsi Muscle (R/L ahead of abbreviation depicts left or right)
LES:	Lumbar Erector Spinae Muscles (R/L ahead of abbreviation depicts left or right)
LG:	Larger Group
MVC:	Maximum Voluntary Contraction
NPD:	Non-pain Developer
OBCC:	Over Breast chest circumference
ODAU:	Data Acquisition Unit
PD:	Pain Developer
RA:	Rectus Abdominis Muscle (R/L ahead of abbreviation depicts left or right)
RSES:	Rosenberg Self-esteem Scale
SCU:	System Control Unit
SD:	Standard Deviation
SE:	Standard Error
SG:	Smaller Group
SPAS:	Social Physique Anxiety Scale

TES_4:	Thoracic Erector Spinae Muscles at T4 level (R/L ahead of abbreviation depicts left or right)
TES_9	Thoracic Erector Spinae Muscles at T9 level (R/L ahead of abbreviation depicts left or right)
UBCC:	Under Breast Chest Circumference
VAS:	Visual Analog Scale

CHAPTER 1:
General Introduction

Large breast sizes in women are widely believed to be associated with low back pain (LBP). Most research into breast size investigates how breast reduction surgery can reduce adverse symptoms of macromastia (large breasts) such as grooving of the shoulders from brassier straps, neck pain, and back pain (Foreman et al., 2009; Mazzochi et al., 2012). Few studies have quantified the effects of breast size on the spine of non-clinical populations (women who do not seek breast reduction surgeries). Likewise, the relationship between breast size and the spine is poorly understood. From the review of existing biomechanical and pain data from women with large breast sizes, exaggerated thoracic and lumbar spine angles, greater estimated lumbar spine compression forces, measured trunk muscle activation, and self-reported back pain have been reported (Findikcioglu et al., 2007; Foreman et al., 2009; Schinkel-Ivy & Drake, 2016); Mazzocchi et al., 2012).

While it is known that breast size can affect posture, it is unknown whether psychosocial factors (self-esteem, social physique anxiety, and body image) can affect posture as well. Previous research has found and established a relationship between posture and emotion (Duclos et al., 1989; Riskind & Gotay, 1982). The posture that someone adopts can affect the emotions they experience (Duclos et al., 1989; Riskind & Gotay, 1982). For example, adopting a slumped posture can lead someone to feel sad (Duclos et al., 1989).

If emotion can affect posture, then emotional experiences such as body image should also affect posture. For instance, does one's embarrassment of their breasts cause them to adopt a slumped posture as an attempt to hide their breasts as opposed to a more neutral posture, which would draw more attention to their chest? Although body image and posture have been investigated individually, they have not been investigated simultaneously or with biomechanical factors in non-clinical populations associated with pain. Prolonged sedentary exposures, such as two hours of standing, is an established model for investigating the effects of pain development. Therefore, this thesis was designed to evaluate the relationship between breast size, spine kinematics, muscle activation and the development of back pain as well as psychosocial factors in non-clinical females during a prolonged standing protocol.

CHAPTER 2:
Research Questions

The primary purpose of this thesis was to determine if breast size in women have a postural effect over time (two hours), and to determine whether there is a difference in muscle activation and pain development between smaller and larger breast sizes. In addition, this thesis investigated whether specific psychosocial factors are related to posture. The following research questions were developed and were addressed in data collection:

1. Will two hours of standing show greater increases in spine angles over time in women with larger compared to smaller breast sizes?
2. Will two hours of standing show a difference in muscle activity particularly in the erector spinae muscles between smaller and larger breasted women?
3. Is having larger breasts related to a greater development of pain in the upper, mid and low back than having smaller breasts?
4. Is there a relationship between breast size and self-esteem, social physique anxiety and body image?

CHAPTER 3:
Literature Review

The purpose of this chapter is to provide an understanding of the scope of this thesis. Firstly, the prevalence of LBP and the associated functional anatomy of the spine is outlined as is the anatomy of the breast. This is followed by a review of the literature concerning breast size and biomechanical responses, psychosocial factors and associated questionnaires, prolonged standing protocol, determining self-reported pain, and evaluating lumbopelvic control. The literature reviewed provide context for the evaluations used in this thesis.

3.1 Low Back Pain

LBP will affect 80% of the population at least once in their lifetime (Friedly et al., 2010). In turn, this has cost Canada $8.1 billion in medical expenses. Risk factors of LBP include, but are not limited to lifting, work intensity, holding static positions, frequent bending and twisting, sex, and age (Marras et al., 1993; Hoy et al., 2010). In addition to physical risk factors, psychological factors such as stress may be related to the development of LBP (Hoy et al., 2010). However, not all risk factors of LBP are understood. Further, how breast size and psychosocial factors, such as self-esteem, social physique anxiety, and body image, are related to the development of LBP is unknown.

3.2 Functional Anatomy of the Spine

It is important to note the functionality of the thoracic and lumbar spine muscles. The erector spinae muscle is subdivided into three groups: longissimus, iliocostal and spinalis groups

(Snell, 1992). The longissimus and iliocostal groups have different architecture and functionality in their thoracic and lumbar regions (Bogduk, 1980; McGill & Norman, 1987). Sirca & Kostevc (1985) found that the thoracic region had a greater number of slow twitch fibres while the lumbar region had a greater mix of slow and fast twitch fibres. Thus, the thoracic and lumbar regions of the erector spinae should be investigated separately.

Additionally, handling anterior loads during lifting tasks, for example, can cause a large amount of internal load on the spine (McGill, 2007). It has been found that lifting 27kg in a squat styled lift can produce over 7000N of compressive load on the neutral lumbar spine (McGill, 2007). In weaker spines, 7000N of compression can cause damage in the lumbar spine (Adams & Dolan, 1995). Although, an average healthy male can withstand between 12,000-15,000N of compression before damage begins (Adams & Dolan, 1995). Shear cannot be tolerated as well in the spine as compression. Only 500N of shear is required to cause catastrophic failure in spines (McGill, 2007), with much less being required to initiate damage. The greater the anterior load, acting at a greater distance from the spine, the greater the anterior shear and flexion moment generated. This requires both an extensor moment and posterior shear force to offset the load. The extensor moment is generated by muscle activation, but at the penalty of increasing compression. When the spine is in a neutral posture, the erector spinae muscles orientation enables them to also resist the anterior shear and spare the passive posterior elements of the spine from loading (e.g. intervertebral disc, and ligaments) (McGill, 2007). However, when the spine posture becomes flexed (e.g. with slump and/or bending), the erector spinae muscles lose their oblique line of action and can no longer resist anterior shear forces (McGill, 2007). These muscles are still able to contribute to extensor moment generation (with a higher compression cost), but the passive elements are left to resist the shear forces (McGill, 2007). It is suspected that large breasts may influence the spine in a similar manner to anterior load lifting tasks. Therefore, the evaluation of breast size (anterior load) on muscle activation and spine posture are required.

3.3 Anatomy of the Breast

As typically described in anatomical texts, the female breast lies anteriorly to the pectoralis major muscles of the thorax and runs from the second to sixth rib (Snell, 1992). Medio-laterally, the breast typically extends from the sternum to the midaxillary line and the axillary tail (process) of the breast extends laterally and typically upwards towards the axillary fossa (armpit) to meet with the lower pectoralis major (Figure 3.1; Moore et al., 2010). Superficial to the pectoralis major lies pectoral fascia which makes up the bed of the breast (Moore et al., 2010). Superficial to the bed of the breast lies a layer of loose connective tissue known as retromammary space which allows movement of the breast (Moore 2010; Snell 1992). The main body of the breast is composed of fat and suspensory ligaments which help support the breast (Moore et al., 2010). In addition, the main body of the breast contains lobules, lactiferous ducts and alveoli each of which play a role in the production of milk in nursing mothers (Figure 3.2; Moore et al., 2010). The lactiferous ducts connect to the nipple which protrudes from the exterior of the breast (Moore et al., 2010). The nipple is surrounded by coloured skin called the areola (Snell, 1992). The breast is mostly made up of subcutaneous fat until pregnancy when new glandular tissue forms (Moore et al., 2010). The shape and composition of the breasts vary from person to person and can depend on genetics, ethnicity, and diet (Moore et al., 2010). It is important to note that individuals will likely have at least some differences from the anatomical description of the breast provided above, which is why using a measure that can incorporate differences in the distribution and tissue types in the breast is important for research.

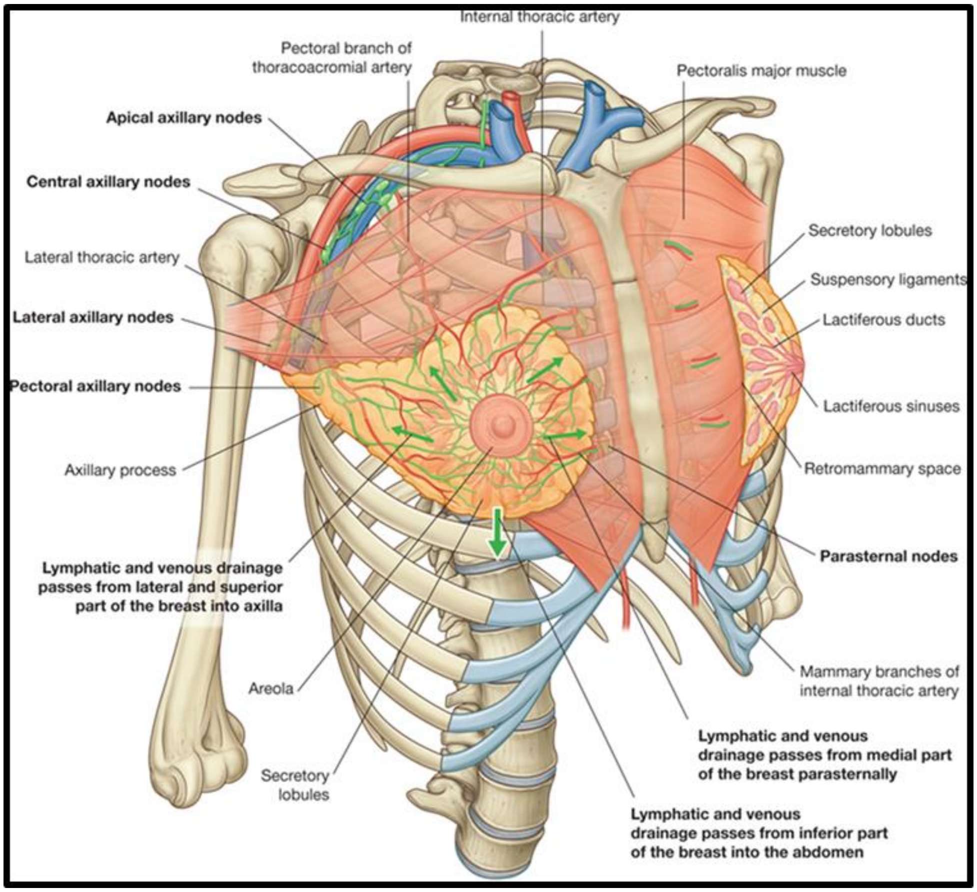

Figure 3.1: Generally, the breast extends from the second to sixth rib. The axillary process extends laterally towards the armpit. (Reprinted with permission from: Drake, R., Vogl, A., Mitchell, A. 2012. Gray's Basic Anatomy. Churchill Livingstone; Figure 3.2, pp. 59.)

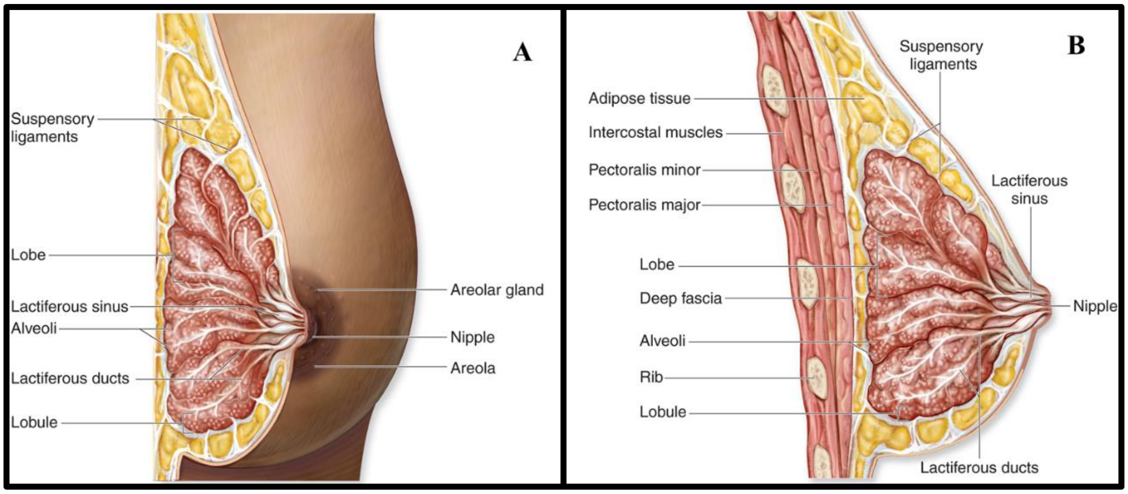

Figure 3.2: Anterior (A) and sagittal (B) view of the breast illustrating the various components of the breast such as adipose tissue, suspensory ligaments, lactiferous ducts and the nipple. (Reprinted with permission from McKinley, M., & O'Loughlin, V. 2011. Human Anatomy (3rd Ed.). New York: McGraw-Hill, Figure 28.10, pp. 860.)

The size of breasts has been shown to be related to one's body mass index (BMI). Previous research relates women with high BMI (≥ 25 – 29.9 kg/m^2) to greater breast volume (Coltman, Steele & McGhee, 2017; Brown & Scurr, 2016; Avșar et al., 2010). Likewise, women with smaller breasts often have lower BMIs (Coltman, Steele & McGhee, 2017; Brown & Scurr, 2016; Avșar et al., 2010). Further, women with large breasts ('DD' cup) typically have significantly higher body fat percentages than women with smaller breasts ('A' cup; Brown et al., 2012). As BMI and body fat percentage are related to breast size, it is important to consider these measures when evaluating breast size.

3.4 Biomechanical Factors and Breast Size

Few studies regarding the effects of breast size on the spine have been conducted. There are typically two main types of methods of quantifying breast size. The most common is to measure the over bust chest circumference (OBCC) and under bust chest circumference (UBCC) and take the difference between the two to calculate cup size (McGhee & Steele, 2006; Findikcioglu et al., 2007; Schinkel-Ivy & Drake, 2016). Each 2.54cm (1 inch) increment of difference is assigned an ascending alphabet letter (McGhee & Steele, 2006). The other method is to calculate the volume of the breasts by either measuring water displacement (Mazzocchi et al., 2012) or by three-dimensional (3D) imaging (Coltman, McGhee & Steele, 2016). However, these volume measurements can be take time to acquire, the required equipment is expensive, and these approaches require the participant to be unclothed from the waist up during the measurement (Coltman, McGhee & Steele, 2016). Thus, the measurement of circumferential difference (cup size) is preferred. It is important to note that none of these methods are perfect for measuring breast size as can accurately accommodate breast composition and shape in an upright standing position. Ideally, the weight of the breasts should be used, but this measure is not yet easily measured, and is therefore not used in studies. Likewise, methods that can easily and accurately measure breast weight need to be developed.

Research quantifying the effects of breast size on the spine mainly focuses on clinical populations using methods such as 3D motion analysis, inverse dynamics and radiographs before and after women undergo breast reduction surgery (Mazzocchi et al., 2012; Foreman et al., 2009). Findikcioglu et al. (2007) used radiographs to calculate spine angles and found that women with large breasts have greater thoracic kyphosis angles as well as lumbar lordosis angles. After determining cup size for each participant ($n = 100$), using UBCC and OBCC measurements, Findikcioglu et al. (2007) found that the smallest breast size category ('A' cup) compared to the largest ('D' cup) had significantly different thoracic kyphosis angles, in that the larger group had greater kyphosis than the smaller group ($p = 0.023$). Findikcioglu et al. (2007)

also found that the larger breasted women ('D' cup group) had significantly greater lordosis angles compared to smaller women ('B' cup group; $p = 0.045$). In addition, Karabekmez et al. (2014) found a mean improvement (more upright posture) of 13.9° ± 4.3 in kyphosis angles and mean improvement of lumbar lordosis angles (less lordotic) of 6.9° ± 3.0 in 22 women two months after receiving breast reduction surgery. Following breast reduction surgery, women had straighter spines, that is less thoracic flexion (less kyphosis) and less lumbar extension (lordosis, Karabekmez et al., 2014). Large breasts have also been found to cause greater estimated low back compression forces (using an inverse dynamic model) which was reduced on average by 35% after breast reduction surgery (Foreman et al. 2009). Schinkel-Ivy & Drake (2016) investigated fifteen healthy women without back pain, two of which were classified as 'B' cup, seven as 'C' cup, and six as 'D' cup. Using 3D motion analysis and electromyography (EMG), these researchers found the 'D' cup group had greater muscle activation in the lumbar erector spinae muscles (LES) and a moderately strong correlation between larger breast size and increased thoracic flexion (Schinkel-Ivy & Drake, 2016). While Schinkel-Ivy & Drake's (2016) research advanced our knowledge, the effects of breast size on spine motion, posture and muscle activation are still not fully understood and therefore require further investigation.

3.5 Body Image

Body image is the psychological experience and embodiment of how one sees, feels, thinks and acts towards one's own body (Cash, 2004; Ginis, McEwan & Bassett-Gunter, 2013). When investigating body image, the four dimensions of body image should be considered: affective, behavioural, cognitive, and perceptual (Thompson et al., 1999). The affective dimension targets how an individual feels about his or her body (Thompson et al., 1999). This can be negative or positive, such as, shame or pride, respectively (Thompson et al., 1999). The behavioural dimension investigates how an individual behaves due to body image (Thompson et al., 1999). For instance, does an individual stand a certain way to hide or draw attention to their body? The cognitive dimension reflects how an individual thinks or what their beliefs are regarding their body (Thompson et al., 1999). For example, an individual may think that his or her thighs are too large, regardless of actual measure or comparison to population average. Lastly, the perceptual dimension investigates how accurately an individual refers to their body (Thompson et al., 1999). For example, an individual may perceive he or she is shorter compared to a friend when in fact he or she is not. The behavioural dimension is of particular interest in this thesis, as it can be most closely compared to biomechanical measures during an exposure. For instance, Duclos et al. (1989) compared the posture participants adopted while inducing various emotions such as happiness and anger. The study found that participants adopted a more slumped posture when experiencing anger (Duclos et al., 1989). The magnitude of how much body image influenced posture is unclear. However, emotion effecting posture could be an indication that body image may affect posture.

Although the primary function of female breasts is to produce milk and feed infants, breasts have become sexualized and have become a major factor to a woman's body image (Einon, 2012). Media has a strong influence over beauty ideals and frequently objectifies women's bodies which affects how men see women's bodies and how women see their own bodies (Einon, 2012). Media today depicts the ideal beautiful woman as having large breasts and a thin, muscular figure (Einon, 2012). Due to the strong emphasis that society has on this version of attractiveness, women can be self-critical of their breasts and practice self-checking in mirrors, camouflaging their breasts, and comparing themselves to women in media regardless of breast size (Sarwer et al., 1997). Women with small breasts may look for options of obtaining larger breasts, and consider options of surgical augmentation (Einon, 2012). However, women with very large breasts may also express unhappiness about their breasts due to the physical discomfort, unwanted attention, and self-consciousness associated with them (Einon, 2012). Therefore, understanding the impact of breast size on psychosocial factors is important if we are to stimulate change.

3.6 Questionnaire

Questionnaires have been shown to be an excellent method of evaluating psychosocial factors. The relevant questionnaires pertaining to this thesis are the *Rosenberg Self-esteem Scale* (*RSES*) to evaluate self-esteem, *Social Physique Anxiety Scale* (*SPAS*) to evaluate social physique anxiety and *Body Shape Questionnaire* (*BSQ)* to evaluate body image.

The *RSES* is a commonly used, 10-item scale that evaluates self-esteem (Rosenberg, 1979; Robins, Hendin, & Trzesniewski, 2001). Although self-esteem is not part of body image, *RSES* has been used in studies evaluating body image to provide an evaluation of one's self worth (Singh et al., 2015; Barnes & Caltabiano, 2017). Singh et al. (2015) found approximately 60% of their participants were concerned about their bodies, but only about 20% had low self-esteem (n=550). Example questions from *RSES* are as followed: "On the whole I am satisfied with myself", "I certainly feel useless at times" (Rosenberg, 1979). The design of this survey is to evaluate self-esteem and is frequently used in studies evaluating body image to provide an individual's overall self-worth.

The *SPAS* is a 12-item survey which evaluates the level of anxiety an individual feels when they think others are evaluating his or her body (Hart, Leary & Rejeski, 1989). The *SPAS* showed a correlation with concerns of others' evaluations as well as concern of one's own body shape (Hart, Leary & Rejeski, 1989). An example question from *SPAS* is "When I look in a mirror I feel good about my physique or figure" (Hart, Leary & Rejeski, 1989). The *SPAS* has been used to evaluate differences in body image between 102 female athletes, who were either swimmers, rhythmic gymnasts or ballet dancers (Kosmidou, Giannitsopoulou & Moysidou, 2017). Only 34.8% of ballet dancers were content with their bodies while 38.3% of rhythmic gymnasts and 43.8% of swimmers had positive body image (Kosmidou, Giannitsopoulou & Moysidou, 2017). Further, Clode, Lewis & Fuller-Tyszkiewicz (2016) compared body image in males and females and how social physique anxiety can affect their work (n=93). Clode, Lewis & Fuller-Tyszkiewicz (2016) used *SPAS* as well as the 69-item *Multidimensional Body Self-Relation Questionnaire* to evaluate body image. This questionnaire was not used in this thesis due to accessibility. Likewise, *SPAS* was used in this thesis as it provides an understanding of the behavioural dimension of body image.

The *BSQ* was originally designed as a diagnostic tool to screen for eating disorders such as bulimia and anorexia nervosa (Cooper et al., 1987). The *BSQ* is a 34-item survey in which the questions assess cognitive self reflection of body shape and behavioural habits associated with body image (Cooper et al., 1987). Although, the *BSQ* was developed to evaluate eating disorders, it is also used to evaluate body image. Uchoa et al. (2017) used the *BSQ* as well as the *Figure Rating Scale* (which targets the perceptual dimension) and the *Sociocultural Attitudes Towards Appearance Questionnaire* to evaluate body image in 450 adolescents (males and females) between 14 and 16 years old. The *Figure Rating Scale* and *Sociocultural Attitudes Towards*

Appearance Questionnaire was not used in this thesis as a connection between psychosocial biomechanical factors was of interested and it was thought that the behavioural dimension would be the most associated with postural changes. Using the *BSQ* Uchoa et al. (2017) found that 47.1% of private school girls had severe negatively impacted body image while only 11.4% of private school boys presented negative body image. In addition, Rochelle & Hu (2017) evaluated 45 women aged between 18 and 25 and used the *BSQ* to determine body image. Women who were exposed to a body ideal video before competing the *BSQ* reported greater negative body image than women who were not exposed to the body ideal video (Rochelle & Hu, 2017). An example question from *BSQ* is “Has being with thin women made you feel self-conscious about your shape?” (Cooper et al., 1987). Although designed to evaluate eating disorders, *BSQ* is frequently used to evaluate body image in non-clinical populations.

In summary, the *RSES, SPAS* and *BSQ* are often used in studies evaluating body image. These surveys will help determine whether psychosocial factors impact posture, and whether breast size impacts psychosocial factors in this thesis.

3.7 Prolonged Standing

Prolonged standing has been shown to induce transient LBP in 40 – 65% of asymptomatic male and female participants ranging between 18 and 50 years of age (Nelson-Wong et al., 2008; Nelson-Wong & Callaghan, 2014). In both sexes, the development of transient LBP during prolonged standing can be a predictor of future LBP development (Nelson-Wong & Callaghan, 2014). Individuals who developed transient LBP during prolonged standing were three times more likely to experience LBP at least once within the following three years (Nelson-Wong & Callaghan, 2014). Due to the consistent moderately high rates of LBP development compared to other methods, prolonged standing protocols are frequently used to induce transient LBP in unaffected populations to further investigate changes in biomechanical variables (Gregory & Callaghan, 2008; Gallagher & Callaghan, 2015; Sørensen et al. 2016). The prolonged standing protocol commonly used requires participants to stand for two hours and perform tasks such as sorting money, dealing cards, disassembling and reassembling pens and a boredom task of quiet standing (Gregory & Callaghan, 2008; Nelson-Wong & Callaghan, 2010; Sørensen et al., 2016). Participants were asked to not lean on the table or rest their feet on the supports of the table as these actions could alter variables of interest (Nelson-Wong & Callaghan, 2014; Gallagher & Callaghan, 2015). In addition, during the standing protocol, 3D kinematics were recorded with EMG using surface electrodes (Gregory & Callaghan, 2008; Nelson-Wong & Callaghan, 2010). Sørensen et al. (2016) used a standing protocol to investigate whether LBP was related to psychological factors such as fear related to pain in a healthy population (n=57). Participants completed *The Fear of Pain Questionnaire-III* and *The Pain Catastrophizing Scale* prior to the standing protocol to evaluate their psychological measures of interest and used a 100mm Visual Analog Scale (VAS) to measure perceived pain (Sorenson et al., 2016). The study found that individuals who had greater than a 20mm change on a 100mm VAS scale showed a relationship between LBP intensity and psychological factors (Sørensen et al., 2016). Since the prolonged standing protocol is well established and has been used to investigate other psychological measures, the model was used for this thesis to investigate the relationship between biomechanical variables, and self-esteem, social physique anxiety and body image.

3.8 Visual Analog Scale

VAS is a common method used to evaluate self-reported perceived pain (Gregory & Callaghan, 2008; Nelson-Wong & Callaghan, 2010). VAS is a 100mm line with one end labelled "no-pain" and the other end labelled "worst pain imaginable" on which participants mark their perceived pain. Using VAS investigators can track participant pain over the course of the experiment, allowing changes in perceived pain to be calculated. VAS can be used to record pain in various areas of the body during the same task, including multiple sections of the spine (i.e. upper and lower back; Nelson-Wong et al., 2008). The minimum difference considered to be clinically different in VAS can range from 9mm (Kelly, 1998) to 13mm (Bijur, Latimer, Gallagher, 2003). However, in prolonged standing protocols, 10mm was determined to be the most appropriate value and is now commonly used to identify clinical differences of pain in university aged, unaffected populations (Gregory & Callaghan, 2008; Gallagher & Callaghan, 2015; Sørensen et al. 2016). A minimum change of 10mm represents the development of a clinically relevant level of pain, and is used to categorize participants into pain or non-pain developers (<10mm). Sørensen et al. (2016) who had 57 asymptomatic participants, further divided their participants into an extreme pain category with individuals who experienced a change in VAS ≥ 20mm, which is considered a clinical level of pain. VAS has been used to relate biomechanical measures and pain development and has been shown to have good validity and repeatability (Nelson-Wong & Callaghan, 2014; Summers, 2001; Revill et al., 1976). Likewise, the use of VAS has been well established and accepted as an appropriate method for evaluating self-reported perceived pain.

3.9 Active Hip Abduction Test

The Active Hip Abduction (AHAbd) test is a controlled side lying leg raise that evaluates lumbopelvic control and can be used to predict the development of LBP (Nelson-Wong, Flynn & Callaghan, 2009). Poor lumbopelvic control (score ≥ 2), is associated with greater risk of developing LBP (Davis et al., 2011; Nelson-Wong, Flynn & Callaghan, 2009). Each AHAbd trial (leg raise) is scored based on performance cues provided by the ordinal scale found in Table 3.1 (Nelson-Wong, Flynn & Callaghan, 2009). AHAbd trials are scored by at least three trained individuals (which can include the investigator/s). Each rater scores each video on the first week and score the videos again on the fifth week after a three week wash out period (Davis et al., 2011). The worst score of the legs is taken as the participant's score (Nelson-Wong, Flynn & Callaghan, 2009). If there is a disagreement in a score between the raters, the final score is discussed and raters came to a unanimous decision (Babiolakis, Kuk & Drake, 2015). AHAbd test scoring has a moderate to high interrater reliability when scored by a single rater and had high interrater reliability when multiple raters were used (Davis et al., 2011). The AHAbd can reliably be used to identify those at a greater risk of developing back injury when used in conjunction with a 2-hour standing protocol, however AHAbd has never been investigated with breast size as a factor.

Table 3.1: Scoring cues for the Active Hip Abduction Test. Reprinted with permission from Nelson-Wong, E., Flynn, T. & Callaghan, J. 2009. Development of active hip abduction as a screening test for identifying occupational low back pain. *Journal of Orthopaedic & Sport Physical Therapy.* 39(9): 649-657. Permission was received for redistribution.

Examiner Score	**Cues to Differentiate Test Performance**
Test score, 0 (no loss of pelvis frontal plane)	• Participant smoothly and easily performs the movement. • Lower extremities, pelvis, trunk and shoulders remain aligned in the frontal plane.
Test score, 1 (minimal loss of pelvis frontal plane)	• Participant may demonstrate a slight wobble at initiation of the movement, but quickly regains control. • Movement may be performed with noticeable effort or with a slight ratcheting of the moving limb.
Test score, 2 (moderate loss of pelvis frontal plane)	• Participant has a noticeable wobble, tipping of the pelvis, rotation of the shoulders or trunk, hip flexion, and/or internal rotation of the abducting limb. • Movement may be performed too rapidly, and participant may or may not be able to regain control of the movement once it has been lost.
Test score, 3 (severe loss of pelvis frontal plane)	• Participant demonstrates the same patterns as in a test score of 2, with greater severity. • Participant is unable to regain control of the movement and may have to use a hand or arm on the table to maintain balance.

CHAPTER 4:
Hypotheses

This study was designed as a biomechanical investigation on the role of breast size in spine response to a prolonged exposure, with the novel addition of concurrently evaluating psychosocial factors in addition to biomechanical variables. Three-dimensional full body motion capture, EMG, self-reported pain (using VAS) and questionnaire data were used to determine spine angles, muscle activation, pain development and psychosocial metrics, respectively, during a prolonged standing protocol (2 hours) in females with varying breast sizes. Considering the design of the thesis, the following hypotheses were developed.

1. Individuals with larger breast sizes will have a greater muscle activation in the upper and lower thoracic and lumbar regions of the spine (upper and lower erector spinae muscles) compared to smaller breast sized individuals.
2. Individuals with larger breast sizes will have increasing thoracic flexion over time but will not have greater positive body image relative to entire participant population.
3. Individuals with smaller breast sizes who have greater thoracic flexion initially, will not have greater positive body image relative to other individuals of similar breast size who do not have as exaggerated thoracic flexion initially.
4. Body image will not be correlated to breast size.
5. Individuals with larger breast sizes will have greater pain development in the upper, mid and low back compared to individuals with smaller breasts.

CHAPTER 5:
Specific Introduction to Thesis

Large breast sizes in women, also known as macromastia, have been found to cause symptoms such as grooving of the shoulders from bra straps, shoulder pain, and back pain (Foreman et al., 2009). Most research on the effects of breast size are outcomes studies investigating improvements after breast reduction surgery in women (Foreman et al., 2009; Karabekmez et al., 2014). Few investigate the effects of breast size on the spine in clinical and non-clinical female populations. Likewise, determining the role breast size plays in spine biomechanical responses to various exposures is warranted.

Research has found that women with larger breasts (‘D’ cup sizes relative to smaller cup sizes; n = 93) have greater thoracic kyphosis angles and lumbar lordosis angles (Findikcioglu et al., 2007). These women also have greater compression and shear forces on the spine (Foreman et al., 2009) and have greater activation in their abdominal and back muscles (Schinkel-Ivy & Drake, 2016). It has been found that most of these symptoms are reduced by breast reduction surgery (Berg et al., 1994: Foreman et al., 2009). However, this type of major surgery is not a solution for everyone as it can be expensive, known to have caused problems with breast feeding (Shakespeare & Postle, 1999), and is typically reserved for women with the largest breast sizes leaving other women to deal with the pain. Therefore, it is imperative that the relationship between breast size, back pain development, and spine neuromuscular and musculoskeletal responses, are better understood.

Another relationship that requires further investigation is the relationship between psychosocial factors and posture. While it is not known whether body image can affect posture, it is known that posture is related to emotion (Duclos et al., 1989; Riskind & Gotay, 1982).

Duclos et al. (1989) found that participants' emotions changed and reflected the emotion of the posture that they adopted. For example, when participants adopted a slumped posture, the emotions they were experiencing changed and reflected sadness which are associated with a slumped posture (Duclos et al., 1989). If the emotional experiences are related to posture, then other emotional experiences such as self-esteem, social physique anxiety and body image should also influence posture. For instance, would an individual who is embarrassed about their breast size adopt a slumped posture in an attempt to minimize attention towards them? An online survey by Frederick et al. in 2006 found that only 41% of 26,983 women felt positive about their bodies as either "great" or "good" and the remainder of women felt that their bodies were "just okay" or "unattractive". Further, 55% of 120 surveyed women surveyed wanted larger breasts, 29% wanted smaller breasts and only 16% were satisfied with their breasts (Tantleff-Dunn & Thompson, 2000). If negative emotions can affect posture negatively, then negative body image may have a negative affect on posture, which can affect muscle activation and back pain development due to altered biomechanics. Therefore, the relationship between psychosocial factors and posture needs to be investigated.

Since LBP will affect 80% of the population at least once in their lifetime (Friedly et al., 2010) and cost Canada $8.1 billion in medical expenses (Coyte et al., 1998) further research is warranted. Prolonged standing has been found to induce transient LBP and is commonly used to investigate LBP development (Nelson-Wong & Callaghan, 2014). In order to explore the role of breast size and psychosocial factors with the development of LBP, a prolonged standing exposure model can be used. Prolonged standing has been found to induce transient LBP from 35.9% (Nelson-Wong & Callaghan, 2014), 43.8% (Gallagher & Callaghan, 2015) to 81.2% (Gregory & Callaghan, 2008) in asymptomatic individuals and can be a predictor of future LBP

(Nelson-Wong & Callaghan, 2014). This prolonged standing model is frequently used in studies to induce LBP to further understand LBP (Gallagher & Callaghan, 2015; Nelson-Wong & Callaghan, 2010; Nelson-Wong et al., 2008). For these reasons, the prolonged standing model was chosen as the exposure with which to investigate the measures of interest.

In summary, women with large breasts experience various symptoms in their spine and often experience pain. However, it is unclear how biomechanical effects (anterior load of the chest) and self-esteem, social physique anxiety and body image contribute to changes in spine kinematics and kinetics and the development of back pain. Therefore, this thesis study was designed to investigate the relationship between breast size, spine angles, muscle activation, pain development and psychosocial metrics using a prolonged standing protocol in females of varying breast sizes.

CHAPTER 6:
Methods

6.1 Overview

Muscle activation, kinematics, self-reported pain ratings, were collected throughout the 2-hour standing exposure. These measures were compared to the responses from the questionnaire to determine potential relationships with self-esteem, social physique anxiety and body image. All protocols included in this study were approved by York University's Office of Research Ethics (Certificate # e2015-371).

6.2 Participants

Twenty-one healthy female participants between 19 and 30 years of age with mean (standard deviation (SD) mass 61.24kg (9.43), height 1.67m (0.07), age 21.8 years (2.71), BMI 21.99 kg/m^2 (2.42), percent body fat 21.05% (5.36), and waist circumference 70.52cm (6.07) were recruited to participate in this study. Participants had not experienced back pain that required them to miss school or work within the previous twelve months at the time of the data collection. In addition, participants had no surgery in the chest (i.e. breast reduction, breast augmentation), and had not been pregnant at the time of the data collection or have been previously pregnant (as pregnancy can alter breast size, biomechanical responses, pain ratings and psychosocial factors). All participants provided written consent prior to participating in the study. As this was a novel study, no exclusion criteria were included to screen for psychosocial factors.

6.3 Electromyography

Muscle activation was recorded from eight muscles bilaterally using two AMT-8 EMG amplifier systems (Bortec Biomedical Ltd., Calgary, Canada). Each muscle was collected using pairs of disposable AG/AG-Cl surface electrodes (Ambu® Blue Sensor N, Ambu A/S, Denmark) which were placed over the muscle bellies after the skin was shaved and swabbed with alcohol to maximize adherence of the electrodes and minimize electrical impedance. EMG data were collected from the following muscles bilaterally: rectus abdominis (RA), external obliques (EO), internal obliques (IO), latissimus dorsi (LD), thoracic erector spinae at the T4 level (TES_4), thoracic erector spinae at the T9 level (TES_9), lumbar erector spinae at the L3 level (LES), and gluteus medius (GM). Reference electrodes were placed on the right and left clavicle. Details on the approximate muscle electrode placements and references for each can be found in Table 6.1 and Figure 6.1. This thesis uses “L” and “R” ahead of muscle abbreviations to refer to left and right muscles specifically. For example, left RA would be referred to as LRA and right RA as RRA. All EMG signals were differentially amplified (frequency response 10 Hz – 1000 Hz, common mode rejection 115 dB at 60 Hz, input impedance 10 GΩ), and the analog to digital conversion was at a rate of 2048 Hz (Northern Digital Inc., Waterloo). A baseline of EMG data were collected from a 5-minute quiet rest for each participant. EMG data were normalized to maximal voluntary contractions (MVCs). To determine MVCs, manually resisted tasks that isolate the muscles of interest were collected. Briefly, the tasks used were the back extension off a therapy table, LD pull downs, modified sit-up and side-lying leg abduction (for back, abdominal and buttock muscles respectively). A summary of the MVC tasks can be found in Table 6.2.

Table 6.1: Summary of electrode placements used to collect muscle activation from eight bilateral muscles in the anterior and posterior of the trunk and pelvis. Note: All electrodes were placed over the largest portion of the muscle belly, and as such the placements listed below are approximations.

Muscle	**Electrode Placement**
Rectus abdominis	~3cm lateral to umbilicus (Callaghan et al., 1998)
External obliques	~15cm lateral to umbilicus (Callaghan et al., 1998)
Internal obliques	Below external obliques and superior to the inguinal ligament (Callaghan et al., 1998)
Latissimus dorsi	Lateral to T9 (Callaghan et al., 1998)
Upper thoracic erector spinae	~5cm lateral from T4 spinous process (Burnett et al., 2009)
Lower Thoracic erector spinae	~5cm lateral to T9 spinous process (Callaghan et al., 1998)
Lumbar erector spinae	~3cm lateral to L3 spinous process (Callaghan et al., 1998)
Gluteus medius	~15cm inferior and 5 cm posterior iliac crest (Nelson-Wong et al., 2008)

Table 6.2: Summary of manually resisted tasks that isolate muscles of interest to collect MVCs necessary for the normalization of the muscle activation. All trials were performed against researcher applied resistance.

Muscle	**Resisted MVC Task**
Rectus abdominis	Bent knee sit-up posture, crunch (McGill, 1992)
External obliques	Bent knee sit up posture, twist (McGill, 1992)
Internal obliques	Bent knew sit up posture, lateral bend (McGill, 1992)
Latissimus dorsi	Modified pull down (Arlotta et al., 2011)
Upper and lower thoracic erector spinae & Lumbar erector spinae	Back extension (McGill, 1992)
Gluteus medius	Side lying hip abduction (Nelson-Wong et al., 2008)

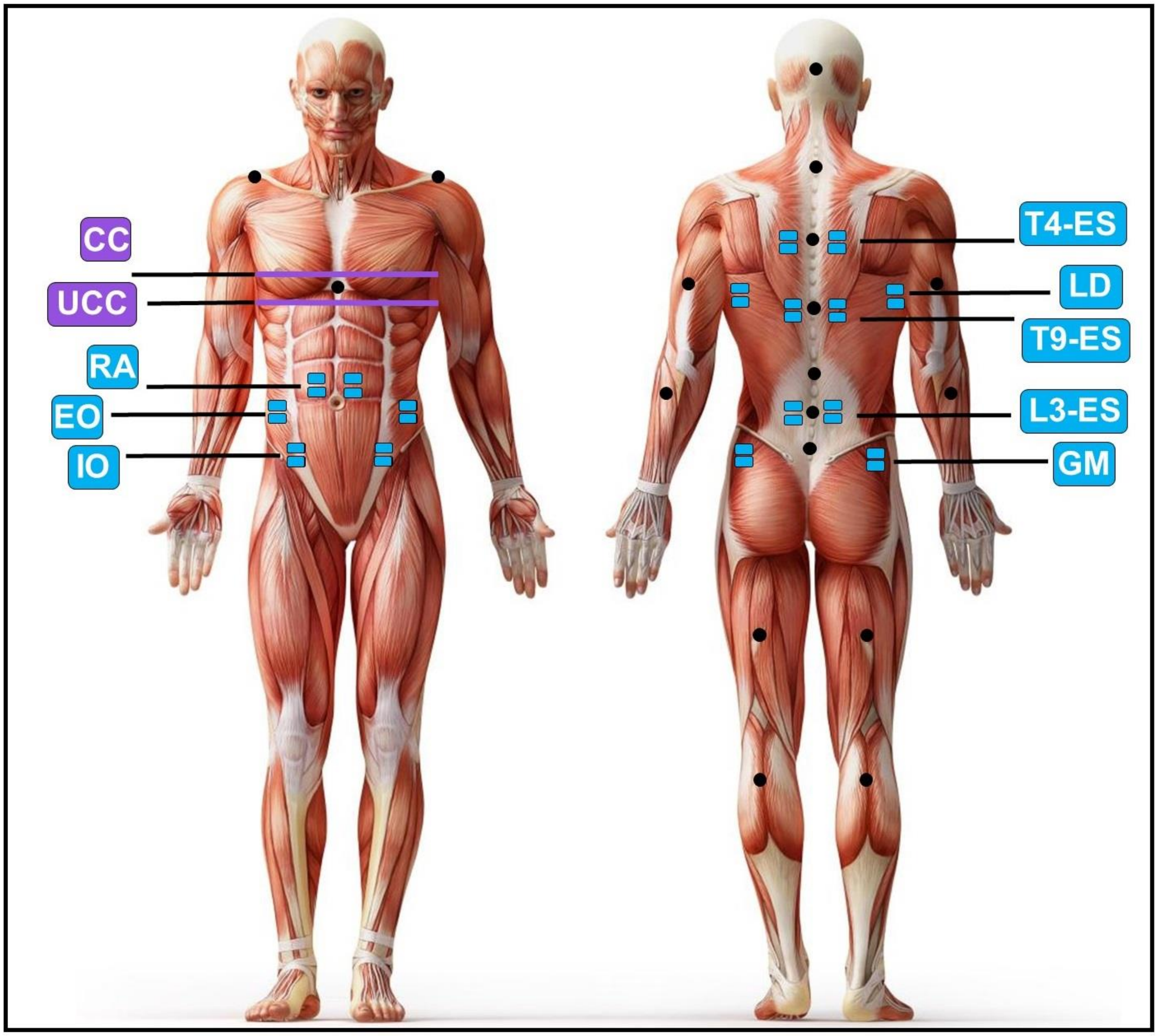

Figure 6.1: Depiction of the placements for the electrodes (blue rectangles) and IREDs (black circles) on participants, and the locations of where OBCC and UBCC measurements (purple) were taken. (Base Image Retrieved June 14, 2017 from: http://anatomyorgan.com/human-anatomy-full-body-picture/human-anatomy-full-body-picture-human-anatomy-full-body-picture-human-anatomy/)

6.4 Kinematics

Spinal motion and posture were measured using an infrared 3D motion analysis system (3D Investigator™, Northern Digital, Ontario, Canada) with five position sensors (Figure 6.2) and were collected at a rate of 32 Hz. Motion was tracked via infrared emitting diodes (IREDs) that were fixed on a rigid surface in either a five-marker rigid body orientation and adhered to the spine or a three-marker rigid body adhered to the head and extremities (Figure 6.2). Rigid bodies were placed on the head, upper arms, upper and lower legs and approximately on C7, T4, T9, T12, and S2 for a total of 5 five-marker rigid bodies and 7 three-marker rigid bodies (46 IREDs; Figure 6.1). A total of 37 bony landmarks were digitized using the system's digitizing probe to define segments, which are relative to the rigid bodies (Figure 6.3). The digitized bony landmarks are the following; head (left and right temple and angle of the mandible; total of 4), trunk (acromia, xiphoid process, left and right of C7 vertebrae, T4 vertebrae, T9 vertebrae and T12 vertebrae; total of 11), pelvis (anterior superior iliac spines, posterior superior iliac spines, iliac crests; total of 6), arms (lateral joint centres of the shoulder, medial and lateral epicondyles; total of 6) and legs (greater trochanters, medial and lateral epicondyles, medial and lateral malleoli; total of 10). While detailed below, briefly the protocol required the participants to perform three reference postures: upright stand, T-pose (participant stands normally with their arms held to the sides at shoulder height) and a 3D motion trial which includes trunk flexion, extension, lateral bend and axial twist to ensure that all markers were visible and functioning correctly. Full body 3D kinematics were collected throughout the 2-hour standing trial.

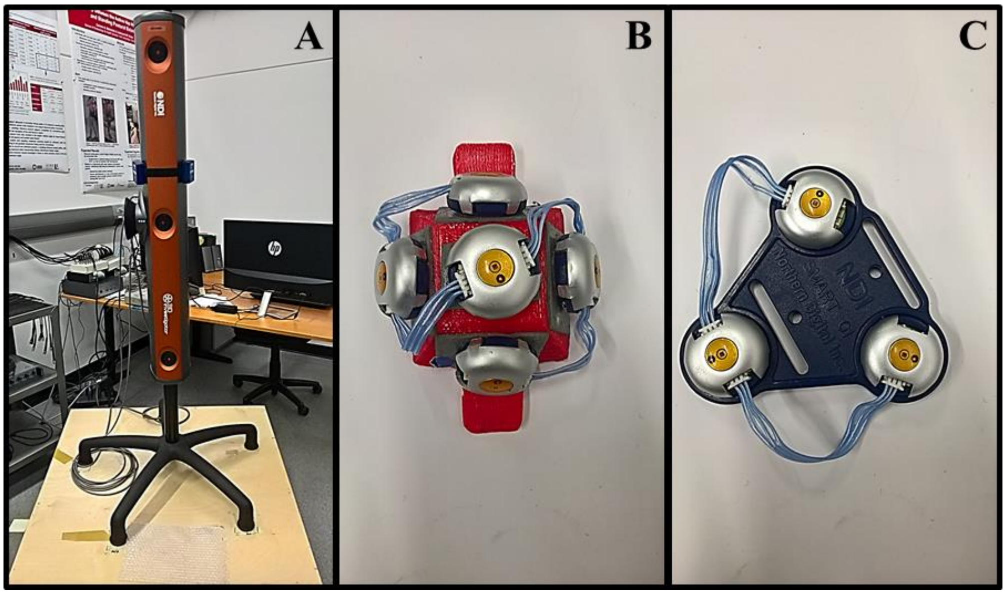

Figure 6.2: An example of one of the five position sensors used for capturing motion data (A), one of the five-marker spine rigid bodies used to track spine segments (B) and one of the three-marker rigid bodies used to track the head, arms and legs (C).

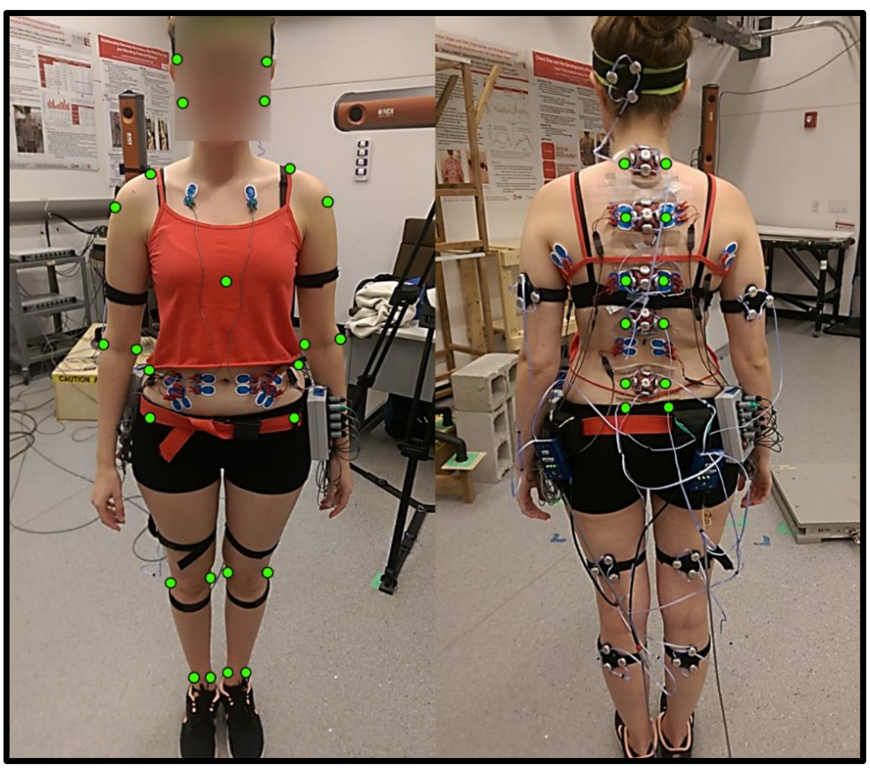

Figure 6.3: Complete instrumentation of a participant and the digitized bony landmarks used (green dots).

6.5 Questionnaire

The questionnaire was made up of pre-existing, validated surveys and newly developed questions. Three surveys were chosen to evaluate self-esteem, social physique anxiety and body image. Respectively, these pre-existing surveys are: *RSES* (Rosenberg, 1979), *SPAS* (Hart et al., 1989) and *BSQ* (Cooper et al., 1987). The newly developed questions evaluated how the participants feel about their breasts. An example of the developed questions is: "Individuals with smaller chests than me make me feel jealous". The purpose of these questions was to provide context and were therefore not validated. These questions were mixed into the *BSQ*. The questionnaire had a total of 73 questions. A breakdown of the questionnaire in terms of the pre-existing and newly developed questions can be found in Table 6.3. The complete questionnaire can be found in Appendix A. Participants were sent the questionnaire via email one week prior to the date of the collection. Participants completed the questionnaire prior to coming into the lab, and submitted the completed questionnaire upon arrival to the collection.

Table 6.3: A breakdown of each survey in the questionnaire and their respected question numbers.

Section of Questionnaire	**Question Number**
Section I	
Rosenberg Self-esteem Scale	Questions: 1 – 10
Section II	
Social Physique Anxiety Scale	Questions 11 – 22
Section III	
Body Shape Questionnaire	Questions: 23 – 56
Section IV	
Newly Developed Breast Specific Questions	Questions: 57 – 73

6.6 Pain Development

VAS was used to record and track self-reported perceived pain and classify participants as pain developers (PD). The spine was divided into three sections for pain evaluation: upper (C7-T4), mid (T4-T12), low (lumbar) back. VAS was given for each spine segment; thus, three VAS strips were given during each evaluation (Figure 6.4). VAS was recorded prior to beginning the 2-hour stand and subsequently collected every 15 minutes throughout the trial, and were not permitted to see their previous ratings. Participants were classified as PDs if there was a change of 10mm or greater at any point of the 2-hour stand. Participants were classified as non-pain developers (NPD) if they had an overall change less than 10mm throughout the 2-hour stand. Again, a change of 10mm of self-reported pain is considered clinically relevant and 20mm is considered a clinical or extreme level of pain.

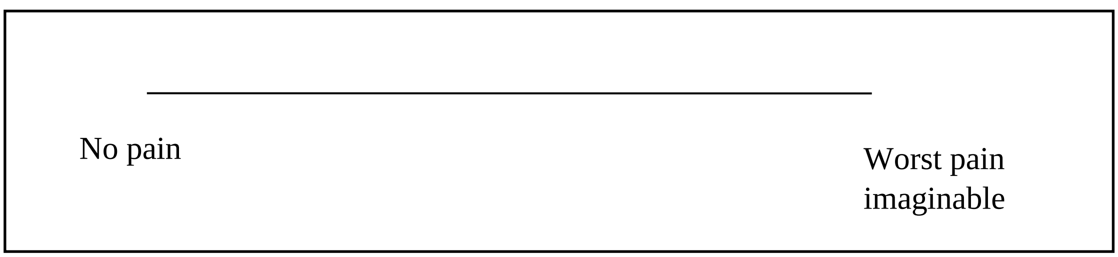

Figure 6.4: An example VAS given to participants. Participants were given three VAS strips each time for the upper, mid and low back.

6.7 Lumbopelvic Control

AHAbd tests were conducted after MVC trials were completed and were repeated after IRED clusters were removed from participants following the 2-hour stand. Participants were instructed to lay straight on their side on the massage table, cradle their head with the arm that is beneath them and rest their above arm on their chest (Nelson-Wong, Flynn & Callaghan, 2009). Participants were then instructed to abduct their top leg in a controlled manner to comfortable height without losing lumbopelvic control and were told that they were not allowed to support themselves with their hands unless they felt they were losing control (Figure 6.5; Nelson-Wong, Flynn, Callaghan, 2009). Before beginning the first trial, their body position was corrected if needed and the participant was allowed to have a practice trial. Participants performed the task twice on each leg.

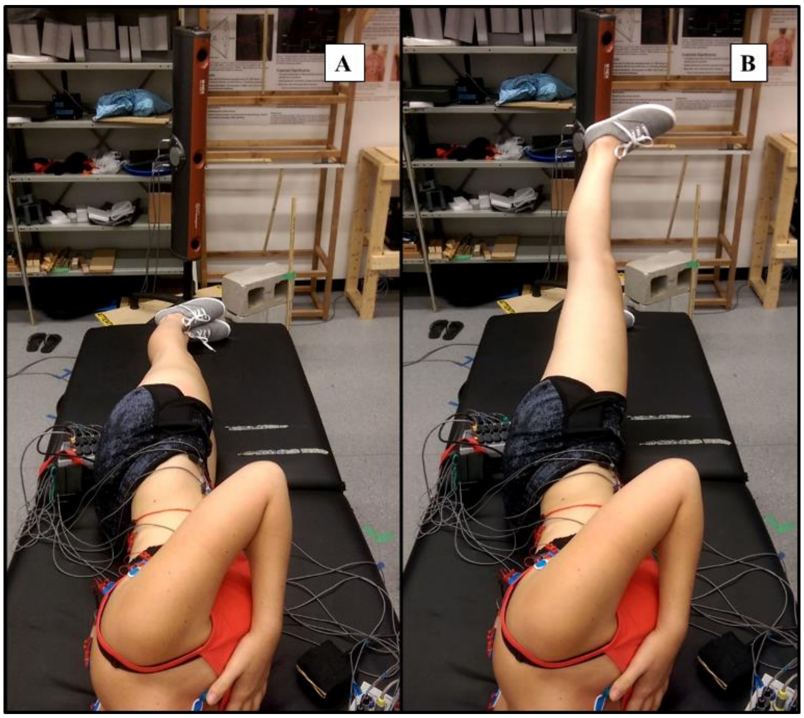

Figure 6.5: Participant performing an AHAbd trial. (A) depicts the start and end points of the trial. (B) depicts an example of max leg abduction height reached by a participant.

6.8 Breast Size Measurements

To determine breast size, two measurements were required from the participants. The first is the UBCC. This circumference was taken at the infra-mammary fold of the breast (Figure

6.6; McGhee & Steele, 2006). The second measurement taken was the OBCC. This measurement is taken at the widest point of the breasts (Figure 6.6; McGhee & Steele, 2006). Participants measured themselves in a private room and without a brassiere. Participants were instructed to keep the measuring tape straight along their back and to have the measuring tape held firmly, but not tight so that the breasts were indented by the tape (McGhee & Steele, 2006). In addition, the participants were instructed to record each measurement after a complete expiration (McGhee & Steele, 2006). Participant's recorded each measurement three times, and researchers took the average to calculate the cup size. Breast size was assigned to 'cup size', with the difference between OBCC and UBCC used to determine the cup size. A difference of 2.54cm was an 'A' cup, a difference of 5.08cm was 'B' cup, a difference of 7.62cm was a 'C' cup, etc. Breast sizes 'B' to 'C' cups were the smaller group (SG; n=11) and larger group (LG; n=10) was made up of cup sizes 'D-E'. Once categorized into breast size groups a ratio of OBCC/UBCC was calculated to provide a specific numerical value regarding participants' breast size. A ratio of the two measurements were used to account for different body sizes.

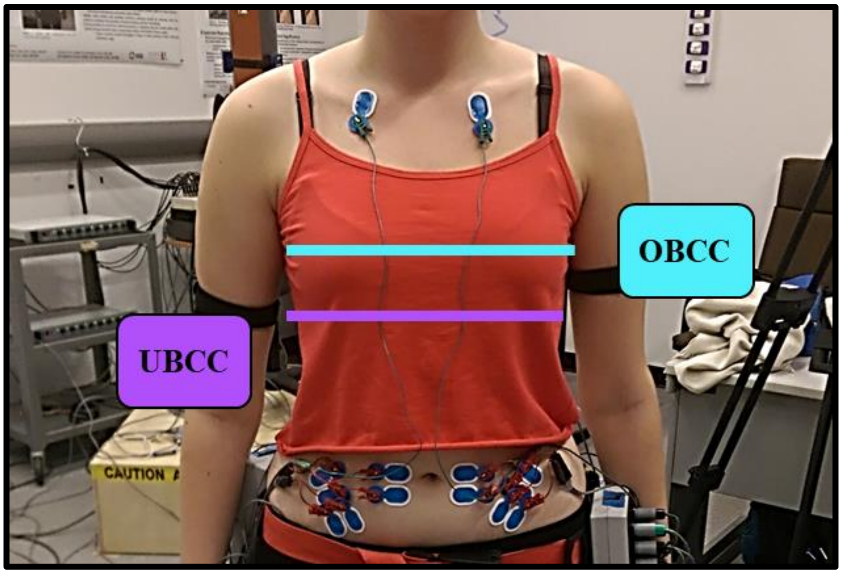

Figure 6.6: An example of where participants were instructed to take OBBC (blue) and UBCC measurements (purple).

6.9 Collection Protocol

Prior to the participant's arrival, all amplifiers, data acquisition units (ODAUs: which allowed synchronized collection of all EMG data), system control unit (SCU), position sensors and force plate were calibrated. Force plate data were used in a separate analysis and were not reported in this thesis. The questionnaire was emailed to the participant a week prior to their data collection date, and participants were asked to bring the completed questionnaire to the data collection session. Participants were instructed to bring compression shorts, running shoes and wear a bra in which they feel most comfortable to acquire a habitual response (eliminate effects a new bra may have on measures of discomfort and or postural behaviour) for the study.

When the participants arrived at the lab, they were given the consent form to read and sign. Before allowing them to go change into their collection attire in a private change room, they were given a measuring tape, pen, clipboard with a sheet to record UBCC and OBCC measurements. Participants were instructed to take measurements as outlined in section 6.8. They were also given a tank top to wear over their bra to help them to feel comfortable in the space and with the researchers. The back of the tank top was cut out to allow for marker and electrode placement on the back. Once back in the lab, the participant's age, weight, height, waist circumference (measured at the top of the iliac crest by 'The Canadian Society for Exercise Physiology – Physical Activity Training for Health' guidelines), body fat percentage (via body impedance analysis (BIA)) and self-reported bra size were recorded.

Next, EMG electrode sites were located via palpation and at these sites the skin was shaved and swabbed with alcohol, and then electrodes were placed per Table 6.1. After all electrodes were placed, the participant laid on the massage table for a 5-minute quiet rest (for baseline activity). The participants then performed two repeats of each MVC resisted task listed in Table 6.2, followed by two AHAbd trials per leg. The IREDs (motion tracking markers) were then placed on the participant at the locations specified in Figure 6.1 and reference postures (upright stand and t-pose) were collected. Three 10-second upright standing trials were collected. Then the table was setup for the prolonged standing trial at which point a baseline VAS was recorded and participants began their 2-hour stand (Figure 6.7). During the 2-hour stand, participants performed four tasks (15 minutes each) in random order. These tasks included cashier task (sorting money), small object assembly (disassembling and reassembling pens), playing/dealing cards mimicking a casino dealer (solitaire), and a reading task on a laptop (Gregory & Callaghan, 2008). The primary purpose of the tasks was to keep the participants occupied during the collection so that they did not turn/look around the lab out of boredom. At the end of each 15-minute task, additional VAS were recorded on blank VAS sheets as not to be influenced by previous scores. After the 2-hour stand, the IREDs were removed, and participants repeated the AHAbd trials. After which all remaining electrodes were removed, and the collection was concluded.

Figure 6.7: Sagittal view of a fully instrumented participant during the 2-hour standing trial.

6.10 Data Processing & Analyses

All kinematic and EMG data were analyzed using Visual3D^{TM} (v6, C-Motion Logistics Inc., Ontario, Canada). Surveys scores were calculated according to each survey guideline, and all statistical analyses were performed using SAS 9.4 (SAS Institute Inc., NC, USA).

6.10.1 EMG

All raw EMG signals were high-passed filtered with a dual pass 4^{th} order Butterworth filter with a cut-off frequency of 30Hz (to remove interference from the electrical activity of the heart; Drake & Callaghan, 2006). Signals were then full wave rectified and low-pass filtered with a dual pass 4^{th} order Butterworth filter with a cut-off of 2.5Hz (Brereton & McGill, 2006). For each muscle, the maximum value was determined from the MVC trials. The EMG channels from the upright trials and 15 minute epochs were normalized to each muscles' respective maximum values from the MVC trials. Mean EMG for each muscle was taken from three upright trials and were used as initial or starting values of prolonged standing. In addition, the mean %MVC of each muscle was taken for each 15-minute epoch of prolonged standing. Mean EMG was taken opposed to maximum EMG, as the maximum may represent a single muscle twitch, which is not reflective of muscle activity throughout the 15-minute epoch.

6.10.2 Kinematics

Visual3D™ was used to create specific 3D models of each participant using the collected reference postures and anthropometric data. Using the spine IRED marker clusters, the model was constructed by dividing the spine into four segments: upper thoracic (C7-T4), mid thoracic (T4-T9), lower thoracic (T9-T12) and lumbar (T12-S2). Raw marker data were low-pass filtered using a dual pass 4^{th} order Butterworth filter with a cut-off frequency of 2.5 Hz (Winter, 2009). The mean angles for each spine segment were calculated between the three upright trials, and were used as the initial or starting spine angles of prolonged standing. Mean angles for each spine segment, for each of the 15 minute epochs of prolonged standing were calculated, and subtracted from the upright standing trial mean angles.

6.10.3 Questionnaire

Each question of the *RSES* was scored between 0 and 3 (Rosenberg, 1979). According to Rosenberg (1979), questions 1, 3, 4, 7 and 10 an answer of ‘Strongly Agree” was scored 3, ‘Agree’ was scored 2, ‘Disagree’ was scored 1 and ‘Strongly Disagree’ was scored 0. For questions 2, 5, 6, 8, and 9 the scoring guide was inverted (Rosenberg, 1979). The scores were summed, and a larger score reflected higher self-esteem (Rosenberg, 1979).

The *SPAS* used a 5-point scale, ‘not at all characteristic of me’ scored 1 through to ‘extremely characteristic of me’ which scored 5 (Hart et al., 1989). For questions 1, 2, 5, and 11, the scores were inverted before summing (Hart et al., 1989). After summing, a greater score reflected greater social physique anxiety (Hart et al., 1989).

The *BSQ* used a 6-point scale which ranged from ‘Never’ worth a score of 1 and ‘Always’ worth a score of 6 (Cooper et al., 1987). The score was summed, and a greater score reflected a greater dissatisfaction with one’s body shape and negative body image (Cooper et al., 1987).

6.10.4 Lumbopelvic Control

Three reviewers (including the researcher SYW) evaluated the AHAbd videos. The videos were evaluated twice: once (week 1) and then again after a three week wash out period (week 5). Each reviewer was given different randomized orders to evaluate the videos to minimize reviewer bias. A score between 0 and 3 represents no loss to severe loss of pelvic control in the frontal plane was given for each trial and each leg based on the descriptions of Table 3.1. When scores were inconsistent between reviewers, reviewers convened, re-watched the trial together and deliberated on the score until a unanimous decision was reached. The worst score across both legs was taken as their final score.

6.10.5 Statistical Analyses

All statistical analyses used an alpha level of 0.05 to indicate statistical significance and were performed using SAS 9.4 (SAS Institute Inc., NC, USA). Two-way repeated measure mixed model analysis of variance (ANOVA) was used to evaluate significance between breast size (2 levels: SG, LG), epoch (9 levels: initial, and 8x 15-minute time epochs) and spine angles (each spine segment assessed separately). Similarly, two-way repeated measure mixed model ANOVAs were used to evaluate significance between breast size (2 levels: SG, LG), epoch (9 levels: initial, and 8x 15-minute time epochs) and EMG for each muscle. Tukey post hoc tests were used to evaluate factors for all ANOVAs.

Pearson product moment correlations were performed between each survey and breast size, survey and pain scores (upper, mid and low back) and survey and upright angles. These correlations were used to evaluate whether self-esteem, social physique anxiety and body image have a possible relationship with breast size, pain scores and upright spin angles. Correlation coefficients were categorized as followed: 0.00-0.19 (very weak), 0.20-0.39 (weak), 0.40-0.59 (moderate), 0.60-0.79 (strong) and 0.80-1.00 (very strong; Swinscow, 1997). One-way ANOVAs were performed on breast size (2 levels: SG and LG) and survey score.

CHAPTER 7:
Results

Generally, the two breast size groups were consistent over time in EMG and kinematics, but both groups increased in pain over time. However, the LG group reached clinically relevant levels of pain sooner and had a greater overall magnitude of pain than the SG group in the upper, mid and low back regions. A summary of mean anthropometrics for SG and LG can be found in Table 7.1. No statistical differences were found between SG and LG for age, mass, BMI, body fat percentage, or waist circumference.

Table 7.1: Mean age, mass, BMI, BIA, waist circumference, OBCC-UBCC measurements and cup size for SG and LG groups.

	SG (n= 11)	**LG** (n= 10)
Age (years)	23.36 ±2.58	20.10 ±1.66
Mass (kg)	60.66 ±11.39	61.90 ±7.25
BMI (kg/m^2)	21.78 ±2.39	22.21 ±2.56
BIA (%)	20.25 ±4.84	21.94 ±6.01
Waist Circumference (cm)	70.50 ±8.09	70.55 ±4.06
OBCC-UBCC (cm)	7.39 ±2.11	13.97 ±1.80
Average Cup Size	~B-C	~D-E

7.1 EMG

Mean EMG showed abdominal muscles (RRA, LRA, REO, LEO, RIO, LIO) had no statistically significant differences between breast size groups. Both groups had relatively consistent activation levels over the 2-hour stand (Figure 7.1). For REO specifically (p=0.99), the SG group had a range of 2.66-3.37%MVC while the LG group had a range of 3.09-3.61%MVC (Figure 7.1).

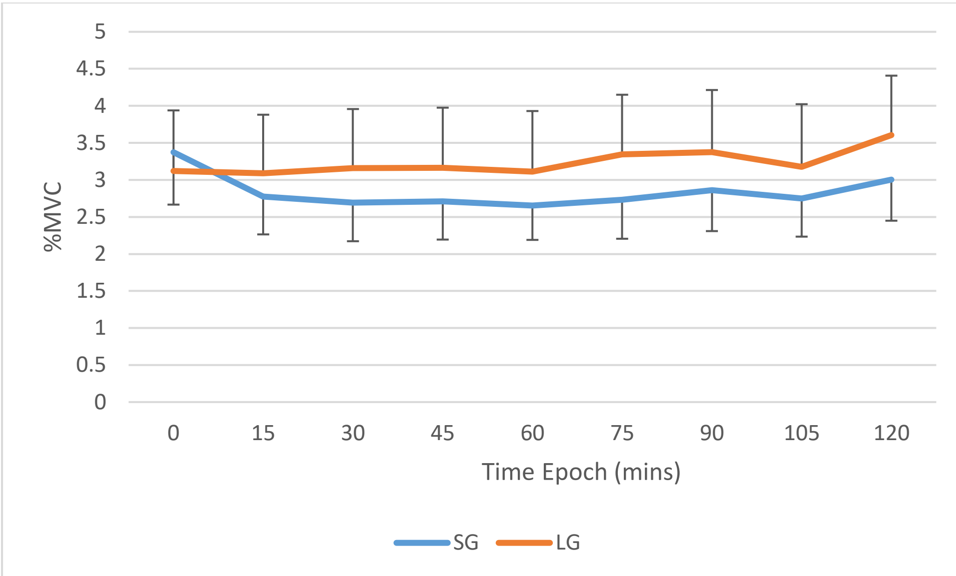

Figure 7.1: Muscle activation of REO during the 2-hour stand. Both SG and LG had low variability in muscle activation (%MVC) throughout the trial. Error bars represent standard error (SE).

Similar to the abdominal muscles, gluteal muscles LGM and RGM were relatively consistent (not changing) over the 2-hour stand (Figure 7.2). SG's range in muscle activation in RGM (p=0.88) was 3.27-5.31%MVC while LG's range is 3.03-8.27%MVC (Figure 7.2). In the final epoch, LGM (p=0.96) mean activation appears to spike to 8.27%MVC due to a large increase in the data from one participant (Figure 7.2), however, there was no statistical difference between breast size groups for any epoch for the gluteal muscles.

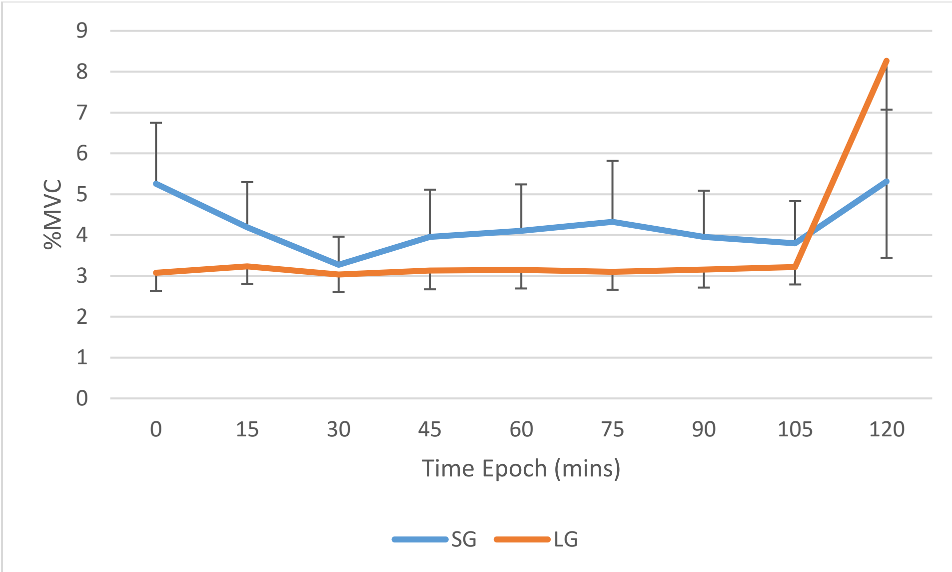

Figure 7.2: Muscle activation (%MVC) of RGM during prolonged standing. SG had a non-significant increase muscle activation in the final epoch. Error bars represent SE.

Similar to the abdominal and gluteal muscles, the mean muscle activation all of the levels of the ES muscles (LTES_4, RTES_4, LTES_9, RTES_9, LLES and RLES) were also consistent throughout the 2hours of standing. There were no statistically significance differences in TES_4, TES_9 or LES between SG and LG. RTES_4 (p=0.99) is an example of the low variability which ranged between 3.16%MVC - 5.04%MVC in the SG group and 1.97%MVC - 4.01%MVC in the LG group (Figure 7.3). Overall, there were no differences in mean muscle activation between SG and LG for each muscle.

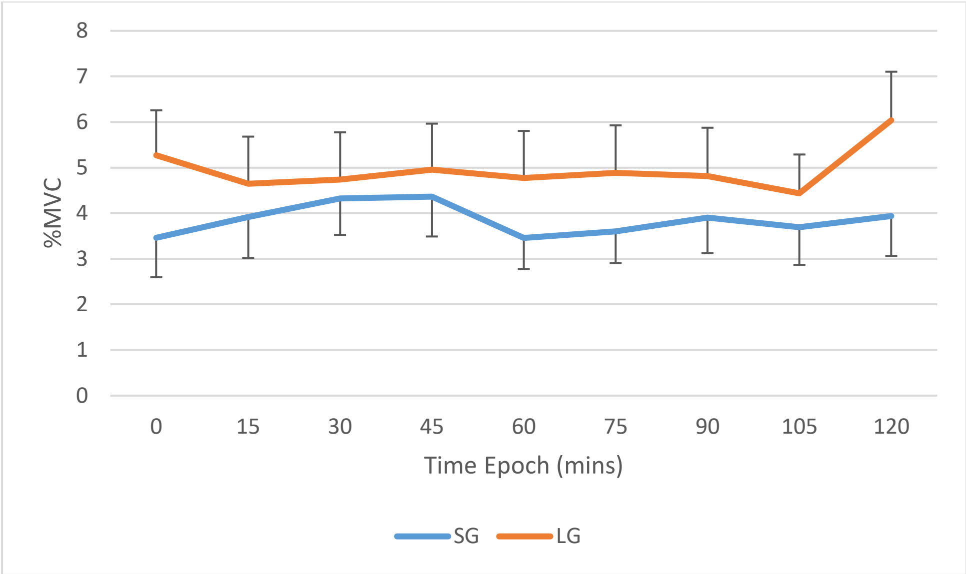

Figure 7.3: Mean muscle activation (%MVC) of RTES_4 for SG and LG which portrays the low variability displayed across TES_4, TES_9 and LES. Error bars represent SE.

To be able to compare mean %MVC with previous research, Pearson product moment correlations were calculated between breast size and mean %MVC across the 2-hour stand for each muscle. LGM, LLES, LRA, RRA, RTES_4 and RTES_9 had a weak correlation with breast size. All other muscles had very weak correlations to breast size (Table 7.2).

Table 7.2: Correlation coefficients between breast size and mean %MVC across the 2-hour stand for each muscle.

Muscle	r-value
LEO	0.02
LGM	0.20
LIO	0.13
LLES	0.25
LRA	0.31
LTES_4	0.11
LTES_9	0.08

Muscle	r-value
REO	0.15
RGM	-0.16
RIO	-0.08
RLES	-0.12
RRA	0.20
RTES_4	0.29
RTES_9	0.20

7.2 Kinematics

Upper thoracic, mid thoracic, lower thoracic and lumbar angles were subtracted from the upright standing values and showed similar patterns between SG and LG over time. Both breast size groups are not very variable in any of these angles. Both SG and LG began the prolonged standing trial similarly and remain similar over the two hours (Figure 7.4). There were no statistical differences between SG and LG for all spine angles (upper thoracic: p=0.72, mid thoracic: p=0.98, lower thoracic: p=0.99, lumbar: p=0.99). Additionally, upright angles within SG group were not different from one another. Overall, there were no differences in all mean spine angles between SG and LG. Thoracic angles were also collapsed across levels and were analyzed as upper and mid thoracic (C7-T9) as well as upper, mid and lower thoracic (C7-T12) together in case the division of the thoracic spine into three segments masked responses. However, no differences in these aggregated mean angles were found between SG and LG in either analysis (C7-T9 p=0.99; C7-T12 p=0.89).

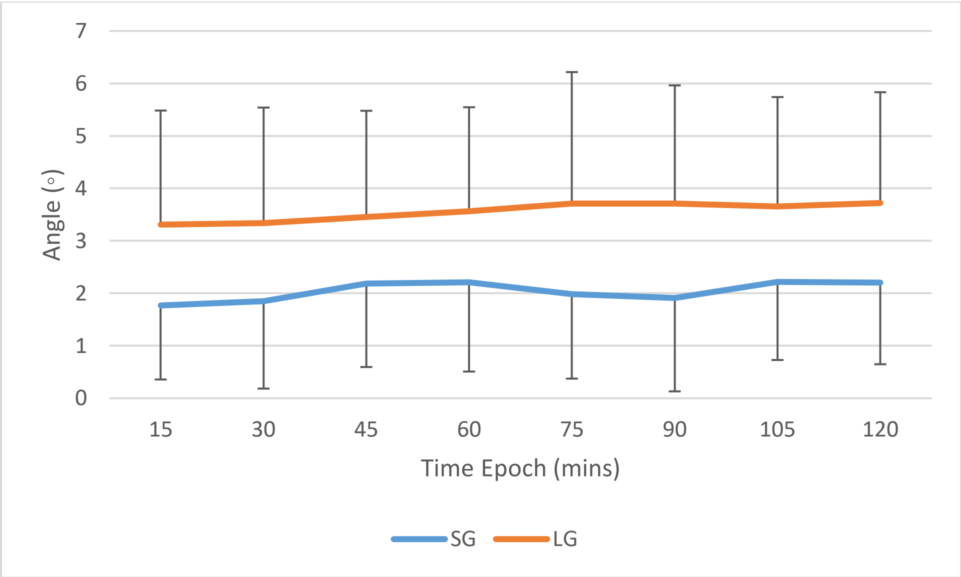

Figure 7.4: Mean upper thoracic spine angles of SG and LG (p=0.72). Both groups remain similar throughout the standing trial. Error bars represent SE.

7.3 Pain Development

Self-reported perceived pain of three regions in the spine were recorded from the participants using VAS. Recall, if participants had an overall change less than 10mm they were classified as NPDs and if equal to or greater than 10mm were classified as PDs. Again, 10mm change is a level of pain considered clinically relevant. PD and NPD percentages were determined for the upper, mid and low segments (Table 7.3). During the two-hour stand in the upper back, 90% of the LG were PDs while only 54.4% of the SG developed clinical levels of pain (Figure 7.8). In the mid back, 70% of LG developed pain and 45.5% of SG were PDs (Figure 7.9). Both LG and SG had more PDs than NPDs in the low back at 80% and 72.7% for LG and SG respectively (Figure 7.10). These data show that overall more participants in LG had higher levels of pain in the upper and mid back than SG. In the upper and mid back, SG is almost split evenly between PDs and NPDs. For the low back, both SG and LG were similar in that both groups had a greater number of PDs than NPDs. The samples overall (n=21) yielded 71.4% PDs in the upper back, 57.1% in the mid back and 76.2% in the low back. In addition, Sørensen et al. (2016) had defined a change of ≥ 20mm as extreme or clinical level of pain development (Table 7.4). In the upper back, only 36.4% of participants in the SG group developed extreme pain while 80% of LG group developed extreme pain. Similarly, in the mid back, 36.4% and 70% of SG and LG developed extreme pain respectively and 45.5% and 70% of SG and LG developed extreme pain in the low back.

Table 7.3: Percentage of PDs and NPDs from VAS scores in SG, LG groups and the overall sample, for upper (C7-T4), mid (T4-T12) and low (Lumbar) back segments with a change ≥ 10mm.

	Upper (%)		Mid (%)		Low (%)	
	NPD	PD	NPD	PD	NPD	PD
SG (n=11)	45.5	54.5	54.4	45.5	27.3	72.7
LG (n=10)	10	90	30	70	20	80
Overall (n=21)	28.6	71.4	42.9	57.1	23.8	76.2

Table 7.4: Percentage of PDs and NPDs from VAS scores in SG, LG groups and the overall sample, for upper (C7-T4), mid (T4-T12) and low (Lumbar) back segments with a change ≥ 20mm.

	Upper (%)		Mid (%)		Low (%)	
	NPD	PD	NPD	PD	NPD	PD
SG (n=11)	63.6	36.4	63.6	36.4	54.5	45.5
LG (n=10)	20	80	30	70	30	70
Overall (n=21)	42.9	57.1	47.6	52.4	57.1	42.9

When comparing mean changes in upper VAS at each time epoch between SG and LG groups (Figure 7.5), SG group had clinical levels of pain in the upper back after 60 minutes had passed while the LG group experienced clinical levels of pain after only 30 minutes, which is 50% faster than the SG group. The maximum mean change in SG was 16.9mm while LG had a max difference of 28.5mm. The greatest difference in mean changes in pain between SG and LG was found in the mid back. The LG group showed a clinically relevant change in mid back VAS score after 45 minutes (Figure 7.6). However, the SG group showed a clinically relevant change after the completion of 2 hours. This shows that the LG group developed clinical levels of pain in the mid back 62.5% faster than the SG group. The maximum difference in LG was 21.7mm while SG had a maximum difference of only 13.7mm for the mid back segment. The pattern of mean changes in VAS scores between SG and LG in the low back was similar (Figure 7.7), with both the SG and LG groups developing clinically relevant levels of pain after 45 minutes. However, the SG group had a maximum change of 19.1mm, while the LG groups had a maximum difference of 27.6mm. Overall, LG had a greater number of individuals develop clinically relevant levels of pain in the upper, mid and low back than the SG group. Additionally, LG developed clinically significant pain 50% faster than SG in the upper back and 62.5% faster in the mid back. Both SG and LG developed clinically relevant levels of pain after 45 minutes in the low back.

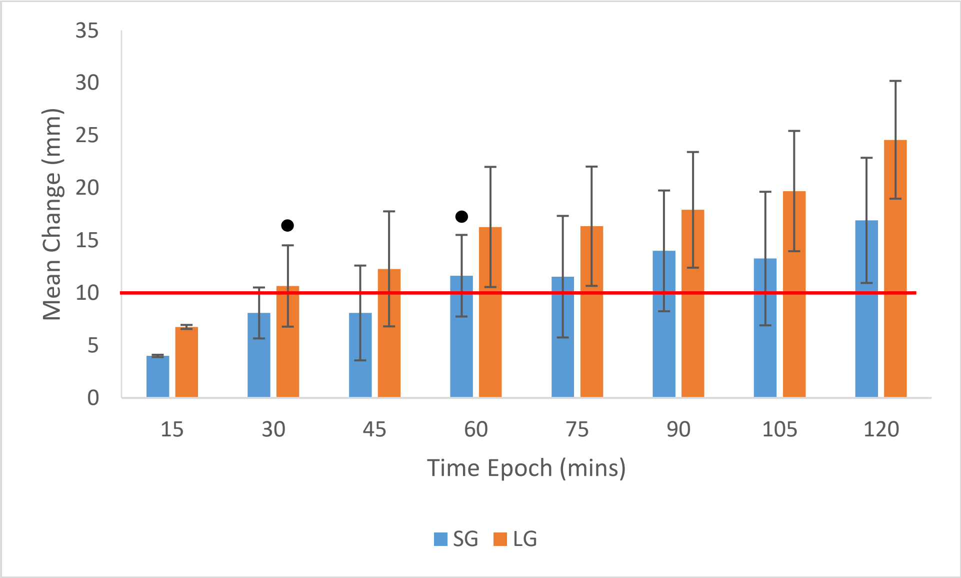

Figure 7.5: Mean changes of upper back VAS scores between SG and LG groups. Both SG and LG increase in pain over the 2 hours of standing. However, SG does not experience as great of a change as the LG group. ● represents in which epochs SG and LG experience clinical levels of pain (change is ≥ 10mm). Error bars represent SE.

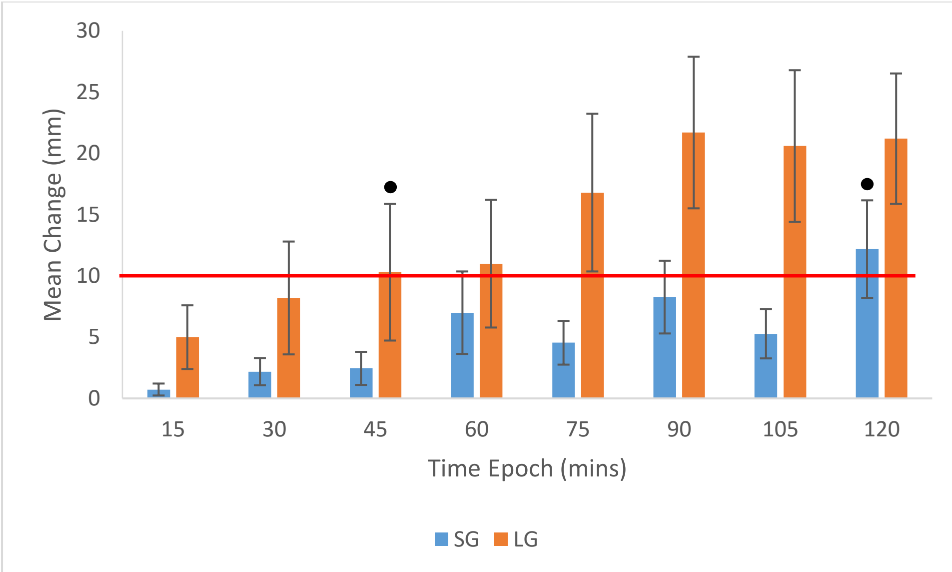

Figure 7.6: Mean changes of mid back VAS scores between SG and LG groups. The SG group's pain remains relatively the same until 2 hours, whereas pain in the LG groups increases at a greater magnitude than SG until 90 minutes at which point changes remain relatively the same. ● represents in which epochs SG and LG experience clinical levels of pain (change is ≥ 10mm). Error bars represent SE.

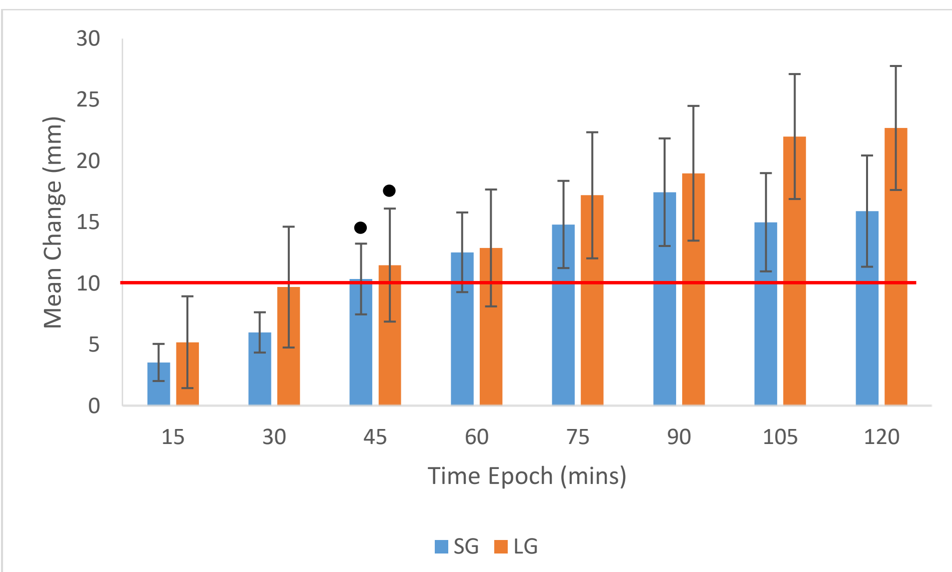

Figure 7.7: Mean changes of low back VAS scores between SG and LG groups. Both SG and LG groups increase in pain over the 2 hours of standing. ● represents in which epochs SG and LG experience clinical levels of pain (change is ≥ 10mm). Error bars represent SE.

7.4 Lumbopelvic Control

From the AHAbd videos, participants were determined to have good lumbopelvic control (score of 0 or 1) or poor lumbopelvic control (score of 2 or 3). The participants were assessed with different groupings using two different criteria. Participants were first analyzed by breast size groups (SG and LG). Approximately half of each SG and LG groups had good lumbopelvic control (Table 7.5, A). The participants were also grouped by PD and NPD using the low back VAS scores to permit comparisons with previous research. Only five individuals were categorized as NPD and of these five individuals only one participant was found to have poor lumbopelvic control (Table 7.5, B). Sixteen individuals were categorized as PDs and half were found to have poor lumbopelvic control (Table 7.5, B).

Table 7.5: A) Shows the number of participants with good and poor lumbopelvic control divided by breast size groups. Approximately 50% of both SG and LG groups had poor lumbopelvic control. B) Shows the number of participants with good and poor lumbopelvic control dived by PD or NPD from low back VAS scores. 50% of PDs had poor lumbopelvic control where as 20% of NPDs had poor lumbopelvic control.

A	Good Lumbopelvic Control (AHAbd score 0-1)	Poor Lumbopelvic Control (AHAbd score 2-3)
SG (n=11)	4	7
LG (n=10)	5	5

B	Good Lumbopelvic Control (AHAbd score 0-1)	Poor Lumbopelvic Control (AHAbd score 2-3)
NPD (n=5)	4	1
PD (n=16)	8	8

7.5 Questionnaire

Survey scores were calculated per survey guidelines and mean scores for SG and LG were calculated for each survey (*RSES*, *SPAS* and *BSQ*). Mean *RSES* were 20.36 and 18.1 out of a possible total of 30, for SG and LG respectively, which suggests LG had lower self-esteem than SG. Mean *SPAS* scores were 34.09 and 40.9 out of 60, for SG and LG respectively, suggesting that LG had greater social physique anxiety. Lastly, mean *BSQ* scores were 73.18 and 111.70 out of 204, for SG and LG respectively, suggesting that LG had more negative body image than SG. A comparison of mean survey scores between SG and LG can be found in Figure 7.8. Overall, SG group preformed more positively in all three questionnaires than LG.

Pearson product moment correlations were calculated for each survey against the following variables: breast size, upper back VAS, mid back VAS, low back VAS and the initial upright standing angles of the upper thoracic, mid thoracic, low thoracic and lumbar segments (to determine if self-esteem, social physique anxiety and body image effect posture prior to the prolonged exposure). Correlation coefficients (r) for breast size and surveys were 0.38 (weak), 0.52 (moderate) and 0.63 (strong) for *RSES*, *SPAS* and *BSQ* respectively (Swinscow, 1997). One-way ANOVAs were performed to determine differences between breast size groups and survey scores. ANOVAs showed no significant difference between breast size and *RSES* or *SPAS* (p=0.26, p=0.07, respectively). The only significance found was between breast size and *BSQ* (p=0.01) suggesting that breast size may be related one’s body image.

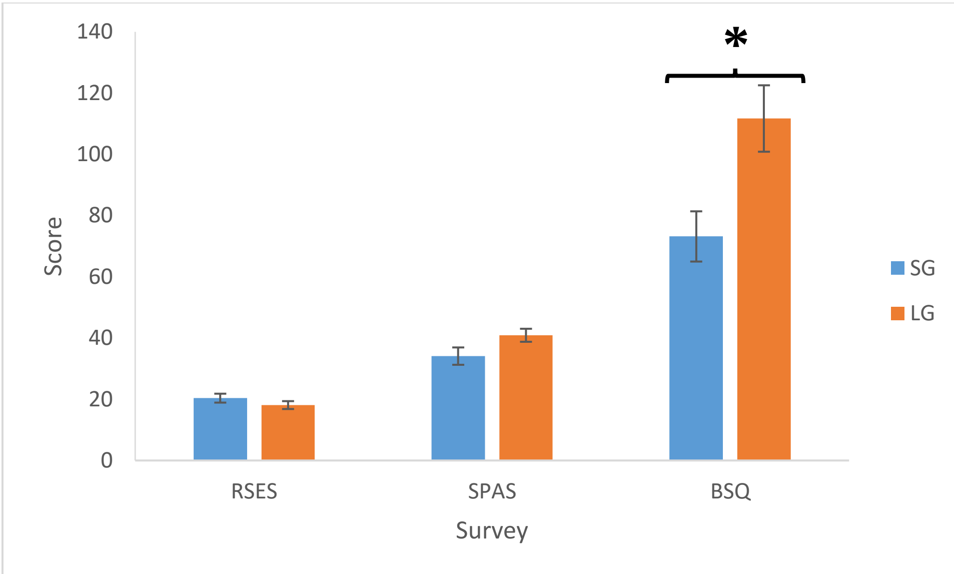

Figure 7.8: Mean scores of RSES, SPAS and BSQ for SG and LG groups with error bars indicating SE. A significant difference was found between breast size groups and BSQ scores $*p<0.05$.

Correlation coefficients for *RSES* and *SPAS* compared to upper, mid and low VAS scores were all between 0.03 and 0.25 suggesting a weak relationship and so there may not be a relationship between self-esteem and anxiety, and perceived pain. However, VAS scores compared to *BSQ* scores yielded correlation coefficients for upper, mid and low back of 0.37 (weak), 0.31 (weak) and 0.12 (very weak) respectively. The correlation coefficients of upper and mid back for *BSQ* indicate a possible weak relationship between the two variables.

To determine if self-esteem, social physique anxiety and body image are related to posture, Pearson product moment correlations were calculated between survey scores and mean upright angles for each of the four segments of the spine. These correlation coefficients can be found in Table 7.6. The r-values of upper thoracic and mid thoracic for *RSES* were are considered positively, moderate and so suggest that there may be a correlation between the angles of the spine segments and self-esteem.

Table 7.6: Summary of calculated correlation coefficients of each spine segment for each survey. Upper thoracic and mid thoracic angles had a positive moderate correlation with self-esteem.

	Upper Thoracic	Mid Thoracic	Low Thoracic	Lumbar
RSES (*r*)	0.44	0.45	0.06	-0.03
SPAS (*r*)	-0.23	0.26	0.33	-0.11
BSQ (*r*)	-0.13	0.18	-0.19	-0.09

CHAPTER 8:
Discussion

Overall, the findings did not support the hypotheses of this study. Muscle activation and spine angles were not different between SG and LG, and perceived pain showed that LG had a greater number of individuals develop clinical levels of pain. Additionally, *BSQ* scores showed a strong positive correlation with breast size. While the measures were not statistically different between SG and LG, the differences between the groups may be clinically related as a greater number of LG were PDs and had an earlier onset of clinical levels of pain than SG. These findings suggest further research on breast size and biomechanics are required to better understand the mechanisms causing pain development in larger breasted women.

While height and weight were not different between SG and LG, surprisingly, there were no differences between SG and LG in BMI or body fat percentage. This is not consistent with previous research which found that women with larger breasts have a significantly greater BMI and body fat percentage in a population that ranged from ‘A’ cup to ‘DD+’ cups (Coltman, Steele & McGhee, 2017; Brown et al., 2012). Likely the similar BMI and body fat percentage across participants in the current study was due to recruiting methods (predominantly Kinesiology and Health Science students). Also, the findings from the previous research that found differences in spine angles, muscle activation, BMI, and/or body fat percentage may have been found due to the smaller breast sized women in their sampled populations. This thesis did not have any participants who were an ‘A’ cup. The absence of small chested women may be the reason why a difference was not found between SG and LG as the SG group was relatively large compared to previous research (Findikcioglu et al., 2007; Karabekmez et al., 2014). Future research should consider methods to recruit a wide range of women with varying breast sizes.

This novel study combined EMG, kinematics, pain development and psychosocial factors analyses and as such there have not been many previous studies that investigated breast size and muscles activity. Schinkel-Ivy & Drake (2016) found a positive, moderate strength correlation between breast size (ranged from B to D cup) and mean %MVC of LLES, LRA and REO muscles during short upright standing trials (10 seconds long). However, this study found that LGM, LLES, LRA, RRA, RTES_4 and RTES_9 had weak positive correlations with breast size. RTES_4 was borderline moderate (0.29). SG and LG groups did not have any statistical differences in the mean activation of any of the collected muscles over the two hours of standing. Schinkel-Ivy & Drake (2016) may have found stronger correlations due to shorter trials or because the upright standing trials were mixed with motion trials such as maximal forward flexion. Non-neutral spine activities, such as bending, are a key factor since there would be a suspected greater extensor moment required by the back muscles to offset the greater flexion moment caused by the increased mass in the breasts and increased moment arm of the mass distributions. While it was hypothesized that the LG group would have greater muscle activation over the two hours of standing than SG, it is suspected that the data did not support the hypothesis due to several possible reasons. First, the mean activation in LG may not have increased over time because the muscles in the LG individuals may have adapted to the gradually increasing load of breasts as the individual developed particularly in muscles in the back (TES_4, TES_9 and LES) help counterbalance the weight of the breasts and maintain a neutral posture (Stauber, 1989). Second, it is possible that there are underlying changes from the loading to passive tissues or deep muscles that cannot be captured with surface EMG. Third, the prolonged standing exposure might not have been sufficiently sensitive to measure the impacts of breast size on mean muscle activation, or may have impacted only the motor-control of the muscles (i.e. co-contraction, activation patterns). Future research should consider alternate methods to evaluate biomechanical responses and psychosocial factors to breast size and/or change to a dynamic exposure as opposed to a sedentary exposure.

The suggestion that the muscles in LG group have adapted to the extra weight of larger breasts is also reflected in the spine angles. LG group did not have statistically greater thoracic kyphosis or lumbar lordosis compared to the SG group initially and over time. Muscles adapting to the constant and slow increase in anterior load (the breasts) could potentially be the reason why the women's posture in LG group were found to be more neutral than hypothesized (Stauber, 1989). However, LG group having similar kyphosis or lordosis than smaller breasted women is not reflected in the literature. Previous literature found that women with larger breasts had greater kyphosis and lordosis than women with smaller breasts (Findikcioglu et al., 2007). Findikcioglu et al. (2007) had investigated 93 radiographs and compared spine angles between different cup sizes. Twenty-five individuals were in the A and C cup groups, 24 in the B cup group and 19 in the D cup group (Findikcioglu et al., 2007). Findikcioglu et al. (2007) may have seen a difference in spine angles as they had 25 individuals in the A cup group while the current study did not have any individuals with A cup sized breasts. As previously discussed, this study did not have individuals with 'A' cup breast sizes, and so perhaps the SG and LG difference in anterior load was not enough to separate the groups. A difference between SG and LG may have been seen had there been a greater difference in size between the groups (A cups versus E+ cups) as a greater anterior load at a greater distance from the spine elicits greater anterior shear and flexion moment (McGill, 2007). Further, Karabekmez et al. (2014) found that women had greater kyphosis and lordosis prior to receiving breast reduction surgery and after surgery spine angles improved. However, this could be due to a decrease in anterior load as the weight of the breasts decreased allowing for muscles to maintain a neutral posture easier than with a heavier load. While breast reduction surgery has shown to improve spine angles, surgery is costly, can cause complications with breast feeding (Shakespeare & Postle, 1999), and is usually reserved for extreme cases and therefore is not a solution for everyone. Lastly, the segmentation of the thoracic spine into multiple segments (upper, mid, low) versus one segment (like kyphosis measures) would have impacted the angles measured which may have masked the changes occurring in LG. Although the findings in this thesis do not reflect previous literature, further research investigating the relationship between breast size and biomechanical responses of the spine is warranted.

Changes in perceived pain over time were not statistically different for upper, low and most of mid back, but LG had more individuals reach clinically relevant levels of pain in each segment and reached clinically relevant levels of pain faster than SG individuals. Previous research shows that during prolonged standing 40 – 65% of individuals develop transient LBP (Nelson-Wong et al., 2008; Nelson-Wong & Callaghan, 2014). Overall, this study had 76.2% of participants develop transient pain in the low back, which is a little higher than the literature shows (Nelson-Wong et al., 2008; Nelson-Wong & Callaghan, 2014). However, 72.7% of SG developed transient LBP, which is slightly closer to findings in previous literature, which uses similar methods to measure pain development (Nelson-Wong et al., 2008; Nelson-Wong & Callaghan, 2014). In contrast, 80% of LG developed clinically relevant levels of pain in the same segment. The greater number of PDs in LG group may be related to breast size, though this cannot be confirmed. The high number of PDs in SG compared to previous literature could again be due to the lack of 'A' cup and small number of 'B' cup individuals in the study. Anecdotally, previous research in prolonged standing had unintentionally used smaller chested women

(Gregory & Callaghan, 2008; Nelson-Wong & Callaghan, 2010). However, there is support that breast size may have a relationship with the development of pain in the upper and mid back. Specifically, there was a greater divide in PDs and NPDs between SG and LG in the upper and mid back. 90% of individuals in LG were PDs while only 54.5% of SG developed clinically relevant levels of transient pain in the upper back. This could be due to pain associated with brassier straps on the shoulders in larger chested women, which was found to decrease after individuals underwent breast reduction surgery (Adham et al., 2010). Similarly, 70% of LG developed pain in the mid back while only 45.5% of SG developed pain in the same area. The mid back is where the band of a brassiere typically rests and it is speculated that the cause for greater PDs in the LG group as the band helps support the load of the breasts. Further, the onset of clinically relevant levels of pain was achieved faster in the LG group than SG in the upper and mid back. On average, the LG group developed clinically relevant levels of pain in half the time that the SG group did (30mins vs 60mins) in the upper back (Figure 7.5). Likewise, LG group developed clinically relevant levels of pain 62.5% faster than SG (45mins vs 120mins) in the mid back (Figure 7.6). Unlike the upper and mid back, both groups developed clinically relevant levels of pain after 45 minutes of standing in the low back (Figure 7.7).

Further, more individuals in the LG group developed extreme or clinical levels of pain (≥ 20mm) in the upper, mid and low back (Table 7.4). Sørensen et al. (2016) found only 21% of their PDs developed extreme pain in the low back. However, 45.5% of SG and 70% of LG developed extreme pain which is greater than what Sørensen et al. (2016) had found. It should be noted that Sørensen et al. (2016) collected on both female (n=24) and male (n=28) participants and did not record breast size. The greater number of extreme PDs observed in this study could be due to having larger breast sized women overall compared to Sørensen et al. (2016). In addition, poor lumbopelvic control may have been a factor in low back pain development. Although the overall changes in VAS score is not statistically significant, the rate at which LG developed pain in the upper and mid back compared to SG (50% and 62.5% faster respectively) is too high not to be clinically or life relevant (effect individuals' day to day living). If having larger breasts is the cause for increased pain in the back, then these women require a solution to avoid or minimize back pain.

The relationship between breast size and psychosocial factors was evaluated using survey scores for SG and LG. Again, correlation coefficients (r) for all Pearson product moment correlations were designated: 0.00-0.19 (very weak), 0.20-0.39 (weak), 0.40-0.59 (moderate), 0.60-0.79 (strong) and 0.80-1.00 (very strong; Swinscow, 1997). Correlation calculations yielded a weak, positive correlation between breast size and *RSES* and a moderate, positive correlation between breast size and *SPAS*. This suggests that self-esteem and social physique anxiety may not be related to one's breast size. *BSQ* scores had a strong, positive correlation between breast size and *BSQ* suggesting that there may be a relationship between breast size and body image. For breast size groups, only breast size and *BSQ* was significant (p=0.01) suggesting a significance between breast size and body image. Women with large breasts had a more negative body image, suggesting that women with large breasts may be unhappy about their bodies. However, breast size and *SPAS* had a p-value of 0.07, which could suggest a possible significance between breast size and social physique anxiety had the sample size been larger. Similar to body image, women with large breasts may be more anxious about their bodies in public and may feel that their bodies are under scrutiny. Correlation coefficients for *RSES*, *SPAS* and VAS scores were very weak or weak suggesting there may not be a relationship between self-esteem or social physique anxiety and pain development. Similarly, *BSQ* and VAS scores for upper, mid and low back were very weak or weak as well. Although upper back VAS and *BSQ* scores had a positive, weak correlation (0.37) it is borderline moderate and therefore may show a stronger correlation had there been a larger sample size, which could suggest a relationship between development of upper back pain and body image. Upright standing spine angles were very weak or weak (Table 7.6) with the exception of *RSES* versus upper and mid thoracic angles which were moderate (0.44 and 0.45 respectively) which may suggest a relationship between self-esteem and posture. A more negative self-esteem score suggests that an individual may adopt a more slumped posture. This thesis was a novel study combining biomechanics and psychosocial factors research measuring the impact of breast size, therefore further research is required to better understand these potential relationships.

Although there are no statistical differences between breast size groups (SG: B-C cup; LG: D+ cup), muscle activation, spine angles and changes in pain over time, there is much to consider for future research. Considering the large difference in number of PDs and the onset of pain between the two groups, having larger breasts seems to be related to pain development in the back, which gives reason that further research into differences in muscle activation and kinematics between breast sizes is required. Further, it is suggested that there may be a correlation between breast size and psychosocial factors, although this cannot be confirmed. However, this finding gives precedent to further investigate the relationship. While the currently used metrics for EMG and kinematics did not show differences between breast size groups, there is evidence that there is some pain generating mechanisms with increasing breast size. Future research should consider combining biomechanics, and psychosocial factors to further understand their relationships with breast size. Additionally, a rehabilitation and preventative exercise or coping program should be developed to help alleviate pain in women across all breast sizes and help minimize the development of pain in adolescents.

8.1 Limitations

It is important in research studies that limitations be considered. Firstly, it should be noted that the size, shape and composition of breasts can be variable between the left and right breasts of an individual and are also highly variable between women (Moore et al., 2010). Consequently, breast size measurements (OBCC and UBCC) are not always reflective of breast size as the measurements do not consider breast shape. The ideal method to divide individuals into SG and LG groups would be to measure the weight of breasts. However, there are currently no means of measuring the weight of breasts. Additionally, the SG group was relatively large compared to other breast size or biomechanical studies, as there were no ‘A’ cup sized women, and the average size of SG was a ‘C’ cup. The study may have found significant differences between SG and LG had there been a greater divide in the breast size groups.

Another limitation to consider is that a sample size of 21 is not sufficiently large to have statistical power for the psychosocial metrics of the study (outcomes of the questionnaires). Studies evaluating psychosocial factors can have sample sizes of 550, 93 and 450 for example (Barnes & Caltabiano, 2017; Clode, Lewis & Fuller-Tyszkiewicz, 2016; Uchoa et al., 2017). Although a sample size of 21 is not sufficiently large for the psychosocial metrics, the study was designed primarily as a biomechanics study. Regardless of the low sample size a moderate correlation was found between *SPAS* and breast size and approached significance (p= 0.07). Similarly, a strong correlation between *BSQ* and breast size with a significant difference between the two (p=0.01). Further, a strength of this study is that BMI and body fat percentage were not found to be different between SG and LG, which is unusual as large breasts can be mainly made up of adipose tissue (Moore et al., 2010). Again, it is possible that BMI and body fat percentage were not significant different between groups because from the majority of participants were from York University's Kinesiology and Health Sciences program, which may have resulted in participants who were more physically active compared to an average population. It is well known that exercise has shown to improve body image and anxiety (Reel, 2007). As the participants have above average levels of physical activity, it is possible that the population has higher positive body image and lower social physique anxiety than usual due to their participation in physical activity. However, both SG and LG groups had participants with high physical activity (noted from exit survey), which suggests that the effects exercise can have on body image and anxiety, effected both sample groups. The psychosocial metrics were added to determine if there may a possible relationship between body image and posture and whether more research needs to be conducted in the area. Even with these limitations, the results of this study suggest that there may be a clinical relationship between breast size, the development of back pain and psychosocial metrics and suggests further research is needed.

CHAPTER 9:
Hypotheses Revisited

Hypotheses #1: *Individuals with larger breast sizes will have a greater muscle activation in the upper and lower thoracic, and lumbar regions of the spine (upper and lower erector spinae muscles) compared to smaller breast sized individuals.*

No significant differences were found between breast size groups. Mean muscle activation levels were similar between SG and LG throughout 2-hours of standing in all the collected muscles. However, positive weak correlations were found between breast size and LGM, LLES, LRA, RRA, RTES_4 and RTES_9.

Therefore, this hypothesis was REJECTED.

Hypothesis #2: *Individuals with larger breast sizes will have increasing thoracic flexion over time but will not have greater positive body image relative to entire participant population.*

The LG group showed no statistically significant increases in thoracic flexion over 2-hours of standing. However, the LG group did not have greater positive body image compared to SG. Regardless of a more negative body image, the LG group did not increase in thoracic flexion over time.

Therefore, this hypothesis was REJECTED.

Hypothesis #3: *Individuals with smaller breast sizes who have greater thoracic flexion initially, will not have greater positive body image relative to other individuals of similar breast size who do not have as exaggerated thoracic flexion initially.*

Initial upright angles were not different within the SG group. Therefore, body image relative to upright angles in SG group was not testable.

Therefore, this hypothesis was REJECTED.

Hypothesis #4: *Body image will not be correlated to breast size.*

While *RSES* had a weak correlation with breast size, *SPAS* and *BSQ* showed to have a moderate and strong correlation with breast size respectively. A significant difference was found between SG and LG groups in *BSQ* scores only. Body image may be correlated to breast size. However, further research with a greater sample size is required to confirm the correlation.

Therefore, this hypothesis was REJECTED.

Hypothesis #5: *Individuals with larger breast sizes will have greater pain development in the upper, mid and low back compared to individuals with smaller breasts.*

Pre-post prolonged standing pain development between SG and LG was not statistically different in the upper, mid and low back. However, analysis of epoch pain development revealed that LG had significantly larger pain develop in the mid back than SG. Also, LG had a greater number of individuals develop pain in all three regions of the back compared to SG, and developed pain faster in the upper and mid back ≥ 10mm and ≥ 20mm. This suggests that there is a clinical relevance between breast size and pain development in the back, albeit not the same for each back segment.

Therefore, this hypothesis is REJECTED.

CHAPTER 10:
Conclusion

It is known that large breasts in women can cause symptoms such as back pain, grooving shoulder straps, and also greater kyphosis and lordosis angles (Foreman et al., 2009; Karabekmez et al., 2014). However, little is known about the mechanisms that cause increased pain, muscle activation patterns, kyphosis and lordosis and the affect of psychosocial factors on biomechanical responses in relation to breast size.

This study found no statistical differences between smaller and larger breasted women in muscle activation, spine angles and back pain during prolonged standing, which was potentially found due to a lack of ‘A’ cup individuals. It was found however, that women with larger breasts develop back pain at a faster rate and are more likely to develop back pain. Further, a positive, moderate correlation was found between breast size and body image. The relationship between breast size and muscle activation and posture and their effects on back pain development needs to be further investigated. Likewise, the effects of psychosocial factors on posture and muscle activation also needs to be better understood. It is not until these relationships are understood can effective non-surgical intervention methods can be developed to help women with large breasts manage, minimize and avoid developing pain. Progressive steps could include determining different brassiere designs or developing a simple exercise regime and educate the population so that women are aware and can actively minimize the risks associated with large breasts.

CHAPTER 11:
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Appendix A:

Complete Questionnaire

Code: ___________________

Study Questionnaire

We are interested to know about your body esteem and body image. Please answer all of the questions honestly and return this package to Susari Wanninayake. The information you provide will not be shared and will remain completely anonymous.

Rosenberg Self-esteem Scale (Rosenberg, 1979) **Section I:** Please circle ONE of the answers below which best represents how you feel.	Strongly Disagree	Disagree	Agree	Strongly Agree
1. On the whole, I am satisfied with myself.	SD	D	A	SA
2. At times I think I am no good at all.	SD	D	A	SA
3. I feel that I have a number of good qualities.	SD	D	A	SA
4. I am able to do things as well as most other people.	SD	D	A	SA
5. I feel I do not have much to be proud of.	SD	D	A	SA
6. I certainly feel useless at times.	SD	D	A	SA
7. I feel that I am a person of worth, at least on an equal plane with others.	SD	D	A	SA
8. I wish I could have more respect for myself.	SD	D	A	SA
9. All in all, I am inclined to feel that I am a failure.	SD	D	A	SA
10. I take a positive attitude toward myself.	SD	D	A	SA

Social Physique Anxiety Scale (Hart, Leary & Rejeski, 1989)

Section II: Please circle ONE of the answers below which best represents how you feel.

1 = Not at all characteristic of me
2 = Slightly characteristic of me
3 = Moderately characteristic of me
4 = Very characteristic of me
5 = Extremely characteristic of me

	Not at all characteristic of me	Slightly characteristic of me	Moderately characteristic of me	Very characteristic of me	Extremely characteristic of me
11. I am comfortable with the appearance of my physique or figure.	1	2	3	4	5
12. I would never worry about wearing clothes that might make me look too thin or overweight.	1	2	3	4	5
13. I wish I wasn't so up-tight about my physique or figure.	1	2	3	4	5
14. There are times when I am bothered by thoughts that other people are evaluating my weight or muscular development negatively.	1	2	3	4	5
15. When I look in the mirror I feel good about my physique or figure.	1	2	3	4	5
16. Unattractive features of my physique or figure make me nervous in certain social settings.	1	2	3	4	5
17. In the presence of others, I feel apprehensive about my physique or figure.	1	2	3	4	5
18. I am comfortable with how fit my body appears to others.	1	2	3	4	5
19. It would make me uncomfortable to know others were evaluating my physique or figure.	1	2	3	4	5
20. When it comes to displaying my physique or figure to others, I am a shy person.	1	2	3	4	5
21. I usually feel relaxed when it's obvious that others are looking at my physique or figure.	1	2	3	4	5
22. When in a bathing suit, I often feel nervous about how well proportioned my body is.	1	2	3	4	5

Body Shape Questionnaire (Cooper et al., 1987) **Section III:** Please circle <u>ONE</u> of the answers below which best represents how you feel. 1. Never 2. Rarely 3. Sometimes 4. Often 5. Very Often 6. Always	Never	Rarely	Sometimes	Often	Very Often	Always
23. Has feeling bored made you brood about your shape?	1	2	3	4	5	6
24. Have you been so worried about your shape that you have been feeling you ought to diet?	1	2	3	4	5	6
25. Have you thought that your thighs, hips or bottom are too large for the rest of you?	1	2	3	4	5	6
26. Have you been afraid that you might become fat (or fatter)?	1	2	3	4	5	6
27. Have you worried about your flesh being not firm enough?	1	2	3	4	5	6
28. Has feeling full (e.g. after eating a large meal) made you feel fat?	1	2	3	4	5	6
29. Have you felt so bad about your shape that you have cried?	1	2	3	4	5	6
30. Have you avoided running because your flesh might wobble?	1	2	3	4	5	6
31. Has being with thin individuals made you feel self-conscious about your shape?	1	2	3	4	5	6
32. Have you worried about your thighs spreading out when sitting down?	1	2	3	4	5	6
33. Has eating even a small amount of food made you feel fat?	1	2	3	4	5	6
34. Have you noticed the shape of other people and felt that your own shape compared unfavourably?	1	2	3	4	5	6

Please circle <u>ONE</u> of the answers below which best represents how you feel. 1. Never 2. Rarely 3. Sometimes 4. Often 5. Very Often 6. Always	Never	Rarely	Sometimes	Often	Very Often	Always
35. Has thinking about your shape interfered with your ability to concentrate (e.g. while watching television, reading, listening to conversations)?	1	2	3	4	5	6
36. Has being naked, such as when taking a bath, made you feel fat?	1	2	3	4	5	6
37. Have you avoided wearing clothes which make you particularly aware of the shape of your body?	1	2	3	4	5	6
38. Have you imagined cutting off fleshy areas of your body?	1	2	3	4	5	6
39. Has eating sweets, cakes, or higher calorie food made you feel fat?	1	2	3	4	5	6
40. Have you not gone out to social occasions (e.g. parties) because you have felt bad about your shape?	1	2	3	4	5	6
41. Have you felt excessively large and round?	1	2	3	4	5	6
42. Have you felt ashamed of your body?	1	2	3	4	5	6
43. Has worry about your shape made you diet?	1	2	3	4	5	6
44. Have you felt happiest about your shape when your stomach has been empty (e.g. in the morning)?	1	2	3	4	5	6
45. Have you thought that you are in the shape you are because you lack self-control?	1	2	3	4	5	6
46. Have you worries about other people seeing rolls of fat around your waist or stomach?	1	2	3	4	5	6
47. Have you felt that it is not fair that other women are thinner than you?	1	2	3	4	5	6

Please circle <u>ONE</u> of the answers below which best represents how you feel. 1. Never 2. Rarely 3. Sometimes 4. Often 5. Very Often 6. Always	Never	Rarely	Sometimes	Often	Very Often	Always
48. Have you vomited in order to feel thinner?	1	2	3	4	5	6
49. When in company have you worried about taking up too much room (e.g. sitting on a sofa, or bus seat)?	1	2	3	4	5	6
50. Have you worried about you flesh being dimply?	1	2	3	4	5	6
51. Has seeing your reflection (e.g. in a mirror or shop window) made you feel bad about your shape?	1	2	3	4	5	6
52. Have you pinched areas of your body to see how much fat there is?	1	2	3	4	5	6
53. Have you avoided situations where people could see your body (e.g. communal changing rooms or swimming baths)?	1	2	3	4	5	6
54. Have you taken laxatives in order to feel thinner?	1	2	3	4	5	6
55. Have you been particularly self-conscious about your shape when in the company of people?	1	2	3	4	5	6
56. Has worry about your shape made you feel you ought to exercise?	1	2	3	4	5	6

Newly Developed Breast Specific Questions **Section IV:** Please circle <u>ONE</u> of the answers below which best represents how you feel. 1. Never 2. Rarely 3. Sometimes 4. Often 5. Very Often 6. Always	Never	Rarely	Sometimes	Often	Very Often	Always
57. Individuals with smaller breasts than me make me feel jealous.	1	2	3	4	5	6
58. Getting breast reduction surgery is something that I think about.	1	2	3	4	5	6
59. Have you hunched forward in order to feel comfortable while sitting for a long time due to your breasts?	1	2	3	4	5	6
60. I feel that the size of my breasts impact my ability to exercise.	1	2	3	4	5	6
61. I think my breasts are too small.	1	2	3	4	5	6
62. I am embarrassed of my breasts, so I slouch in order to hide them.	1	2	3	4	5	6
63. Has being with people who have bigger breasts that yours made you feel self-conscious about your breasts?	1	2	3	4	5	6
64. While standing or walking for a long time, I hunch forward in order to feel comfortable because of my breasts.	1	2	3	4	5	6
65. I wear certain clothes to bring attention to my breasts.	1	2	3	4	5	6
66. I think about getting breast augmentation surgery.	1	2	3	4	5	6
67. I often feel jealous of individuals who have larger breasts than me.	1	2	3	4	5	6
68. I think that my breasts are too large.	1	2	3	4	5	6
69. Have you worn certain clothes in order to hide your breasts.	1	2	3	4	5	6

Please circle <u>ONE</u> of the answers below which best represents how you feel. 1. Never 2. Rarely 3. Sometimes 4. Often 5. Very Often 6. Always	Never	Rarely	Sometimes	Often	Very Often	Always
70. Has being with people who have smaller breasts than yours have made you feel self-conscious about my breasts?	1	2	3	4	5	6
71. Have you hunched forward in order to feel comfortable while standing or walking for a long time due to you breasts?	1	2	3	4	5	6
72. Have you felt frustrated with the size of your breasts?	1	2	3	4	5	6
73. My breast size impacts my confidence to exercise.	1	2	3	4	5	6