COMPARISON OF NORMAL PLANTAR CUTANEOUS SENSATION BETWEEN CHILDREN WITH OBESITY AND PEERS WITH HEALTHY WEIGHT

A Thesis

by

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This thesis meets the standards for scope and quality of
Texas A&M University-Corpus Christi and is hereby approved.

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ABSTRACT

Obesity is a chronic disease resulting from excessive fat accumulation and body mass. There have been equivocal findings regarding plantar cutaneous in sensation children. Deficits in plantar sensation can impact postural control, balance, and the capacity to proficiently engage in physical activity. Therefore, it is important to establish whether normal plantar cutaneous sensation differs between children who have healthy weight and those who are obese.

Twenty-seven subjects from 3rd, 4th, 9th – 12th grades (mean ± standard deviation 12.90 ± 3.6 years) participated in this study. Ten subjects were obese and 17 had healthy weight. Plantar cutaneous sensation was measured using a Semmes-Weinstein pressure aesthesiometer kit. Each subject was tested by one of four assessors whose interrater reliability ($\alpha = .710$; $p = .005$) was previously established. Nine sites were tested on each foot. The respective force gram magnitudes required to bend the two thinnest monofilaments (i.e., 0.07 g and 0.4 g) was assigned whenever a subject reported sensing touch at a specific site. Both filaments are associated with normal sensation.

An independent samples t-test was calculated to determine plantar sensation differences between children who have healthy weight and those with obesity. Mann-Whitney U test was calculated where assumptions of normality were violated. Statistical significance was set at $p < .05$.

There were 10 and 17 subjects in the obese and healthy weight groups, respectively. There were no significant differences ($p > .05$) in normal whole foot sensation (i.e., .07 g and 0.4 g monofilaments) on the right and left feet between the groups. Right whole foot sensation of healthy weight subjects (3.5929 g $\pm$ 0.64742) and right whole foot sensation of obese subjects (3.3410 g $\pm$ 0.85461) did not differ significantly from each other, $t(15.132) = 0.806$, $p = 0.433$.

Left whole foot sensation of healthy weight subjects (3.4468 g $\pm$ 1.01623) and left whole foot sensation of obese subjects (3.2390 g $\pm$ 1.06027) did not differ significantly from each other, $t(18.342) = 0.499$, $p = 0.623$.

Additionally, sensitivity among foot regions did not indicate effect of foot region on plantar sensation. Subjects who were obese in this study reported to feel less than subjects with healthy weight. However, there was no significant difference in the values of the plantar sensation scores.

It was concluded that normal plantar cutaneous sensation does not differ between preadolescents with obesity and peers with healthy weight. Given the small current sample size, more subjects need to be tested, in order to increase confidence and substantiate findings from this study.

DEDICATION

I dedicate this to my parents who have made unimaginable sacrifices just to give my siblings and me educational opportunities far away from our homeland, Venezuela.

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CHAPTER I: Introduction

Obesity is considered a chronic disease resulting from excessive fat accumulation and body mass (Baselga Torres and Torres-Pradilla, 2014). According to the World Health Organization, over 340 million children and adolescents aged 5-19 were overweight or obese in 2016. The Data Resource Center for Child and Adolescent Health reported 21.8% of Hispanic children nationwide between the ages of 10-17 years to be obese. Specifically, 23.4% of Hispanic children in Texas were reported to be obese (Data Resource Center for Child and Adolescent Health, 2012). Hispanic and Black non-Hispanic children are reported to be the two highest populations linked with obesity in Texas. According to the 2010 Census, Hispanics are now the largest and fastest growing minority composing 16% of the US population (Ennis, Ríos-Vargas, Albert, 2010) and by 2050, that number is expected to grow to 25% (National Research Council (US) Committee on Population, 2002). The incidence of childhood overweight and obesity among school-age children in Corpus Christi, Texas exceeds national rates. In 2013, 53.36% (22,882 of 44,881 students sampled) of elementary school students assessed using FITNESSGRAM criteria in the Corpus Christi Independent School District were overweight or obese (Castetbon and Andreyeva, 2012).

Physical inactivity can lead to energy imbalance (i.e., decreased energy expenditure through physical activity relative to energy consumed through diet) and can increase the risk of becoming overweight or obese (US Department of Health and Human Services, 2008; Institute of Medicine, 2005). According to the Centers for Disease Control and Prevention (2015), children and adolescents are recommended to do 60 minutes (1 hour) or more of physical activity each day. Only 21.6% of 6 to 19-year-old children and adolescents in the United States attained

60 or more minutes of moderate-to-vigorous physical activity on at least 5 days per week (National Physical Activity Plan Alliance, 2016).

A possible deterrent to activity in obese children is the flattening of the foot's medial longitudinal arch and higher plantar pressures are thought to be a cause of foot discomfort, pain or dysfunctions in obese children (Dowling et al., 2004; Riddiford – Harland et al., 2000). In a study by Riddiford – Harland et al. (2000), higher peak plantar pressures generated during walking were significantly associated with lower levels of physical activity (Riddiford – Harland et al., 2014). Tactile inputs in the skin of the foot are important for postural awareness (Roll, Kavounoudias, & Roll, 2002). Hohne et al. (2009) found that alterations in sensitivity can impact changes in the plantar pressure distribution during upright posture. Children with obesity have been reported to have decreased plantar sensation and increased pressure (da Rocha et al., 2014). Deficits in postural control, balance and motor skills engendered by obesity increases associated fall risk in children (Sayegh et al., 2010). Nantel, Centomo, and Prince (2005) proposed that instability in quiet standing could be exacerbated in dynamic conditions and may increase the risk of falling in children with obesity. Higher prevalence of falls is compounded by the fact that children who are obese fall with relative greater force, which results in increased likelihood of serious injury like sprains and fractures (Sayegh et al., 2010). Activities of daily living and playing (eg, standing, walking, running, and jumping) place a considerable demand on the postural control system to maintain stability (Bouffard, Watkinson, Thompson, Dunn, & Romanow, 1996). A study concluded that these differences in postural control demands could have an impact on obese children's confidence in participating in physical activities (McGraw, McClenaghan, Williams, Dickerson, and Ward, 2000).

Obesity is is a risk factor for the development of type 2 diabetes, or noninsulin dependent diabetes mellitus. The onset of this disease—formerly observed only in adults—now occurs during childhood (CDC, 2011). Data from Blue Cross and Blue Shield of Texas (BCBSTX) show high incidence of diabetes with chronic conditions (e.g., chronic kidney disease, CKD) in South Texas and a 107 percent increase in diabetes in 2016 (BCBSTX, 2017). One in 7 South Texas residents are affected by CKD and Texas has the second highest CKD costs in the U.S. (BCBSTX, 2017). Although the percentage of CKD cases among children under 20 years of age remain unclear, the incidence of childhood overweight and obesity among school-age children in underserved predominantly Hispanic communities in Corpus Christi exceeds national rates. Sensory neuropathy is also commonly associated with diabetes and often precipitates the loss of protective sensation in the skin (Caputo et al., 1994). The presence of peripheral neuropathy in diabetic patients contributes to episodes of trauma and ulcerations, causing gradual loss of protective sensitivity, and the perception of plantar pressure and temperature (Feitosa, dos Santos Dantas, da Silva, & Pereira, 2016).

Overweight and obesity is also associated with cardiovascular disease (CVD) risk factors among young children. According to the Bogalusa Heart Study, it is possible that the successful prevention and treatment of obesity in childhood could reduce the adult incidence of cardiovascular disease (Freedman, Dietz, Srinivasan, & Berenson, 1999). One of the most prevalent treatments of obesity is physical activity (CDC, 2015). In addition to CVD risks, pulmonary complications in relation to childhood obesity have been reported in previous studies. In one study of both obese and non-obese children, > 80% of obese children had a decrease of at least 15% in performance with exercise on one of the standard pulmonary function tests, compared to only 40% of the non-obese children (Kaplan & Montana, 1993). According to Must and Strauss (1999), increased bronchial hyperactivity may contribute to both higher rates of reactive airway disease and decreased exercise tolerance in obese children.

In extreme cases, obesity has been linked to nonalcoholic fatty liver disease (NAFLD). By definition, NAFLD is a liver disease characterized by excessive fat accumulation in the form of triglycerides in more than 5% of hepatocytes that is not caused by alcohol intake, drugs, toxins, infectious diseases, or any other specific etiologic factors that induce liver disease (Oldfield, Doug, & Johnson, 2015). All subsequent U.S. multiethnic population-based studies on pediatric NAFLD confirmed that Hispanics have the highest prevalence of NAFLD and present with a more aggressive pattern of the disease (Loomba et al., 2009; Berardis & Sokal, 2014; Pardee, Lavine, & Schiwimmer, 2009). A study by Loomba et al. (2009), found that the prevalence of NAFLD was highest in obese children (38%) regardless of age. This study also observed that prevalence and severity of the disease varied among ethnicities, with the highest prevalence in Hispanic children (Loomba et al., 2009). Since it is recommended to maintain a healthy diet and exercise to reduce risks of developing NAFLD, it is imperative that children are able to functionally participate in physical activity. One dire projection is that obesity may lead to a generation with a shorter life span than that of their parents (American Heart Association, 2010; Olshansky et al., 2005). Therefore, impediments to movement must be urgently addressed among children living in South Texas.

Altered plantar sensation can impact postural control and the capacity to enjoy and safely engage in physical activity. However, it is unclear whether normal plantar sensation differs between children who have a healthy weight and those who are obese. Therefore, it is important to establish the prevalence of decreased foot sensation among children. The purpose of this study is to determine whether normal foot sensation differs between children whose BMI percentiles are categorized as "healthy" and "obese." The knowledge from this study can help determine whether weight impacts normal plantar sensation.

Statement of the Problem

Since physical activity is a key component to combating overweight and obesity, it is important to understand whether obesity affects normal plantar sensation, especially considering its adverse impact on controlling posture while engaging in physical activity. This study will address the following research questions: (1) Does whole foot normal plantar sensation differ between children who have healthy weight and children who are obese? (2) Does regional foot normal plantar sensation differ between children who have healthy weight and children who are obese?

It is hypothesized that normal plantar sensation will differ between children who are obese and those who have healthy weight.

CHAPTER II: Review of Literature

Weber's Law

In psychophysics, the proposition that the smallest detectable difference in the magnitude of a stimulus, or the Weber fraction, is proportional to the magnitude of the lesser stimulus (Colman, 2015). The ability to detect a change stimulus change depends directly on whether that change exceeds some constant percentage of the initial signal (i.e., a differential threshold) (Teasdale N et al., 2013). For example, the smallest difference in weight that is detected is proportional to the original weight. This would imply that most people will barely feel the difference between an object weighing 2 pounds and 2.02 pounds. This small increment in the magnitude of a stimulus has been determined experimentally as constant $k = 1/53$ for weight discrimination (Colman, 2015). Weber's law uses the difference threshold in physical magnitude (ΔI) , the magnitude of the lesser stimulus (I), and the Weber fraction (k). This law is expressed in the following equation:

$$(\Delta I)/I = \mathrm{k}$$

Weber's law states that the difference in intensity needed to discriminate two stimuli is proportional to their objective. It was named after the German psychophysiologist Ernst Heinrich Weber (1795-1878) (Colman, 2015). Under Weber's law, discrimination performance is modulated by the ratio of the intensities rather than their absolute difference (Cantlon, Platt, Brannon, 2008). Through the explanation of this ratio, for any given difference between the stimuli there will be a corresponding percentage of correct judgements. In a thorough explanation of Weber's Law by Solomons (1900), it was stated that the difference between the stimuli is more than twice the greatest variation of I, then 100 percent of judgements can be reached.

This law would suggest that the primary cause of differences in the ability to detect changes in the center of pressure (CoP) between individuals who are obese and those who have a healthy weight is due to higher plantar pressures in those who are obese (loading-induced decrease in plantar mechanoreceptor sensitivity). Therefore, there should not be differences in plantar sensation when the foot is unloaded. However, it is unclear whether this decreased sensitivity persists when the feet are unloaded. The persistence of a greater differential threshold in plantar cutaneous sensitivity between children who are obese and those who have healthy weight may suggest other causes, such as metabolic alterations and increased inflammatory responses (due to obesity), which affect the sensitivity of neural receptors in the foot. According to Weber's law, the ability to detect a change stimulus change depends directly on whether that change exceeds some constant percentage of the initial signal (i.e., a differential threshold) (Teasdale et al., 2013). Therefore, there is a basis to expect differences in the ability to detect changes in loading stimuli underfoot between those who have healthy weight and those who are obese.

Plantar Cutaneous Sensation

The human foot serves to provide important sensorial information for balance and gait (Zhang and Li, 2013). Cutaneous mechanoreceptors are sensory neurons that detect a wide range of mechanical stimuli and relay sensory information about a stimulus to the somatosensory cortex of the brain via the spinal cord (Abraira & Ginty 2013).

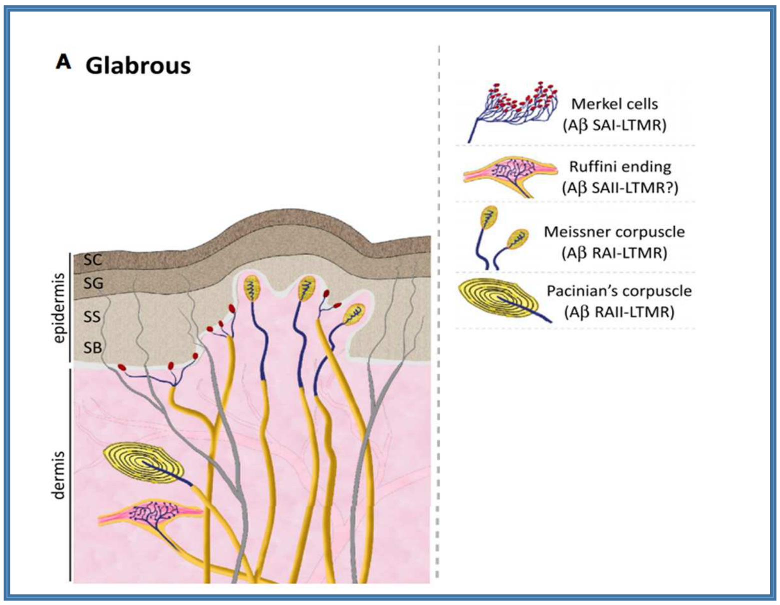
According to Abriara and Ginty (2013), the perception of innocuous and noxious touch sensations relies on special mechanosensitive sensory neurons that fall into two general categories. For the purpose of this study, we will focus on the low-threshold mechanoreceptors (LTMRs) which react to innocuous mechanical stimulation. Skin is divided into hairy and nonhairy (glabrous) skin. One of the four types of LMTRs that innervates glabrous skin are the rapidly adapting receptors (RAI). These RAI-LTMRs can be further divided into two categories: RAI- and RAII-LMTRs (Abraira & Ginty 2013). Responses from RAI are generally associated with small receptive fields and low-frequency vibrations, such as tapping (1-10 Hz) (Abraira & Ginty 2013). Alternatively, RAII responses are associated with larger receptive fields and high-frequency vibrations (from 80-300 Hz) (Vallbo & Johansson, 1984). Slowly adapting responses exhibit maintained firing during sustained indentation (Abraira & Ginty 2013). The slowly adapting low-threshold mechanoreceptors (SA-LTMRs) can be further divided into two types (SAI and SAII) of responses (Wellnitz et al., 2010). For the purpose of this study, only SAII-LTMR will be covered. SAII afferent conduction velocities fall within 20-100 m/s and are one-sixth as sensitive as SAIs to skin indentation (Abraira & Ginty 2013; Johnson et al., 2000). Psychophysical and microneurography studies suggest two major functions of SAII afferents in touch perception, both resulting from their sensitivity to skin stretch (Abraira & Ginty 2013). One of the major functions of SAII-LTMRs is proprioception, which is likely integrated with information conveyed from muscle spindles and joint afferents (Abraira & Ginty 2013). The second major function suggested is in the detection of object motion and velocity when the direction of object movement produces skin stretch (Abraira & Ginty 2013). Fibers that make up SAII-LTMRs are suggested to sense mechanical stretch applied to collagen fibers of the Ruffini ending (*Figure 1.)* (Rahman et al., 2011). However, the functions of SAII-LTMRs in and the morphological properties of SAII-LTMR endings remain unknown (Abraira & Ginty 2013).

Located within glabrous skin are four types of mechanosensory end organs: Pacinian corpuscles, Ruffini endings, Meissner corpuscles, and Merkel's discs (*Figure 1.*) (Abraira & Ginty 2013). Meissner corpuscle of primates and rodents is the best characterized anatomically and it is made up of flattened lamellar cells arranged as horizontal lamellae embedded in connective tissue. They are localized to dermal papillae in glabrous skin, most notably in fingerprint skin of the human hands and the soles of feet (Abraira & Ginty 2013). The anatomical structure associated with RAI-LTMRs in glabrous skin are the Meissner corpuscles (Abraira & Ginty 2013). Upon indentation of glabrous skin, collagen fibers that connect the basal epidermis to lamellar cells of the corpuscle provide the mechanical force that deforms the corpuscle and triggers action potential volleys that quickly ease as a result of the rapidly adapting nature of RAI-LTMRs (Abraira & Ginty 2013). When the stimulus is removed, the corpuscle regains its shape, and in doing so it induces another volley of action potentials, generating the distinctive on-off responses of RAI-LTMRs (Abraira & Ginty 2013). In conclusion, Merkel's discs are slowly adapting type I and Meissner corpuscles are fast adapting type I. Ruffini endings are slowly adapting type II and Pacinian corpuscles are fast adapting type II.

The Pacinian corpuscle (PC) is the cutaneous mechanoreceptor responsible for sensation of high-frequency (20–1000 Hz) vibrations (Quindlen-Hotek & Barocas, 2018). PCs lie deep within the skin, often in multicorpuscle clusters with overlapping receptive fields (Quindlen-Hotek & Barocas, 2018). PC afferents may account for our ability to detect high-frequency vibrations and result from the remarkable response properties of RAII-LTMRs (Abraira & Ginty 2013). RAII-LTMRs are extremely sensitive, with amplitude thresholds lower than those of RAI-LTMRs, often responding to motions in the nanometer range (Lynn, 1971).

Ruffini endings, which are located in the dermis, are thin spindle-shaped cylinder composed of layers of perinueral tissue including collagen fibers and an inner core composed of nerve terminals surrounded by a capsule space filled with fluid (Halata, 1977). Historically, Ruffini endings have been associated with SAII-LTMR responses, which respond best to skin stretch, though such correlations remain highly controversial (Abraira & Ginty 2013). Though SAII-LTMR responses have been observed in both glabrous skin of humans and hairy skin of mice, they have only been postulated to arise from Ruffini endings, though direct evidence to support this idea is lacking (Chambers et al., 1972).

Figure 1. Mechanoreceptors in glabrous skin. SC, stratum corneum; SG, stratum granulosum; SS, stratum spinosum; SB, stratum basalis (Abraira & Ginty 2013).



The sensorimotor system uses information from receptors in the ligaments of foot arches, joint capsules, intrinsic muscles and cutaneous mechanoreceptors in the plantar surface to regulate motor actions (Wright et al., 2012). Additionally, changes in foot contact area may also affect availability of sensorial information to the central nervous system (Phethean and Nester, 2012). The threshold of detection for human tactile cutaneous receptors has been measured with as low as a few milligrams of force (Bell-Krotoski, Fess, Figarola, & Hiltz, 1995).

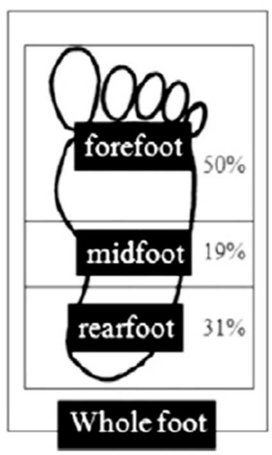
In a recent study by Yumin, Simsek, Sertel, and Ankarali (2016), it was determined that there was a relation between the body mass index (BMI) value and plantar sensation and that plantar sensitivity decreased as BMI increased in healthy adults. In this study, plantar cutaneous sensation was assessed using the nylon Semmes-Weinstein monofilaments. The application of the monofilaments was described as bending stress to the skin and create a sense of pressure, and the amount of pressure they apply is indicated by numbers ranging from 1.65 to 6.65 (Yumin et al., 2016). The highest monofilament value was indicated as the hardest filament, which can only be bent with difficulty. Monofilaments with thickness values of 4.17 and 5.07 were used in this study (Yumin et al., 2016). The individuals were asked to lie on their backs with their feet bare and their eyes open. A researcher, who was a physiotherapist, stood by the individual and applied the monofilament at a 90-degree angle for 1.5 seconds (s) to 7 areas on the plantar surface of the foot where the load was applied on the individual and which was inclined to ulceration (first toe, fifth finger, first and fifth forefoot, hindfoot, medial and lateral sides of the foot (midfoot)), and the patient was asked whether the subject felt it or not (Yumin et al., 2016). This was repeated for both feet with each monofilament in the 7 areas assessed in this study. Additionally, the load on the feet increased with the increase in weight in healthy individuals especially around the first toe and heel, and this led to a loss of sensitivity in the areas where excessive load was placed (Yumin et al., 2016). However, since this study reported on adult female subjects and findings from this research may not be representative of plantar sensation in children.

A study by da Rocha et al. (2014) suggested lower foot sensitivity in obese children can be considered a risk factor for a variety of injuries related to foot loading as well as during long term exercises. Long term exercises are frequently recommended for obese to control the weight and should be included in physical examination of the obese children (da Rocha et al., 2014). However, this study did not define exactly how long or what defines long term exercises.

Plantar Pressure

In a study by da Rocha et al. (2014), plantar pressure for obese and non-obese children was recorded and computed considering the foot divided in forefoot, midfoot, and rearfoot (*Figure 2.*). They found that obese subjects had higher pressure for all foot regions when compared with non-obese, and the highest pressure was observed in the rearfoot (da Rocha et al., 2014). Additionally, it was reported that plantar pressure for obese subjects differed between all foot regions. From this study, the differences in plantar pressures may be a resulting factor from an increase in body mass. The results from this research suggest that higher loading may have long-term effects on mechanoreceptor activity, which may result in lower foot sensitivity (da Rocha et al., 2014).

Figure 2. Regions of the foot (Rocha et al., 2014).



Another issue that may be due to excessive loading is that it may stretch ligaments beyond their elastic limit, damaging soft tissues and increasing the risk of foot discomfort and subsequent development of foot pathologies (Dowling et al., 2001). In the study done by Dowling et al. (2001), no main effect of obesity on the peak pressures exerted on the plantar surface of the children's feet was found. However, the increased forces generated by the obese subjects were distributed over a larger area of their feet. This means that the peak pressure was distributed and caused children to have flatter feet (Dowling et al., 2001).

In addition to foot discomfort in children due to increased pressure values, collapse of the medial longitudinal arch due to excessive loading of the feet as a result of continually bearing additional body mass can potentially disable normal foot function later in life (Mickle, Steele, & Munro, 2006; Shiang, Lee, Lee, & Chu, 1998). However, since this longitudinal arch collapse is based from theory, more research needs to be done in order to help understand the cause of flat feet in obese children. In a study by Mickle et al. (2006), it was found that overweight/obese children displayed a significantly lower plantar arch height compared with that in the non-overweight children ($p = 0.04$). This same investigation indicated that it was the first to show that overweight children, not only obese children, display greater midfoot contact with the ground. It also supported the notion that increased adiposity is associated with flatter feet and supports the fact that foot structure can be affected by overweight and obesity (Mickle et al., 2006). However, this study recruited children from preschools and further research is needed to confirm the application of these findings to other children at different ages. Mickle et al. (2006) also found that significantly lower plantar arch height found in the overweight/obese children suggests that their flatter feet may be caused by a lowering of the longitudinal arch, most probably caused by their feet continually bearing excess mass. Therefore, foot structure and pressure characteristics need to be taken into consideration in future studies to help prevent foot complications in obese and overweight children.

Hyperkeratosis

Depending on duration and severity, obesity has been associated with plantar hyperkeratosis (i.e., thickening of the outer layer of glabrous skin on the bottom of the foot in response to increased mechanical loading/pressure) (Baselga Torres and Torres-Pradilla, 2014). Presumably, this thickening may alter plantar cutaneous sensitivity. Therefore, higher plantar pressures could chronically alter plantar sensitivity via this mechanism.

The development of distinct patterns of pathological plantar hyperkeratosis hypothetical differences in foot kinematics and load distribution under the forefoot creating risks for pain. Specifically, the thickening of the stratum corneum (outermost layer of the epidermis, consisting of dead cells) in response to repeated high levels of load is generally acknowledged as associated with an increased plantar pressure (Freeman, 2002; Jannink et al., 2006; Menz, Zammit, & Munteanu, 2007; Sage, Webster, & Fisher, 2001).

As mechanical stresses on the skin increase, the body attempts to protect irritated skin by forming a hyperkeratotic lesion, such as a corn or a callus (Freeman, 2002). Corn and callus formation is the skin's natural attempt to compensate for prolonged or excessive pressure, friction and other forms of local irritation by increasing its thickness at sites of excessive mechanical stress (Grouios, 2004). Therefore, the size of the lesion can cause discomfort and can be painful with while performing physical activities. A vicious cycle develops which is only broken by decreasing the size of the hyperkeratotic growth and relieving or eliminating pressure on the affected area of the skin (Grouios, 2004).

Diabetes

The prevalence of type 2 diabetes mellitus in children and adolescents in the United States is approximately 12:100000 (Reinehr, 2013). Obesity, which is the most common cause of insulin resistance in children, is the most important risk factor for the development of type 2 diabetes mellitus in youth (Weiss et al., 2004). Indeed, the increasing prevalence of overweight and obesity closely parallels the rise in the number of cases of type 2 diabetes (Hannon, Rao, &

Arslanian, 2005). The onset of type 2 diabetes—formerly observed only in adults—now occurs during childhood (CDC, 2011). The adverse effect of obesity on glucose metabolism is evident early in childhood. A study by Weiss et al. (2004) observed 439 obese, 31 overweight, and 20 nonobese children and adolescents on the effect of varying degrees of obesity on the prevalence of the metabolic syndrome and its relation to insulin resistance. This study found that each half-unit increase in the body-mass index, converted to a z score, was associated with an increase in the risk of the metabolic syndrome among overweight and obese subjects (Weiss et al., 2004). The prevalence of the metabolic syndrome is high among obese children and adolescents, and it increases with worsening obesity (Weiss et al., 2004).

Earlier onset of diabetes leads to earlier onset of complications including progressive neuropathy (Hannon, Rao, & Arslanian, 2005). Sensory neuropathy is also commonly associated with diabetes and often precipitates the loss of protective sensation in the skin (Caputo et al., 1994). The presence of peripheral neuropathy in diabetic patients contributes to episodes of trauma and ulcerations, causing gradual loss of protective sensitivity, and the perception of plantar pressure and temperature (Feitosa, dos Santos Dantas, da Silva, & Pereira, 2016).

Postural Sway and Balance

Tactile inputs in the skin of the foot are important for posture awareness (Roll, Kavounoudias, & Roll, 2002). A study by Hohne et al. (2009) found that alterations in sensitivity can be a relevant factor to changes in the plantar pressure during upright posture. This could explain differences in plantar pressure between foot regions (da Rocha et al., 2014).

In a study by D’Hondt et al., (2010), postural balance control and the relative contribution of sensory information was examined. Specifically, sensory information to the maintenance of stability during quiet bilateral stance under normal and experimentally altered sensory conditions in normal-weight versus overweight children was investigated. This study found that lower plantar cutaneous sensation was shown to be associated with higher center of pressure (COP) velocities and maximal excursion of the COP in the medial-lateral direction for the overweight group. Regardless of the condition, higher variability was shown in the overweight children within the 7–9-year-old subgroup for postural sway velocity, and more specifically medial–lateral velocity (D’Hondt et al., 2010). Although this study did not establish any clear sensory organization impairments, it did indicate that there may be another underlying mechanism accounted for overweight and obese children’s balance deficiencies. D'Hondt et al. (2008) also found that children who were overweight and obese did not differ from those with healthy weight on measures of postural sway (i.e., center of pressure (COP) parameters) during quiet stance. However, it is possible that quiet stance was not dynamically challenging enough to have elicited differences; sensory redundancy (i.e., the simultaneous availability of vestibular and proprioceptive feedback) likely sufficiently compensated for deficits in plantar cutaneous sensation and precluded any degradation of postural control (Matthew C. Hoch, 2016).

Deficits in postural control, balance and motor skills engendered by obesity increases associated fall risk in children (Sayegh et al., 2010). A study by Nantel, Centomo, and Prince (2005) proposed that instability in quiet standing could be exacerbated in dynamic conditions and may increase the risk of falling in children with obesity. Higher prevalence of falls is compounded by the fact that children who are obese fall with relative greater force, which results in increased likelihood of serious injury like sprains and fractures (Sayegh et al., 2010). Activities of daily living and playing (eg, standing, walking, running, and jumping) place a considerable demand on the postural control system to maintain stability (Bouffard, Watkinson, Thompson, Dunn, & Romanow, 1996).

Physical Activity Participation

Only ten states in the U.S. use a defined physical activity that requires moderate to vigorous activity for at least 60 minutes per day for full-day and 30 minutes per day for part-day (State of Obesity, 2016). Physical activity, by definition, results in an increase in energy expenditure due to the cost of the activity itself and is also hypothesized to increase resting metabolic rate (RMR) (Poehlman, 1989).

Sensorial information is an important component of motor control for a range of daily activities as well as during physical exercise. Physical activity is often recommended to reduce body mass and BMI in children with obesity (da Rocha et al., 2014). Nevertheless, changes in foot function in obese children may result in increased foot pain and risks of lower extremities mediated by exercise.

A study by Riddiford – Harland, Steele, and Storlein (2000) found that structural changes in the foot associated with obesity may be a factor that hinders the participation of obese children in physical activity. Structural foot changes associated with obese children's feet increase pressure within the foot or compromise foot function and these changes are associated with increased pressure in obese children during the most common activity of daily living (Dowling et al., 2004; Riddiford – Harland et al., 2000). This in turn may lead to increased foot discomfort, particularly during weight-bearing activities prohibiting children from participating in physical activity. However, this is just an assumption and further investigation is needed in order to find if changes in foot structure hinder participation in physical activity.

Goran, Reynolds, and Lindquist (1999) reported that the most effective strategies for promoting physical activity in children are likely to be theory based and involve school and community interventions as well as significant family involvement. Therefore, these efforts will require concerted attempts among various partnerships, including government, school education boards, parents, educators, industry and trade organizations, professional organizations, and the mass media (Goran et al., 1999). There are no direct interventions regarding physical activity as the promotion of it is complex and requires more extensive research in many areas of obesity and its causations.

It is known from previous research that physical inactivity has been identified as a major factor contributing to the development of overweight and obesity in children (Hills, Okely, & Baur 2010). A possible deterrent to activity in obese children is the flattening of the foot's medial longitudinal arch and higher plantar pressures are thought to be a cause of foot discomfort, pain or dysfunctions in obese children (Dowling et al., 2004; Riddiford – Harland et al., 2000). Increasing physical activity is a recommended approach to combating the high prevalence of obesity among children (Hills et al., 2010; Lobstein, Baur, & Uauy, 2004). However, there has been no systematic investigation of the types of activity that obese children should participate in and how this affects plantar pressure distributions, plantar sensations and foot development (Riddiford-Harland et al., 2016). A study by Riddiford-Harland et al. (2016), revealed that overweight and obese children who participated in a physical activity program that stabilized their body mass, avoided increases in plantar pressures after a 6-month period. However, this study also noted that as pressure-time integrals increased post intervention, these children's feet remained at risk for possible foot pain and discomfort. Riddiford-Harland et al. (2016) also found that there was an insignificant change in the amount of time children spent being physically active following participation in a physical activity intervention program. Therefore, further investigation is needed in order to determine an optimal physical activity program for children at risk for developing foot complications.

CHAPTER III: METHODOLOGY

Subjects

Subjects recruited for the study were recruited from two schools under an agreement with the Corpus Christi Independent School District to investigate altered plantar sensation among school-aged children.

Given the need to be able to articulate whether they sense touch at the bottom of their feet, elementary school students between 3rd - 4th grades and high school students in the 9th, 10th, 11th, and 12th grades were assessed. Grade levels were chosen in elementary school based on the cognitive maturity level necessary in order to articulate the presence or absence of touch sensation underneath the feet. Also, overweight and obesity rates tend to be significantly higher between 3rd - 5th grades compared to kindergarten - 2nd grades. Although the foregoing schools are predominantly Hispanic, no child was excluded based on their ethnicity. Students who could not read, write, and speak English will be excluded from the assessments.

The research proposal was submitted to the Institutional Review Board of Texas A&M University – Corpus Christi. Once accepted, consent forms were sent out to the parents of 3rd – 5th graders. The children that were given parental consent to be part of the study were asked to participate in the assessment by the physical education teachers.

Twenty-seven children participated in this study. Assessment of body fat in children and teenagers is approached differently than for adults. Children's body fat composition changes as they grow, and growth patterns are different for boys and girls. Consequently, measurement of body mass index (BMI) for children is age and gender specific. Therefore, calculations for subject’s BMI were performed using the Center for Disease Control and Prevention growth charts.

BMI-for-age categories are:

Classification	Percentile
Underweight	Less than the 5th percentile
Healthy weight	5th percentile to less than the 85th percentile
Overweight	85th to less than the 95th percentile
Obese	Equal to or greater than the 95th percentile

(National Survey of Children's Health, 2011,2012)

According to the subject's BMI obtained from the Center for Disease Control and Prevention BMI Percentile Calculator for Children and Teens, 10 and 17 children were categorized to the obese and healthy weight group, respectively. Since there was only one child in the overweight category and an underweight category was outside of the scope of this research, those two subject's data were excluded from further analyses.

Assessment Procedure

On the day of assessment, one of the resident physical education teachers walked students who opted to participate in the study to the room designated for the assessments. Students who opted to not participate continued with the planned physical education activity for that day (as implemented and overseen by their physical education teachers). Students who opted to perform the assessment were escorted to the assessment room by the coach in groups of 4 or 5, undergo the 5-8-minute assessment, and escorted back to their regular physical education class by a physical education teacher or one of the researchers. In the separate room, the researchers further explained the study and obtained child assent. The subjects were each given a designated identifier number in order to keep data confidential. Researchers explained the study and students were given the opportunity to ask questions and clarifications if needed. The subjects were also made aware that they may withdraw from the study at any point in the assessment.

Once assent forms were collected, researchers then measured each student's height and body mass using a digital stadiometer (seca, Hamburg, Germany). All children were tested by the one of four research assistants that were trained in the usage of the filaments. The assessors interrater reliability ($\alpha = .710$; $p = .005$) was previously established. Based off of this information it can be concluded that the assessors proved to be reliable illustrated by the high Intraclass Correlation Coefficient.

The researchers then assessed plantar cutaneous sensation (i.e., bottom of the foot's sensitivity to touch) using Semmes-Weinstein pressure aesthesiometer at 9 sites of the foot (DanMic Global, LLC, San Jose, CA, USA) (*Figure 3a, b*). The room where the assessment occurred consisted of four testing stations in opposing sides of the room. The foot aesthesiometer set consists of six nylon monofilaments of different intensities and equal length described in (*Figure 3c., Table 1*). The monofilaments are noninvasive and are used to apply repeatable graded force to the skin on the sole of the foot and its mechanoreceptors, thereby allowing the evaluation and determination of touch and pressure detection thresholds.

Figure 3. **(a)** The nine specific sites in the foot tested for foot sensitivity and separated regions, **(b)** Assessment model, **(c)** Precise Tactile Sensory Evaluator Six Piece Foot Kit (Rocha et al., 2014).

a.¶ **b.** **c.**

Table 1. Characteristics of the filament and respective implications are presented according to manufacturer information (g = gram).	
Filament force-gram sensed	**Implication**
Subject senses 2.83 (0.07 g)	Normal sensitivity to the hand and foot
Subject senses 3.61 (0.40 g)	Still within the normal sensitivity to the foot; possibly diminished light touch
Subject senses 4.31 (2.0 g)	Decreased protective sensation, but enough to prevent injuries; difficulty to discriminate shape and temperature
Subject senses 4.56 (4.0 g)	Loss of protective sensation to the hand, and sometimes to the foot; vulnerable to injuries; loss of discrimination for temperature
Subject senses 5.07 (10 g)	Protective sensation to the foot is lost; may still feel deep pressure and pain
Subject senses 6.65 (300 g)	Sensitivity to deep pressure maintained and can still feel pain
Subject does not sense 6.65 (300 g)	Loss of sensitivity to temperature, pain and deep pressure

According to the manufacturer recommendation for use, (Holewski et al., 1988), subjects were tested without shoes or socks while resting in a supine position in a quiet, distraction free environment. The children were asked to focus on a fixed spot on the ceiling in order to avoid observation of their feet or probes during testing (da Rocha et al., 2014). The filaments were pressed onto the plantar surface at nine specific sites of both feet (i.e., heel, medial midfoot, lateral midfoot, first, middle, and fifth metatarsal heads, hallux (big toe), third toe, and fifth toe (small toe) (*Figure 3a*). Researchers randomized the order in which the feet are tested in order to counteract any order effects. Tactile threshold was determined by applying thinner filaments until the subject was not able to detect touch (Breger, 1987).

Statistical Analysis

Descriptive statistics were calculated for 17 healthy weight and 10 obese subjects. The average sensitivity for was computed for whole foot, forefoot, midfoot and rearfoot based on the gram-force values attributed for each filament. For the purpose of this study, only the two lowest monofilaments were used in scoring (0.07g & 0.40g) because this meant the sensation was still within the normal sensitivity to the foot (*Table 1*). Values were added at each of the nine areas where subject felt touch with the 0.07 g and 0.40 g monofilaments for whole foot. For the forefoot, the score out of 6 sites were added for 0.07 g and 0.40 g monofilaments. For the midfoot, the score out of the 2 sites were added for 0.07 g and 0.40 g monofilaments. Lastly, for the rearfoot, the score of the one site on the heel was added for the 0.07 g and 0.40 g monofilaments. A priori significance level was set at 0.05 for all statistical procedures. Data from subject's plantar sensation score and weight category were compared between groups using the Mann-Whitney U test. All data was processed using SPSS (SPSS version 22.0, IBM Corporation). Independent t-tests of all foot regions were determined. Data for overweight children had a very small sample size and the underweight category fell outside of the scope of the research. Therefore, those scores were not included in this research. The four assessors included in this study were examined for interrater reliability.

CHAPTER IV: RESULTS

Body mass was measured and BMI was calculated for 27 subjects (mean ± standard deviation 12.90 ± 3.6 years). Numerical data are reported for age, gender, and weight classification in *Table 2*. Ten subjects were assigned to the obese category and 17 subjects made up the normal weight group.

Table 2. Weight classification, age and gender data of subjects included in this study (mean ± SD).

	All Subjects n = 27	**Healthy Weight n = 17**	**Obese n = 10**
Age (years)	12.90 ± 3.6	12.82 ± 3.5	13.2 ± 3.76
Gender	16 males, 15 females	9 males, 8 females	5 males, 5 females

An Independent Samples Test was performed to determine if there was an effect of obesity for right nor left whole foot sensitivity. There were no statistical significance differences ($p > .05$) in normal sensation (i.e., .07 g and 0.4 g monofilaments) on the right and left feet between the groups. Right whole foot sensation (in grams) of healthy weight subjects (3.5929 ± 0.64742) and right whole foot sensation of obese subjects (3.3410 ± 0.85461) did not differ significantly from each other, $t(15.132) = 0.806$, $p = 0.433$. Left whole foot sensation (in grams) of healthy weight subjects (3.4468 ± 1.01623) and right whole foot sensation of obese subjects (3.2390 ± 1.06027) did not differ significantly from each other, $t(18.342) = 0.499$, $p = 0.623$. However, obese subjects sensed less in right and left whole foot sensation than healthy weight subjects (*Figure 4)*.

The comparison of sensitivity among foot regions in obese and healthy weight subjects indicated little effect of foot region on plantar sensation. Therefore, there was no statistical significance between sensitivity of different regions of the foot and normal weight and obese subjects.

Right forefoot sensation (in grams) of healthy weight subjects (2.4782 ± 0.42543) and right forefoot sensation of obese subjects (2.3980 ± 0.51409) did not differ significantly from each other, $t(16.230) = 0.417$, $p = 0.682$. Additionally, left forefoot sensation (in grams) of healthy weight subjects (2.4488 ± 0.57557) and left forefoot sensation of obese subjects (2.3240 ± 0.69473) did not differ significantly from each other, $t(16.245) = 0.480$, $p = 0.638$. However, obese subjects were reported to sense less than healthy weight subjects for the right and left forefoot scores (*Figure 5*).

Right midfoot sensation (in grams) of healthy weight subjects (0.8282 ± 0.18712) and right midfoot sensation of obese subjects (0.7150 ± 0.20711) did not differ significantly from each other, $t(17.455) = 1.421$, $p = 0.173$. Additionally, left midfoot sensation (in grams) of healthy weight subjects (0.8071 ± 0.23129) and left midfoot sensation of obese subjects (0.6510± 0.36528) did not differ significantly from each other, $t(13.329) = 1.215$, $p = 0.245$. However, obese subjects were reported to sense less than healthy weight subjects for the right and left midfoot scores (*Figure 6*).

Right rearfoot sensation (in grams) of healthy weight subjects (0.3041 ± 0.21486) and right rearfoot sensation of obese subjects (0.2350 ± 0.23482) did not differ significantly from each other, $t(17.641) = 0.762$, $p = 0.456$. Additionally, left rearfoot sensation (in grams) of healthy weight subjects (0.3276 ± 0.23129) and left rearfoot sensation of obese subjects (0.2280 ± 0.22798) did not differ significantly from each other, $t(19.232) = 1.091$, $p = 0.289$. However, obese subjects were reported to sense less than healthy weight subjects for the right and left rearfoot scores (*Figure 7*).

Figure 4.

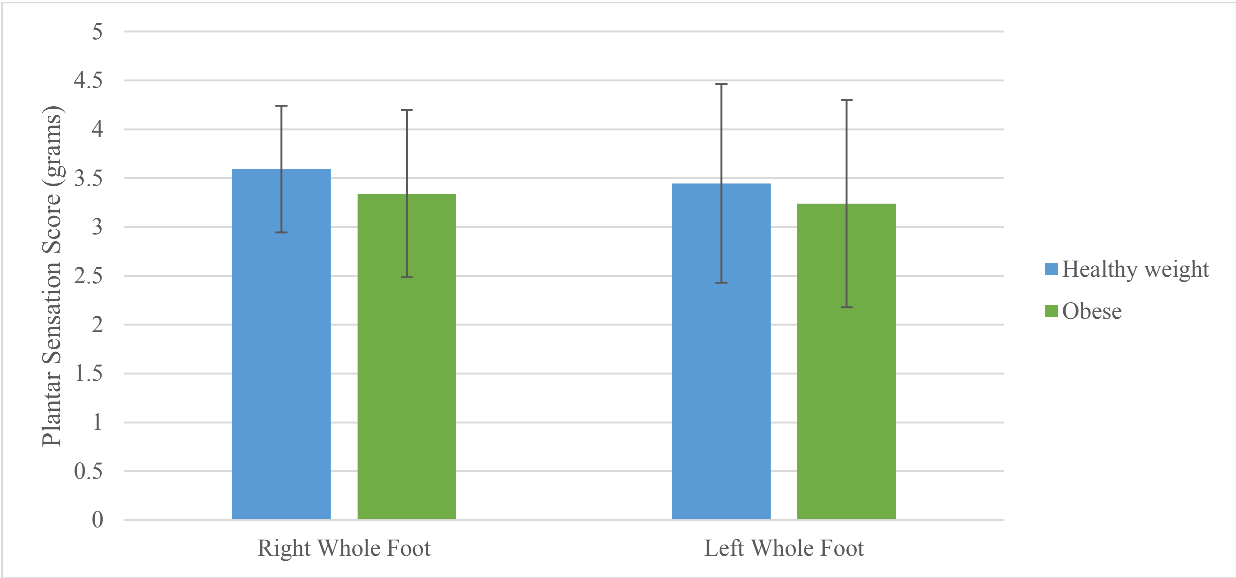


Figure 5.

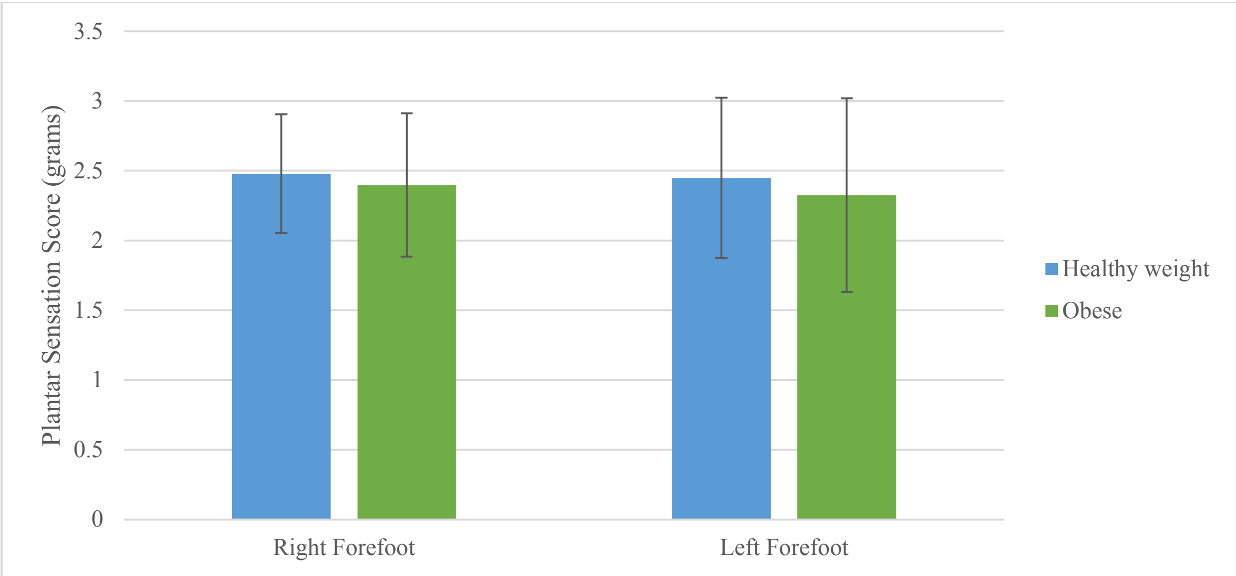


Figure 6.

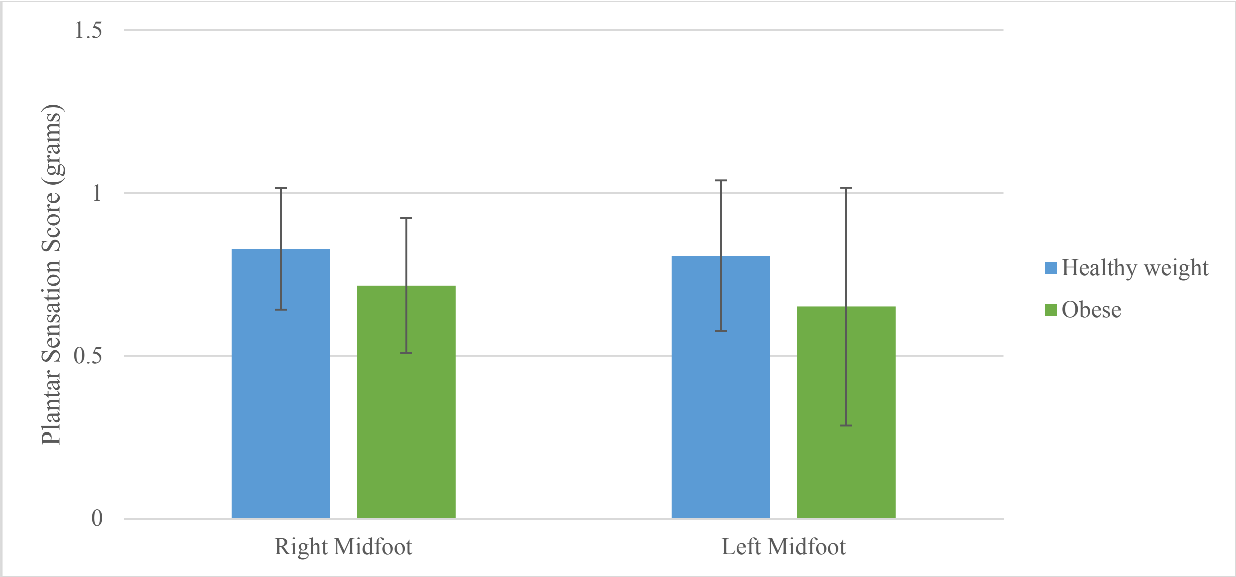
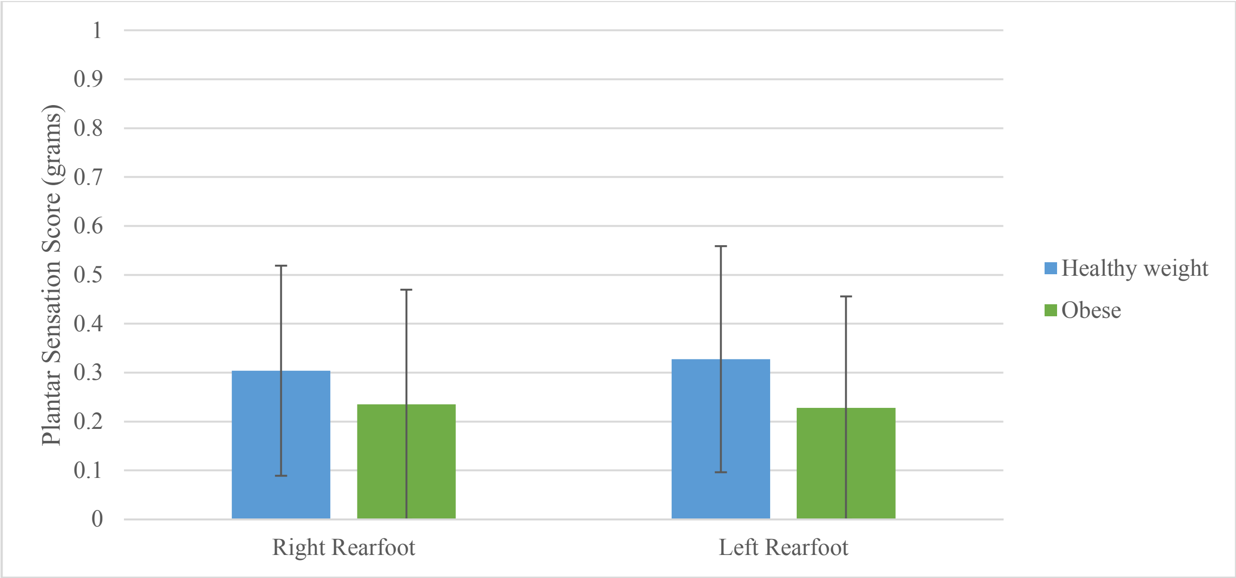


Figure 7.



CHAPTER V: DISCUSSION

The purpose of this study was to determine whether normal plantar sensation differed between children whose BMI percentiles are categorized as "healthy" and "obese." The knowledge from this study can help elucidate associations between weight and plantar sensation. This study addressed the following research questions: (1) Does plantar sensation differ in children who have healthy weight and children who are obese? (2) Is there a difference between whole foot plantar sensation and regional plantar sensation? It was hypothesized that plantar sensitivity will differ between children who are overweight, obese, and those who have healthy weight.

Previous studies suggested lower foot sensitivity in obese children can be considered a risk factor for a variety of injuries related to foot loading as well as during long term exercises frequently recommended for obese children to control the weight and should be included in physical examination of the obese children (da Rocha et al., 2014). This same study reported obese children having lower foot sensitivity than non-obese children. In this study, obese children had similar sensitivity across all foot regions, whereas non-obese children were able to discriminate touch in different intensities for the different foot regions (da Rocha et al., 2014). In a more recent study by Yumin, Simsek, Sertel, and Ankarali (2016), it was determined that there was a relation between the BMI value and plantar sensation and that plantar sensitivity decreased as BMI increased in healthy adults. Additionally, the load on the feet increased with the increase in weight in healthy individuals especially around the first toe and heel, and this led to a loss of sensitivity in the areas where excessive load was placed (Yumin et al., 2016). However, this study was performed on adult subject and cannot be applicable to children. Other explanations for decreased plantar sensitivity could include visual loss, hearing loss, foot problems, and neuropathy.

It was concluded that normal plantar cutaneous sensation does not differ between preadolescents and children with obesity and peers with healthy weight. Given the small current sample size, more subjects need to be tested, in order to increase confidence and substantiate findings from this study

Limitations

While this study attempted to find differences, if any, of decreased plantar sensation in different weight statuses, there were several limitations that impeded the results. Given the small current sample size, more subjects need to be tested, in order to increase confidence and substantiate findings from this study.

Plantar sensation testing is dependent on feedback and it cannot be assumed that what the children were saying was always true (i.e. if the subjects felt a monofilament and responded that they did not). Additionally, in the present study, the presence, or lack of, medical illness that could potentially affect sensory function was not accounted for.

While there is related literature that supports the usage of monofilaments as the tool for plantar sensation assessment (Hennig & Sterzing, 2009; Jeng, Michelson, & Mizel, 2000), there are contradicting studies that support the usage of monofilaments for testing on the upper extremity (Smieja et al., 1999). The battery was originally designed and intended for use in the upper extremity, and, consequently, the tests were selected due to their reliability in adult upper extremity measurement, and their strong correlation to hand function; the same cannot be said for the foot (Booth, Estevez, Cooper, & Majnemer, 1998).

One reason for a variation in results is instrument-related error (Massy-Westropp, 2002). Monofilaments may deliver a different range of pressures if a monofilament is the wrong length, kinked, or even fatigued after multiple uses (Booth & Young, 2000). More research is indicated in the ongoing development of this lower extremity sensory assessment tool for school-aged children (Booth et al., 1998).

There is limited research on the assessment of plantar cutaneous sensation on children who are obese and have healthy weight. In a study by Perry (2006), it was determined that monofilaments were beneficial when used for assessing age-related insensitivity and that the older adults had plantar-surface insensitivity at an important level when compared with the young adults. Since plantar cutaneous sensation has been established to decrease with increasing age, it is important to state that a limiting factor in this research is the lack of comparability with previous research.

Body mass index in childhood changes substantially with age. Cole, Bellizzi, Flegal, and Dietz (2000) reported that at birth the median of BMI is as low as 13 kg/m^2, increases to 17 kg/m^2 at age 1, decreases to 15.5 kg/m^2 at age 6, then increases to 21 kg/m^2 at age 20. Therefore, a cutoff point related to age is also needed in order to utilize reference percentiles of children who are obese. This study did not collect information on how long children have been obese. There is suggestion in the literature that the severity and duration of obesity can mediate plantar sensation outcomes

Implications for Practice and Future Research

Abarca-Gomez et al. (2017) reported that more children and adolescents worldwide are moderately or severely underweight than obese. However, if trends continue, child and adolescent obesity is expected to surpass moderate and severe underweight by 2022 (Abarca-Gomez et al., 2017). Since decreased plantar cutaneous sensation can impair postural stability, contribute to decreased physical activity and increased fall risk, and indicate metabolic changes associated with excess weight and type 2 diabetes, it is important to test additional school-aged children and adolescents, especially in schools where obesity is prevalent. Previous studies report children and adolescent in underserved communities are more exposed to the risk for decreased physical activity, increased adiposity, and excess body mass. This knowledge can help identify any previously undetected loss of protective sensation, which may indicate early signs of pre-diabetes, particularly among children who are obese. There is a need for more studies on how an increase in body weight influences plantar cutaneous sensation between children who are obese and who have healthy weight.

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APPENDIX

Appendix A – Institutional Review Board Approval

Appendix B – Parental Consent Form

Appendix C – Child Assent Form

Appendix D – Assessor Training Instructions

Appendix E – Monofilament Scoring Sheet

Appendix A

TEXAS A&M UNIVERSITY CORPUS CHRISTI

OFFICE OF RESEARCH COMPLIANCE
Division of Research, Commercialization and Outreach
6300 Ocean Drive, Unit 5844
Corpus Christi, Texas 78412
O 361.825.2497 • F 361.825.2

Human Subjects Protection Program — Institutional Review

DATE: March 22, 2018

TO: Toyin Ajisafe, Assistant Professor
College of Education and Human Development

CC: Andrea Gilson, Graduate Student

Frank Spaniol, Professor
College of Education and Human Development

Theresa Garcia
Assistant Professor, College of Nursing & Health Sciences

FROM: Office of Research Compliance

SUBJECT: Reportable Event Review

On March 6, 2018, the Texas A&M University-Corpus Christi Institutional Review Board reviewed the following submission:

Type of Review:	Non-compliance Report
Level of Review for Reportable Event:	Full Board
Protocol Title:	Relative Altered Plantar Sensation Prevalence among Children with Different Weight Statuses
Investigator:	Toyin Ajisafe
IRB ID:	143-17
Funding Source:	None
Documents Reviewed:	IRB Protocol Form Script for Physical Education Teachers Parental Consent Form Assent Form for High School Age Assent Form for Elementary School Age Explanation Letter to IRB Explanation Letter to Parents

Changes requested were reviewed and acknowledged on March 21, 2018. TAMU-CC IRB **acknowledges** the event and **approved** the corrective action plan. Please do not hesitate to contact the Office of Research Compliance with any questions at irb@tamucc.edu or 361-825-2497.

Respectfully,

Rebecca Ballard, JD, MA, CIP — Digitally signed by Rebecca Ballard, JD, MA, CIP Date: 2018.03.22 09:48:00 -05'00'

Rebecca Ballard, JD, MA, CIP
Director, Research Compliance and Export Control Officer
Division of Research, Commercialization and Outreach

Appendix B

PARENTAL CONSENT FORM

DIFFERENCES IN PLANTAR CUTANEOUS SENSATION BETWEEN CHILDREN WHO ARE OVERWEIGHT, OBESE, AND HAVE HEALTHY WEIGHT

Introduction

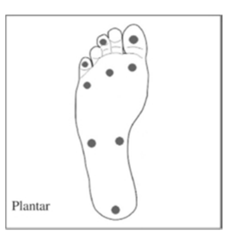
The purpose of this form is to provide you (as the parent of a prospective research study subject) information that may affect your decision as to whether or not to let your child participate in this research study. This form will also be used to record your consent if you decide to let your child be involved in this study.

If you agree, your child will be asked to participate in a research project studying the ability of children to detect or feel when the bottom of their foot is touched. This is important, because reduced ability to feel touch on the bottom of the foot can affect the body's ability to be stable, especially during physical activity. The purpose of this study is to understand whether body weight affects the ability of children to feel when the bottom of their foot is touched. This study also seeks to understand whether reduced feeling on the bottom of the feet is common among children in Corpus Christi.

Your child was selected to possibly participate, because he/she is in 3rd, 4th, 5th, 9th or 10th grade and is enrolled in physical education. He/she is also mature enough to be able to say whether he/she can feel or cannot feel a touch on the bottom of their feet. This study is being sponsored/funded by Blue Cross Blue Shield and Texas A&M University – Corpus Christi.

What will my child be asked to do?

If you allow your child to participate in this study, they will be asked to spare 8-10 minutes of their time during physical education class being tested for sensation on the bottom of their feet. One of the PE coaches will escort your child and other classmates to the physical education room designated for the testing. We will introduce ourselves and read the details of the study to your child. We will ask if your child would like to participate in the study. If you allow, and your child chooses to participate, they will be asked to sign their name and date an assent form. We will then measure your child's height and weight. We will ask them to remove their shoes and socks and lay comfortably on a cushioned table and look at the ceiling. We will touch nine different areas on the bottom of their feet (**Picture 1)** using a **<u>really light material that bends</u>** (**Picture 2)**. After each touch, we will ask if they "feel anything." We will ask them to respond "yes" or "no."



Picture 1

Picture 2

We will ask them to put their socks and shoes back on. They will then return to physical education class with their coach or be escorted back by the researchers.

What are the risks involved in this study?

One of the associated **risks** with this study is that the testing material used to touch your child's feet may sometimes tickle. In addition, as a result of this testing, we may find that your child has decreased sensation to his/her feet. If this occurs, we will provide you with that information through your school nurse, and provide you with the name of a local physician you can contact to further discuss this finding. The risks associated in this study are minimal and are not greater than risks your child ordinarily encounters in daily life.

What are the possible benefits of this study?

Your child will receive no direct benefit from participating in this study; however, by allowing your child to participate, you can help us find out if weight affects children's ability to feel on the bottom of their feet which could affect their balance and their ability to be stable during physical activity.

Does my child have to participate?

Your child does NOT have to participate in this research study. If you do not allow, or your child does not want to participate, they will simply remain in physical education class with their coaches and participate in the regularly scheduled PE activity.

What if my child does not want to participate?

In addition to your permission, your child must agree to participate in the study of their own accord. If your child does not want to participate, they will NOT be included in the study. They will not lose or gain any privileges for choosing not to participate. If your child initially agrees to be in the study, they can withdraw at any point during the study without any penalty.

Who will know about my child's participation in this research study?

This study is confidential. All subjects will be assigned a participation ID, in order to protect their identity when writing and publishing this study. No identifiers linking you or your child to this study will be included in any sort of report that might be published. All of the data collected will be kept in a locked storage filing cabinet in the kinesiology department at Texas A&M University – Corpus Christi Kinesiology. Only Dr. Ajisafe (Principal Investigator) and Andrea Gilson (Co-Principal Investigator) will have access to the cabinet.

Whom do I contact with questions about the research?

If you have questions regarding this study, you may contact, Dr. Toyin Ajisafe, 361-825-3834, toyin.ajisafe@tamucc.edu.

Whom do I contact about my child's rights as a research subject?

This research study has been reviewed by the Institutional Review Board and/or the Office of Research Compliance at Texas A&M University-Corpus Christi. To report a problem or for questions regarding your rights as a research subject, contact Rebecca Ballard, JD, MA, CIP, Research Compliance and Export Control Officer: 361-825-2497 or Rebecca.Ballard@tamucc.edu.

Signature

Please be sure you have read the above information, asked questions and received answers to your satisfaction. You will be given a copy of the consent form for your records. By signing this document, you consent to allow your child to participate in this study.

Signature of Parent/Guardian: ________________________________ Date: ______________

Printed Name: ____

Printed Name of Child: ____

Appendix C

ASSENT FORM

DIFFERENCES IN PLANTAR CUTANEOUS SENSATION BETWEEN CHILDREN WHO ARE OVERWEIGHT, OBESE, AND HAVE HEALTHY WEIGHT

Introduction
My name is ________, and I am a Research Assistant at Texas A&M University – Corpus Christi. I am doing a study on how well children feel when the bottom of their foot is touched.

I would like you to help with my study because we do not know much about how weight affects how well you can feel on the bottom of your feet.

What will I be asked to do?
This study will take about 5-8 minutes. If you want to help with my study and sign this document, you will be asked to do the following. Before you continue reading, it is important that you understand that this will **NOT** hurt.

1.) First, we will take your height and weight measurements without your shoes on.
2.) Second, you will be asked to lay with your back on the table and ask you to either 1.) close your eyes OR 2.) focus on a spot on the ceiling.
3.) Then, I will touch 9 (nine) different parts of the bottom of your foot (**Picture 1**) with a filament (**Picture 2).**
4.) Then, I will ask if you can feel me touching the bottom of your foot at each of the 9 places. I will ask, "Can you feel anything?" and you will respond **YES** or **NO**.

Picture 1

Picture 2

What are the risks to me?
The only risks to you is that the touch of the filament may tickle.

What good can happen?
By helping me in this study, you can help us know if a person's weight affects how well they feel touch.

Do I have to be part of the study?
No. You do not have to be part of the study. Your parents said you can be in the study, but you do not have to because they said you can. You should only be part of this study because you want to.

Who will know I am part of the study?
Your name will be kept secret from everyone except your teacher and your parents. You can stop being part of the study whenever you want to. You can tell your parents, your teacher, me, or any adult that you would like to stop, and it is OKAY.

Signature
If you agree to be our study, you can ask questions or tell us to stop anytime. We will **NOT** be upset if you decide not to be in the study. Your parents will not be upset if you ask to stop.

Please sign your name below if you agree to be part of this research study.

____ ______________________
Signature of Subject Providing Assent Date

____ ______________________
Printed Name of Person Obtaining Assent Date

____
Signature of Person Obtaining Assent

Appendix D **SUBJECT NUMBER: ______________**

MONOFILAMENT SCORING & INFORMATION SHEET

DIFFERENCES IN PLANTAR CUTANEOUS SENSATION BETWEEN CHILDREN WHO ARE OVERWEIGHT, OBESE,
AND HAVE HEALTHY WEIGHT

School: ____

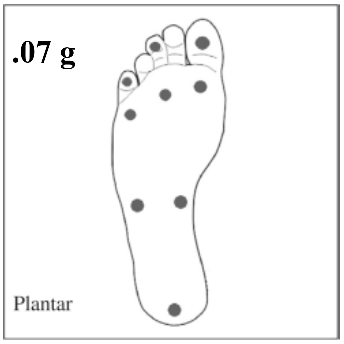
Height: ______________ **Weight: ______________**

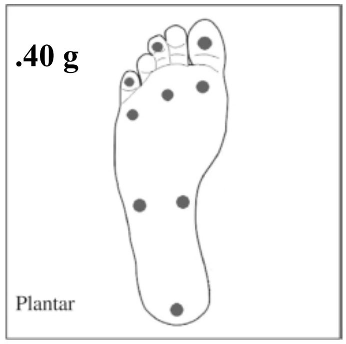
Age: _________________ **DOB: ________________**

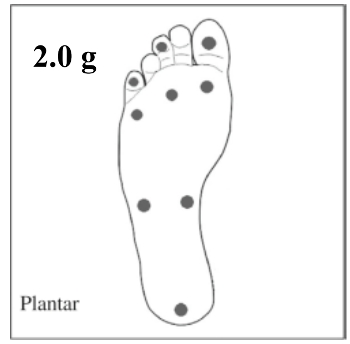
Instructions for Research Assistant:

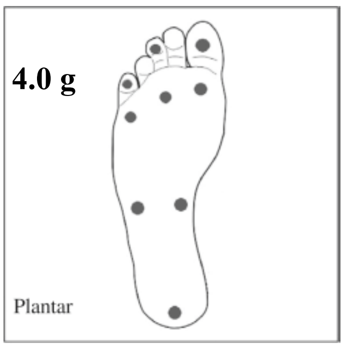
1.) Put on a new pair of gloves.
2.) Ask student to remove socks and hold onto socks.
3.) Remind the subject that this foot sensation test will **NOT** hurt and that they may ask to stop at any time during the study.
4.) Demonstrate the probes. Touch their hand with one of them and say "This is what I will be doing to the bottom of your foot."
5.) Ask student to lie on their back with their feet slightly hanging off the table.
6.) Ask student to either close their eyes or to focus on a fixed spot on the ceiling. Tell them to not look at you or they can hurt their neck.
7.) Ask and record their age and the year they were born.
8.) Explain to them that you will ask if they can feel you touching the bottom of their foot at each of the 9 sites. They will need to respond **YES** or **NO** at each of the 9 (nine) sites.
9.) Touch the filament randomly to each of the nine sites on the bottom of the subject's foot. If necessary, touch the filament along the side of and NOT directly on an ulcer, callus, or scar. Push hard enough to make the filament bend or "buckle". Do not allow the filament to slide across the skin or make repetitive contact at the test site.
10.) The total duration of the approach, skin contact, and departure of the filament should be approximately 2 seconds.
11.) Ask, "Can you feel this?" for each site and mark a check in blue if the answer is **YES**. Mark an X in red if the answer is **NO**. (Responses like "maybe" or "I don't know" should be marked with a red X.
12.) Repeat steps 9 through 11 for each monofilament intensity. (Total of 6).
13.) Switch to the opposite foot and score.
14.) After use, wipe each filament with an alcohol wipe and change gloves.
15.) Ask student to proceed putting on socks and shoes.

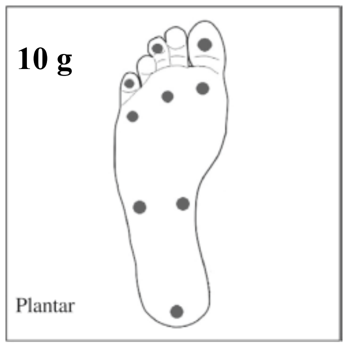
RIGHT FOOT: **Right foot total score: ________________**

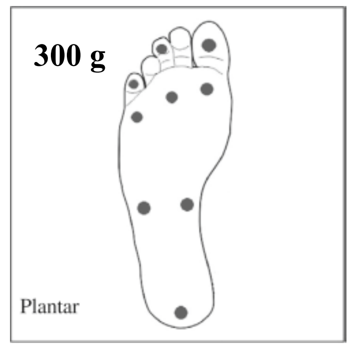












LEFT FOOT: **Left foot total score: _________________**