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A Comparative Analysis of Tractor Seating for Individuals with Spinal Cord Injury Using a Pressure Mapping System

William Kennington
University of North Dakota

Veronica Boeser
University of North Dakota

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by

William Kennington, MOTS

Veronica Boeser, MOTS

Advisor: Carla Wilhite, OTD, OTR/L,

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Approval Page

This Scholarly Project Paper, submitted by William Kennington and Veronica Boeser in partial fulfillment of the requirement for the Degree of Master's of Occupational Therapy from the University of North Dakota, has been read by the Faculty Advisor under whom the work has been done and is hereby approved.

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ABSTRACT

Purpose: Research is limited in addressing the many factors and variables associated with enabling farmers/ranchers with disabilities and health impairments to sit within and operate dynamic agricultural equipment safely, comfortably, and without integument and musculoskeletal injury. As an initial foray into investigating this problem, an independent study project by graduate students in an occupational therapy program compared the seated pressure distribution of two people with paraplegia. Six testing conditions were completed while participants were seated upon two different tractor seats under static conditions.

Methodology: Using a quantitative cross-over design, two adult subjects with paraplegia meeting the inclusion criteria were recruited using a convenience sampling method to participate in this study. The subjects reported having a complete injury of a motor and sensory function below the level of the lesion T5 and T8. Utilizing a clinical protocol for pressure mapping from XSensor®, each participant completed six trials on two different tractor seats: without a cushion, with a Low Profile® ROHO ® air bladder cushion, and with a Mid Profile® ROHO® airbladder cushion. Analysis of the data was conducted through selected clinical methods.

Results: Of the six testing conditions in this particular study, incorporating a Mid Profile® ROHO® cushion is indicated for use on both tractor seats by both subjects in the study to achieve lower overall average pressures, distribute body weight over a greater surface area, increase immersion and flotation on the seating surface, and lower pressures under bony prominences such as the ischial tuberosities.

Conclusion: Due to limited participants in this exploratory study, statistical conclusions cannot be made and generalization of the results to a larger population cannot be drawn at this time. The findings do support the need for future tractor seating studies with people with different disabilities and health impairments within static and dynamic systems. For purposes of clinical decision-making, the independent study provides important information for farm operators with disabilities and health impairments and the professionals providing services to them to better understand the many factors and variables associated with seating in agricultural machinery. Pressure mapping is clearly one clinical tool to be used when considering the seating needs of people with disabilities in agricultural equipment.

CHAPTER I

INTRODUCTION

Farmers and ranchers with spinal cord injuries (SCI) often return to operating agricultural machinery with the assistance of assistive technologies such as powered lifts and hand controls. However, very little, if any, empirical evidence to support the seating considerations of such persons has been found in the agricultural health or rehabilitation literature. Instead, many farmers and ranchers use the existing pan or foam seat, are encouraged to use low profile air-bladder wheelchair cushions (Willkomm, 2002), or are advised to follow principles of seating for wheelchairs (Cook & Hussey, 2002; Minkel, 2000) on the assumption that such principles translate to the dynamic conditions under which farm machinery is operated. However, seating in agricultural machinery is situated contextually and uniquely in ways that subject the system to extreme physical forces (e.g., rotational, vibration, and translational), environmental elements (e.g., time, season, weather, temperature, humidity, lighting), and human factors (e.g., physical, cognitive, and psychological actions) not generally found in typical wheelchair seating situations.

The objective of seating is to achieve the human need for comfort, stability, and safety, prevent injury to the integument barrier and musculoskeletal system, and yet provide considerable allowance and degrees of freedom for human operation and monitoring of the machine as it is engaged in agricultural production tasks (e.g., tillage, planting, harvesting, and chemical application).

Since seating within an agricultural machine system is subject to such state changes and unpredictable conditions, dynamical systems theory emerges as a viable framework for looking at the intertwining subsystems that exist in a tractor environment including the biological, cognitive, social, environmental and mechanical properties that impact and influence the health of the human operator (Capra, 2002). One principle of a dynamical systems approach is considering living systems, like humans, as "embedded within, and open to, a complex environment" (Smith & Thelen, 2003, p. 343).

Current scholarly evidence also suggests that physical changes within the human system, when subjected to extreme environmental and mechanical conditions (like those faced by farmers and ranchers in agricultural machinery), is best considered through dynamical systems theory (Davids, Glazier, Araujo, & Bartlett, 2003; Glazier, Davids, & Barlett, 2003). Dynamical systems theory emphasizes that no one element in a system determines the outcome of forces upon a human body, but rather it is a combination of all interacting subsystems (Smith & Thelen, 2003).

Davids et al. (2003) describes dynamical systems theory as, "a multidisciplinary, systems-led approach, encompassing mathematics, physics, biology, psychology and chemistry, [that] describes systems which are constantly changing and evolving over different timescales" (p. 246). In order for these subsystems to function appropriately, a significant number of smaller interacting components must be present and working properly. For example, in the instance of physical movement, interacting components such as blood cells, oxygen molecules, muscle tissue, metabolic enzymes, connective tissue and bone that are in a constant state of change and flux must be organized and working in the proper order for movement to occur, accompanied by the volitional decision to move (Davids et al., 2003).

Without proper self-organization of biological subsystems and all components required for movement, movement patterns will not be generated. In turn, a person's musculoskeletal system interacts with the cognitive and sensory capacities of the person, as well as conditions in the exterior environment such as lighting, terrain, objects, and weather (Davids et al., 2003). Thus, dynamical systems theory works as a framework for investigating the interactions and complexities of the human operator embedded within a mechanical system (tractor), which in turn is acted upon by multiple physical forces induced by the machine itself and the exterior environment.

Dynamical systems is also conceptualized in updated models of human occupation (Kielhofner, 2002, p. 32), new occupational models (Lazzarini, 2004) or influential in understanding the "self-organizing behavior" of human systems (Giuffrida & Rice, 2010, p. 699; James, 2003, p. 244). In addition, the human operator is recognized as a complex bio-psychosocial system engaged intentionally in agricultural work that gives meaning and purpose (Lazzarini, 2004).

CHAPTER II

LITERATURE REVIEW

Current research is limited in addressing the many factors and variables associated with enabling farmers/ranchers with disabilities and health impairments to operate agricultural equipment safely. In this literature review, the authors seek to discover the multiple influences and complexities that impact the seating of individuals with spinal cord injuries within the dynamics of a tractor system, including biomechanical conditions, environmental conditions, mechanical properties of the tractor, and dynamics operating upon the tractor in motion.

Famers/Ranchers and Spinal Cord Injury (SCI)

Agricultural producers are known to work long hours, with most averaging 66 hours per week, to ensure that they complete a given task before the day ends or the weather changes (Mathew, Field, & French, 2009; Wray, Borgelt, Downs, & Funkenbusch, 2001). Such individuals frequently work in environments where the weather is harsh and hazardous to the human body as well as to the human interface with the machines (Wray et al., 2001). Because of these reasons, farming is consistently ranked by the National Safety Council as one of the most dangerous vocations in the United States, with over 140,000 disabling injuries occurring each year (Mathew, Field, & French, 2009). According to Mathew, Field, and French (2009) the numbers of agricultural workers who have sustained injuries are estimated to be in the range of 1.14 million to 2.23 million; however, they reported that this number depends on which survey or census is being used to extrapolate data. Unfortunately, it has been found that many farm-related injuries result in extensive or permanent disabilities (Mathew, Field, & French, 2009).

In an analysis completed with 2,500 clients, AgrAbility determined that paraplegia is one of the five most prevalent primary disabilities, regardless of farm type (Schuler, Adams, & Meyer, 2005). Of disabilities sustained in an agricultural setting, paraplegia accounts for approximately 10% of total reported disabilities (Schuler, Adams, & Meyer, 2005). Schuler, Adams, and Meyer (2005) also report that, when comparing gender, men have a higher prevalence (11.5%) of paraplegia as compared to women (5.5%). It should be noted that severe disability such as paraplegia in a farm family significantly impacts not only the farmer/rancher but also his or her spouse, children, parents, and others who are closely related (Deboy, Jones, Field, Metcalf, & Tormoehlen, 2008).

Paraplegia refers to motor and sensory impairment at the thoracic, lumbar, or sacral segments of the spinal cord (Atkins, 2002). Depending on the level of the lesion, individuals with SCI may have limited arm function/stability, impaired trunk, legs, and pelvic organs (Atkins, 2002). The level of lesion within the spinal cord is diagnosed by a physician according to the motor and sensory level determined by testing 10 key muscles and the sensation of 28 key points on each side of the body (Atkins, 2002). Atkins defines the neurological level as “the lowest level at which key muscles can be moved against gravity and sensation is intact for this level’s dermatome” (2002, p. 1173).

Injuries are also classified by whether they are complete or incomplete injuries using criteria from the American Spinal Injury Association (ASIA). Complete injuries consist of absence of sensory or motor function in the lowest sacral segments (ASIA, 2000). Incomplete injuries include partial preservation of sensory and/or motor function below the neurological level, including sacral segments (ASIA, 2000). Individuals with paraplegia can range from having complete injuries or incomplete injuries from T1 to S4-5 (Atkins, 2002). Individuals who have sustained SCI from T1 through S4-5 may experience, depending on the neurological level, loss of finger abductors, hip flexors, knee extensors, ankle dorsiflexors, long toe extensors, ankle plantar flexors, and voluntary anal contraction (ASIA, 2000).

During the rehabilitation phase subsequent to SCI, the person with paraplegia receives rehabilitative services, such as occupational therapy (OT), to learn how to manage sequelae such as autonomic dysreflexia, orthostatic hypertension, and bowel and bladder management. The individual and his or her family members also learn to complete functional transfers, engage in functional mobility, and complete all activities of daily living (ADL) such as dressing and grooming, as well as instrumental activities of daily living (IADL) such as driving, and are taught to engage in pressure relief periodically due to decreased sensation and motor movement (Atkins, 2002).

Upon returning home, many farmers/ranchers who have spinal cord injuries are still determined to continue working and refuse to be held back by functional health impairments, despite the hazards of production in agriculture (Mathew, Field, & French, 2009). According to Mathew, Field, and French (2009), many farmers and ranchers with

SCI do not feel that full recovery has occurred in the hospital stage of rehabilitation, but instead occurs when they are able to return to work (Mathew, Field, & French, 2009). Aspects of rehabilitation specifically important to agricultural workers with paraplegia when engaging in operating agricultural machinery include the ability to operate lifts in order to transfer in and out of the tractor safely, the capacity to maneuver around the tractor in various environments and on terrain, and the ability to become proficient in operating hand controls in order to safely and efficiently operate the machinery (Willkomm, 2002; Wray et al., 2001).

Factors Related to Seating and SCI

The seated position for individuals with SCI is the foundation from which individuals perform essential activities of daily living (Minkel, 2000). Most individuals with SCI can become successful within their environment using a standard or motorized wheelchair (Minkel, 2000). However, due to the harsh environmental conditions often present in country areas, tractors rather than other wheeled mobility have become one of the primary work stations for agricultural producers with disabilities (Willkomm, 2002). Many farmers/ranchers with SCI can spend hours at a time overseeing agricultural operations from the tractor seat (Willkomm, 2002). Pressure ulcers are a dominant health problem for individuals with spinal cord injuries who spend significant time in a seated position (Eitzen, 2004). Treatment of pressure ulcers is time consuming and costly. Therefore, preventing pressure ulcers should be a priority for famers/ranchers with SCI when operating agricultural machinery, as well as prevention of other injuries to the integument, organs, and musculoskeletal system.

Under typical conditions, when low pressure is applied to skin the body's physiological response creates heat (Petrofsky, McLellan, Prowse, Bains, Berk & Lee, 2010) and has the protective effect of increasing local circulation. Yet "when greater pressure is applied to the skin, blood flow is occluded" (Petrofsky et al., 2010, p. 153) and even though oxygen saturation remains relatively high at first (Hahn, 2007), within two hours of consistent pressure oxygen deprivation, coupled with an accumulation of metabolic end products, irreversible tissue damage occurs and there is the appearance of a lesion (Porth, 2005).

Such lesions are called pressure ulcers and are defined as "ischemic lesions of the skin (epidermis) and underlying structures (dermis, subcutaneous) caused by external pressure that impairs the flow of blood and lymph" (Porth, 2005, p. 500). Pressure ulcers occur most commonly when the external pressure exceeds the normal capillary filling pressure (approximately 32 mm Hg) and capillary flow is obstructed (Patterson & Bennett, 1995). Pressure ulcers are most likely to develop over a bony prominence, with the ischial tuberosities and sacrum as the most frequent site of development, followed by the heel, scapula, and occipital protuberance of the skull (Porth, 2005). Although vertical pressure resulting in skin breakdown is the most common mechanism of injury, shearing and tensile forces also can injure skin (Petrofsky, et al., 2010).

Within the dynamical tractor system, many risk factors can contribute to skin breakdown and lead to the development of pressure ulcers or other integument injuries (Willkomm, 2002). Some of the risk factors for integument injury intrinsic to the person include loss of intact sensation, decreased muscle tone, one's body type, nutritional status, presence of moisture, infection, age-related changes, spinal stability, choice of clothing, and the function of time. Extrinsic factors include seat materials, positioning constraints, rough terrain, equipment vibration, rotation, as well as shearing, contact compression, translational, acceleration, deceleration and rotary forces, and age (Cook & Polgar, 2008; Eitzen, 2004; Willkomm, 2002).

The body typically responds to prevent tissue damage by moving to relieve pressure over an area (Cook & Polgar, 2008). Normally, when there is a lack of oxygen and chemical irritation, pain signals from the nerve endings trigger postural changes, resulting in little tissue damage (Cook & Polgar, 2008). Individuals who lack normal sensation, such as farmers/ranchers with SCI, are unable to recognize and respond to these signals; thus, they are particularly susceptible to the development of pressure ulcers (Cook & Polgar, 2008).

The body type of the individual also has some effect on pressure distribution. A thin person has less subcutaneous fat to act as padding, and therefore forces per unit area of the skin are increased (Cook & Polgar, 2008). An overweight individual has more fat padding over which to distribute pressure (Cook & Polgar, 2008), but may actually be more susceptible to vertical and shearing forces secondary to poorer circulation (Petrofsky et al., 2010). Also, it should be noted that an overweight individual may have a more difficult time performing pressure relief exercises (Cook & Polgar, 2008).

Inadequate nutrition is often associated with weight loss and muscular atrophy, both of which reduce the amount of tissue between the seat surface and the bony prominences (Cook & Polgar, 2008). Inadequate dietary intake results in anemic conditions, decreased protein levels and vitamin C deficiency that have been shown to interfere with normal integrity of the tissue, pressure ulcer development and delayed healing (Breslow, 1991). On the contrary, an increased intake of protein and calories has been shown to improve the healing rate of pressure ulcers (Breslow, 1991).

Infection can contribute to pressure ulcer development by increasing the metabolic rate (Cook & Polgar, 2008). Increasing the metabolic rate causes an increased demand for oxygen and leads to ischemic conditions. Also, severe infection can affect the nutritional balance in the body and localized bacteria increase the demand on the body's metabolism (Cook & Polgar, 2008).

Older people may have a greater proportion of body fat, thinner and more fragile skin, poorer circulation, and may have less physiological ability for circulatory vasodilation (essentially reducing blood flow even further) than younger people (Petrofsky et al., 2010). As people age, the skin loses some of its elasticity and muscles atrophy (Cook & Polgar, 2008). Losing elasticity increases the integument's vulnerability to friction and shearing forces. Vascular and neurological diseases associated with aging (e.g., diabetes, renal disease) affect the circulation and may also increase susceptibility to skin breakdown (Cook & Polgar, 2008).

The microclimate between the body and the seating surface is a critical factor that is often overlooked. The temperature of the skin and the presence of moisture both affect the formation of pressure ulcers (Cook & Polgar, 2008). An increase in skin temperature of 1 degree Celsius is accompanied by a 10% increase in the metabolic demands of the tissue (Stewart, Palmieri & Cochran, 1980) and the greater the pressure the greater the hyperemia (Petrofsky et al., 2010). In tissue that already has limited oxygenation as a result of pressure, the potential for breakdown is exacerbated (Cook & Polgar, 2008). Wet skin is weaker than dry skin and therefore more likely to incur damage as a result of compression and friction (Cook & Polgar, 2008). Additionally, moisture increases the potential for bacterial growth and infection (Cook & Polgar, 2008).

Tissue can also be damaged by shearing forces. Shearing forces are caused by the sliding of one tissue layer over another with stretching and angulations of blood vessels, causing tissue injury and thrombosis (Porth, 2005). Injury caused by shearing forces in individuals with SCI commonly occurs when the individual is seated or semi-reclined and the head is elevated, causing the torso to slide down and put added pressure on buttocks and lower extremities (Porth, 2005). When this happens, friction and perspiration cause the skin and superficial fascia to remain fixed against clothing or seating material while the deep fascia and skeleton slide downward due to gravity.

In a study completed at the University of Pittsburgh, 21 farmers with SCI were surveyed and 12 reported having a pressure ulcer (Willkomm, 1997). This study suggests that there is an extremely high incidence rate (57%) of pressure ulcers among farmers/ranchers when compared to the normal incidence rate of 27% for pressure ulcers in individuals with SCI (Chen, DeVivo, & Jackson, 2005). Willkomm (1997) concludes by stressing that more research needs to be done in order to establish a foundation for which prevention of pressure ulcers among farmers/ranchers seated in agricultural machinery can be obtained.

Postural Considerations in SCI

Minkel (2000) has stated that providing postural support for individuals with SCI is a critical consideration when trying to prevent skin breakdown. Postural support is also important for preventing or accommodating spinal deformity and preventing impairment of pulmonary structures and visceral functioning. When looking at proper sitting posture of individuals with neurological disorders such as SCI, the pelvis is the key point of control (Cook & Polgar, 2008; Mayall, 2000). However, before proper positioning can be attained, each person needs to be assessed individually in order to determine the most appropriate position of the pelvis, hips, and lower extremities in relation to his or her unique biomechanical characteristics (Cook & Polgar, 2008).

The position of the pelvis greatly affects the posture of the rest of the body and is the first area addressed in positioning. The desired positions of the pelvis are neutral or in a slight anterior tilt (Mayall & Desharnais, 1995). Improper pelvic alignment will create increased shearing force and pressure on the integument when seated in wheelchairs (Cook & Polgar, 2008), thus contributing to the process of skin breakdown. Some of the asymmetrical or undesired postures of the pelvis include pelvic obliquities, pelvic rotation, pelvic tilt, and windswept hips (Cook & Polgar, 2008). However, if musculoskeletal structures cannot be appropriately aligned, then postural support must accommodate deviations to prevent further structural compromise.

Proper pelvic alignment for individuals with SCI seated in a wheelchair can be accomplished using a typical lap belt or a rigid pelvic stabilizer (Cook & Polgar, 2008). Research has shown that rigid pelvic stabilizers have less impact on daily function when compared to a lap belt (Cook & Polgar, 2008). However, these findings are based on research with individuals who have cerebral palsy and did not take into consideration the effect of the dynamical situation present within the tractor cab. Also, rigid pelvic stabilizers currently have not been used in tractor seating systems (Willkomm, 1997) and the beneficial and/or deleterious effects of pelvic stabilizers in tractor seating are unknown.

In contrast, Cook and Polgar (2008) recommend two lap belts, positioned at 45 degrees and 90 degrees relative to the thighs, in conjunction with a seat-to-back angle reclined to approximately 15 degrees in order to maintain proper pelvic alignment and prevent forward loss of balance when seated in wheelchairs. This slight incline has also been shown to prevent the buttocks from sliding forward and provides greater trunk stability (Trefler, Taylor, Shaw & Monahan, 1993). However, in a study by Petrofsky et al. (2010), waist belts were found to have significant vertical and shearing forces on exercising individuals, especially those who were overweight; indicating a one size fits all solution is less than optimal if injury is to be avoided and comfort and safety is to be provided. Thus, if lap belts are to be used for safety and postural support in tractors, consideration must also be given to the design and materials used.

Cook and Polgar (2008) also recommend that the hips be flexed at approximately 90 degrees for most individuals for proper positioning. This angle of hip flexion has been found to inhibit extensor tone and reduce posterior tilt of the pelvis, thus keeping the individual positioned correctly in the seat. However, Willkomm (1997) notes that a pelvic/hip angle greater than 90 degrees is often preferred in tractor seating because this will prevent the operator from sliding out of the tractor seat. Cook and Polgar (2008) also recommend legs be positioned at approximately 90 degrees with the femurs at neutral with respect to abduction, adduction, and rotation when seated in wheelchairs.

Support for the feet is also important in maintaining hip and knee position (Cook & Polgar, 2008). If the feet are left to hang or are positioned too low, pressure increases under the anterior thigh, thus impeding blood flow and making this area at risk for developing pressure ulcers (Cook & Polgar, 2008). In contrast, positioning the feet too high will cause extra pressure on the ischial tuberosities and sacrum, thus increasing the risk of developing a pressure ulcer (Cook & Polgar, 2008). Mayall and Desharnais (1995) also recommend that feet be positioned flat and with 90 degrees of ankle flexion to prevent plantar contracture and maintain the plantigrade position of feet for transfer.

In tractor seating, Willkomm (2002) suggests that self-tightened straps can secure the feet of operators with SCI, in conjunction with a lap belt, in order to prevent feet from inadvertently moving forward underneath the clutch and brake controls (Willkomm, 2002). Wedge shaped foot platforms have also been used within tractor environments to achieve the same benefit, as well as to prevent the lower torso from submarining out from underneath the lap belt (C. Wilhite, personal communication, November 15, 2010). Although the benefits or dangers of using straps or platforms have not been studied, the problem of forward movement is not to be minimized. Anecdotally, a female tractor operator with SCI sustained a serious femur fracture when sliding forward while coming to a stop in a tractor (R. Peterson, Nebraska AgrAbility, personal communication, October 22, 2010). She was not using a lap belt, straps, or wedge at the time, despite their use having been recommended. After recovery from the fracture, she has not had a similar incident since using a foot platform wedge and lap belt.

After the pelvis and lower extremities have been positioned correctly in wheelchair seating, the trunk is aligned in midline as much as possible (Cook & Polgar, 2008). The amount of trunk support required depends on the trunk control and presence of spinal deviations. If the individual has significant impairment in the trunk musculature, lateral supports might be used to compensate and help maintain a midline position (Cook & Polgar, 2008). Lateral supports placed high on the trunk and close to the body provide greater control than those placed lower on the trunk (Mayall & Desharnais, 1995). Contravening opinion for the use of lateral supports with wheelchairs is supported by Trefler et al. (1993) who state, "Lateral supports can interfere with functional activities and are, therefore, to be avoided" (p. 177). By extension, it should be noted that tractor operators spend a significant amount of time reaching for controls above, below, and beside the operator seat, as well as rotating the trunk and head to watch trailing equipment.

Willkomm (1997) suggests that lateral support can be achieved in tractors by selecting the proper seat, armrest adjustments, and using flexible positioning belts that will allow some flexibility when moving over rough terrain and operating machine controls. According to Willkomm (1997), great care should be taken if using lateral supports in a tractor system to ensure that the placement of supports is correct and made of proper material in order to prevent tissue damage due to forces such as shearing that likely will be present within the tractor cab. However, research has not been conducted to determine what, if any, lateral support is appropriate, what is correct placement of such supports, or what are appropriate restraining materials within the dynamic tractor system, beyond that extrapolated from the wheelchair literature, and thus, only assumes that they will be the same and/or necessary. Other mechanical factors must also be considered.

Tractor Vibration

All vehicles when in motion are exposed to vibrations; however, vibrations in agricultural machinery are further perpetuated due to numerous interacting mechanical factors (Temmerman, Deprez, Hostens, Anthonis & Ramon, 2005). Mechanical vibrations in agricultural equipment are caused by the moving components of the machine, variable environmental terrain, and changing speeds (Anthonis, Deprez, & Ramon, 2001; Dewangan & Tewari, 2008; Marsili, Ragni, Santoro, Servadio & Vassalini, 2002). These vibrations are not only a health risk to the operator but also can make the operator uncomfortable, which can lead to fatigue, injuries and high medical costs (Temmerman et al., 2005). Researchers have been looking at the impact these vibrations have on farmers/ranchers for many years (Anthonis, Deprez, & Ramon, 2001).

For example, Balasubramanian, Burks, Lehtola, and Lee (2006) conclude that tractor induced shock and vibration, currently known as whole-body vibration, is a health and safety concern for all operators. Whole-body vibration is defined as the "ride vibration transmitted to the body as a whole through the buttocks of the seated operator" (Balasubramanian et al., 2006 p. 293). Exposure to whole-body vibration causes a complex distribution of oscillatory motion and forces within the body (ISO, 1997). Whole-body vibration may cause discomfort or annoyance, influence human performance capability, or present health and safety risks that include pathological and/or physiological damage (Balasubramanian et al., 2006). At high levels of vibration, arteries within the body exhibit vasoconstriction (Govindaraju, Bain, Eddinger, & Riley, 2008). Vasoconstriction impacts cellular nutrient transport and has been shown to be associated not only with skin breakdown, but also with numerous health effects including disorders of the spine, nervous system, gastrointestinal system, circulatory system, vestibular system, and the female reproductive system (Balasubramanian et al., 2006; Govindaraju et al., 2008).

Dewangan and Tewari (2008) have stated that many components come into play when discussing the effects vibrations will have on the hand, wrist, and arm and that specifying the amount and magnitude of vibration produced in actual field conditions has proven to be difficult due to the variability of tractor systems, environments, and body structure of operators. Yet efforts to reduce vibration transmission are also being studied. Servadio, Marsili, and Belfiore's (2007) research suggests that a conservative way to reduce vibration transmission is to drive in a straight line from one end of the field to the other. This method of operation is known as “parallel driving” (p. 292) and has been shown to promote relaxed driving and improved performance. Large manufacturers have also been committed to developing ways to decrease the amount of tractor vibration to the farmer/rancher. Recently, adjustments have been made to the tractor, including the cab, seat and suspension systems, in order to reduce the amount of vibration the individual may receive (Marsili et al., 2002), and warrants further discussion.

Force Reduction Strategies in Tractor Seating

Historically, tractor seating has consisted of suspension systems that include pneumatic (air), hydraulic (oil), mechanical, or a combination of any of these systems (Drakopoulos, 2007). Mechanical seating systems demonstrate the ability to reduce the horizontal and vertical vibrations that arise when traveling at higher speeds than usual, when working with rear attachments, or when working in rough ground (Drakopoulos, 2007). The mechanical seating system has been described as “suitably designed to absorb the vibrations and jolts typically occurring in agricultural vehicles “(Drakopoulos, 2007, para. 14). Pneumatic suspension systems, on the other hand, are complex in design and some offer seat acclimatization, which carries away body perspiration and maintains a normal temperature. Some seats also provide active weight adjustment, which uses sensors and electronics that acclimate the seat to the driver’s weight.

Regardless which suspension system is used, a vital function of seating is to prevent skin breakdown due to the effect that high vibration has on the integument. Drakopoulos (2007) also notes that, even if a seating system has the latest technology, it does not do any good unless the operator can understand the different adjustments, find the adjustments, and finally make the necessary adjustments properly to provide comfort and prevent skin breakdown (Drakopoulos, 2007).

Seat cushioning material plays a dominant role in supporting the operator's posture, isolating vibration and improving ride quality (Mehta & Tewari, 2001). It is estimated that tractor seat cushions support 60-70% of the body's static mass depending on body shape, size and sitting posture. Because of greater vertical acceleration forces as compared to fore-aft or lateral acceleration forces under dynamic conditions, it is generally recommended that the thickness of the tractor seat cushion at the seat pan be of a greater thickness than at the backrest (Mehta & Tewari, 2001).

Research indicates that an air polymer-based gel seat cushion in conjunction with the standard seating system has been shown to decrease lower back and neck pain while driving the tractor, as well as to decrease back pain after tractor driving (Scutter, Fulton, & Cheng, 1999). On the other hand, wheelchair flotation cushions have also been shown to be excellent in allowing for changes in seat pressure (Cook & Polgar, 2008) for wheelchair users. Cushions using a combination of materials have been shown to achieve significant stability while effectively distributing pressure as well as having dampening characteristics that allow for shock and vibration absorption (Trefler et al., 1993). A honeycomb cushion provides internal contouring for uniform load distribution, excellent shock absorption and stability over rough ground (Drakopoulos, 2007). A simple modification many farmers use, due to its low cost and effectiveness, is to add a foam cushion to the seating system (Drakopoulos, 2007).

Although cushions have been used in agricultural machinery for some time now, and have been shown to be effective by anecdote and some research, little if any research supports their application to individuals with SCI who are operating agricultural machinery. Further information is needed, including consideration of the dynamic forces inherent inside and upon the tractor system.

Lifts

Climbing stairs or a ladder can prove to be difficult or impossible for individuals with paraplegia (C. S. Wilhite, personal communication, September 15, 2010). Therefore, many farmers/ranchers use lifts to enable them to continue operating agricultural machinery (C. S. Wilhite, personal communication, September 15, 2010). There are a variety of lifts that enable the farmer/rancher to determine the best fit for his or her lifestyle. Lifts can be attached to the tractor either on the left or right side to ensure others can continue operating the machine (C. S. Wilhite, personal communication, September 15, 2010). Lifts can also be placed on the back of a pickup to lift the operator to the seat of the agricultural machine (C. S. Wilhite, personal communication, September 15, 2010). Operators need to be cautious when operating the lifts. No matter what type of lift is being utilized, it is suggested that the motor should be off when the lift is being operated, seatbelts should be used at all times, obstacles such as power lines need to be avoided, and all operators need to have an alternative place for exiting the machinery in case of an emergency (C. S. Wilhite, personal communication, September 15, 2010).

Lifts are used by farmers/ranchers for short durations multiple times a day. It is essential to keep in mind that lifts place stress on the integument through vibrations and sheering forces during transfers (C. S. Wilhite, personal communication, September 15, 2010). This is an important aspect to consider because of the impact that these forces have during transfers into and out of equipment. It should be noted that, if transfers are done improperly and these forces are not considered, integument injury may occur or become a contributing factor to skin breakdown of the operator (C. S. Wilhite, personal communication, September 15, 2010).

Tractor Modifications/Adaptations

There are many different types of modifications/adaptations that can be made on tractors or machinery to enable farmers and ranchers with SCI to be successful within their environment. Prather (2003) suggests these modifications could include: extending the key, knobs or handles; replacing clutches with hand clutches; using a spinner knob on the steering wheel; and adding power assistance for a 3-point hitch control and extensions for hand and foot controls in order to decrease the reach and effort necessary for successful operation. Prather (2003) also identified the necessity of modification to the braking system for individuals with SCI to enable the braking system to be operated by the fingertips.

Casey and Kiso (1990) found that there are preferred locations for certain types of tractor controls. Custom fabrication and placement of controls is important as it ensures safety and efficiency. The hand controls should be mounted so that they do not block the operator's access to the exit or the pathway to the operator's seat (Kelso, Stangherlin, & Mann, 2008). This may be accomplished by permanently mounting the control so that it is not in the way, using a removable shaft, or installing an adjustable control that moves out of the pathway when necessary.

Hsiao et al. (2005) found that the placement of hand controls in some tractors actually creates an impediment to body movements. Hand controls can be placed to enable ease of control access, but reduce interference with clothing or other aspects of the human body that could promote negative effects. It is recommended that hand controls be constructed of round material and proper padding to minimize the impact of potential bodily contact (Kelso, Stangherlin, & Mann, 2008). It should also be noted that operators should maintain neutral wrist posture and refrain from excessive wrist extension and/or flexion. It is also recommended that hand controls be placed to allow changes in body posture.

Tewari, Bhoi, and Dhar (2002) stated that, "when compared to hand controls, foot controls often restrict the posture of the user, and an inappropriate pedal design may contribute to muscle fatigue and cause discomfort to the driver" (p. 4). Wilkomm (1997) suggests that the footrest can be fabricated from a "piece of wood or insulation that is stacked, wrapped and fastened to the floor with non-slip material" (p. 3). Drakopoulous and Mann (2007) further suggest that the steering wheel and all other handles should not impede the driver's legs, thighs, hips or stomach. It has also been suggested that all controls be placed on the right hand side as this is the dominant side for the majority of the population (Tewari, Bhoi, & Dhar, 2002). However, this has been shown to be difficult for manufacturers, due to the limited space inside the tractor cab (Tewari, Bhoi, & Dhar, 2002).

All devices in the tractor cab should be within a functional reach, which is defined by Pheasant (1986) as “the horizontal distance from the operator’s shoulder to the tip of the thumb, measured with the subject’s shoulders against the seat, the arm extended forward and the index finger touching the tip of the thumb”(p. 2.19). Drakopoulos and Mann (2007) have shown that “most controls (89%) are located so that they can be operated by the driver’s right hand; however, only 75% of controls were located within the functional reach” (p. 2.21).

Visibility is also another important aspect that needs to be considered during tractor operation (Drakopoulos & Mann, 2007). All text, symbols and guidance systems must be kept in mind as visibility helps keep the driver safe and efficient. Visibility is important both inside and outside the tractor cab. According to the National Occupational Health and Safety Commission, it is recommended to place visual displays at or just below the eye level (Ima & Mann, 2003). However, as of recently, these recommendations have been challenged as many believe visual targets should be placed even lower. This demonstrates that it is essential to place all light bars, switches, toggles, symbols and all other items the farmer/rancher must visually acknowledge in the center of the visual field. It is recommended that the controls be approximately 50 cm from the operator (Drakopoulos & Mann, 2007).

Because each individual’s eyes are different, the seat or display should be adjustable so that optimum vision can be obtained. Having all controls on the inside of the cab identified by either text or symbol decreases the chance of error caused by selecting and initiating the wrong control. Lighting, space and visibility are all key factors when using this method of identifying the different devices in the tractor. Ima and Mann (2003) recommend using labels as it takes too much time to read and lack of space makes this difficult (Ima & Mann, 2003). All labels should be placed above the switch or toggle so that clothing does not interfere with the visibility of the label.

Color perception is of equal importance as it helps the driver determine the type of signal. It is essential to carefully choose both the signal color and background color for all controls needing to be seen. Ima and Mann (2003) recommend that blue LEDs be used rather than red LEDs due to reduced transmission guidance and steering error when using blue LEDs as compared to red LEDs. Ima and Mann (2003) also suggest keeping flashing lights to a minimum and using them only for extreme errors in order to reduce distractions to the operator.

Summary of Literature Review

This literature review highlights several aspects related to seating considerations for people with paraplegia and of the intertwining subsystems that exist in the tractor environment. This review emphasizes biological, environmental and mechanical properties that impact and influence the health of the human operator. It is duly noted that cognitive, psychological, and social forces will also impact the health of the human tractor operator; however, these dynamic aspects are outside the scope of the present study.

The literature also highlights a significant need for further consideration of dynamic properties impacting on and interacting with the seated operator of tractors in order to enable farmers/ranchers with disabilities, aging, and/or health impairments to operate agricultural equipment safely. Because of the vast number of variables present within the dynamic tractor environment, the student investigators propose a baseline study under static conditions to provide a foundation for future investigation in real-time dynamic environments. This baseline study will limit the variables under investigation to two different tractor seats, without the effects of suspension or active forces, and with individuals seated statically (no movement) with and without air cushions to observe differences in total weight distribution.

CHAPTER III

METHODOLOGY

IRB Approval

The students' independent study met the approval of the University of North Dakota Institutional Review Board (IRB-201004-326, see appendix A) and a letter of cooperation was obtained to utilize Casper College laboratory facilities. Prior to the study, each subject was provided written and oral information (see appendix B) about the experiment and each participant signed an informed consent before participation in the study. To ensure the confidentiality of the participants, identifying information has been removed from all public documents.

Hypothesis

Pressure mapping is one way of objectively measuring an individual's pressure distribution and enables the prevention of pressure ulcers (University of Washington, 2004). The technology maps pressure distribution by using a thin sensor mat that is placed between the seat surface and the user's buttocks (Eitzen, 2004). Using the pressure mapping system, an individual's pressure distribution and pressure gradient are measured in millimeters of mercury, which can indicate the "hot spots" or areas where there is a significant possibility of developing a pressure ulcer. Pressure mapping technology is used as an objective clinical measure to help guide equipment changes or other modifications needed to accommodate an individual's unique postural needs in order to reduce "hot spots" or other issues that may cause skin breakdown. In this study, pressure mapping was used to test differences in pressure distribution of tractor seating under static conditions with individuals who have sustained paraplegic injuries.

Due to the limited amount of empirical research, the following study proposes to be a starting point and baseline to explore differences in pressure distribution of tractor seating with individuals with paraplegia under static conditions. The hypothesis is that there will be a clinically observable difference in pressure distribution of paraplegic individuals when comparing a standard John Deere seat to a John Deere Active Seat™ and when incorporating a Low Profile® and Mid Profile® ROHO® cushion. The authors also anticipate that future research will be based on replicating these findings and that further testing of tractor seating considerations under real time dynamic conditions will be conducted in order to ensure improved seating conditions and the health and safety of farmers/ranchers with SCI when operating agricultural machinery.

Sample Selection

Tractor Seats

The authors of the study selected a standard John Deere three-piece foam seat and a John Deere Active Seat™. The standard three-piece foam seat is chosen since similar seating situations are found in the older tractors of farmers and ranchers with spinal cord injuries who are seen by AgrAbility specialists (C. S. Wilhite, personal communication, August 31, 2010). The seat has minimal contouring and has an approximately four-inch foam base and is usually mounted within tractors on mechanical or air suspension. The second seat chosen was a John Deere Active Seat™, which is ergonomically designed and has contoured foam. When the Active Seat™ is utilized within the tractor system in conjunction with its sensor activated electro-hydraulic technology and air suspension, dynamic forces are decreased on the operator according to the manufacturers' sales manuals (John Deere, 2006; Sears Seating, 2006a; Sears Seating, 2006b). The seats were obtained from a John Deere dealership, and were in used but good condition.

For this research project, the seat and participants were placed in static conditions to illustrate the basic clinical differences in pressure distribution. Both seats were secured to a platform of oriented strand board upon a base constructed from two by four inch lumber. The dimensions of the three-piece seat are as follows: the back of the Active Seat™ is 23 inches tall, 19 inches wide, 13 inches thick at the top and 16 inches thick at the bottom. The three-piece foam seat is 16 inches long, 18 inches wide at the back of the cushion and 21 inches wide at the front of the cushion (Fig. 1). The seat is covered with a textured fabric.

The three-piece standard seat's dimensions are 18 inches long, 21 inches wide, 17 inches wide at the back of the seat and 21 inches wide at the front of the seat. The back on this seat also has no contouring and is approximately 17 inches tall, 15 inches wide at the bottom and 12 inches wide at the top (Fig. 2). The seat is covered with a textured fabric.

Cushions

A Low Profile® ROHO® Quadtro Select® wheelchair cushion was selected for the study, since many tractor operators with paraplegia use this cushion in their agricultural machinery (C. S. Wilhite, personal communication, August 31, 2010). The cushion is lightweight, washable, repairable and well ventilated, allowing air to reach the surface of the skin and provide a cool environment (ROHO® Group, 2010a). The cushion is inflated using a hand pump, which can fill the cushion within a matter of seconds. The Low Profile® ROHO® Quatro Select® also has the capability to adjust the posture of the individual by pushing a button in the inflation tube which will lock the air in place, thus allowing the user to make postural adjustments without having to transfer on and off the cushion (ROHO® Group, 2010a). This cushion fits wheelchairs ranging in width from 12 inches to 20 inches.

Students also selected a Mid Profile® ROHO® Quadtro Select® wheelchair cushion to compare and contrast pressure distribution properties of the cushions on top of the tractor seats. This cushion is similar to the Low Profile®; however, this cushion is 3 inches tall and fits wheelchairs ranging in width from 15 inches to 18 inches (ROHO® Group, 2010b).

Design of Study

A quantitative cross-over design was used during this study. The design enables the comparison of pressure distributions in each of the study conditions: Three-piece foam seat with and without cushion and Active Seat with and without cushion. The design also allows each seat to serve as its own control when comparing the pressure distributions, and again, when incorporating the Low Profile® and Mid Profile® ROHO® cushions to the seating interface. The research took place in a life science laboratory used by the occupational therapy department at Casper College in Casper, Wyoming.

The full protocol of the study can be found in appendix C. A brief protocol for the experiment is as follows. Upon arrival of the human subjects, a consent form was explained and subjects gave consent. After consent, each participant transfered to a plinth in a private area to complete skin inspection of buttocks, sacrum, coccyx, ischial tuberosities, and back in order to determine if the integument was intact. The conditions observed during this inspection were documented in writing. The participant was asked to transfer to one of the tractor seats and a thin pressure mat was inserted beneath the participant. An independent vendor with expertise in pressure mapping provided on-site consulting to the students conducting the study and the pressure mapping equipment calibration was established by the product dealer.

Adjustments were made to the foot rests, arm rests, and participant's posture to ensure that the seating system fit the participant properly and allowed the greatest pressure distribution. Lastly, the sensor pad was adjusted under the participant to ensure that the system was square and no tightness was present in order to avoid hammocking, which can skew the data. Hand checks were completed with palm down between the client and the mapping pad to ensure the bony prominences (ischial tuberositities) were distributing weight equally and the cushion was not bottomed out. Once the system set up was confirmed and the software was determined to be working properly, the pressure mapping was initiated. Preview mode was used to record baseline data for 8 minutes to allow the participant "to sink into the cushion." Hard data was recorded for two minutes to collect pressure distribution. This same process was repeated using a Low Profile® and Mid Profile® ROHO® cushions.

After all of the tests were completed on the first seat, the subject transfered to a private area to complete skin inspection of buttocks, sacrum, coccyx, ischial tuberosities and back for redness of the skin and time until re-perfusion of the skin. The conditions observed during this inspection were documented in writing. The skin inspection was a necessary step, since the pressure map only captures a moment in time, and does not take the place of a thorough examination to ensure the skin is intact and healthy (University of Washington, 2004). The participants then transferred to the second seat and the same process was repeated. After all tests were completed on the active seat, the subjects transfered to a private area to complete skin inspection of buttocks, sacrum, coccyx, ischial tuberosity and back for redness of the skin. The conditions observed during this inspection were documented in writing.

Instrumentation and Data Collection

Data was collected using the Xsensor® X3 PX200 pressure mapping system, which has a measureable area of 36x36 inches with 1296 measuring sensor cells sized 1cm². Accuracy has been determined to be + or - 1% as tested by XSENSOR's® production calibration process. After the settling-in process, the average pressure, highest peak pressure, and the size of the subjects' contact area on the cushion were measured continuously (two frames per second) for each trial and stored in the X3 display unit according to the protocol stated above (see appendix D). On average, 251 frames of information were recorded during the two-minute recording interval for each trial. Output data was then recorded from the display unit and saved on a laptop for further analysis. Results of skin inspection were hand recorded on forms created prior to the study procedures. After the collection of data was complete, Xsensor's® X3 medical v6.0 software was used to compare the different trial images and extrapolate the hard data. The hard data was then compared and contrasted using statistical analysis.

CHAPTER IV

Results

Recruitment

Two adult subjects (one female and one male) with paraplegia were recruited for this study using a convenience sampling method. The subjects reported having a complete injury of motor and sensory function below the level of the lesion of T5 and T8. Both subjects are more than one year post injury and are full-time manual wheelchair users. The subjects met the inclusion criteria established by the students prior to gathering research data. These criterion included: adults with paraplegia who do not currently have an unhealed pressure ulcer or decubitus ulcer on the posterior or back or current underlying health issues that would compromise the integumentary system. Participants were compensated with a token gift card of $20 for their participation.

Data Analysis

Two subjects, one female and one male, participated in this study. Both subjects completed all six trials. The female subject was 43 yeas of age, 1 year post injury with a complete neurological level of T5, weighed 136 pounds and was 5 feet 7 inches tall. The male subject was 37 years of age, 11 years post injury with a complete neurological level of T8, weighed 150 pounds and was 6 feet tall. The average pressure (P avg) of each experimental condition was recorded in frames continuiously for two-minute intervals.

The total mean average pressure (P avg) of each participant trial was then calculated using all the recorded average pressures of each frame (See Table 1).

Table 1

Total Average Pressure

Subject(s)	Trial	P Avg
Client 1	Standard Foam Seat	41.8
Client 1	Standard Foam, Low Profile® ROHO®	37.9
Client 1	Standard Foam, Mid Profile® ROHO®	44.8
Client 1	Active Foam Seat	45.1
Client 1	Active Foam, Low Profile® ROHO®	43.3
Client 1	Active Foam, Mid Profile® ROHO®	38.3
Client 2	3 piece Standard Foam Seat	47.9
Client 2	Standard Foam, Low Profile® ROHO®	51.2
Client 2	Standard Foam, Mid Profile® ROHO®	40.6
Client 2	Active Foam Seat	45.2
Client 2	Active Foam, Low Profile® ROHO®	47.9
Client 2	Active Foam, Mid Profile® ROHO®	41.4

Note. All pressures are measured in mmHg.

The averages for each trial of both participants were then added together and divided by 2 to obtain the overall pressure average of the trial (See Table 2). The standard and active seats were used as the control and each trial was subtracted from the control to figure the difference (trial – control).

Table 2

Trial Total Average Pressure and Difference

Trial	Total P Avg	Difference
Standard Foam Seat	44.85	control
Standard – Low Profile® ROHO®	44.55	-.3
Standard –Mid Profile® ROHO®	42.7	-2.15
Active Foam Seat	45.15	control
Active – Low Profile® ROHO®	45.6	+.45
Active – Mid- Profile® ROHO®	39.85	-5.3

Note. All pressures are measured in mmHg

Using the standard and active seats as the control, the differences in average pressures between the Low Profile® and Mid Profile® ROHO® cushions were calculated (cushions – control). Because the overall pressure distribution is an average of the whole area and does not take into account specific areas that are subject to skin breakdown, the pressure distribution per square inch was then calculated (P avg/surface area) (See table 3).

Table 3

Total Average Pressure Per Square Inch

Participant	Trial	Surface Area
Client 1	Standard Foam Seat	.23
Client 1	Standard Foam, Low Profile® ROHO®	.29
Client 1	Standard Foam, Mid Profile® ROHO®	.24
Client 1	Active Foam Seat	.25
Client 1	Active Foam, Low Profile ROHO®	.24
Client 1	Active Foam, Mid Profile® ROHO®	.23
Client 2	3 piece Standard Foam Seat	.40
Client 2	Standard Foam, Low Profile® ROHO®	.39
Client 2	Standard Foam, Mid Profile® ROHO®	.26
Client 2	Active Foam Seat	.29
Client 2	Active Foam, Low Profile® ROHO®	.30
Client 2	Active Foam, Mid Profile® ROHO®	.22

Note. Surface area is measured in mmHg/in².

After the pressure distribution per square inch was figured, the students noted that this again only identifies an average of the whole picture and does not take into account specific hot spots. The students then determined that most of the hot spots were a result of pressure caused by the participant's bilateral isichial tuberosities. Using the grid system avaliable in the X3 Medical Software, indivdual sensor readings were identified and recorded. To ensure that there was consistency, the same number of cells for each participant in each trial were recorded. Also, to make sure that the cells recorded were the same cells in other trails, the grid system was used to measure and identify the specific area of interest. (For specfic sensor readings for each trial, see appendix E). The sensor readings were then compared, and averaged (sum total/# of sensors) and the total averages (right Ischial tuberosity + left ischial tuberosity/2) for bilateral tuberosities were calculated (Table 4).

Table 4

Average Pressure of Ischial Tuberosities

Participant	Trial	Avg. P. of L. I.T	Avg. P. of R. I.T	Avg. P. of B. I.T
Client 1	3 piece Standard Foam Seat	123.57	41.44	82.51
Client 1	Standard Foam, Low Profile® ROHO®	26.78	21.37	24.08
Client 1	Standard Foam, Mid Profile® ROHO®	85.34	29.07	57.21
Client 1	Active Foam Seat	112.17	62.11	87.14
Client 1	Active Foam, Low Profile® ROHO®	58.78	38.28	48.53
Client 1	Active Foam, Mid Profile® ROHO®	49.0	28.13	38.57
Client 2	3 piece Standard Foam Seat	122.89	116.16	119.53
Client 2	Standard Foam, Low Profile® ROHO®	84.54	57.45	71.0
Client 2	Standard Foam, Mid Profile® ROHO®	31.32	46.5	38.91
Client 2	Active Foam Seat	114.03	111.75	112.89
Client 2	Active Foam, Low Profile® ROHO®	61.98	50.0	55.99

Note. Avg. P. of L. I.T is the average pressure of the left ischial tuberosity; Avg. P. of R. I.T is the average pressure of the right ischial tuberosity; Avg. of P. of B. I.T is the average pressure of the bilateral ischial tuberosities. All averages are measured in mmHg.

The averages (client 1 trial + client 2 trial/2) and differences for each trial were then calculated (Table 5).

Table 5

Average Ischial Tuberosity Trial Pressure and Difference

Trial	Total I.T P. Avg.	Difference
3 piece Standard Foam Seat	101.02	control
Standard Foam, Low Profile® ROHO®	47.54	-53.48
Standard Foram, Mid Profile® ROHO®	63.06	-37.96
Active Foam Seat	100.02	control
Active Foam, Low Profile® ROHO®	52.26	-47.82
Active Foam, Mid Profile® ROHO®	38.69	-61.33

Note. Total I.T P. Avg is the total average pressure of the ischial tuberosities. All averages are measured in mmHg.

To further explore the differences between the trials and when incorporating the Low Profile® and Mid Profile® ROHO® cushions, the students identified, using the X3® Medical software, the number of sensors that recorded specific pressures ranging from 200 mmHg to 0. The pressure continuum was further broken down and categorized according to colors in order to provide a visual representation of the number of sensors that recorded pressure within that specific range. The pressure ranges according to color were as follows: red (200 - 187.7 mmHg), orange (181.6 - 157.1 mmHg), yellow

(151 - 138.7mmHg), green (132.6 - 108.1 mmHg), blue (101 - 34.5 mmHg), and dark blue (28.4 - 0 mmHg). The students then identified the number of sensors for each trial that recorded pressures within each of the color categories on the pressure continuum (See Tables 6 and 7).

Table 6

Color Categorization of # of Sensors Recording Specific Pressures For Standard Foam

Color	Standard Foam	Standard Low Profile® ROHO®	Standard Mid Profile® ROHO®
Red	40	3	1
Orange	16	8	6
Yellow	11	9	4
Green	27	33	43
Blue	339	483	658
Dark Blue	2159	2056	1880

Note. Pressure continuum is measured from 0-200 mmHg. Color categorization is as follows: red (200 - 187.7 mmHg), orange (181.6 - 157.1 mmHg), yellow (151 - 138.7mmHg), green (132.6 - 108.1 mmHg), blue (101 - 34.5 mmHg), and dark blue (28.4 - 0 mmHg).

Table 7

Color Categorization of # of Sensors Recording Specific Pressures For Active Foam

Color	Active Foam	Active Low Profile® ROHO®	Active Mid- Profile® ROHO®
Red	13	1	0
Orange	18	4	4
Yellow	7	6	5
Green	38	39	15
Blue	583	716	657
Dark Blue	1933	1826	1911

Note. Pressure continum is measured from 0-200 mmHg. Color categorization is as follows: red (200 - 187.7 mmHg), orange (181.6 - 157.1 mmHg), yellow (151 - 138.7mmHg), green (132.6 - 108.1 mmHg), blue (101 - 34.5 mmHg), and dark blue (28.4 - 0 mmHg).

Because of the number of sensors that were in the blue and dark blue categories, the students decided to exclude these categories when comparing and contrasting the standard trials and incorporating the Low Profile® and Mid Profile® ROHO® cushions due to the inability to account for the small differences within the color categories. The red, orange, yellow, and green categories were graphed in order to compare each of the trials and the cushions (See Figures 1 and 2).

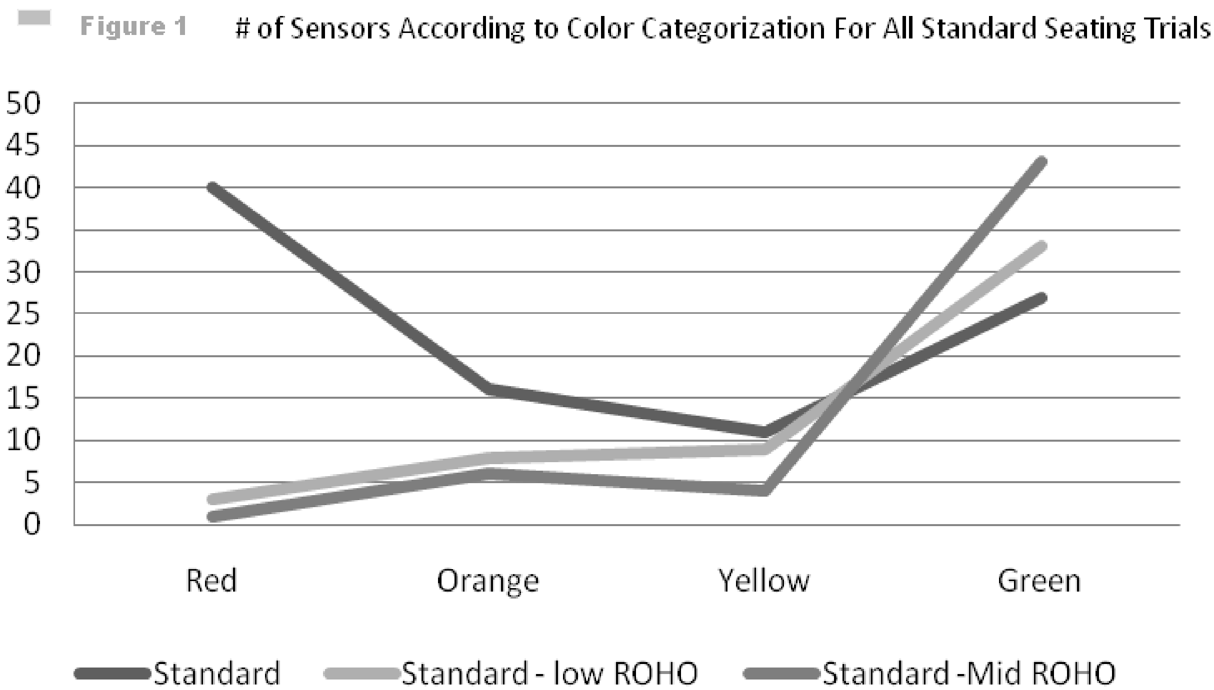

Figure 1. The numbers on the left of the graph represent the number of sensors that recorded the various pressure ranges. The numbers below the graph represent the various pressure ranges categorized according to color (Red, Orange, Yellow, Green). The pressure ranges are as follows: red (200 - 187.7 mmHg), orange (181.6 - 157.1 mmHg), yellow (151 - 138.7mmHg), green (132.6 - 108.1 mmHg), blue (101 - 34.5 mmHg), and dark blue (28.4 - 0 mmHg). The lines (dark grey, grey, light grey) on the graph represent the various trials of the standard seating system.

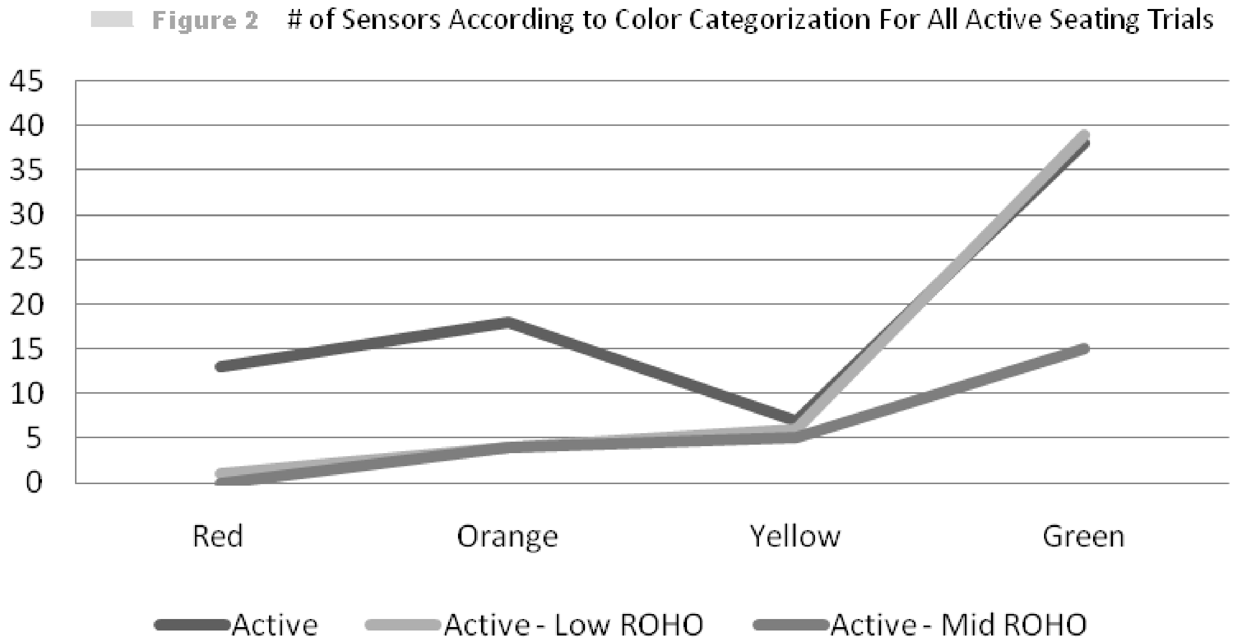

Figure 2. The numbers on the left of the graph represent the number of sensors that recorded the various pressure ranges. The numbers below the graph represent the various pressure ranges categorized according to color (Red, Orange, Yellow, Green). The pressure ranges are as follows: red (200 - 187.7 mmHg), orange (181.6 - 157.1 mmHg), yellow (151 - 138.7mmHg), green (132.6 - 108.1 mmHg), blue (101 - 34.5 mmHg), and dark blue (28.4 - 0 mmHg). The lines (dark grey, grey, light grey) on the graph represent the various trials of the standard seating system.

CHAPTER V

SUMMARY

Discussion

The purpose of this independent study was to explore pressure differences of two individuals with paraplegia when seated on two different tractor seats under static conditions with and without the incorporation of a Low Profile® and Mid Profile® ROHO® cushion. Due to the limited number of participants within the study and the overall design, statistical conclusions could not be made. From the data analysis, it can be concluded that incorporating a ROHO® cushion with either the standard or active tractor seats, within a static setting, at the moment of measurement has a lower overall average pressure for 3 out of the 4 trials, distributes pressure over a greater surface area, has lower pressures over bony prominences such as the ischial tuberosities, and a decreased number of sensors recording over 200 mmHg. It appears that the Mid Profile® ROHO® cushion outperforms the Low Profile ROHO® in pressure distribution and increased surface area; however, distinct conclusions could not be made due to researcher error and hammocking present in the trial of client 1 on the active seat incorporating a Mid Profile® ROHO®, thus skewing data.

The findings also support the need for future tractor seating studies under static and dynamic conditions, including consideration of body morphology, age, health/disability status, and types and designs of postural supports and constraints, their relative safety, and the materials from which they are fabricated. For further student research purposes, the students propose testing the differences between the

Low Profile®, Mid Profile®, and High Profile® ROHO® cushions upon tractor seats. Also, the students propose testing seating considerations for people with paraplegia in real-time, dynamic contexts with multiple kinds of contemporary tractor seats and cushion materials to discern which, if any, are most effective. However, such research is outside the scope and resources of the present independent study. Researching different combinations of dynamic and static forces and the use of cushions and seats have previously been identified by Hubbard (2007) during the 2007 National AgrAbility Workshop in Sacramento, California.

Limitations

As in most quantitative research, accounting for all variables present within a dynamic system is very difficult. Due to the limited number of participants, time, resources, and experience of the students carrying out the independent study, the findings are impractical to generalize to a larger population. Specific statistical conclusions could not be made; however, clinical conclusions can be drawn from the images and averages identified. The students in the independent study were educated and demonstrated competency in correctly placing the pressure mapping system and performing hand checks; however, due to the students both performing the pressure mapping protocol and having limited experience, exact precision was not obtained.

The pressure mapping equipment provided a quantitative, computerized measure but all participant posture and appropriate positioning on the mat were done according to the skill level of the students, thus affecting measured results. The participants presented various body types and clothing, thus affecting the uniformity of testing conditions. This study was also completed on both seats in a static setting mounted on top of platforms created by the students for safety and convenience. It should be realized that, without the function of the suspension and other computer assisted technology to enhance optimal seating, this static condition does not represent real-time activities of the dynamic setting. Thus, conclusions can only be made on pressure distribution that was only present during the snapshot of time recorded by the pressure mapping system.

Conclusion

Research is limited in addressing the many factors and variables associated with enabling farmers/ranchers with disabilities to operate agricultural equipment safely. The dynamical systems theory is a multidisciplinary, systems-led approach that can be used as a viable framework to outline numerous intertwining subsystems that exist in the tractor environment. The dynamical systems theory can also be used to account for the complexities of the human operator embedded within a mechanical system.

Because of the vast number of variables present within the dynamic tractor environment, the students developed a baseline study under static conditions to provide a foundation for future investigation in real-time dynamic environments. From the beginning of the research process, the students determined that due to the nature of the study conclusions could not be generalized. However, from a clinical perspective, the students anticipate that clinical findings do support the design of future tractor seating studies within both static and dynamic environments.

It is anticipated that the dynamical systems theory and research protocol used within this study can be utilized in dynamic environment, thus yielding conclusions that are more likely to be generalized to the larger population of farmers/ranchers with disabilities. It is further anticipated that over time and through future studies the many variables within a dynamic tractor environment will be accounted for, allowing farmers/ranchers the opportunity to have an optimal seating and task environment and participate healthily in agricultural operations, thus increasing the productivity and sense of fulfillment and life satisfaction of agricultural workers with disabilities.

Finally, because funding for AgrAbility is contingent on ongoing congressional support, and monies are to be used for the purpose of serving AgrAbility customer as opposed to conducting research; those with expertise in research from multi-disciplines, including agricultural health and safety, private industry, extension, agricultural and bioengineering, and health professions (among others) are encouraged to support the research needs AgrAbility, and especially of agricultural producers with disabilities, aging, and health conditions who are seeking satisfactory participation in agriculture.

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APPENDICES

Appendix A
University of North Dakota IRB

University of North Dakota Human Subjects Review Form

All research with human participants conducted by faculty, staff, and students associated with the University of North Dakota, must be reviewed and approved as prescribed by the University's policies and procedures governing the use of human subjects. It is the intent of the University of North Dakota (UND), through the Institutional Review Board (IRB) and Research Development and Compliance (RD&C), to assist investigators engaged in human subject research to conduct their research along ethical guidelines reflecting professional as well as community standards. The University has an obligation to ensure that all research involving human subjects meets regulations established by the United States Code of Federal Regulations (CFR). When completing the Human Subjects Review Form, use the "IRB Checklist" for additional guidance.

Please provide the information requested below:

Principal Investigator: William Kennington and Veronica Boeser

Telephone: (307)248-0635 (620)214-0508 E-mail Address: wkennington@medicine.nodak.edu; vboeser@medicine.nodak.edu

Complete Mailing Address: 125 College Drive, Life Science 101, Casper, WY 82601

School/College: UND/ Casper College Department: Occupational Therapy

Student Adviser (if applicable): Dr. Carla Wilhite

Telephone: (307)268-2534 E-mail Address: cwilhite@medicine.nodak.edu

Address or Box #: 125 College Drive, Life Science 101, Casper, WY 82601

School/College: Casper College Department: Occupational Therapy

Project Title: A comparative analysis of tractor seating for individuals with spinal cord injury using a pressure mapping system

Proposed Project Dates: Beginning Date: 04/01/10 Completion Date: 03/31/11 (Including data analysis)

Funding agencies supporting this research: None

Did the contract with the funding entity go through UND Grants and Contracts Administration? ☐ YES or ☒ NO
Attach a copy of the contract. Do not include any budgetary information. The IRB will not be able to review the study without a copy of the contract with the funding agency.

☐ YES or ☒ NO Does any researcher associated with this project have an economic interest in the research, or act as an officer or a director of any outside entity whose financial interests would reasonably appear to be affected by the research? If yes, submit on a separate piece of paper an additional explanation of the financial interest. The Principal Investigator and any researcher associated with this project should have a Financial Interests Disclosure Document on file with their department.

☐ YES or ☒ NO Will another organization (ex., hospitals, schools, YMCA) help in the recruitment of research subjects, or will assistance with the data collection be obtained from another organization?

If yes, list all institutions:

Letters from each organization must accompany this proposal. Each letter must illustrate that the organization understands their involvement in that study, and agrees to participate in the study. Letters must include the name and title of the individual signing the letter and should be printed on letterhead.

Does any external site where the research will be conducted have its own IRB? ☐ YES ☒ NO ☐ N/A

If yes, does the external site plan to rely on UND's IRB for approval of this study? ☐ YES ☐ NO ☒ N/A

(If yes, contact the UND IRB at 701 777-4279 for additional requirements)

If your project has been or will be submitted to other IRBs, list those Boards below, along with the status of each proposal.

______________________ Date submitted: ________ Status: ☐ Approved ☐ Pending

______________________ Date submitted: ________ Status: ☐ Approved ☐ Pending

(include the name and address of the IRB, contact person at the IRB, and a phone number for that person)

Type of Project: Check "Yes" or "No" for each of the following.

☒ YES or ☐ NO New Project

☐ YES or ☒ NO Dissertation/Thesis/Independent Study

☐ YES or ☒ NO Continuation/Renewal

☒ YES or ☐ NO Student Research Project

☐ YES or ☒ NO Is this a Protocol Change for previously approved project? If yes, submit a signed copy of this form with the changes bolded or highlighted.

☒ YES or ☐ NO Does your project involve abstracting medical record information? If yes, complete the HIPAA Compliance Application and submit it with this form.

☐ YES or ☒ NO Does your project include Genetic Research?

Subject Classification: This study will involve subjects who are in the following special populations: Check all that apply.

☐ Children (< 18 years)

☐ UND Students

☐ Prisoners

☐ Pregnant Women/Fetuses

☐ Cognitively impaired persons or persons unable to consent

☒ Other Adults with paraplegic spinal cord injury

Please use appropriate checklist when children, prisoners, pregnant women, or people who are unable to consent will be involved in the research.

This study will involve: Check all that apply.

☐ Deception (Attach Waiver or Alteration of Informed Consent Requirements)

☐ Stem Cells

☐ Radiation

☐ Discarded Tissue

☐ New Drugs (IND) IND # _______Attach Approval

☐ Fetal Tissue

☐ Investigational Device Exemption (IDE) # _______Attach Approval

☐ Human Blood or Fluids

☐ Non-approved Use of Drug(s)

☐ Other _____

☒ None of the above will be involved in this study

I. Project Overview

Please provide a brief explanation (limit to 200 words or less) of the rationale and purpose of the study, introduction of any sponsor(s) of the study, and justification for use of human subjects and/or special populations (e.g., vulnerable populations such as children, prisoners, pregnant women/fetuses).

Farmers and ranchers with spinal cord injuries often return to operating agricultural machinery with the assistance of assistive technologies, such as manlifts and hand controls. However, there is no published empirical evidence to support the seating considerations of such persons. Instead, many farmers and ranchers use the existing pan or contour foam seat; are encouraged to use low profile air bladder wheelchair cushions (Willkomm, 2000); or are advised to follow principles of seating for wheelchairs (Cook & Hussey, 2002) on the assumption that these elements translate to the dynamic conditions under which farm machinery is operated. The researchers propose basic quantitative research to compare two tractor seats under static conditions using pressure mapping with adult subjects that have the condition of paraplegia from spinal cord injury. The researchers anticipate this study will result in baseline data upon which future studies can be formulated. No vulnerable subjects will be used during the research process.

II. Protocol Description

Please provide a succinct description of the procedures to be used by addressing the instructions under each of the following categories.

1. **Subject Selection.**

a) Describe recruitment procedures (i.e., how subjects will be recruited, who will recruit them, where and when they will be recruited and for how long) and include copies of any advertisements, fliers, etc., that will be used to recruit subjects.

Subjects will be recruited using a convienience sampling method. At the present time the researchers have identified subjects known in the community whom fit the inclusion criteria. However, these individuals have not been approached at this time. Due to the small scale of the projected study it is anticipated that up to five individuals will be recruited that have acquired a spinal cord injury below the neurological level of a T2 and who have absent or significantly diminished motor and sensory function below the level of the lesion.

b) Describe your subject selection procedures and criteria, paying special attention to the rationale for including subjects from any of the categories listed in the "Subject Classification" section above.

Subject inclusion criteria are: adults with paraplegia who do not currently have an unhealed pressure ulcer or decubitus ulcer on the posterior or back; or current underlying health issue that would compromise the integumentary system. The subjects should have a complete transection injury or a significant impairment of motor and sensory function below the level of the lesion.

c) Describe your exclusionary criteria and provide a rationale for excluding subject categories.

Any subject that has an open decubitus, unhealed pressure ulcer, integumentary condition, or does not have a spinal cord injury with paraplegia will be excluded. Also, subjects unable to give informed consent for the study will be excluded.

d) Describe the estimated number of subjects that will participate and the rationale for using that number of subjects.

Up to five subjects will be recruited for the study. Due to the limited time to conduct the research, access to limited resources, and experience level of the graduate students, a small population was deemed to be manageable for purposes of this project.

e) Specify the potential for valid results. If you have used a power analysis to determine the number of subjects, describe your method.

Due to the baseline level of study, no attempt is being made to reach a statistically significant result that can be generalized to the larger population. Each subject will act as their own control in comparing results when contrasting and analyzing seating.

2. **Description of Methodology.**

a) Describe the procedures used to obtain informed consent.

Prospective subjects will be approached after the research is approved. The purpose of the research will be explained, as well as any potential risks and benefits, confidentiality and limits on confidentiality, and remind the subject that they are free to withdraw from the study at any time. At this time, the subject will be invited to participate. The subjects will be consented by the researchers and consent will be given in writing.

b) Describe where the research will be conducted. Document the resources and facilities to be used to carry out the proposed research. Please note staffing, funding, and space available to conduct this research.

The research will take place in a life science laboratory used by the occupational therapy department at Casper College in Casper, Wyoming. The researchers will be staffing the laboratory and there is no research funding for the project. The researchers will be borrowing or short-term leasing the pressure mapping system. Pro bono consulting by a pressure mapping vendor will be provided to instruct the researchers in set up of hardware, software, and laptop computer. The tractor seats will be loaned from a John Deere dealer in Yuma, Colorado (3-piece standard seat and John Deere Active Seat). A low-profile ROHO air cushion will be borrowed from a local rehabilitation facility.

c) Indicate who will carry out the research procedures.

The primary investigators will be carrying out the research procedures. The student advisor will be directly supervising and in line of sight of the research as it is carried out.

d) Briefly describe the procedures and techniques to be used and the amount of time that is required by the subjects to complete them.

The collection of data will be through non-invasive procedures using a pressure mapping system. The system is comprised of a computer, software, cable array, and a sensing grid which is placed underneath the subjects while seated on a tractor seat. No sensors are applied to the body. The researchers will be following a standard protocol outlined by Ferrarun, Andreoni & Pedotti (2000). First, the sensory mapping pad will be placed on the tractor seat and calibrated with a laptop to ensure accuaracy of data. Second, subject will be seated comfortably and positioned using goniometric measurements as outlined by the protocol. Data will be collected at 1, 5, 10, 15, and 20 minutes from the moment the subject sits down on the pressure mapping system. This process will be repeated using the second tractor seat, as well as under conditions using the low profile ROHO cushion. Data results will then be interpreted at a later time convienent to the researchers and the statistician. Approximate time for obtaining data per subject is estimated at approximately 2 hours. The investigators are primarily interested in documenting the existence of seating pressures that exceed total pressure values (>= to 3mmHg) where capillary blood supply is occluded from tissue, thus increasing risk for injury to the integument and comparing these by 4 different seating configurations and by subject. After each test condition, the subject will transfer to a private, draped area to complete self-inspection of buttocks, sacrum and back for redness of the skin and time until re-perfusion of the skin. The conditions found by the client during this interval will be documented in writing. The skin inspection is a necessary step, since the pressure map only captures a moment in time, and does not take the place of a thorough examination to ensure the skin is intact and healthy (University of Washington, 2004).

e) Describe audio/visual procedures and proper disposal of tapes.

A digital video file of the pressure mapping will be captured during the seating scenarios. Researchers will ensure that these video files will not have any participant identifiying information linked to them to ensure confidentiality. The digital file will only have an assigned subject number on them. Any identifying information will be kept in a separate location in a locked drawer in a locked office of the student advisor.

f) Describe the qualifications of the individuals conducting all procedures used in the study.

Researchers will be competent in acurately setting up, administrating pressure mapping protocol, and interpretating the results. The student advisor, Dr. Wilhite, has nationally acknowledged expertise in the physical rehabilitation, workplace accommodations, and assistive technologies for farmers and ranchers with disabilities, including spinal cord injuries.

g) Describe compensation procedures (payment or class credit for the subjects, etc.).

After the completion of the pressure mapping process, participants will be given a token gift card (not to exceed $25) to a local resturant as compensation for their time as well as their participation.

Attachments Necessary: Copies of all instruments (such as survey/interview questions, data collection forms completed by subjects, etc.) must be attached to this proposal.

3. Risk Identification.

a) Clearly describe the anticipated risks to the subject/others including any physical, emotional, and financial risks that might result from this study.

The research poses only a minimal risk to the participants. The subjects will be seated on a cushioned surface, on an upholstered plinth, or in their personal wheelchair. Steps are being taken to ameliorate any possibility or potential for injury through the use of skin checks. Subjects will be provided with ample opportunity for pressure relief techniques commonly used by seated wheelchair users, except as indicated by the protocol for static seating during mapping. The subject will be assisted during transfers for safety and provided with a sliding board or other transfer aid. Data collection will stop if the subject obtains a minor skin tear, abrasion, or prolonged redness. No significant emotional or financial risks are anticipated.

b) Indicate whether there will be a way to link subject responses and/or data sheets to consent forms, and if so, what the justification is for having that link.
Researchers will ensure that intake interview and data results will not have any participant identifying information linked to them to ensure confidentiality. Subject identifying information will be kept in a separate secure location by the student advisor. The subject will be provided an assigned number used on all other research documents.

c) Provide a description of the data monitoring plan for all research that involves greater than minimal risk.
N/A

d) If the PI will be the lead-investigator for a multi-center study, or if the PI's organization will be the lead site in a multi-center study, include information about the management of information obtained in multi-site research that might be relevant to the protection of research participants, such as unanticipated problems involving risks to participants or others, interim results, or protocol modifications.
N/A

4. Subject Protection.

a) Describe precautions you will take to minimize potential risks to the subjects (e.g., sterile conditions, informing subjects that some individuals may have strong emotional reactions to the procedures, debriefing, etc.).
The researchers will ensure the pressure mapping system is set up correctly to ensure efficient and timely collection of data, as well as safety. The researchers will follow the outlined protocol for completing skin checks and encouraging pressure relief techniques before and after each test. The subjects will be offered hydration, snack, blanket, or other simple measures to remain comfortable in the testing environment.

b) Describe procedures you will implement to protect confidentiality and privacy of participants (such as coding subject data, removing identifying information, reporting data in aggregate form, not violating a participants space, not intruding where one is not welcome or trusted, not observing or recording what people expect not to be public, etc.). If participants who are likely to be vulnerable to coercion and undue influence are to be included in the research, define provisions to protect the privacy and interests of these participants and additional safeguards implemented to protect the rights and welfare of these participants.
No vulnerable subjects will be utilized during this study. The identity of each subject will remain confidential and will only be known to the researchers and advisor. No identifying information will be included on research documents, only a subject number. Separate identifying contact information will be on paper, in a locked drawer, in a locked office of the student advisor that is separated from where the research data will be kept. The reported data will not identify the subjects except by demographic information (age, gender, height/weight, etc.). During skin inspections, a same gender assistant will be available to the subject for general assistance if needed (e.g. transfer, dressing, safety). However, the assistant will not insist upon being present during the inspection, but will remain on the other side of the drape unless needed for safety or other assistance at the request of the subject. The subject may also bring their own assistant if preferred. No photographs of a subject or of subject anatomy will be collected while unclothed. Every effort will be made to preserve the dignity and autonomy of the client, using the above measures.

c) Indicate that the subject will be provided with a copy of the consent form and how this will be done.
After the participant agrees and signs consent form a copy will be made immediately and provided to him/her at that time.

d) Describe the protocol regarding record retention. Please indicate that research data from this study and consent forms will both be retained in separate locked locations for a minimum of three years following the completion of the study.
Describe: 1) the storage location of the research data (separate from consent forms and subject personal data)
2) who will have access to the data
3) how the data will be destroyed
4) the storage location of consent forms and personal data (separate from research data)
5) how the consent forms will be destroyed

The identity of each subject will remain confidential and will only be known to the researchers and advisor. No identifying information will be included on research documents, only a subject number. Separate identifying contact information will be on paper, in a locked drawer, in a locked office of the student advisor that is separated from where the research data will be kept for three years, at which time any identifying data, including consent forms, will be destroyed in a cross cut shredder or by electronic deletion per UND's policy. Other subjects who will have access to de-identified data will be a statistics teacher at Casper College, who will receive the raw data for conversion into meaningful statistics. De-identified raw data and meaningful data sets will remain with the student advisor for the availability of future research.

e) Describe procedures to deal with adverse reactions (referrals to helping agencies, procedures for dealing with trauma, etc.).

If, in the unlikely event, a subject obtains a skin tear, abrasion, or lasting redness or warmth indicating the possibility of a decubitus/pressure ulcer during testing; the subject will be asked to seek immediate care from their personal physician or at urgent care.

f) Include an explanation of medical treatment available if injury or adverse reaction occurs and responsibility for costs involved.

In the event medical treatment is necessary as the result of injury or an adverse reaction, the subject will be asked to seek immediate care. No costs for medical treatment will be provided by the student researchers, advisor, or UND.

III. Benefits of the Study

Clearly describe the benefits to the subject and to society resulting from this study (such as learning experiences, services received, etc.). **Please note:** extra credit and/or payment are not benefits and should be listed in the Protocol Description section under Methodology.

No tangible benefits are expected to accrue to the research participants, however, the participant may benefit from reviewing principles of pressure relief techniques and self-assessment strategies. The participant may also benefit from knowing they have assisted in advancing the knowledge about seating issues for operators with spinal cord injuries of agricultural machinery.

IV. Consent Form

Clearly describe the consent process and be sure to include the following information:

1) The person who will conduct the consent interview
2) The person who will provide consent or permission
3) Any waiting period between informing the prospective participant and obtaining consent
4) Steps taken to minimize the possibility of coercion or undue influence
5) The language to be used by those obtaining consent
6) The language understood by the prospective participant or the legally authorized representative
7) The information to be communicated to the prospective participant or the legally authorized representative

The student researchers will be conducting the consent interview and will conduct the consent process. There will be no coercion of subjects to participate or give consent. The token gift of a $25 dining card is not likely to induce consent, but is seen as a "thank you" compensation for participation. The consent will use simple language at an eighth grade reading level. The prospective subjects will be informed about the purpose of the research, the potential risks/benefits, the steps taken to minimize risk and maintain safety, as well as the payment for any medical care for an unanticipated injury will be at their own expense.

A copy of the consent form must be attached to this proposal. If no consent form is to be used, document the procedures to be used to protect human subjects, and complete the Application for Waiver or Alteration of Informed Consent Requirements. Refer to form IC 701-A, Informed Consent Checklist, and make sure that all the required elements are included. **Please note:** All records attained must be retained for a period of time sufficient to meet federal, state, and local regulations; sponsor requirements; and organizational policies. The consent form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. **The consent form should be written at no higher than an 8th grade reading level**, and it is recommended that it be written in the third person (please see the example on the RD&C website). A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp.

Necessary attachments:

- ☒ Signed Student Consent to Release of Educational Record Form (students only);
- ☒ Investigator Letter of Assurance of Compliance;
- ☒ Consent form, or Waiver or Alteration of Informed Consent Requirements (Form IC 702-B)
- ☒ Surveys, interview questions, etc. (if applicable);
- ☐ Printed web screens (if survey is over the Internet); and
- ☐ Advertisements.

By signing below, you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate and that the project will be completed as indicated.

Signatures:

Veronica Boeser, [signature] — 3/16/10

(Principal Investigator) — Date:

[signature] OTR/L — 3-16-10

(Student Adviser) — Date:

Requirements for submitting proposals:
Additional information can be found on the IRB web site at **www.und.nodak.edu/dept/orpd/regucomm/IRB/index.html.**

Original Proposals and all attachments should be submitted to: Institutional Review Board, 264 Centennial Drive Stop 7134, Grand Forks, ND 58202-7134, or brought to Room 106, Twamley Hall.

Prior to receiving IRB approval, researchers must complete the required IRB human subjects' education. Please go to http:// http://www.und.edu/dept/rdc/regucomm/IRB/IRBEducation.htm for more information.

The criteria for determining what category your proposal will be reviewed under is listed on page 3 of the IRB Checklist. Your reviewer will assign a review category to your proposal. Should your protocol require full Board review, you will need to provide additional copies. Further information can be found on the IRB website regarding required copies and IRB review categories, or you may call the IRB office at 701 777-4279.

In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 5 copies if the proposal is clinical-medical. If the proposed work is being conducted for a pharmaceutical company, 5 copies of the company's protocol must be provided.

Reference

Cook, A. M., & Hussey, S. M. (2002). *Assistive Technologies: Principles and Practice* (2 ed.). St. Louis, MO: Mosby, Inc.

Ferrarin, M., Andreoni, G., & Pedotti, A. (2000). Comparative biomechanical evaluation of different wheelchair seat cushions. *Journal of Rehabilitation Research and Development , 37* (3), 315-324.

University of Washington. (2004). *Northwest Regional Spinal Cord Injury System.* Retrieved January 4, 2010, from SCI forum reports: Picture this... pressure mapping assessment for wheelchair users.: http;//sci.washington.edu/info/forums/reports/pressure_map.asp

Willkomm, T. 2002. *Proper seating and positioning for tractor operators affected by spinal cord injuries.* Retrieved from University of Wisconsin, National AgrAbility Project website: http://www.agrabilityproject.org

INVESTIGATOR LETTER OF ASSURANCE OF COMPLIANCE WITH ALL APPLICABLE FEDERAL REGULATIONS FOR THE PROTECTION OF THE RIGHTS OF HUMAN SUBJECTS

I Veronica Boeser
(Name of Investigator)

agree that, in conducting research under the approval of the University of North Dakota Institutional Review Board, I will fully comply and assume responsibility for the enforcement of compliance with all applicable federal regulations and University policies for the protection of the rights of human subjects engaged in research. Specific regulations include the Federal Common Rule for Protection of the Rights of Human Subjects 45 CFR 46. I will also assure compliance to the ethical principles set forth in the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research document, The Belmont Report.

I understand the University's policies concerning research involving human subjects and agree to the following:

1. Should I wish to make changes in the approved protocol for this project, I will submit them for review PRIOR to initiating the changes. (A proposal may be changed without prior IRB approval where necessary to eliminate apparent immediate hazards to the subjects or others. However, the IRB must be notified in writing within 72 hours of any change, and IRB review is required at the next regularly scheduled meeting of the full IRB.)

2. If any problems involving human subjects occur, I will immediately notify the Chair of the IRB, or the IRB Coordinator.

3. I will cooperate with the UND IRB by submitting Research Project Review and Progress Reports in a timely manner.

I understand the failure to do so may result in the suspension or termination of proposed research and possible reporting to federal agencies.

Veronica Jo Boeser
Investigator Signature

3/16/10
Date

INVESTIGATOR LETTER OF ASSURANCE OF COMPLIANCE WITH ALL APPLICABLE FEDERAL REGULATIONS FOR THE PROTECTION OF THE RIGHTS OF HUMAN SUBJECTS

I William Kennington
(Name of Investigator)

agree that, in conducting research under the approval of the University of North Dakota Institutional Review Board, I will fully comply and assume responsibility for the enforcement of compliance with all applicable federal regulations and University policies for the protection of the rights of human subjects engaged in research. Specific regulations include the Federal Common Rule for Protection of the Rights of Human Subjects 45 CFR 46. I will also assure compliance to the ethical principles set forth in the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research document, The Belmont Report.

I understand the University's policies concerning research involving human subjects and agree to the following:

1. Should I wish to make changes in the approved protocol for this project, I will submit them for review PRIOR to initiating the changes. (A proposal may be changed without prior IRB approval where necessary to eliminate apparent immediate hazards to the subjects or others. However, the IRB must be notified in writing within 72 hours of any change, and IRB review is required at the next regularly scheduled meeting of the full IRB.)

2. If any problems involving human subjects occur, I will immediately notify the Chair of the IRB, or the IRB Coordinator.

3. I will cooperate with the UND IRB by submitting Research Project Review and Progress Reports in a timely manner.

I understand the failure to do so may result in the suspension or termination of proposed research and possible reporting to federal agencies.

William Kennington
Investigator Signature

3/16/10
Date

STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD[1]

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is A comparative analysis of tractor seating for individuals with spinal cord injury using a pressure mapping system ________________________.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

0755267
ID #

Veronica Boeser
Printed Name

3/16/10
Date

Veronica Jo Boeser
Signature of Student Researcher

[1]Consent required by 20 U.S.C. 1232g.

STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD[1]

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is A comparative analysis of tractor seating for individuals with spinal cord injury using a pressure mapping system ________________.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

W0778154
ID #

William H. Kennington
Printed Name

3/16/10
Date

[signature]
Signature of Student Researcher

[1]Consent required by 20 U.S.C. 1232g.

Appendix B
Informed Consent

TITLE: *Comparative analysis of tractor seating for individuals with spinal cord injuries using a pressure mapping system*

RESEARCHERS: *William Kennington, Veronica Boeser & Dr. Carla Wilhite*

PHONE # *(307) 268-2534*

DEPARTMENT: Occupational Therapy, University of North Dakota – Casper

_____________________________, the participant has been asked to take part in this master's research project designed by the students from University of North Dakota. The purpose for this research study is to compare pressure maps between two different tractor seats with and without various ROHO® cushions.

You will not have any costs for participating in the research survey; however, you will be given a token gift card of $20 for participating. The University of North Dakota and the research team are receiving no payments from other agencies, organizations, or companies to conduct this study.

The records of this research study will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Your study record may be reviewed by Government agencies, and the University of North Dakota Institutional Review Board. Any information that is obtained during the study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of removing any identifying information from the research data, and will be kept in a locked file cabinet in the student advisor's office.

Your participation is voluntary. You may choose to not participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota. This study was found to have minimal risks to participants. However, if you do sustain an injury during the study, you will be asked to seek immediate medical attention at your own expense. You will be informed by the research investigator(s) of this study of any significant new findings that develop during the study that may influence your willingness to continue to participate in the study. No potential benefits are expected, however, you may experience pride in contributing to the research process as well as benefit from reviewing skin protection, pressure relief techniques, and self-assessment for spinal cord injury.

The Students conducting this study are William Kennington and Veronica Boeser, students at the University of North Dakota. Dr. Carla Wilhite will advise them. If you have questions, concerns, or complaints about the research please contact William Kennington at (307) 248-0635, Veronica Boeser at (620) 214-0508, or Dr. Carla Wilhite at (307) 268-2534.

If you have questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279. Please call this number if you cannot reach the research staff, or you wish to talk with someone else.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name:____

____ _________________

Signature of Subject Date

Appendix C

Comparative Tractor Data Protocol

Demographics:

Subject Number:___________ Gender:__________________

Weight:_____________

Height: __________ Neurologic Level:__________

Current Skin Breakdown: Y N

Past History of Integument Injury/Condition:

Skin Inspection:

Anatomical Area	**Skin Breakdown**
Buttocks	
Sacrum	
Ischial Tuberosity	
Coccyx	
Back	
Other	

Seat: Standard John Deere Foam without ROHO® cushion. (#1)

Set-Up and Calibration of System complete: Y N
Correct Postural Adjustments: Y N
Hand Check: Y N

Time (In min.)	**mmHg**	**Anatomical Pressure Area**
8 (Preview Mode)		
2 (Hard Data Collection)		

Skin Inspection:

Anatomical Area	**Skin Breakdown**
Buttocks	
Sacrum	
Ischial Tuberosity	
Coccyx	
Back	
Other	

Seat: Standard John Deere Foam with low profile ROHO® . (#2)

Set-Up and Calibration of System complete: Y N
Correct Postural Adjustments: Y N
Hand Check: Y N

Time (In min.)	mmHg	Anatomical Pressure Area
8 (Preview Mode)		
2 (Hard Data Collection)		

Skin Inspection:

Anatomical Area	Skin Breakdown
Buttocks	
Sacrum	
Ischial Tuberosity	
Coccyx	
Back	
Other	

Seat: Standard John Deere Foam with Mid- Profile® profile ROHO® . (#3)

Set-Up and Calibration of System complete: Y N
Correct Postural Adjustments: Y N
Hand Check: Y N

Time (In min.)	mmHg	Anatomical Pressure Area
8 (Preview Mode)		
2 (Hard Data Collection)		

Skin Inspection:

Anatomical Area	Skin Breakdown
Buttocks	
Sacrum	
Ischial Tuberosity	
Coccyx	
Back	
Other	

Seat: John Deere Active without ROHO® cushion. (#4)

Set-Up and Calibration of System complete: Y N
Correct Postural Adjustments: Y N
Hand Check: Y N

Time (In min.)	mmHg	Anatomical Pressure Area
8 (Preview Mode)		
2 (Hard Data Collection)		

Skin Inspection:

Anatomical Area	Skin Breakdown
Buttocks	
Sacrum	
Ischial Tuberosity	
Coccyx	
Back	
Other	

Seat: John Deere Active with low profile ROHO® . (#5)

Set-Up and Calibration of System complete: Y N
Correct Postural Adjustments: Y N
Hand Check: Y N

Time (In min.)	mmHg	Anatomical Pressure Area
8 (Preview Mode)		
2 (Hard Data Collection)		

Skin Inspection:

Anatomical Area	Skin Breakdown
Buttocks	
Sacrum	
Ischial Tuberosity	
Coccyx	
Back	
Other	

Seat: John Deere Active with Mid- Profile® profile ROHO® . (#6)
Set-Up and Calibration of System complete: Y N
Correct Postural Adjustments: Y N
Hand Check: Y N

Time (In min.)	mmHg	Anatomical Pressure Area
8 (Preview Mode)		
2 (Hard Data Collection)		

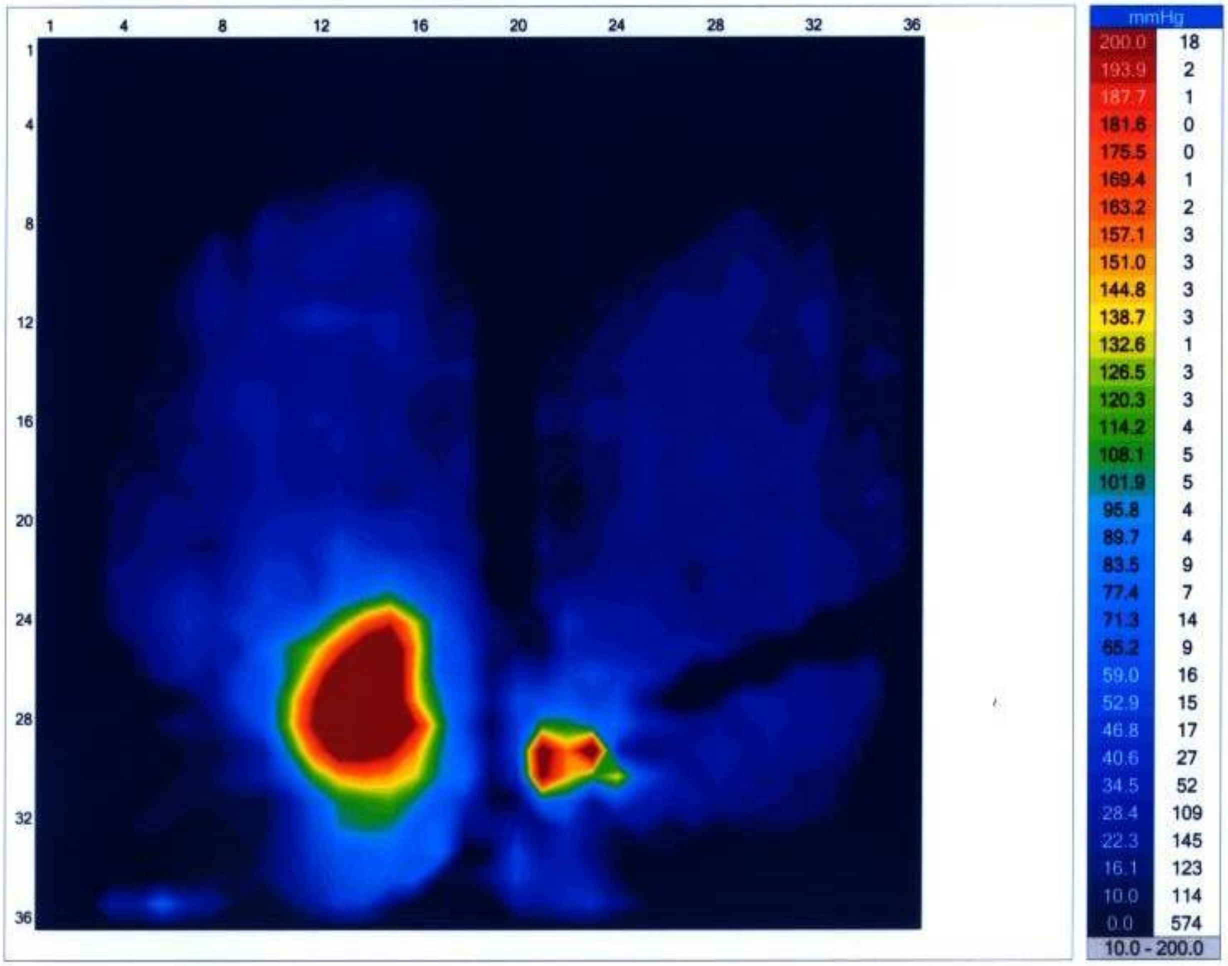
Skin Inspection:

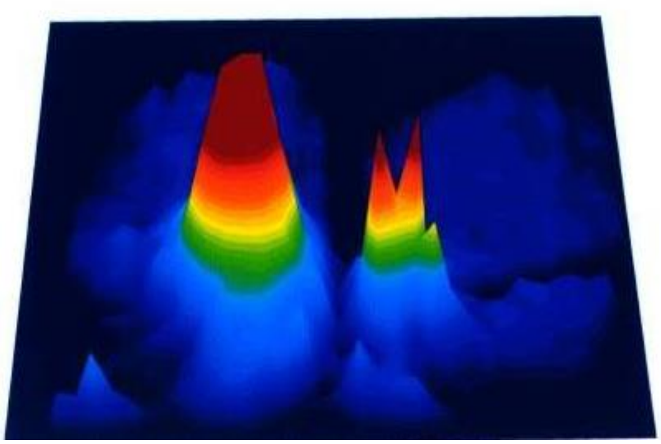
Anatomical Area	Skin Breakdown
Buttocks	
Sacrum	
Ischial Tuberosity	
Coccyx	
Back	
Other	

Appendix D
Sensory Mapping Pictures

XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

File: Client 1 Std Foam_20100929_211852
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 41.8 / 256.0 mmHg
Area: 180.50 in^2

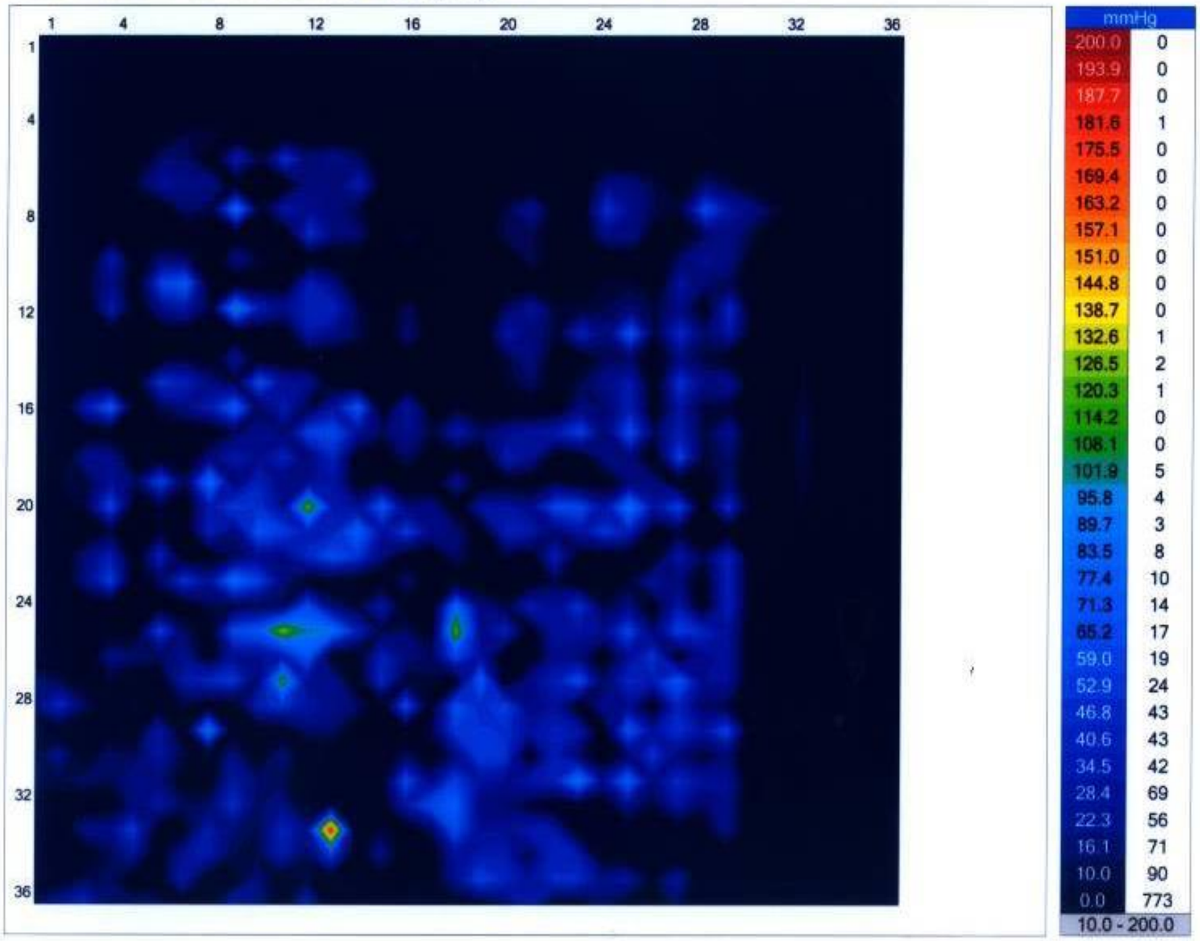


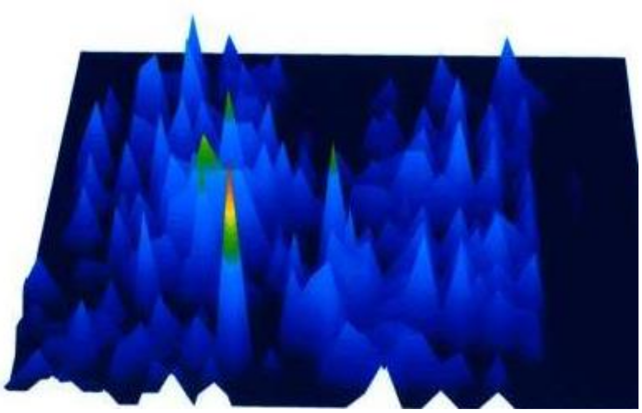


Sensor/Group	Value
S0045	
Avg Pres.	41.8
Peak Pres.	256.0
Area (in^2)	180.5

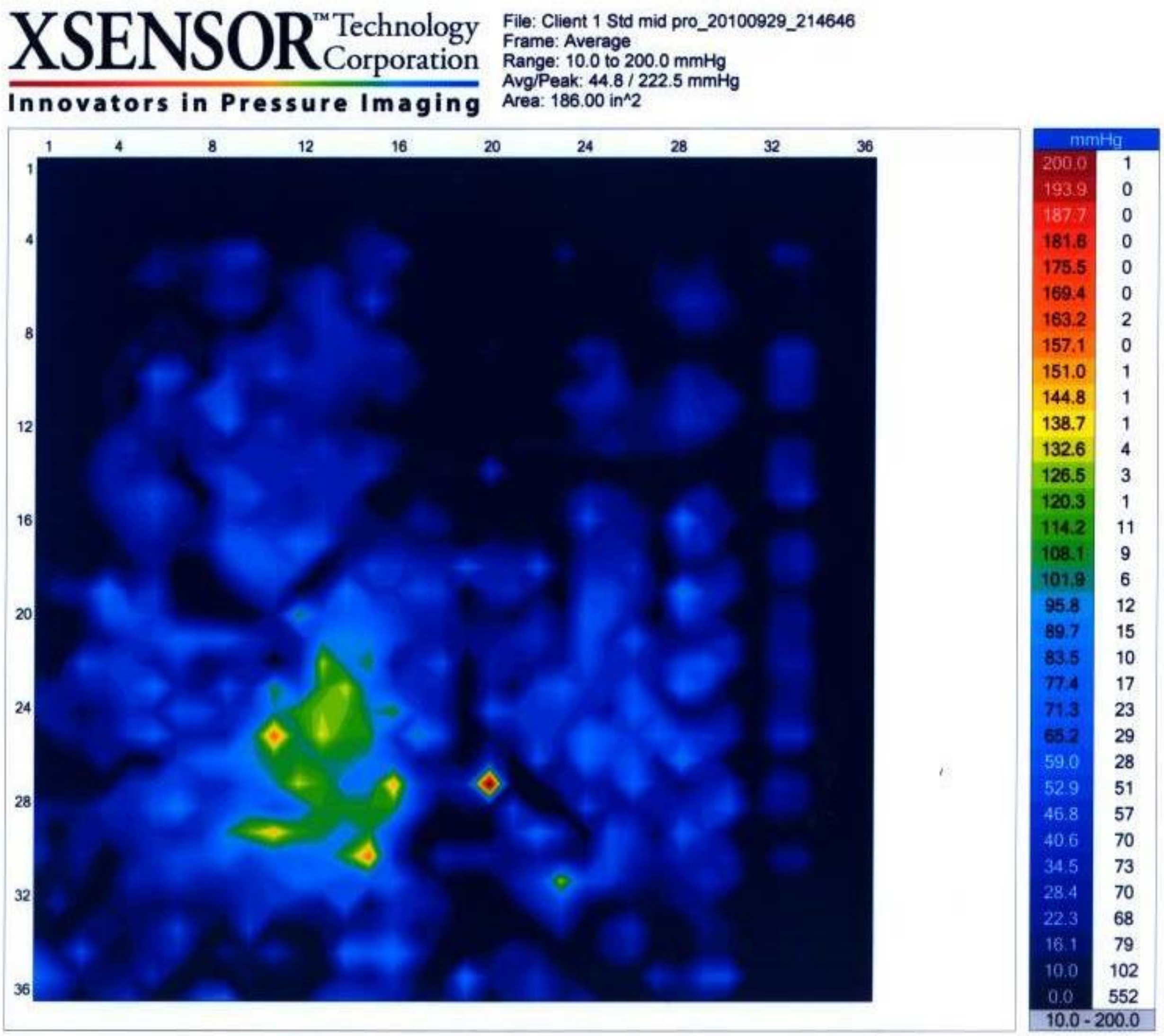
XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

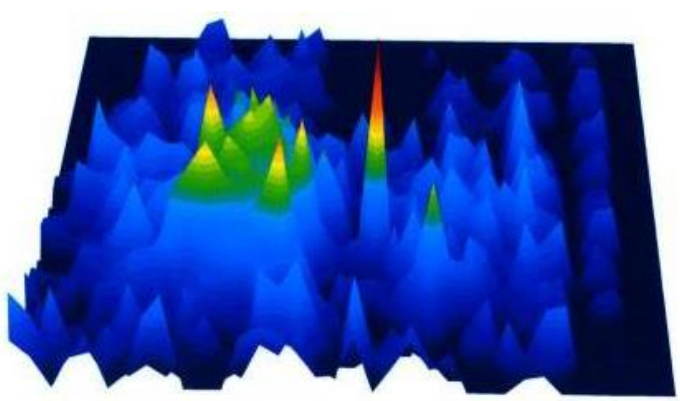
File: Client 1 Std low pro_20100929_213500
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 37.9 / 185.3 mmHg
Area: 130.75 in^2





Sensor/Group	Value
S0045	
Avg Pres.	37.9
Peak Pres.	185.3
Area (in^2)	130.75



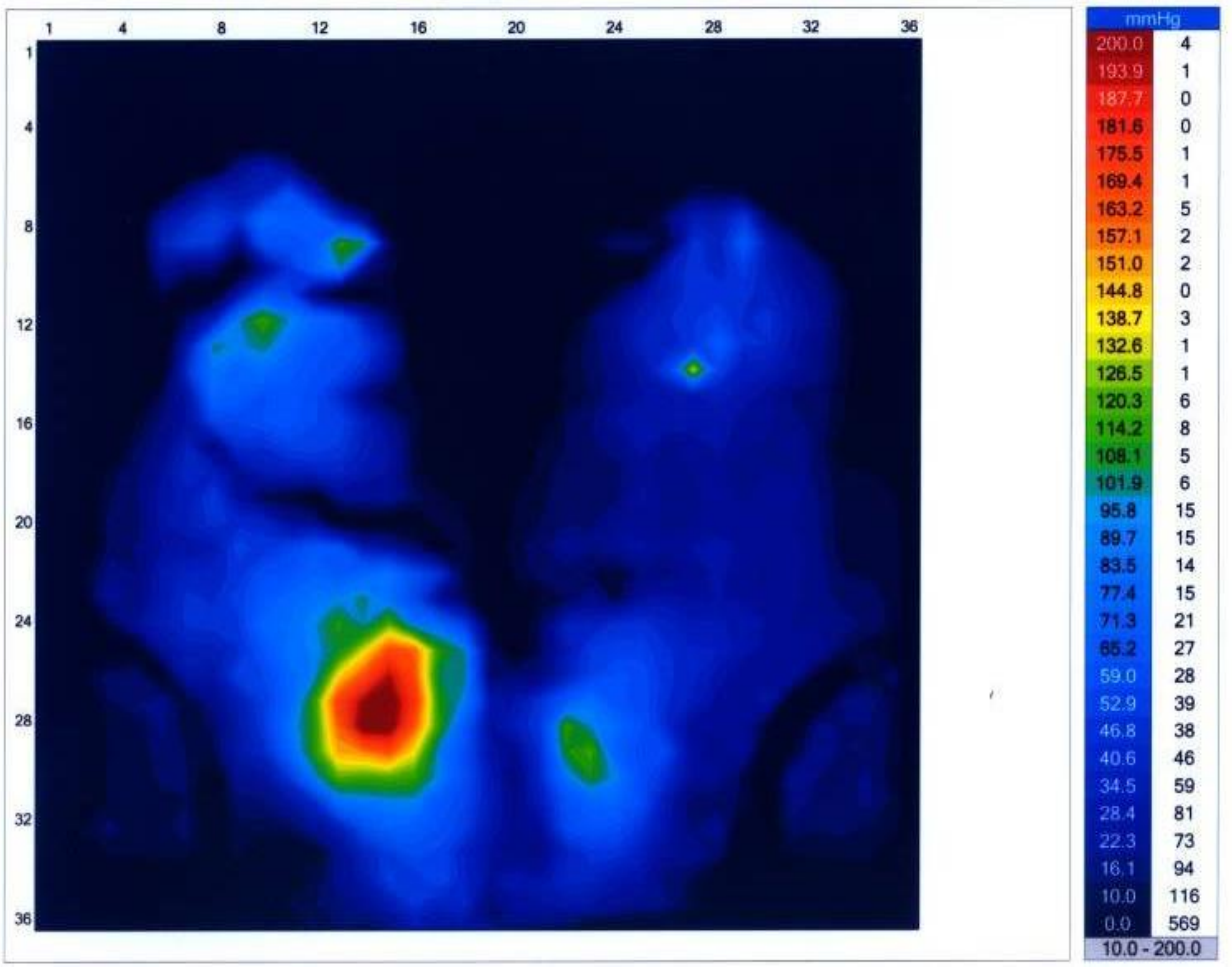


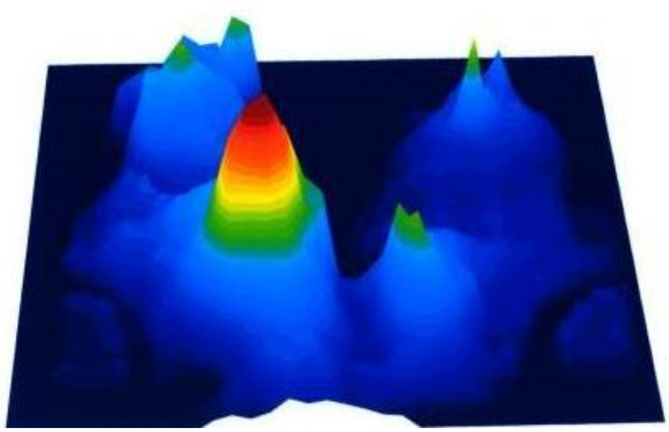
Sensor/Group	Value
S0045	
Avg Pres.	44.8
Peak Pres.	222.5
Area (in^2)	186.0

XSENSOR™ Technology Corporation

Innovators in Pressure Imaging

File: Client 1 Active Foam_20100929_203342
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 45.1 / 209.8 mmHg
Area: 181.75 in^2

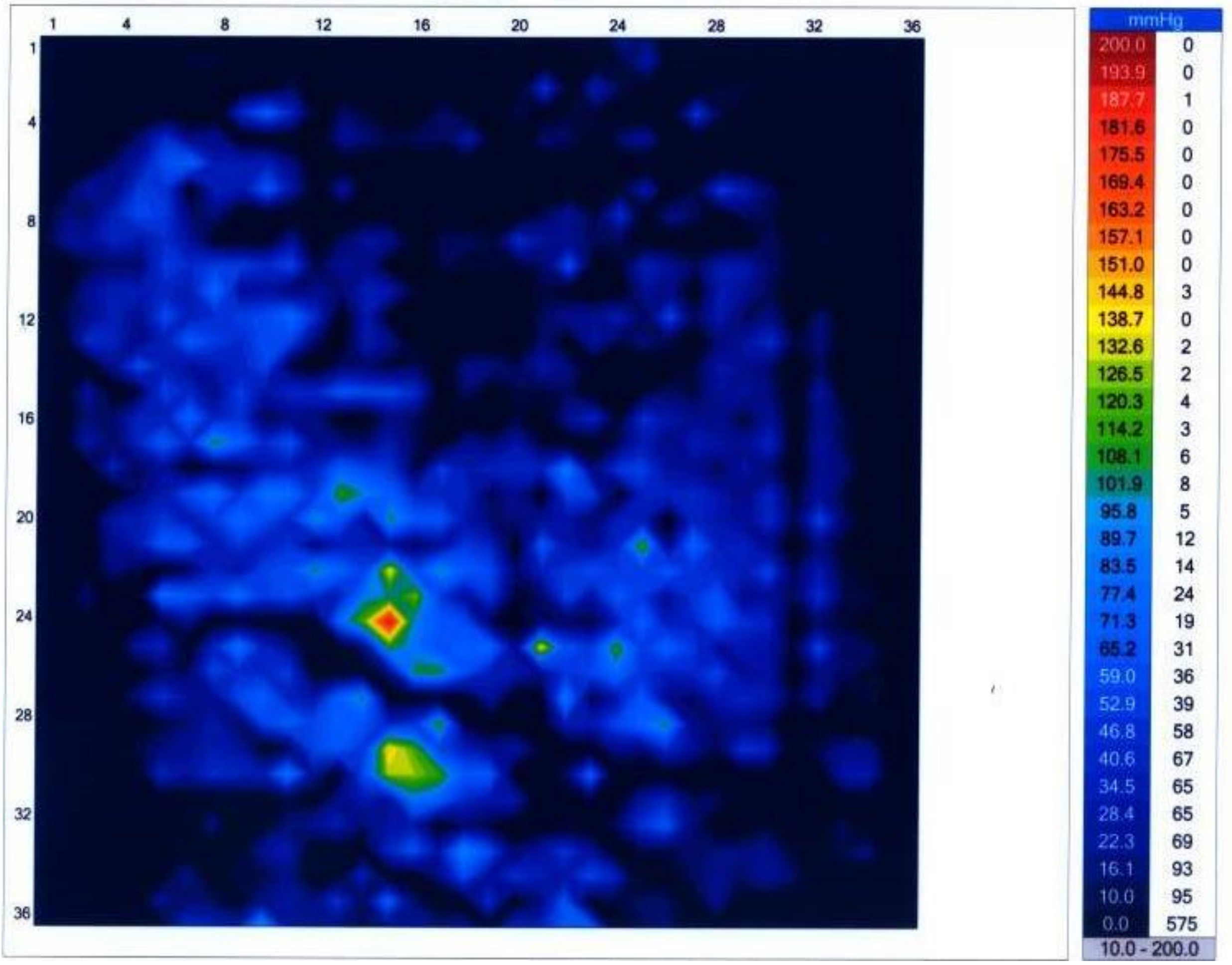


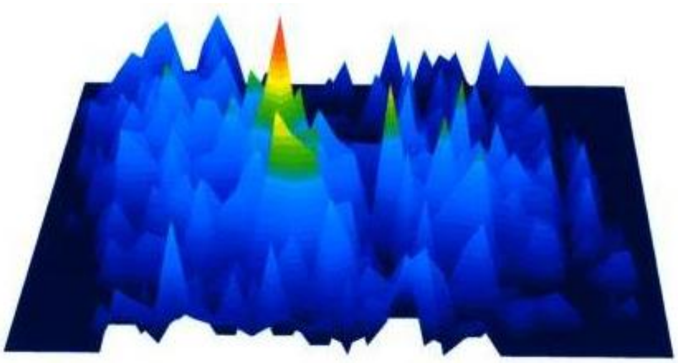


Sensor/Group	Value
S0045	
Avg Pres.	45.1
Peak Pres.	209.8
Area (in^2)	181.75

XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

File: Client 1 Active low pro_20100929_204816
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 43.3 / 192.2 mmHg
Area: 180.25 in^2

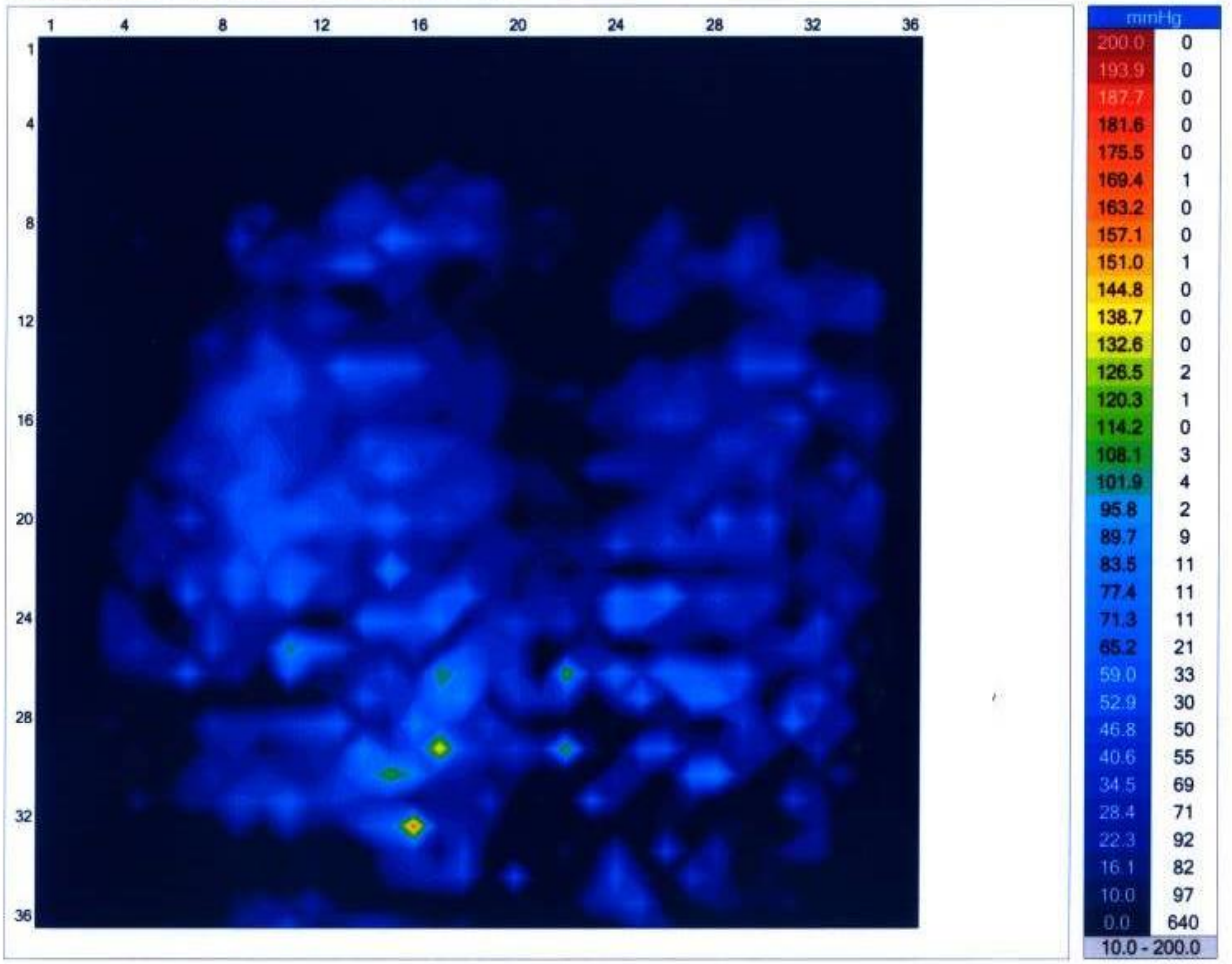


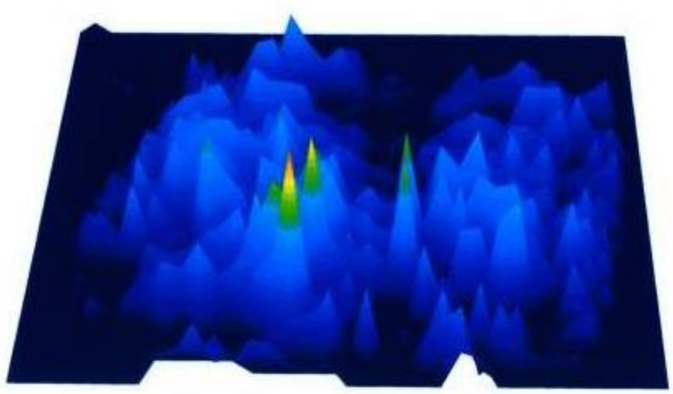


Sensor/Group	Value
S0045	
Avg Pres.	43.3
Peak Pres.	192.2
Area (in^2)	180.25

XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

File: Client 1 Active mid pro_20100929_210350
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 38.3 / 170.3 mmHg
Area: 164.00 in^2

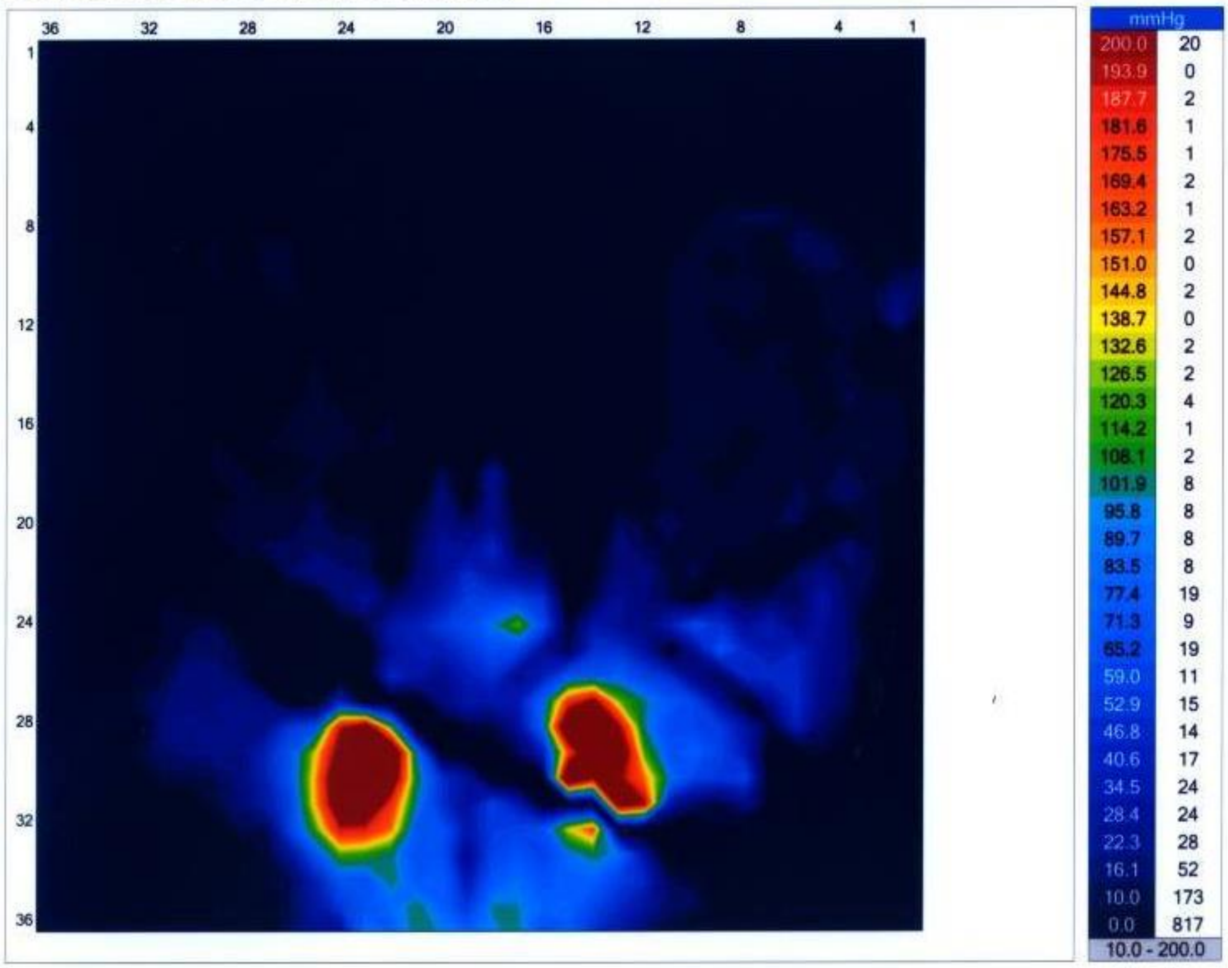


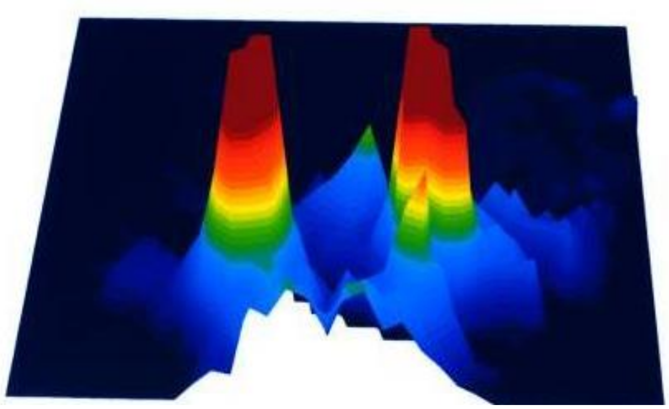


Sensor/Group	Value
S0045	
Avg Pres.	38.3
Peak Pres.	170.3
Area (in^2)	164.0

XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

File: Client 2 Std Foam 20100929_221537
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 47.9 / 256.0 mmHg
Area: 119.75 in^2

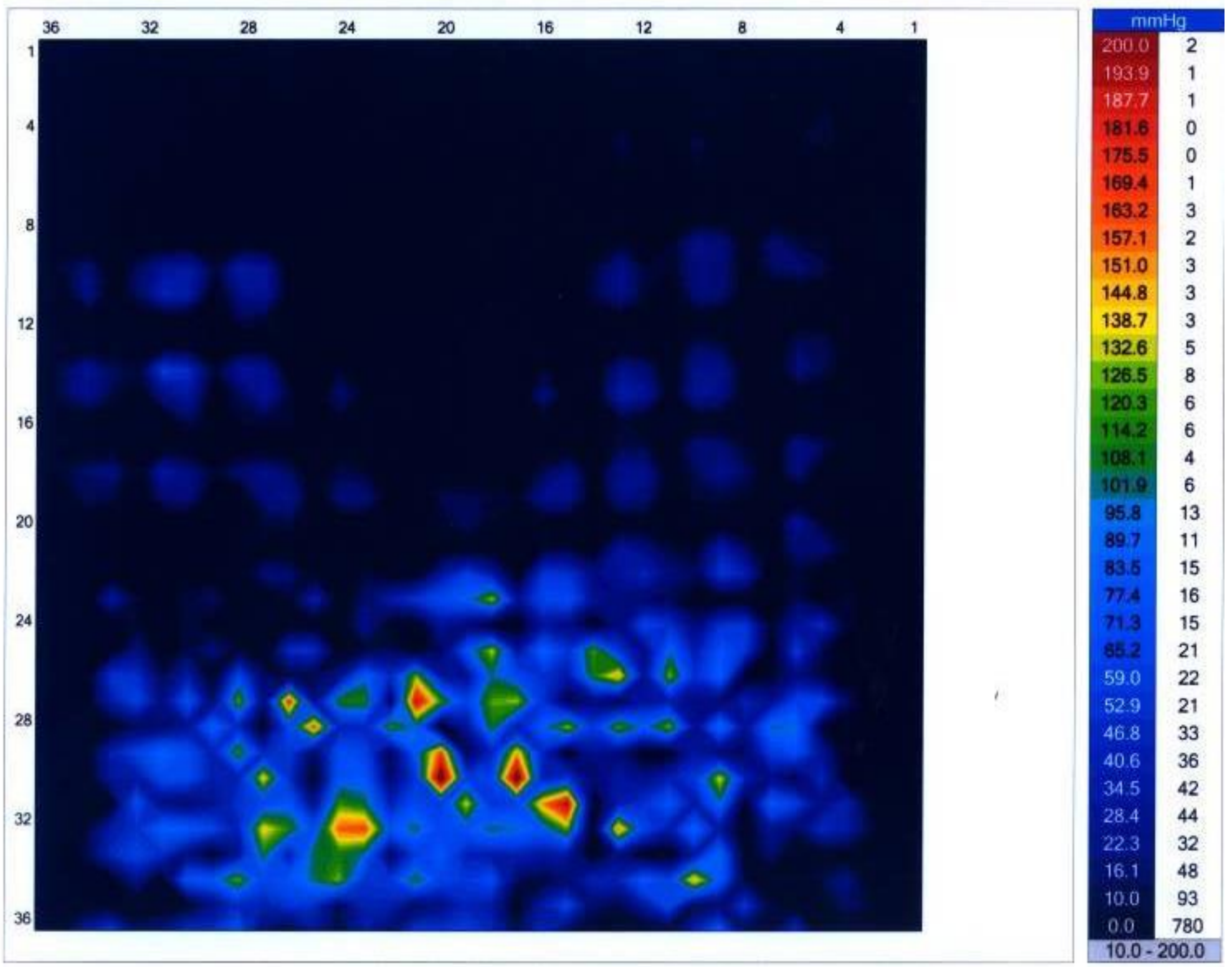


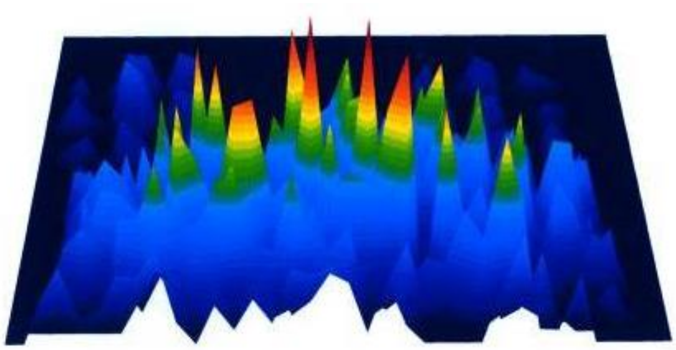


Sensor/Group	Value
S0045	
Avg Pres.	47.9
Peak Pres.	256.0
Area (in^2)	119.75

XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

File: Client 2 Std low pro_20100929_222939
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 51.2 / 219.5 mmHg
Area: 129.00 in^2

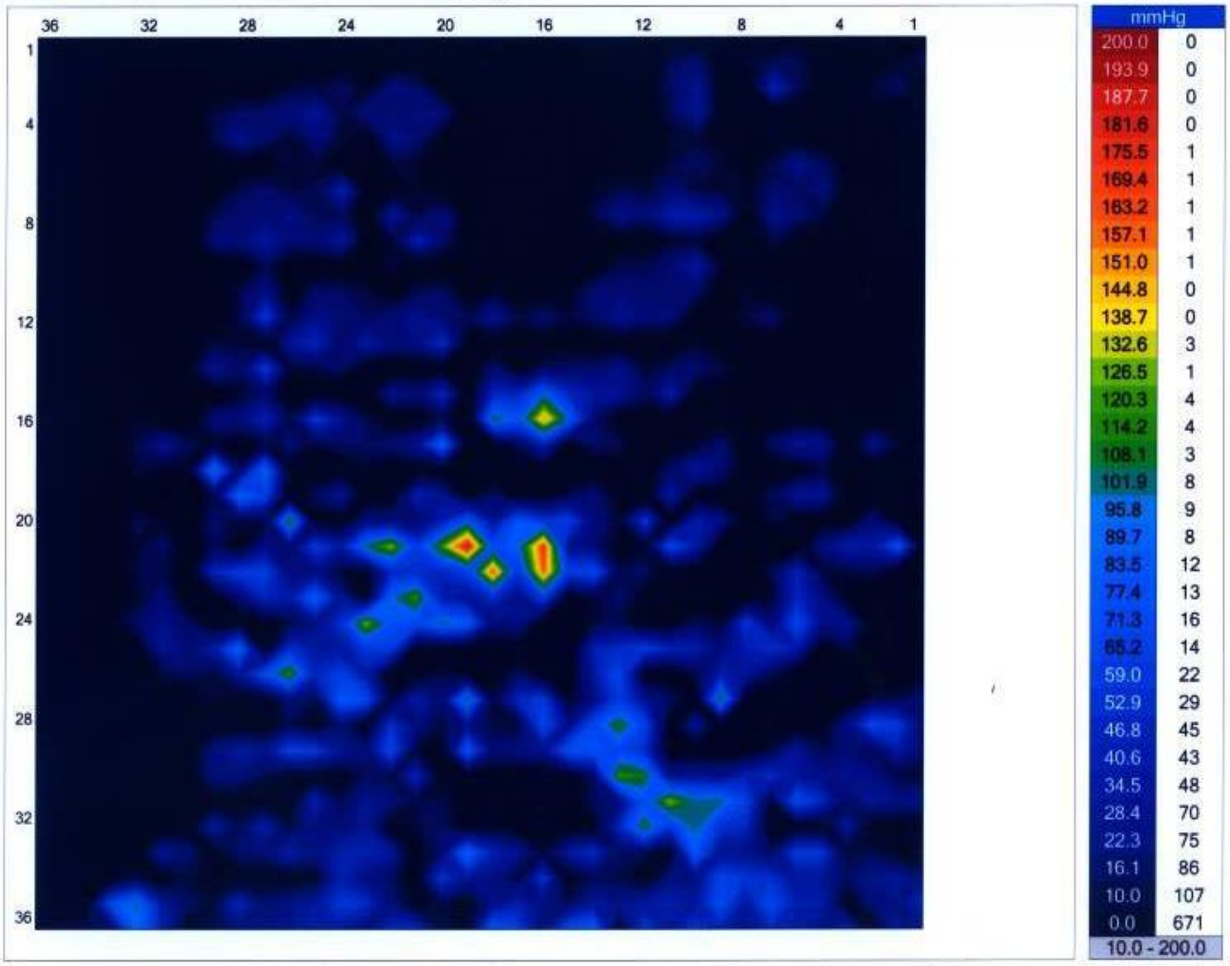


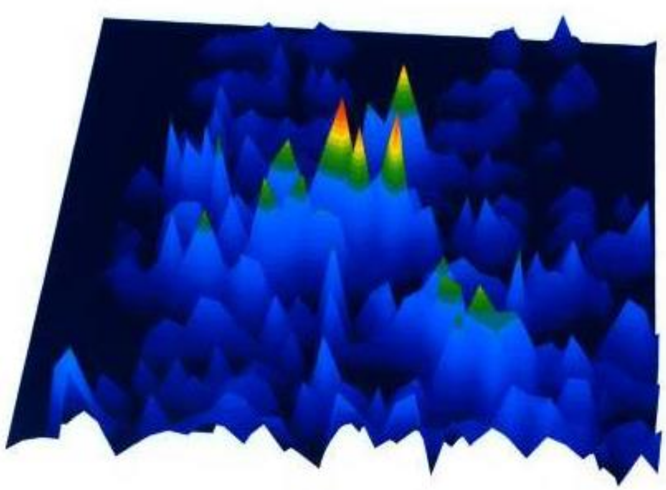


Sensor/Group	Value
S0045	
Avg Pres.	51.2
Peak Pres.	219.5
Area (in^2)	129.0

XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

File: Client 2 Std mid pro_20100929_224342
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 40.6 / 181.5 mmHg
Area: 156.25 in^2

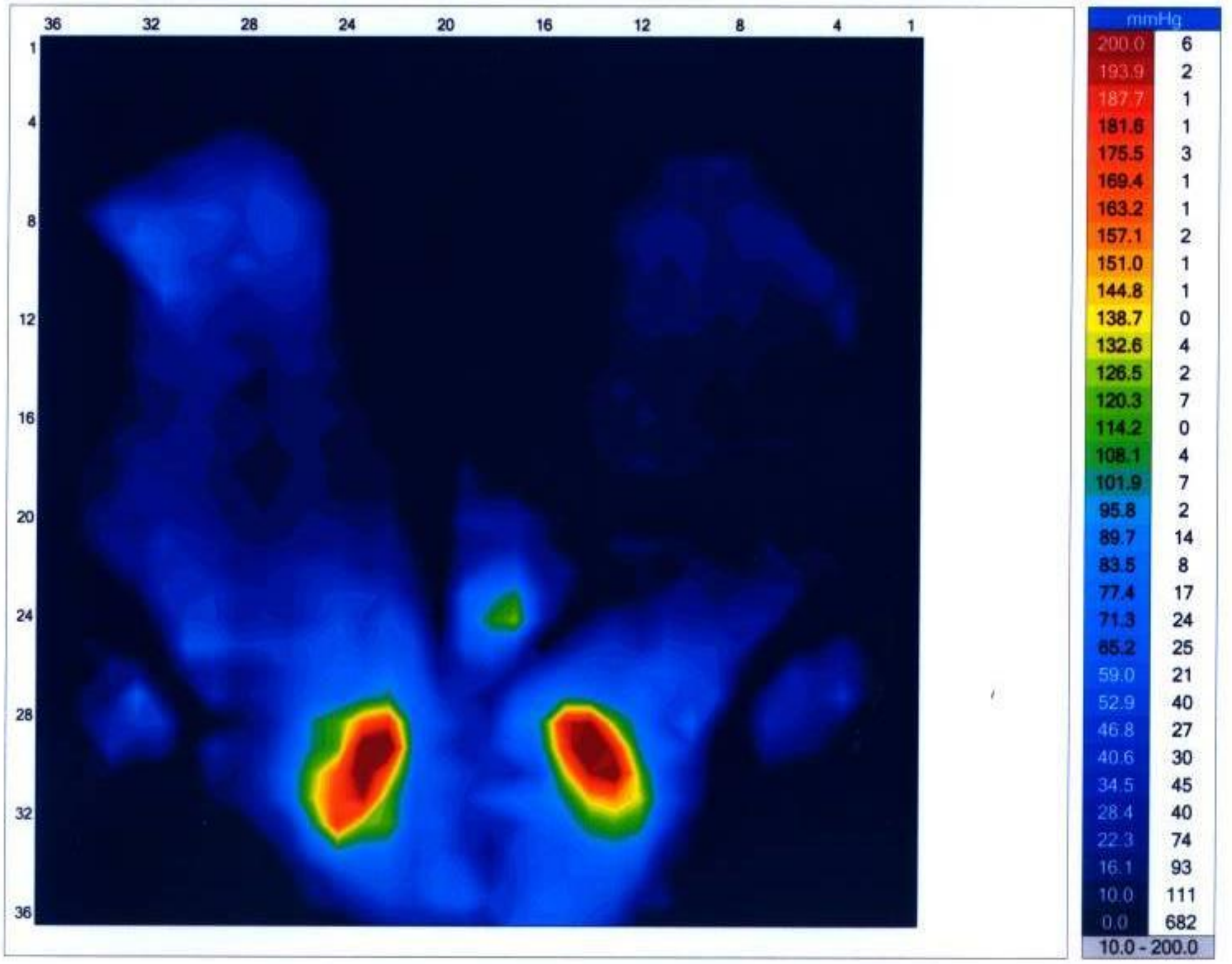


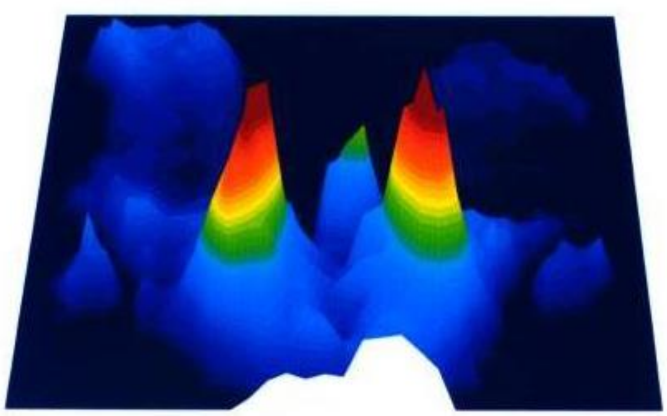


Sensor/Group	Value
S0045	
Avg Pres.	40.6
Peak Pres.	181.5
Area (in^2)	156.25

XSENSOR™ Technology Corporation
Innovators in Pressure Imaging

File: Client 2 Active Foam_20100929_230215
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 45.2 / 239.6 mmHg
Area: 153.50 in^2



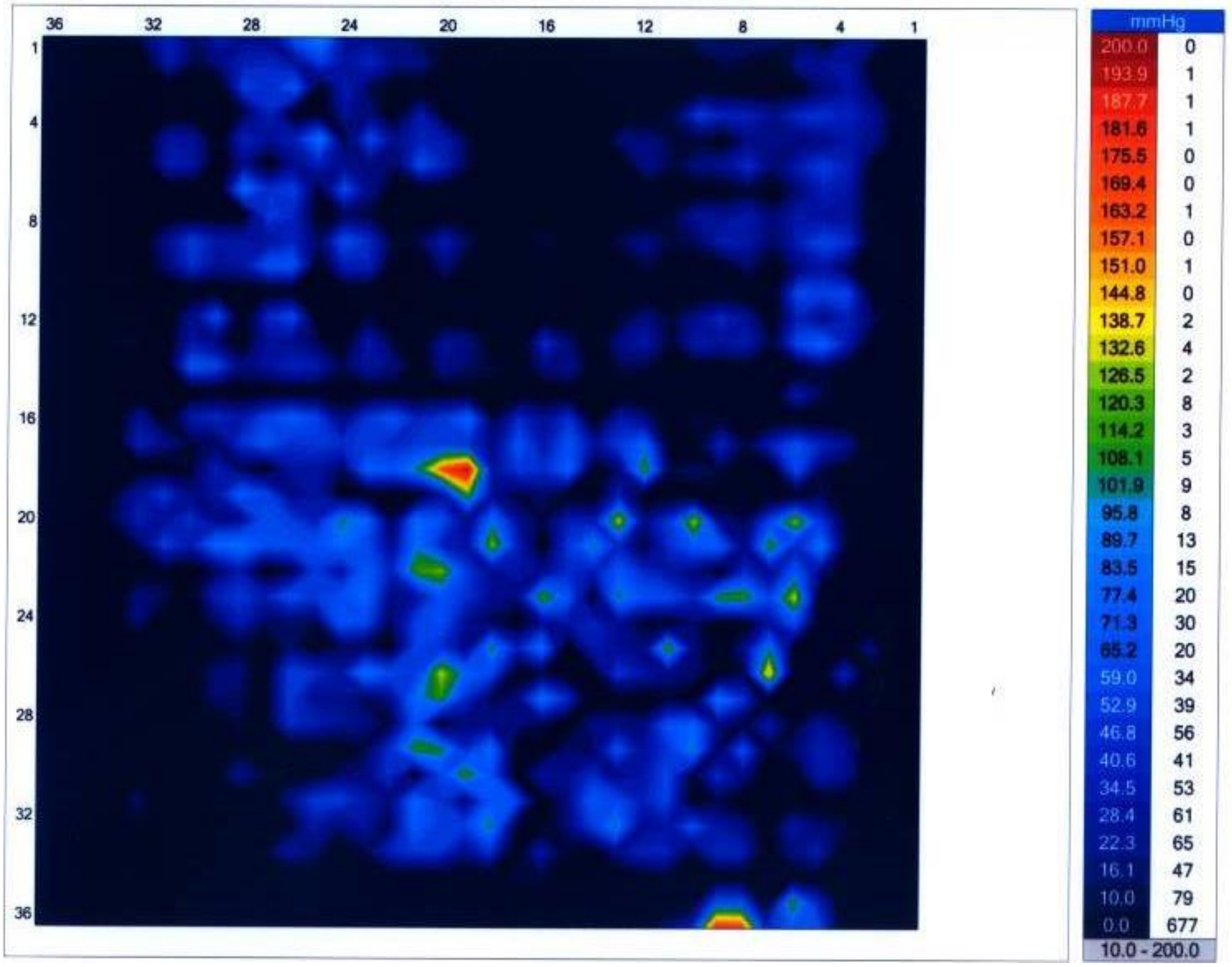


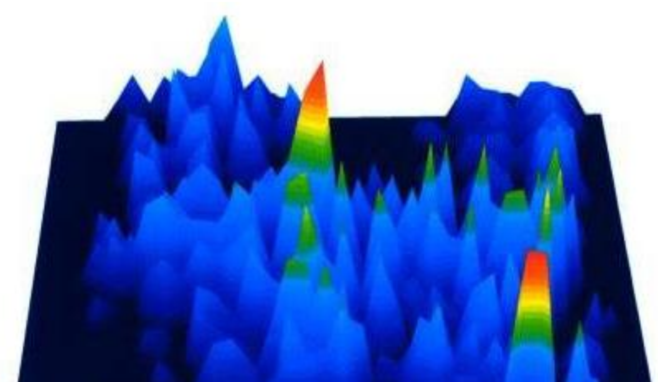
Sensor/Group	Value
S0045	
Avg Pres.	45.2
Peak Pres.	239.6
Area (in^2)	153.5

XSENSOR™ Technology Corporation

Innovators in Pressure Imaging

File: Client 2 Active low pro_20100929_231316
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 47.9 / 194.6 mmHg
Area: 154.75 in^2



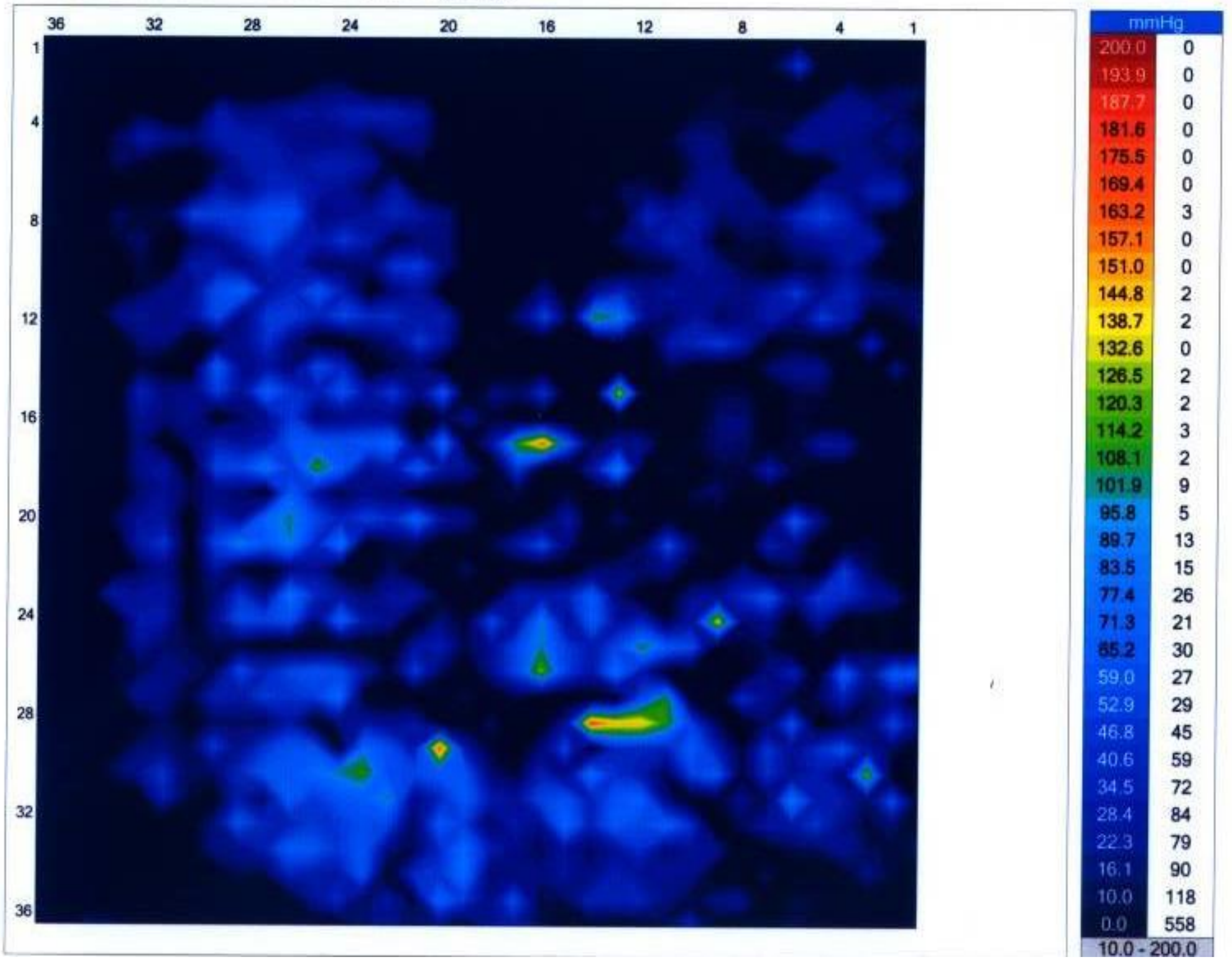


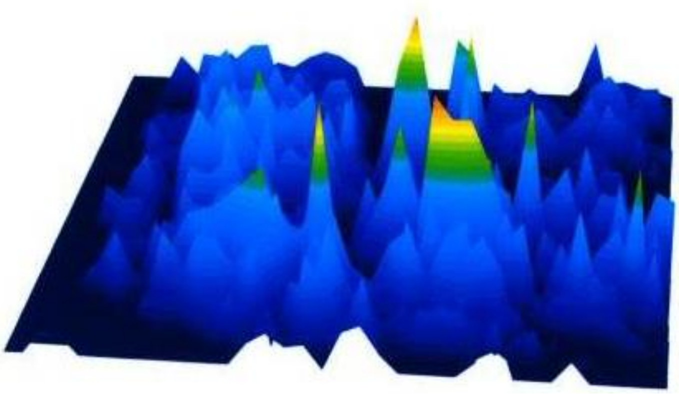
Sensor/Group	Value
S0045	
Avg Pres.	47.9
Peak Pres.	194.6
Area (in^2)	154.75

XSENSOR™ Technology Corporation

Innovators in Pressure Imaging

File: Client 2 Active mid pro_20100929_232443
Frame: Average
Range: 10.0 to 200.0 mmHg
Avg/Peak: 41.4 / 168.9 mmHg
Area: 184.50 in^2





Sensor/Group	Value
S0045	
Avg Pres.	41.4
Peak Pres.	168.9
Area (in^2)	184.5

Appendix E
Sensor Readings of Bilateral Ischial Tuberosities

Client 1 Active Foam (LIT)

75.4	76.7	95	92.6	99.7	95.4	73.6	59.3
80.6	96.5	101.3	113.5	114.3	92.6	76.7	28.8
89.9	101.7	115.4	126.8	100.4	95.9	84.3	76.2
85.8	121.5	105.3	123.1	148.6	161.5	149	112
94	115.8	119.2	163.3	168.3	193.6	170.1	103.3
73.3	113.1	146.4	186.4	206	214	169.9	99.6
71.6	124.2	153.9	192.9	214.4	224.2	149.4	104.9
63.2	117.2	165.4	184.4	181.5	173.2	130.5	89.2
42.6	77.2	138.9	162.2	137.6	138.9	126.9	97.7
22.1	41.4	67.8	117.3	112.4	110.4	99.3	64.1
13.6	16.1	36.5	65	89.6	90.4	84.1	70.2

Avg. 112.17

Client 1 Active Foam (RIT)

0	18.1	42.4	59.7	61.5	62.5	53.8
21.2	23	45.7	63.1	72.3	70.2	54
39.9	57.8	78.9	94.1	72.8	68.9	53
46.5	59.4	121.3	99.8	88.8	72.4	50.6
29.7	54.9	113.2	123.5	81.2	67.4	65.7
21.4	52.3	92.2	113.7	98.7	69.8	53.2
26.9	44.2	72.5	85.3	87.4	69.3	39.3
28.3	31.6	68	75	69.2	55.4	37

Avg. 62.11

Client 1 Active Low Profile (LIT)

64.8	68.4	108.8	83.8	59.7	142.2	66.7	103.8
61.9	732	53.4	40.7	94.7	101.7	108.2	56.2
0	0	0	87.8	127	190.5	98	76.2
46.6	25.8	0	0	26.6	116.9	91.2	71.8
48	63	0	0	0	25.1	110.3	111.7
82.5	44.4	37.9	84.7	106.7	0	0	0
67.1	85.6	64.8	79.7	74.1	43.2	52.6	118
0	10.3	67.2	80.1	51.3	140.8	120.3	62.1
42.3	99	33.5	0	68.5	132.7	129.3	117.3
0	11	0	27.5	42	29	92.4	81.2
0	20.6	30	44.6	19.4	34.9	37.2	0

Avg.
58.78

Client 1 Active Low Profile (RIT)

27.5	146.2	73.3	61.4	119.4	59.6	88.5	
42.8	30.4	58.1	67.5	91.2	56.8	14.7	
0	0	104.2	12.4	37.6	78.3	25.3	
0	0	46.5	44.2	67.6	87.6	110.8	
40.2	12.5	0	0	30	21.5	53.8	
0	0	19.6	84.7	0	0	0	
44.2	0	0	12.4	0	35.5	52.9	
0	0	0	0	18.9	57.1	78.2	
							Avg. 38.28

Client 1 Active Mid Profile (LIT)

61.2	84.1	67.7	41.9	20.5	108.9	38.7	20
49.3	94	41.4	44.9	27.3	31.2	36.4	68.9
30	18.9	0	0	87.3	77	65.7	94
25.7	110.3	81.6	62.5	23.5	22.8	48.7	16
0	80.7	24.6	18.5	40.8	59.6	25.7	113.3
0	0	0	21.5	70.8	46.6	52.4	92.6
38.5	53.6	61.5	79	23.3	25.5	106.5	66
13.1	23.9	40.3	35	101.7	49.5	60.3	149
43.6	30.7	28.6	52	83	120.3	98.5	37.6
52.5	75.1	46.9	53.8	42.5	39.4	0	22.2
0	47.2	16.9	15.7	58.6	74.5	166.2	40.9
							Avg. 49

Client 1 Active Mid Profile (RIT)

46.3	0	13.4	35.4	0	0	30.2	
55.1	0	129.3	46.6	93.2	49.3	90.7	
54.7	47.8	55.8	0	40.3	90.1	19.1	
17.4	0	0	13	0	0	21.4	
57.7	39.1	128.6	20.8	0	69.4	72.3	
25.4	0	0	0	38.1	27	0	
0	13.1	0	76.5	30.4	0	10.2	
0	0	0	0	0	0	17.4	
							Avg. 28.13

Client 1 Standard (LIT)

57.1	57.6	46.1	71	69.8	74.7	59.1	53.9
61.8	56.3	53.2	87.4	97.5	112.7	84.5	62.2
63.4	75.6	93.1	125.5	163.3	189.8	138.5	80.5
84	108.2	131.6	175.3	234.8	245.4	151.3	76.8
73.6	107	159.2	244.8	256	255.9	143.3	81.4

77.7	127.4	196	256	256	256	146.8	101.3
73.6	131.7	204.7	256	256	256	199	117.1
40.2	106.2	167.6	226.5	223.2	207.4	156	104.5
40.2	69.9	121.7	149.1	159.9	152.2	140.3	98.8
11.8	30.9	73.1	110	116	124	101.9	77.5
11.8	34.7	63.4	101.6	108.3	104.5	81.2	85.6
							Avg. 123.57

Client 1 Standard (RIT)

16.6	10.2	46.7	42.2	41.3	36.2	38	
45.6	37.8	57.9	67.9	56.6	51.1	37.8	
67.5	68.5	77	58.9	66.7	28.8	0	
60.7	115	111.5	91.5	85.8	48.4	40.1	
63.1	221.1	158.2	236	42.5	19.8	25.8	
51.7	209.1	149	118.1	144.3	75.2	49.1	
13.6	88.9	85.9	32.2	66.9	40.9	39.7	
40.6	25.2	52.8	31.3	15.9	33.8	10	
							Avg. 41.443

Client 1 Standard Low Profile (LIT)

31.1	26.6	55	78	63.1	25.9	0	0
68.9	26.3	0	0	0	0	25.7	0
14.1	15.8	73.5	22	10.5	44.7	0	0
84.8	134.6	102.9	101.9	51.8	14.7	21.8	0
32.7	41.8	83.5	0	0	51.6	27.8	20.6
22.1	122	30	35	0	56.9	10.2	13.8
49	59.2	40.3	32.1	22.9	0	76.3	0
0	0	20.7	21.2	0	0	0	16.2
0	28.3	0	0	0	0	20.5	0
20.9	17.1	0	0	0	0	74.5	27.4
20.2	28.5	0	11.5	0	0	44.6	74.7
							Avg. 26.67

Client 1 Standard Low Profile (RIT)

52.6	0	40.3	36.8	34.4	72	22.7	
0	0	30.3	26.3	0	34.7	63.3	
0	30	49.6	77.5	20.4	55.9	49.6	
68.8	28.2	38.2	0	34.4	34.1	0	
57.7	39.7	49.6	45.6	0	81.7	38.6	
62.1	0	47.2	19.9	0	19.9	61.4	
33	43.5	49.5	104.4	35.1	89	27.6	
21.5	11	0	0	0	30.4	11.9	
							Avg. 21.373

Client 1 Standard Mid Profile (LIT)

36.5	0	33	136.4	94.1	111.7	28.1	47.6	
40.5	118.8	63.7	119.7	138.2	87.5	56.9	48	
58	100.5	118.3	132.6	127.1	101.8	117.2	57.8	
96.5	165.5	104.4	140.8	115.1	114.1	50.2	110.3	
97.8	112	110.8	106.7	108.3	96.2	72.1	29	
79.7	101	137.8	119.8	90.9	94.7	154.3	60.3	
89.7	63.3	82.9	114.1	114.7	114.2	114.7	59.2	
129.1	150.7	120.3	111.1	91.5	109.6	65.2	10	
58.9	82	81.7	89.8	117.1	165.4	44.9	0	
48.2	58.6	88.7	83.1	66.9	76.9	80	37.4	
48.9	54	37.7	28.5	75.7	10.6	48.4	44.1	
							Avg. 85.344	

Client 1 Standard Mid Profile (RIT)

17.2	32.6	59.9	48.4	92	73.6	54.5	
49.2	0	78.5	27.9	93.3	61.4	78.3	
222.5	0	0	40.9	39.1	35	89.8	
13.6	69.4	0	0	69.1	34.5	35.2	
0	50.6	93.8	52	0	71.5	60.1	
39.7	22.3	35.9	21.1	18.9	69.6	48.3	
0	40.1	59.9	136.4	68	61.5	31.9	
0	10.2	46.8	67.4	20.3	0	15.8	
							Avg. 29.07

Client 2 Active Foam (LIT)

56.3	75.4	83.8	95.6	104.9	84.8
59.7	104.9	123.1	162.9	179.9	89.7
70.1	105.5	122.8	219.1	225.9	91.6
81.6	129.4	168.3	217.9	160.4	84.5
77	135.9	172.3	198.4	122.5	77.4

42.2	106.8	180.1	131.9	123.6	73
27	72.8	104.3	91.3	90.2	64.4
					Avg. 114.03

Client 2 Active Foam (RIT)

90.1	100.5	91.9	81.8	85.1	66.8
102.4	191.4	201.8	124.4	90.9	56.8
91.4	177	239.6	184.1	96.8	81.7
66.4	137.3	198	214.9	126	65
90.8	104.2	145.8	156.3	138.3	76.6
79.8	89.4	113.9	123.7	113.3	61.3
71.5	75.2	88.5	92.9	82.6	27.1
					Avg. 90.2

Client 2 Active Foam Low Profile (LIT)

175	32	119.8	120.6	14.8	188.6
81.5	168.2	49.3	53.9	125.7	100.1
67.1	19	86.9	76.4	11	90.5
59.3	0	89.2	90.5	23.6	64
89.7	31.3	123	109.8	49.9	81.8
121.4	80.1	163	168.8	88.1	109
41.3	110.2	115.3	100	17.8	63
					Avg. 84.54

Client 2 Active Foam Low Profile (RIT)

63.8	12.4	27.3	12.4	41	47.1
96.7	136.4	68.9	129.5	95.6	133.6
54.2	0	37.7	29.5	0	0
47.5	65.9	23.4	44.9	33	50.1
153	197.8	0	47.3	60.6	91
87.6	128.6	0	161	79.4	43.3
42.7	42.1	0	27.5	0	0
					Avg. 57.45

Client 2 Active Mid Profile (LIT)

36.6	19.4	37.7	42	10.2	0	
88.6	40.5	33.3	0	25	11.5	
0	0	0	37.2	46.1	16.3	
70.7	38.5	14	63.7	19.5	0	
92.6	0	0	0	0	17.2	
25.2	36	28.1	36	0	0	
0	93.3	73.5	38.8	166.9	41.7	
						Avg. 30.95

Client 2 Active Mid Profile (RIT)

22.9	0	0	35.1	35.6	56.7	
35.6	50.2	12.2	38.8	143.3	21.7	
69.6	113	81.4	70.4	0	13.2	
95.7	36.9	0	0	0	0	
0	68.9	113.4	0	0	56.7	
149.6	149.7	117.1	65	17.7	0	
49.9	49.2	46.7	85	47.7	11.2	
						Avg. 46.67

Client 2 Standard Foam (LIT)

0	0	51.3	0	0	0	
63.3	74.1	192.9	227.8	121.7	0	
77.5	138.3	217.7	255.5	256	96.4	
77.7	147.8	250.3	256	230.4	111.7	
66.4	146.8	234.7	246.4	178.7	101.1	
68.4	121	191.8	186.4	159.1	80.4	
34.6	75.4	123.4	118.2	105	77.3	
						Avg. 122.89

Client 2 Standard Foam (RIT)

90.1	175	209.3	129.9	104.5	85.1	
92	254.8	255.8	201.7	101.9	75.1	
47.6	164.8	256	246.6	123.4	81.1	
0	256	200.8	203.9	157.6	98.1	
0	0	0	227.6	202.3	43.7	
79.7	137.7	171.2	0	0	0	
68	94	107.8	96.1	89.4	0	
						Avg. 116.16

Client 2 Standard Low Profile (LIT)

175	32	119.8	120.6	14.8	188.6	
81.5	168.2	49.3	53.9	125.7	100.1	
67.1	19	86.9	76.4	11	90.5	
59.3	0	89.2	90.5	23.6	64	
89.7	31.3	123	109.8	49.9	81.8	
121.4	80.1	163	168.8	88.1	109	
41.3	110.2	115.3	100	17.8	63	
						Avg. 84.54

Client 2 Standard Low Profile (RIT)

63.8	12.4	27.3	12.4	41	47.1	
96.7	136.4	68.9	129.5	95.6	133.6	
54.2	0	37.7	29.5	0	0	
47.5	65.9	23.4	44.9	33	50.1	
153	197.8	0	47.3	60.6	91	
87.6	128.6	0	161	79.4	43.3	
42.7	42.1	0	27.5	0	0	
						Avg. 57.45

Client 2 Standard Mid Profile (LIT)

29.4	15.8	93	84.4	11.4	51.2	
18.4	0	24.2	0	61.9	31.6	
74.5	68.6	42.2	27.9	80.8	12.1	
0	0	0	17.1	14.4	57.2	
0	51.2	17.1	37.3	29.3	16.1	
13.6	32.5	24.8	40.4	0	14.2	
48.5	31.2	47.3	51	45	0	
						Avg. 31.32

Client 2 Standard Mid Profile (RIT)

71.8	10.2	30.8	70.3	40	25.7	
80.8	35.6	83.3	117.7	77.6	0	
36.9	85.7	88	78.1	59.2	0	
0	0	19.6	126.6	117	35.8	
0	0	20.5	27.3	84	134.2	
0	0	0	56.1	117.7	64.1	
13.2	45.9	60.4	21.4	17.4	0	
						Avg. 46.50