THESIS

IDENTIFYING FIT ISSUES FOR THE ONE-SIZE-FITS-ALL HOSPITAL PATIENT GOWN: AN ANTHROPOMETRIC APPROACH

Submitted by

Daniela Jankovska

Department of Design and Merchandising

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Master's Committee:

Advisor: Juyeon Park

Yan Ruoh-Nan
David Greene

ABSTRACT

IDENTIFYING FIT ISSUES FOR THE ONE-SIZE-FITS-ALL HOSPITAL PATIENT GOWN: AN ANTHROPOMETRIC APPROACH

The purpose of this study was to identify fit issues associated with the hospital patient gown in order to facilitate a better fit and comfort of the hospital patient gown to as many potential patients as possible. To address the research questions, this study adopted a multi-dimensional fit and comfort evaluation protocol that consisted of a survey, 3D body scanning, scenario activities, and exit interview. Eighty-five participants (47 males and 38 females) participated in this study. The exploration of the fit and comfort of the hospital patient gown across gender, diverse age, and different BMI categories revealed three major issue that must be taken into consideration in order to achieve an the best fit and size for the hospital patient gown: (a) consideration of sensory clothing preferences and hospital patient gown design preferences, (b) 3D body measurements and (c) accommodation to common daily activities such as, walking, laying, bending, reaching up and sitting during hospitalization. Three-dimensional body scanning data identified the following anthropometric body landmarks that caused fit problems: neckline, shoulders, sleeves and armholes, bust/chest, abdomen and stomach, hips and knee circumference. The findings of the study suggest that there are major fit issues with the conventional hospital patient gown, which must be adequately addressed to provide its wearers with acceptable satisfaction with the fit of the gown.

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DEFINITIONS OF TERMS

Anthropometrics	The gathering and analysis of human body measurements (Stirling, 2002, p.5).
Fit	Fit usually has two aspects: comfort (decided by the wearer) and appearance (look, style, and fashion, as decided by the designer or manufacturer) (Broorday, 2011, p. 344).
Body Mass Index (BMI)	BMI is a person’s weight in kilograms divided by the square of height in meters. Formula: weight (kg) / $[\text{height (m)}]^2$ (Center for Disease and Health Prevention, 2012).
Comfort	The pleasant state of physiological, psychological and physical harmony between a human being and the environment (Slater, 1986, p.158).
Sensory Comfort	The stimulation of mechanical, thermal and visual sensations when the clothing is in direct contact with the human body (Li & Wong, 2006, p. 3).
Ergonomic	Ergonomics firstly relies on human capabilities and their limits to design products adapted to the characteristics of the human component, and secondly on studying human activity (Sagot & Gomes, 2002, p. 137).
Scenario Building	Scenario building offers a rapid and inexpensive way of visualizing early design ideas and examining them in the context of human use (Suri & Marsh, 1999, 151).
3D Body Scan	An industrial tool to measure and compare three-dimensional objects at varying stages of assembly for the process of product development

	(Ashdown, et al., 2004, p. 1).
Functional Ease	The need of a garment to accommodate and adapt to the user's movement (Boorady, 2011, p.345).
Functional Ease Formula	Discrepancy between the person's body and the garment. Formula: 3D garment measurement – 3D baseline measurement = functional ease (Langseth-Schmidt, 2014)
Hospital Patient Gown	Apparel attire worn by patients in a hospital setting.

CHAPTER ONE: INTRODUCTION

1.1 Background & Justification

Although the development of medical technology has dramatically advanced in the past 80 years, the hospital patient gown, designed in the early 20th century, has remained almost the same since its development (Cho, 2006; Ulrich et al., 2008). Hospital patient gowns affect the lives of nearly all humans since it is almost certain that one would come across its use at least once in their lifetime. Despite the importance of this apparel, research on the design and functionality of the hospital patient gown has been minimal and it often falls outside of the scope in empirical studies. As a result, there is insufficient and incomplete academic guidance to improve the features of current patient gowns, and thus the medical apparel industry does not have a product yet that fully meets the needs of both patients and medical personnel. Attempts to modify medical gowns have been largely unsuccessful. In addition, hospital patient gowns have become confusing and complex to put on and off. However, hospital patient gowns designs that are modified in order to give patients more dignity and coverage, and provide more flexibility and accessibility in use by the healthcare providers still do not address the fit and sizing issues adequately and sufficiently, which makes all design attempts lacking.

Three general steps need to be completed before a commercially viable product can be sent to manufacturing: identification of the problems of the current product, a new design proposal and finally a universal fit and sizing of the new patient gowns. There is sufficient literature that covers the first two steps and selected studies have been described in the literature section below. This study focuses on the third step and utilizes these findings to deliver the next step in the improvement of the hospital patient gowns. It aims to identify fit issues of the conventional hospital patient gown via novel estimation methods.

Multiple studies have found that the current gowns have shortcomings, and it is very important to note that its diverse functionality is a concern of both patients and healthcare providers. A study by Park (2014) found that the patients were moderately dissatisfied with the design and fit and comfort of the hospital patient gown. It was indicated that the patients believed the current gown was practical for medical purposes, thus they were tolerant with the gown, while the healthcare providers did not think it was medically practical as much as the patients did. Park (2014) implies that patients tended to be relatively more tolerant of the design and performance of the current gown due to the strong beliefs that the existing hospital patient gown holds certain medical benefits. More specifically, the patient gown is known to be not practical in medical procedures, such as taking temperature and blood pressure, cardiac monitoring, delivering intravenous injections by healthcare professionals and patients alike (Black & Torlei, 2013; Jha, 2009). The main finding of these studies is that the conventional hospital patient gown has a major fit problem, which results in lack of comfort, mobility and accessibility. Thus it has been previously highlighted that it is necessary that an adequate size and fit be identified for this universally used garment and this study will directly address this issues. It will be crucial in adjusting the fit and therefore prevent future difficulties with body movement, donning and doffing, as well as easy and quick access of the patients' body (Cho, 2006; Jha, 2009). That is, hospital patient gowns should be sized to increase the overall functionality in terms of fit and comfort, as well as consider physiological, and psychological clothing comfort factors. This study aims to do this by delivering the ideal and insightful solutions for adequately addressing the fit, comfort and size of the newly designed gown.

Empirical results suggest the gown-sizing problem has persisted over time as well. Even after multiple patented efforts to improve the functionality and accessibility of the patient hospital gown (e. g., U.S. Patent No. 1962515 A, 1923; U.S. Patent No. 2701364 A, 1955; U.S. Patent No. 4686715 A, 1987; U.S. Patent No. 6237153 B, 2001), it is still strongly being suggested that sizing needs to be addressed before a new gown can be successfully adopted within the healthcare system (Cho, 2006; Gordon and Guttmann, 2013). In addition, it was indicated that if sizing were not adequately addressed, the issue of comfort and modesty would negatively affect the patients' overall hospital gown experience (Ulrich et al., 2008). However, the appropriate size is hard to find, because the process involves multiple factors and it faces issues such as outdated anthropometric data, lack of standardized sizing system, lack of precise body measurements, lack of fit analysis methods, and variations of body shapes and proportions (Apeagyei, 2010; Ashdown, 1998). Hospital gowns, available on the market, include a single front panel, two back panels, sleeves and a rear opening with two ties (Cho, 2006). This design has been known to offer limited functionality and difficulty in use for several parties, particularly for patients (Black & Torlei, 2013; Cho, 2006; Park, 2014). This study approaches the fit and sizing problem differently and it hopes to improve the fit, as well as to propose the usage of a new method that solves the aforementioned design problems.

In addition, the literature has shown that addressing the fit and size of the conventional hospital patient gown can contribute to multiple improvements in the physical, socio-psychological and environmental surroundings of the patients (Cho, 2006; Ulrich et al., 2008; Park, 2014). For instance, poor fit can restrict body movement when the garment is too tight or loose such as, walking, reaching, or bending; it can limit the overall physical comfort by hindering the ease of donning and doffing; and it can contribute in developing several socio-psychological issues such as, embarrassment when the garment does not fit properly by revealing certain body parts (Cho, 2006; Park, 2014). In addition, poor fit of the hospital patient gown can also lead to limited environmental protection when the garment does not fit properly such as, higher risk of exposing certain body parts (i.e. the buttocks and the back) to the outside environment thus, making those patients who are recovering from post-operation or the elderly (since they have more sensitive skin) more prone to attract bacterial infections. Ulrich et al., (2008) indicated that hospital-acquired infections in hospital settings are very common and leading cause of death in the United States. They argued that the design of the physical environment impacts nosocomial infection rates by affecting all three major transmission routes, such as air, water and contact with other healthcare design (i.e. hospital patient attires) and its environment. In order to make hospitals safer and more healing for patients, they proposed a well-design healthcare setting including the revision of the current hospital patient gowns.

The scope of this study included an extensive search for existing literature on sizing of hospital patient gown, and to the best of the author's knowledge, no studies have attempted to identify an anthropometric solution for a hospital patient gown, with the use of three-dimensional (3D) body scanning technology. The industry revolutionizing three-dimensional (3D) body scanning technology has greatly impacted the development of research and practice in the textile and apparel industry (Istook & Hwang, 2000). The 3D body scanning technology provides rapid and accurate analysis of fit by quantifying the functional ease and the distance between the body and the garment at critical locations. 3D body scanning technology is known to provide with the most effective and accurate body measurements in fit analyses (Apeagyei, 2010; Istook & Hwang, 2000). This research proposes to understand the benefits of this advanced technology in enhancing the fit and comfort of a universally used garment such as, the hospital patient gown.

1.2 Purpose

The purpose of the study is to identify fit and comfort issues associated with the conventional hospital patient gown and to propose insightful solutions that can adequately address these issues of this universally used garment in order to better facilitate the fit and comfort to as many potential patients as possible. This study will adopt multi-dimensional measurement methods including (a) demographic and preference survey questionnaires, (b) 3D body scanning, (c) scenario activities, and (d) exit interview. In particular, this research intends to understand the benefits of 3D body scanning technology in enhancing the fit and comfort of a universally used garment such as, the hospital patient gown. The 3D body scanning technology will be used to provide rapid and accurate analysis of fit by quantifying the functional ease and the distance between the body and the garment at critical locations.

1.3 Research Questions & Hypothesis

This study will identify fit issues associated with the hospital patient gown for the patient gown to facilitate a better fit and comfort to as many potential patients as possible. To achieve the research goals, the following hypotheses are developed, and will be evaluated in this study:

H1: There will be significant differences in the fit and comfort of the hospital patient gown across gender.

H2: There will be a significant relationship between the fit and comfort of the hospital patient gown and age of the individual.

H3: There will be significant differences in the fit and comfort of the hospital patient gown among different BMI groups.

1.4 Limitations

There are several limitations for this study. The generalizability of the study is limited due to the limited sample size and geographical location from which the participants will be recruited. Although the physical profiles of participants will vary, as might their state/country of origin, all of the participants will be recruited from one geographical region (i.e., The State of Colorado). In addition, the study will be conducted in a laboratory setting rather than a real hospital setting, which is a more controlled environment and contributes to the overall limitations of the study. Lastly, I acknowledge that the recruited participants will be relatively in stable physical and mental conditions, and thus this could impact the overall evaluation of the fit and comfort of the hospital patient gown that is typically worn by physically impaired patients.

1.5 Originality of the Study

This study is unique in its sense that it will provide novel information in the improvement of the conventional hospital patient gowns. This study will aim to improve the fit and comfort of the conventional hospital patient gown via novel estimation methods, which will improve the overall mobility and performance of the gown. Additionally, this study will attempt to provide insightful solutions on how optimum size can be achieved, which will aid in the further enhancement of the fit and comfort of the hospital patient gown. In addition, this study will fill a gap in academic literature by providing evidence-based insights into the improvement of the fit of the gown. Thus, the study will provide the medical apparel industry with essential information on the future development of the hospital patient gown.

CHAPTER TWO: REVIEW OF LITERATURE

2.1 Previous design attempts for hospital patient gown

The relevant literature shows that quite a few attempts have been made to improve the conventional hospital patient gown to provide hospital caregivers with greater ease in accessing the patient's body but few have focused on the needs of the patients. There are hundreds of patented patient gowns on the market including a set of different physical and aesthetic attributes. Studies have shown that a lack of good clothing fit can affect the patient's psychological and physiological state of mind, in particular how they view themselves and others when wearing the hospital patient gown (Cho, 2006). In addition, because this garment is usually unisex and has a one-size-fit-all standard, the fit, comfort and aesthetic attributes are often compromised. Hospital patient gowns are typically formed from a unitary piece of material with a releasable fastener in the back. Since the gown opens in the back, the patient's backside is often exposed and the use of an undergarment is required in order to accommodate for adequate coverage of the patient. Moreover, studies have indicated that patients were dissatisfied with expressive and aesthetic attributes of the patient gown in overall quality ($x = 3.44$), gown color/pattern ($x = 3.45$), fabric texture ($x = 3.66$), dignity ($x = 2.77$), embarrassment ($x = 3.42$), and security ($x = 3.44$) (Park, 2014). Although there are several designs of hospital patient attires being patented, a survey of the literature did not show any clear evidence of a large-scale adoption of new hospital patient gowns by the hospitals in the United States.

Black and Torlei (2013) examined a case study that was set to redesign new hospital clothing for UK consumers looking at a user-centered design perspective. They concluded that although the hospital gowns mostly meet the inclusive needs of the garment, it does not meet all hospital needs, especially those for patients in intensive care. The researchers of this study created a new gown design called "Origown" featuring a single piece of fabric that was cut in a way that it transformed from flat into a three-dimensional garment through the process of dressing the patient, while being secured by adhesive stickers (Black & Torlei, 2013, p. 157).

Along the lines, Cho (2006) also proposed two prototypes of the new hospital patient gown that focused on the patient-oriented design features. Prototype A was an A-line style gown with a front opening, enclosed raglan sleeves and a triangular-shaped, free float area in the front. It also featured a back-slit overlap. Prototype B was composed of four panels: three panels in front and one panel in back with cap sleeves, and a front-slit overlap, as well as openings on the upper chest area, and an opening from the armpit to the hem on the right side. Moreover, one of the prototypes was found more suitable than the other in terms of addressing the user's satisfaction of the gown, however, it was marked as lacking medical practicality due to its lack of exploration as well as applicability across both genders.

Moreover, a design by Burbidge (U.S. Patent No. 6012199, 2000) shows a shoulder opening that is extended from the shoulder to the sleeve, which would allow for easier access to the patient's back by opening the closure. In addition, Park (2014) and Gordon and Guttmann (2013) also proposed great designs with major improvements on the conventional hospital patient gowns, which indicated increased satisfaction by the patients and/or healthcare providers. However, both studies indicated that before any design is to be considered on a larger scale adoption, further evaluation of the fit, comfort and sizing of the gown needs to be addressed.

2.2 The Need for Anthropometric Measurements and the Tools Performing Those Measurements

Pheasant (1990) states that anthropometrics is the branch of ergonomics, which deals with and focuses on the measurements and proportions of the human body. Specifically, body shapes and sizes. Although anthropometry can be found in many disciplines of design, one of the most popular is apparel design. Ashdown et al., (2005) argue that the combination of fit data and anthropometrics population is especially essential in developing effective sizing systems for various apparel products. The study states that over 50% of women cannot find satisfactory fitting clothes and given that fit is often one of the main reasons given by consumers for deciding whether to purchase the clothing or not, therefore, the urgency to develop a standardized sizing system or find a way to optimize the clothing size has been greatly increased. Clothing should be comfortable and should not hinder the task at hand. In addition, Paquet, Pena and Victor (2011) state that in order to find the best fit, anthropometric and 3D data should be used together as they yield complimentary results.

As mentioned before, traditionally, anthropometric data were taken manually with simple instruments like tape measures and calipers. However, with the advancement of technology and engineering, 3D surface anthropometry has been utilized in recent years (Park, Nam, Lee & Park, 2009). The developments of 3D body scanners have opened opportunities for measuring the human body more efficiently and accurately (Lu & Wang, 2008). It has been argued that anthropometric characteristics are often related to nutritional characteristics and contribute to factors, such as environmental, lifestyle, health, sociocultural conditions and functional status. For this matter, when anthropometric are being considered, it is recommended that non-pathological factors, such as age, gender and geographical area are taken into account

(Perissinotto, Pisent, Sergi, Grigoletto & Enzi, 2001). This is one of the reasons that contributed toward categorizing the participants of this study by gender, age, and body mass index (BMI).

2.2.1 Fit Analysis

Xu, Huang and Chen (2002), report that the 3D scanning systems provide surface data of a body measurement rapidly and accurately by utilizing a multi-line triangulation technique, which is definitely unattainable by the conventional measuring methods. Body scanning technology and the accompanying software applications enable apparel manufactures to produce custom design to all customers who are seeking personal fit garments. Until recently mass-customization has been challenged in obtaining accurate measurements through traditional anthropometric methods. Lu & Wang (2008) refer to anthropometry as the study that describes dimensions of the human body. Traditionally, human body dimensions have been measured using tapes and calipers, which can be time-consuming and involves direct contact (Kohn & Ashdown, 1998; Meunier & Yin, 2000). Recently, a great number of Western countries endeavored to use 3D scanners to conduct national anthropometric surveys, expanding the popularity of 3D scanning technology.

Simmons and Istook (2003) assert that reliability is closely attached to precision and dependability, and in order for the body measurements to be accurate and reliable they need to be free of any potential errors. The subjects' positioning and instrument application can catch these errors. The traditional methods used to obtain anthropometric data include the following: physical measuring with weight scale, measuring tape, camera (to take photos and videos), spreading clippers or head spanners, which tend to be much less effective and accurate than the 3D body scanners (Kohn & Ashdown, 1998).

In addition, Simmons and Istook (2003) reported several instructions of how to obtain body measurements as accurately as possible. They assert that the posture is highly significant as is wearing minimal clothing. For instance, asking the subjects to adopt a standard stationary posture while holding still for a few seconds can minimize the effect of body movement. Segmenting the 3D scan data at the armpits and crotch can help get the scanning data ready for landmarking (Lu & Wang, 2008). Moreover, using the proper instrumentation such as the ones listed above and correct identification of body landmarks are necessary in the collection of accurate anthropometric data. The results from Simmons and Istook's (2003) study indicated that the body scanning measurement techniques were accurate, instant and did not require any contact.

Defining universally what a well-fitted garment is will depend from one individual to another. Song & Ashdown (2010) reference five factors that help define what good fit is combined of, and they are the following: ease, line, grain, balance and set. They state that clothing that is well-fitted will provide a good balance, adequate amount of functional ease, design ease, and desired silhouette of the body. One of the main reasons why it is so hard to find the appropriate size is because this problem is associated with several factors such as, outdated anthropometric data, lack of standardized sizing system, lack of precise body measurements and lack of variations of body shapes and proportions (Apeagyei, 2010; Ashdown, 1998). Song and Ashdown (2010) state that one of the major issues with fit analysis is the poor visual view and the resolution of the images. 3D scanners can easily eliminate these issues as they have significantly higher resolution than any other camera device and can allow the investigators to rotate, zoom-in, and identify any loose fit and wrinkles. Moreover, they make it easy to understand the depth, origin and path of stress folds around the body. Given this advanced technology we have in today's society, we are able to design a better suiting sizing system that will accommodate a wider variety of body shapes and proportions.

2.2.2 Three-dimensional body scanning technology

Three-dimensional (3D) surface scanning technology was initially developed as an industrial tool to measure and compare 3D objects at different stages of the assembly for the process of product development (Ashdown et al., 2004). Although it was generally used in different industrial sectors, such as engineering and product manufacturing, apparel researchers have adopted this technology for the creation of well-fitted garments (Simmons & Istook, 2003). 3D body scanning technology is known to provide the most effective and accurate body measurements in fit analysis (Apeagyei, 2010; Istook & Hwang, 2000).

3D body scanners provide comprehensive and objective analysis of fit by quantifying the functional ease and the distance between the body and the garment at critical locations using merged cross-section scans; it can also challenge the validation of the sizing system by visualizing body proportions and shapes more clearly and accurately. Although there are few studies that use 3D scanning for visual analysis, there are even fewer to no studies that investigate fit analysis and optimum dress size for a universally used garment like the hospital patient gown. Song and Ashdown (2010) report two main advantages of using 3D body scanning technology. First, 3D body scanners are very quick and can generate over 400 measurements in 5-15 seconds per scan. Secondly, 3D body scanners are capable of capturing 3D visual images, which can be used to identify the participants' body shapes and proportions. This innovative tool has the potential of not only improving sizing systems but also fitting garments on target market consumers.

The ability to customize garments for fit is not only tied to the ability of generating comprehensive measurements but also accurate and efficient measurements. In the apparel industry, approaching a customer's perception of good fit is almost impossible without a set of accurate measurements. Istook and Hwang (2001) reported several beneficial reasons for why 3D body scanning should be used in the apparel industry. Some of them are the followings: obtaining an unlimited number of linear and non-linear measurements of the human body in seconds; obtaining measurements in a more sustainable way by providing precise and reproducible measurements; the time and effort it saves in obtaining these body measurements, which can also serve as 3D objects where garments can mold around them and create apparel; and lastly, 3D cans can be automatically uploaded to apparel CAD systems without additional efforts, which saves on time and potential errors.

The benefits of 3D body scanning can be detrimental to the success of the apparel industry, especially the online apparel businesses (Apeagyei, 2010). In a study by Ashdown et al., 2004, one of objectives of the study was to contribute towards obtaining ways of measuring and analyzing fit that will be beneficial for apparel companies to better understand their customer's wants and needs and to make recommendations on how to design better sizing systems. Simmons and Istook (2003) reported that it is a major frustration for consumers to find apparel that is comfortable and fits properly and one of the main reasons that are contributing to this frustration is the lack of standardization in the current sizing systems. Ultimately, 3D scanning technology enables the apparel industry to produce mass customized garments, which is a growing market and improve the imperfections of the current sizing system (Apeagyei, 2010; Ashdown, Loker & Rucker, 2007). The 3D body scanning technology can capture actual body measurements and provide great reliability and accuracy, which can help identify where an individual is placed within a population (Song & Ashdown, 2013).

CHAPTER THREE: METHODS

3.1 Research Design

The term fit in terms on functional garments encompasses aspects of the wearer's perceived psychological, physiological, and physical comfort, as well as the garment's overall mobility, performance and appearance (Broorday, 2011; Li & Wong, 2006). Qualitative and quantitative data collection methods were used in an attempt to gain a holistic view of the current fit, comfort and sizing issues of the hospital patient gown. Survey questionaries' were used to collect quantitative data on the participants' experience with the fit, comfort and sizing of the hospital patient gown. The anthropometric measurements were obtained using a 3D body scanner where 15 body measurements were selected out of the possible 300+ available measurements. Fit and comfort issues were assessed with the help of scenario activities which were designed to specifically address these issue among potential patients in the hospital setting by performing common physical activities, such as walking, lying, bending, reaching and sitting. Furthermore, qualitative data were collected during an open-ended exit interview sessions with almost all of the recruited participants.

3.2 Study Participation and Recruitment Strategies

Purposeful sampling was used to recruit adult participants who represented diverse body profiles, did not have history of musculoskeletal problems, and resided in the Midwestern region of the United States, near the researcher's university. Flyn and Foster (2009) state that purposeful sampling is used in novel research circumstances when the topic being investigated is new or not feasible to do random sampling. To the best of the author's knowledge, no studies were found that investigated the fit (or sizing) of the conventional hospital patient gowns; hence, no methodological approaches were previously proposed.

The Institutional Review Board (IRB) at Colorado State University approved the protocol of this study before any data was collected (See Appendix A for IRB approval letter). Some of the participants were recruited from selected classes from the researcher's university where the recruited participants were compensated with the opportunity to earn 5 extra credit points. Those who did not wish to participate got the opportunity to do another assignment and earn the same amount of extra credit points. E-mail was sent to each one of the classes with contact information of the researchers and further information of the study protocol, purpose and intentions (See Appendix B for recruitment e-mail). Moreover, other participants were recruited via e-blast emails, which were similarly drafted (containing the same recruitment letter) as the e-mails sent to the students recruited from the classes; however, these participants were offered monetary compensation, which ranged from $5 (30 minutes) to $10 (1 hour) depending on the time it took to complete the. The e-blast email was sent to over 3,500 students from various departments at Colorado State University. In addition, in order to recruit as diverse sample as possible (considering males and females with different ages and BMIs statuses), the researchers of the study also recruited participants from the local community within the State of Colorado, and the Adult Learner and Veteran Services Center from Colorado State University by leaving flyers and sending e-mails, which were distributed to the members of these organizations (see Appendix C for the recruitment flyers). Last but not least, the researcher's of the study applied a snowballing method though which they recruited several dozen participants. Some of the participants volunteered to participate in the study; hence, they did not accept the monetary compensation. In this case, they marked off the monetary compensation section from the consent form and initialed the document for future purposes.

Prior to scheduling a visit to participate in the experiment, to ensure the diversity of demographic and physical profiles, the participants were asked to provide their age, gender, height, and weight. All of the participants complied with the initial pre-screened inclusion criteria and did not report having any musculoskeletal problems. Based on these inclusion criteria, eighty-five participants were selected to participate in this study and were scheduled and appointment to visit the research lab. There were 2 participants whose data was missing due to technical difficulties; hence, their data contribution was excluded from the analysis. One day before the lab visit, the researchers of the study sent a reminder email to the participants to confirm their schedule details. The experiment took place in the Human Body Dimensioning (HBD) Lab, located in Gifford 141 Building at Colorado State University Campus. Each session took from 40 to 60 minutes, and data collection was conducted from February to early April 2015.

3.3 Pilot Study

Prior to the data collection, a pilot study was conducted with 1 male graduate student from the Department of Electrical Engineering and 1 female graduate student from the Department of Design and Merchandising at Colorado State University. The purpose of the pilot study was to improve the clarity and validity of the overall data collection protocol. The pilot study participants donned the hospital patient gown and walked slowly through the whole data collection process raising valid questions and suggestions regarding the instrumentation and timing of the study. In addition, all comments and suggestions were taken into consideration by the researchers. The same researcher conducted the pilot study and the main study appointments in order to maintain the reliability of the data collection.

3.4 Data Collection Procedures

Upon arrival at the HBD Lab, the researcher greeted the participants, explained the purpose of the study and outlined the experiment process of the participant (See Appendix D for data collection outline). Following the outline of the experiment, the researcher asked the participant if they had any questions and/or concerns about the study. The participants were then asked to read and sign one out of two consent forms depending on their recruitment background before they started their participation in the study. The difference between the 2 consent forms is in the compensation section where one was offering extra credit opportunity points (See Appendix E for consent form A) and the other was offering up to $10 of monetary compensation (See Appendix F for consent form B).

Mixed data collection methods were used to gain a holistic understanding of the fit and comfort perception of the hospital patient gown among the participants, in the forms of: (a) demographic and preference survey questionnaires, (b) 3D body scanning, (c) scenario activities, and (d) exit interview. Figure 3-1 presents the data collection process in more detail.

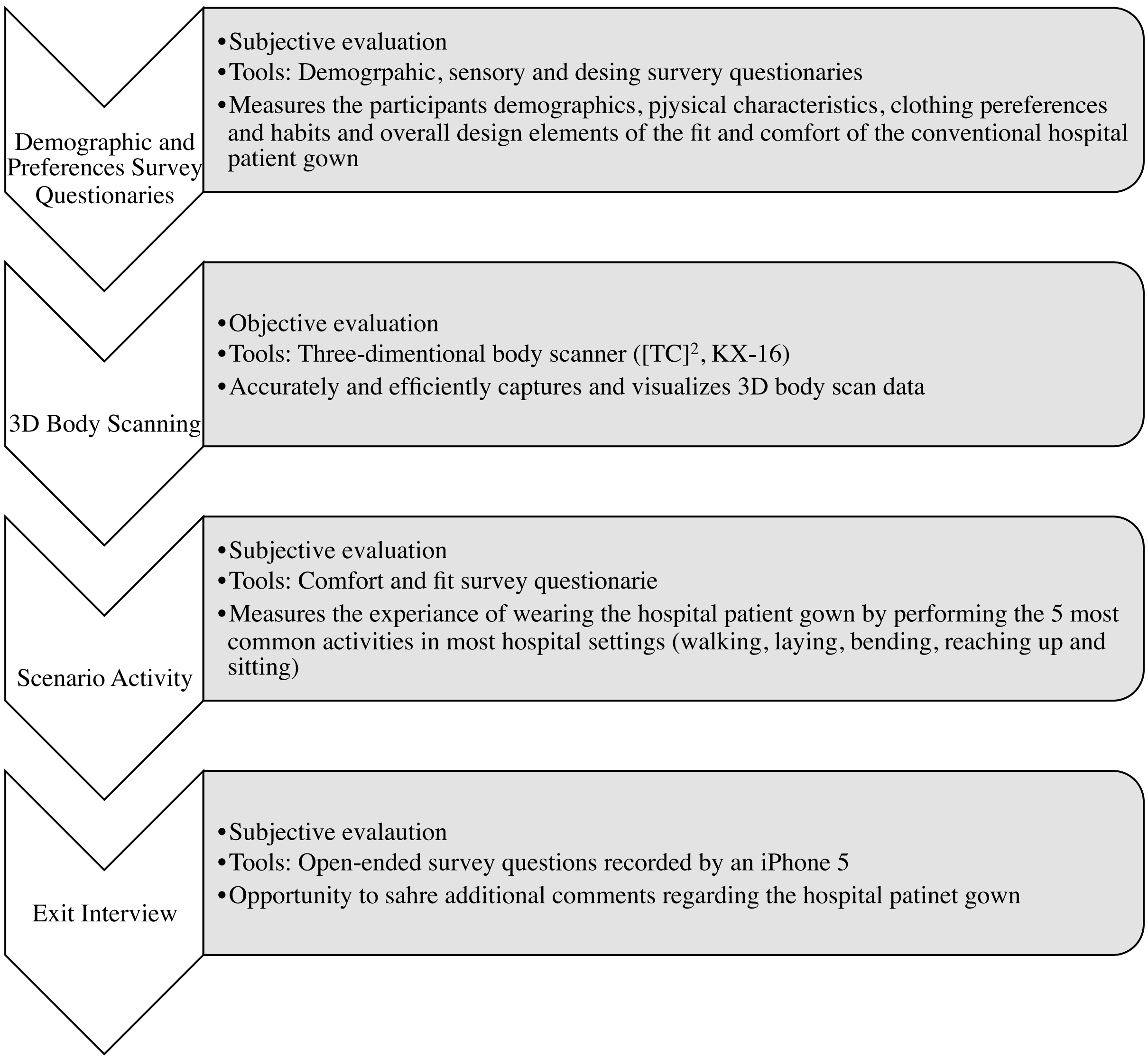


Figure 3-1. Data Collection Process

3.5 Demographic and Preference Survey Questionnaires

At the lab visit, the participant was asked to fill out a survey questionnaire that consisted of the three main sections including demographic profiles (See Appendix G for demographic survey), sensory clothing preferences (See Appendix H for sensory clothing preferences survey), and hospital patient gown design evaluation (See Appendix I for hospital patient gown design survey), which took approximately 30 minutes to complete. The demographic profiles section asked sex, age, height, weight, ethnicity, education, marital status, and clothing size, along with history of musculoskeletal problems. The sensory clothing preferences survey consisted of 16 sensory questions, which measured the participants clothing habits and preferences on a 5-point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree). Additionally, 2 of the questions in this survey questionnaire had a multiple-choice option to choose the type of clothing they usually wear during the week and weekend (i.e., casual, business-casual, formal, sports or other). These evaluations help provide further insights in understanding the discomforts with the hospital patient gown. For instance, if a certain individual does not like wearing loose clothing or is easily bothered by clothing tags, than they are more likely to be bothered by the security or closure system of the hospital patient gown. The patient gown design preference survey consisted of 23 fit and comfort-related questions on a 5-point Likert scale (1=very uncomfortable, 2=uncomfortable, 3=neutral, 4=comfortable and 5=very comfortable). This survey questionnaire evaluated the users perception of fit and comfort with the hospital patient gown, and the participants were offered to try on the conventional patient gown and freely move, as they desired, prior to the survey. The questions included in the survey questionnaires were framed to identify and evaluate the selected design features for the universal design of hospital patient gown.

3.5.1 3D Body Scanning

Following the competition of the demographic and preference surveys, the participants were invited to the 3D body scanning room, and walked through the scanning steps by the researcher. Prior to 3D body scanning, to ensure accurate BMI calculation, the participant's height and weight were measured using a stadiometer (Seca®) and digital weight measurer (Tanita® TBF-310GS). Although the 3D body scanner ([TC]^2, KX-16) can extract over 400 measurements, the following 15 three-dimensional human body measurements were selected for further evaluation: Waist, hips, chest, bust, neck, left knee, right knee, left biceps, right biceps, left elbow, right elbow, left shoulder length and right shoulder length (Figure 3-2). The primary reason why some of these body measurements were selected is because these are the major angle points that our bodies flex the most especially while wearing the hospital patient gown (Cho, 2006). These are the most critical body measurements due to the significant differences they pose across gender, age and BMI (body mass index).

The 3D body scanner uses non-invasive depth sensors to capture a surface representation of approximately 300,000 spatial data points per each scan. There are no known risks associated with the 3D body scanning procedure. Once both parties were ready to begin the process, the participant enabled to trigger the scanning by pushing a button located on the handle bar, inside the scanner. The trigger started a suitable music with further instructions how to properly acquire the necessary measurements. Each participant was scanned with the 3D body scanner at two different levels of clothing layers: 1) in undergarments for baseline measurements (i.e., a bra and underpants for females and underpants for males), 2) hospital patient gown with undergarments. The 3D body scanner captured 2 images in each clothing layer, which took on average 15-20 seconds. The scanner automatically averaged the scan data and produced accurate 3D scan images of the participants' body, thus avoiding any outlaying data. The 3D scans can be visually examined on the computer screen in any direction of the body, on the horizontal axis to see the back, side or front, and on the vertical axis to view the body from different angles.

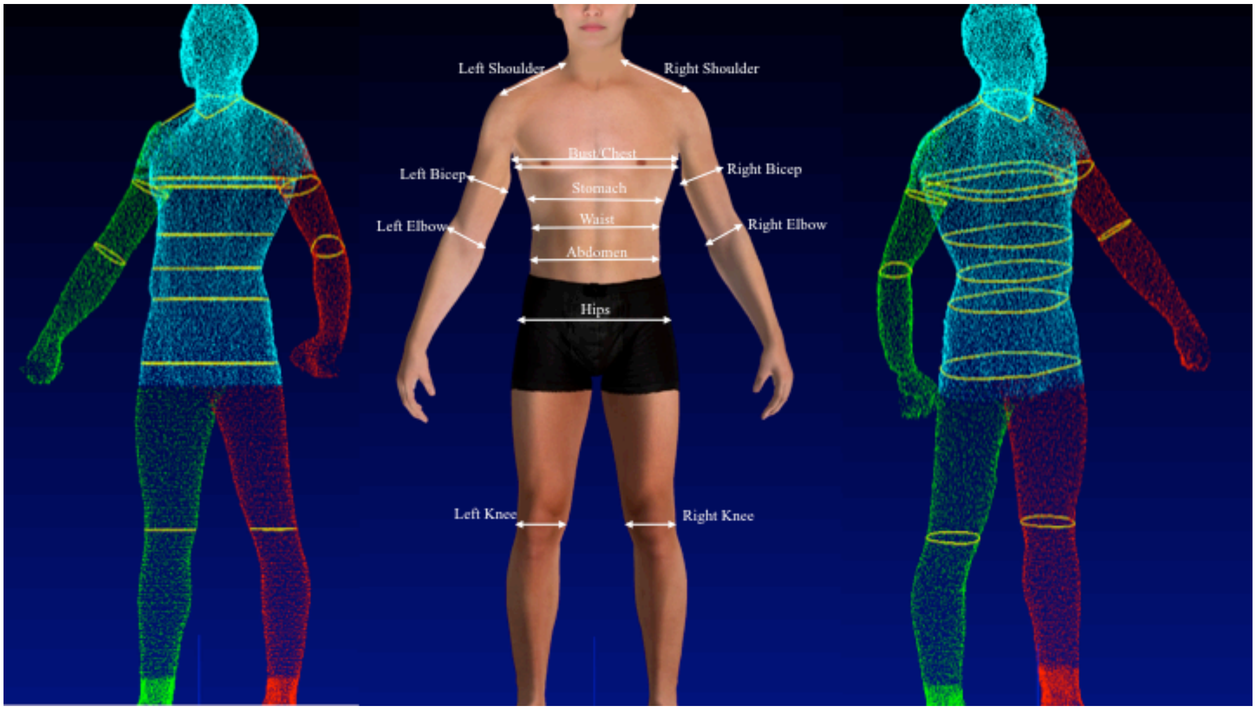


Figure 3-2. Visual representation of the 15 selected 3D human body measurements

3.5.2 Hospital Patient Gown Tie Measurements

The hospital patient gown has 4 ties located on the back of the gown. The upper-back ties (UT) are located around the neckline of the gown (Figure 3-3a) and the lower-back ties (LT) are located near by the waist/hip circumference of the gown (Figure 3-3c). The ties can accommodated for size. Because of this size adjustability, each individual tended to tie the gown at various degrees of tightness. In order to obtain this information, the gown tie choices (the UT #1 provides a slightly tighter fit, and UT #2 provides are slightly looser fit as shown on Figure 3-3b; and the same goes for the lower-back ties, see Figure 3-3d) on both upper and lower back were accounted for, as well as the gown tie length, which was measured using a 10cm ruler (Figure 3-3ab; Figure 3-3d). The distance between the upper (UT1 and UT2) and lower (LT1 and LT2) gown ties is 4 inches.

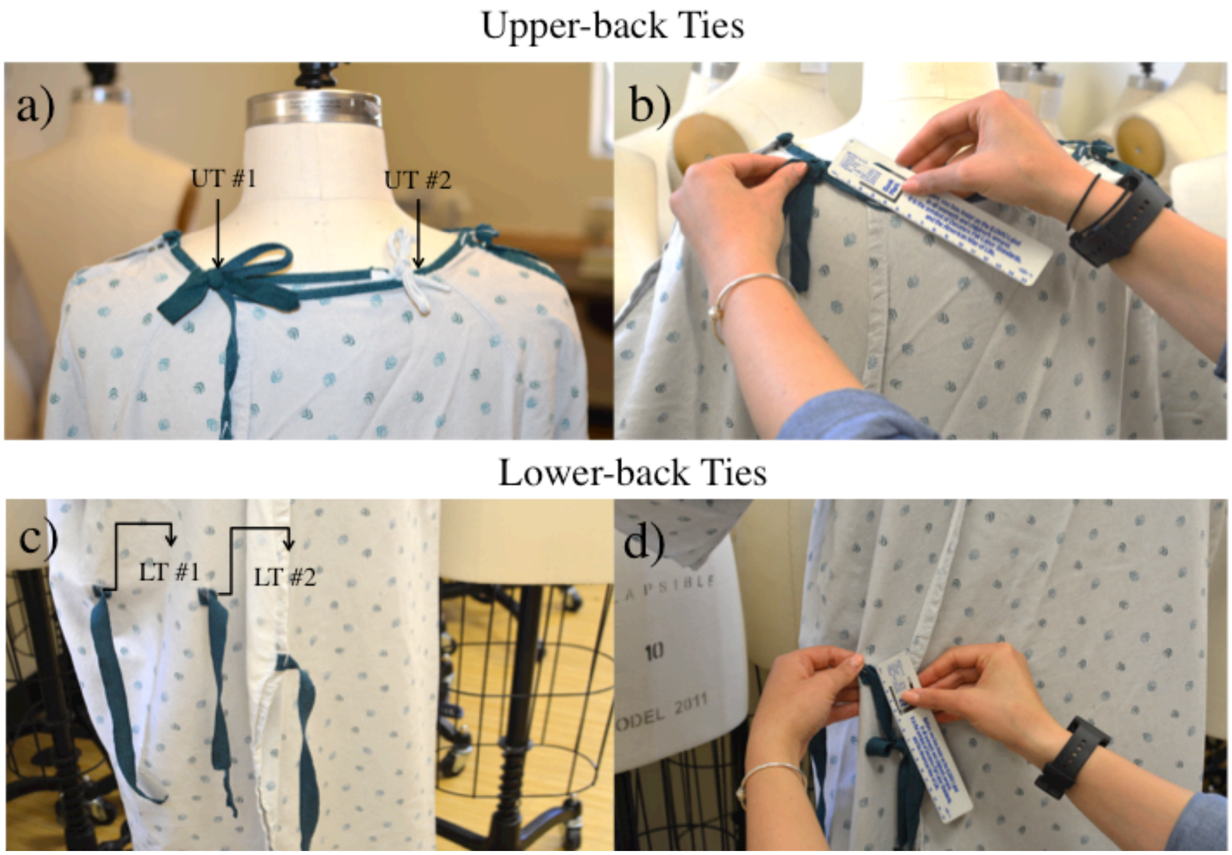


Figure 3-3. Hospital Patient Gown Ties

3.5.3 Scenario Activities

The experiment employed a scenario activity exercise in which the researcher mocked a hospital room setting where each participant was exposed to the same circumstances (i.e., room setting, lightning, bed, comfort pillows and blankets, chair and table). The physical level of the five scenario activities was minimal and the activities were selected among those that were commonly performed by hospital patients. The activities selected were 1) walking, 2) lying down, 3) bending, 4) reaching up and 5) sitting (Figure 3-4). In addition, while each activity was performed, the participants were asked to identify some of the most uncomfortable 11 landmark points (Figure 3-5) related to the fit and comfort of the hospital patient gown though a survey questionnaire (See Appendix J for scenario activity survey), rate them on a 5-point Likert scale and provide a brief description stating why they were troublesome. The scenario exercise started with the first physical activity in which the participants were asked to walk around the research room for few minutes, as a means to help them imagine that they were in a real hospital setting. While walking, the researcher asked the participant to identify any problem areas of the hospital patient gown. For the next scenario activity, the participants were asked to lie down on a single-size bed (17.5-inches from the ground) in a lounge position supported by 2 comfortable pillows and a blanket (Figure 3-4a). The next activity asked the participants to reach up with both hands (i.e., first with both hands at the same time and second with each hand separately) and touch a marked measurement on the wall (65-inches from the ground) assuming they are picking up an object from the shelf at the simulated height (Figure 3-4b). The following activity asked the participants to bend down and pick up a glass of water from a 16-inch table with each arm separately (Figure 3-4c). The last scenario activity involved the participants to identify problem areas of the hospital patient gown while sitting down on a 19.5-inch chair for several minutes (Figure 3-4d). They were encouraged to get up and sit down several times to make sure they fully experience the fit and comfort of the gown while performing this activity. Additional pictures are displayed in the results section.

Figure 3-4. Visual representation of the scenario activities

Figure 3-5. Visual represenation of the 11 hospital patient gown landmark points

3.5.4 Exit Interview

Upon the completion of the aforementioned experiments, the participants were offered to openly share comments regarding the fit and comfort of the hospital patient gown, and the participants' comments were digitally recorded and transcribed verbatim. The exit interview took less than 5 minutes on average, and the questions asked were as such: What are some problem areas that need immediate attention?; If you were to change something about the hospital patient gown in terms of sizing, which areas would you change?; Do you have any suggestions regarding the fit of the hospital patient gown?. These open-ended questions provided the participants with the option to further elaborate on certain problem areas of the hospital patient gown.

3.6 Data Analysis

Independent samples *t*-test, descriptive statistics, ANOVA and regression analyses were performed using the IBM SPSS 22.0 analytical software package to analyze data collected from the experiments: (a) demographic and preferences survey; (b) 3D body scan; (c) scenario activities; and (e) exit interview data. Hypothesis 1 required running independent samples *t*-tests adjusted for multiple comparisons along with descriptive statistics to highlight specific areas of the participant's demographics, physical characteristics, personal clothing preferences, 3D body scan data and scenario activity of the fit and comfort preferences of the hospital patient gown between males and females. Hypothesis 2 required running regression analysis in order to study the linear relationships of the fit and comfort of the hospital patient gown by age. Hypothesis 3 required running descriptive statistics, independent samples *t*-tests adjusted for multiple comparisons, and ANOVA for examining the proposed survey questionnaire data, 3D scan data and scenario activity data among different BMI categories in each gender group. Interview data were transcribed verbatim, organized by common themes identified and used as supporting arguments when findings of certain areas of the survey data, 3D scan data or scenario activity were insignificant, yet essential information related to the overall fit and comfort of the hospital patient gown were brought to light.

CHAPTER FOUR: MANUSCRIPT

4.1 Introduction

Although the development of medical technology has dramatically advanced in the past 80 years, the hospital patient gown, designed in the early 20th century, has remained almost the same since its development (Cho, 2006; Ulrich et al., 2008). Hospital patient gowns affect the lives of nearly all humans since it is almost certain that one would come across its use at least once in their lifetime. Despite the importance of this apparel, research on the design and functionality of the hospital patient gown has been minimal and it often falls outside of the scope in empirical studies. As a result, there is insufficient and incomplete academic guidance to improve the features of current patient gowns, and thus the medical apparel industry does not have a product yet that fully meets the needs of both patients and medical personnel. Three general steps need to be completed before a commercially viable product can be sent to manufacturing (Lamghabbr, Yacout & Ouali, 2007); identification of the problems of the current product, a new design proposal and finally a universal fit and optimal sizing of the new patient gowns. There is sufficient literature (e.g. Boothroyd, 1994; Lamghabbr, Yacout & Ouali, 2007; Suri & Marsh, 2000) that covers the first two steps and selected studies have been described in the literature section below. This study focuses on the third step and utilizes these findings to deliver the next step in the improvement of the hospital patient gowns. It aims to identify fit issues of the new gowns via novel measurement methods of human anthropometry.

Multiple studies have found that the current gowns have shortcomings, and it is important to note that its diverse functionality is a concern of both patients and healthcare providers. Park (2014) found that the patients were moderately dissatisfied with the design, fit and comfort of the hospital patient gown. It was indicated that the patients believed the current gown was practical for medical purposes, thus they were tolerant with the gown; while the healthcare providers disagreed with patients, believing it was not medically practical. More specifically, the patient gown is known to be impractical by healthcare professionals and patients alike in medical procedures, such as taking temperature and blood pressure, cardiac monitoring, delivering intravenous injections (Black & Torlei, 2013; Jha, 2009). The main finding of these studies is that the conventional hospital patient gown has a major fit problem, which results in lack of comfort, mobility and accessibility. Thus it has been previously highlighted that it is necessary that identified for this universally used garment; and thus this study will directly address the issue. It will be crucial in adjusting the fit and therefore prevent future difficulties with body movement, donning and doffing, as well as easy and quick access to the patient's body (Cho, 2006; Jha, 2009). That is, hospital patient gowns should be sized to increase the overall functionality in terms of fit and comfort, and this study aims to do this by delivering the ideal size of the newly designed gown.

Empirical results suggest the gown-sizing problem has persisted over time as well. Even after multiple patented efforts to improve the functionality of the patient hospital gown (e. g., U.S. Patent No. 1962515 A, 1923; U.S. Patent No. 2701364 A, 1955; U.S. Patent No. 4686715 A, 1987; U.S. Patent No. 6237153 B, 2001), studies strongly suggest that sizing needs be addressed before a new gown can be successfully adopted within the healthcare system (Cho, 2006; Gordon and Guttmann, 2013). In addition, Ulrich et al. (2008) suggested that if sizing were not adequately addressed, the issue of comfort and modesty would negatively affect the patients' overall hospital experience. However, identifying fit issues and addressing ideal sizing is complicated by multiple factors such as outdated anthropometric data, lack of standardized sizing system, lack of precise body measurements, and variations of body shapes and proportions (Apeagyei, 2010; Ashdown, 1998).

The scope of this study included an extensive search for existing literature on sizing of the hospital patient gown to date no studies have attempted to identify an anthropometric solution for a hospital patient gown, with the use of three-dimensional (3D) body scanning technology. Although other measurements will be used including demographic and preference survey questionnaires, scenario activities, and exit interview, this study will emphasize 3D body scanning technology for its ability to provide rapid and accurate analysis of fit by quantifying the functional ease and the distance between the body and the garment at critical locations. 3D body scanning technology is known to provide the most effective and accurate body measurements in fit analyses (Apeagyei, 2010; Istook & Hwang, 2000). This study will identify fit issues associated with the hospital patient gown to facilitate a better fit and comfort to as many potential patients as possible. To achieve the research goals, the following hypotheses are developed, and will be evaluated in this study:

H1: There are significant differences in the fit and comfort of the hospital patient gown across gender.

H2: There is a significant relationship between fit and comfort of the hospital patient gown and age of the individual.

H3: There are significant differences in the fit and comfort of the hospital patient gown among different BMI groups.

4.2 Literature Review

4.2.1 Previous design attempts for hospital patient gown

Since its introduction to the healthcare system, the typical hospital patient gown has seen very little change and is therefore long overdue for a redesign. The conventional design of the hospital patient gown is usually unisex with one-size-fits-all dimensions, featuring a back system closure and opening (Cho 2006; Dinsdale 2004). Studies have shown that a lack of good clothing fit can affect the patient's psychological and physiological state of mind, in particular how they view themselves and others when wearing the hospital patient gown (Cho, 2006).

The relevant literature shows that quite a few attempts have been made to improve the conventional hospital patient gown to provide hospital caregivers with greater ease in accessing the patient's body but few have focused on the needs of the patients. There are hundreds of patented patient gowns on the market including a set of different physical and aesthetic attributes; however, none of them have attempted to address the sizing. For instance, Black and Torlei (2013) examined a case study that was set to redesign new hospital clothing for UK patients looking at a user-centered design perspective. The researchers of this study created a new gown design called "Origown" featuring a single piece of fabric that was cut in a way that it transformed from flat into a three-dimensional garment through the process of dressing the patient, while being secured by adhesive stickers. They concluded that although the hospital gowns mostly meet the inclusive needs of the garment, it does not meet all hospital needs, especially those for patients in intensive care. Similarly, Cho (2006) proposed two prototypes of the new hospital patient gown that focused on the patient-oriented design features, where one prototype was found more suitable than the other in terms of addressing the user's satisfaction of the gown, however, it was marked as lacking medical practicality due to its lack of exploration as well as applicability across both genders. Moreover, another design by Burbidge (U.S. Patent No. 6012199, 2000) that has a shoulder opening extending from the shoulder to the sleeve to allow for easier access to the patient's back was not promising enough for larger commercial use. Although there are several designs of hospital patient attires being patented, a survey of the literature does not show any clear evidence of a large-scale adoption of new hospital patient gowns by the hospitals in the United States.

4.2.2 The need for anthropometric measurements and the tools performing those measurements

Pheasant (1990) states that anthropometrics is the branch of ergonomics, which deals with and focuses on the measurements and proportions of the human body, especially body shapes and sizes. Apparel design is one of the design disciplines that have frequently exercised anthropometry in design. The combination of fit data and anthropometrics population is especially essential in developing effective sizing systems for various apparel products (Ashdown et al., 2004). Paquet, Pena and Victor (2011) state that in order to find the best fit, anthropometric and 3D data should be used together as they yield complimentary results. Traditionally, anthropometric data were taken manually with simple instruments like tape measures and calipers. However, with the advancement of technology and engineering, 3D surface anthropometry has been utilized in recent years (Park et al., 2009). The developments of 3D body scanners have opened opportunities for measuring the human body more efficiently and accurately (Lu & Wang, 2008).

3D surface scanning technology was initially developed as an industrial tool to measure and compare 3D objects at different stages of the assembly for the process of product development (Ashdown et al., 2004). Although it was generally used in different industrial sectors, such as engineering and product manufacturing, apparel researchers have adopted this technology for the creation of well-fitted garments (Simmons & Istook, 2003). 3D body scanning technology is known to provide the most effective and accurate body measurements in fit analysis (Apeagyei, 2010; Istook & Hwang, 2000). Song and Ashdown (2010) report two main advantages of using 3D body scanning technology. First, 3D body scanners are very quick and can generate over 400 measurements in 5-15 seconds per scan, which is a very sustainable way to obtain body measurements by providing precise and reproducible measurement data. Secondly, 3D body scanners are capable of capturing 3D visual images, which can be used to identify the participants' body shapes and proportions.

Simmons and Istook (2003) assert that reliability is closely attached to precision and dependability, and in order for the body measurements to be accurate and reliable they need to be free of any potential errors. The subjects' positioning and instrument application can catch these errors. Simmons and Istook (2003) state that the posture is highly significant as is wearing minimal clothing. For instance, asking the subjects to adopt a standard stationary posture while holding still for a few seconds can minimize the effect of body movement. Segmenting the 3D scan data at the armpits and crotch can help get the scanning data ready for landmarking (Lu & Wang, 2008). Moreover, using the proper instrumentation, such as the ones listed above, and correct identification of body landmarks are necessary in the collection of accurate anthropometric data.

Although there are few studies that use 3D scanning for visual analysis, there are even fewer to no studies that investigate fit analysis and optimum dress size for a universally used garment like the hospital patient gown. 3D body scanners provide comprehensive and objective analysis of fit by quantifying the functional ease and the distance between the body and the garment at critical locations using merged cross-section scans; it can also challenge the validation of the sizing system by visualizing body proportions and shapes more clearly and accurately. One instance where an optimization approach was taken to assess a universally used apparel item was in a study done by McCulloch, Paal and Ashdown (1998). They attempted to develop a sizing system that was based on mathematical nonlinear optimization techniques, along with multidimensional information from anthropometric data to design a dress shirt of a military uniform. Past studies have shown that the ability to identify non-accommodated individuals as well as size assignments, results in substantial improvements in fit (Ashdown, Loker, Rucker, 2007; Gupta & Gangadhar, 2004; Meunier & Yin, 2000).

4.3 Methods

4.3.1 Study Participation and Recruitment Strategies

Purposeful sampling was used to recruit adult participants who represented diverse body profiles, did not have history of musculoskeletal problems, and resided in the Midwestern region of the United States, near the researcher's university. Flyn and Foster (2009) state that purposeful sampling is used in novel research circumstances when the topic being investigated is new or not feasible to do random sampling. To the best of the author's knowledge, no studies were found that investigated the sizing of the conventional hospital patient gowns; hence, no methodological approaches were previously proposed. The participants were recruited via multiple channels through flyers that were posted around the university campus and local businesses, e-mail blast to university students, and in-class recruitment. Prior to scheduling a visit to participate in the experiment, to ensure the diversity of demographic and physical profiles, the participants were asked their age, gender, height, and weight. All of the participants complied with the initial pre-screened inclusion criteria and did not report having any musculoskeletal problems.

A total of 85 participants (47 males and 38 females) participated in this study. Table 4-1 and Table 4-2 summarize the demographics and physical profiles of the participants. The average height of males was 70.3 inches (5 feet and 10 inches, SD=3.00) and that of females was 66.3 inches (5 feet 6 inches, SD=2.50), while the average weight was 163.5 lbs (SD=25.88) and 144.6 lbs (SD=36.29) respectively. The average BMI of males was 23.2 kg/m^2 and that of females was 23.6 kg/m^2 (Table 4-3). The age range was between 18 and 52 years old; the average age was 23.15 (SD=5.75) where the average for males was 22.53 (SD=5.02) and 23.92 (SD=6.52) for females. Prior to running data analyses, the raw data was coded numerically. For instance, there were 7 clothing size options where each size received a corresponding number (i.e. XS=1, S=2, M=3, L=4, XL=5, XXL=6, 3XL=7). Based on this data, the average clothing size for males was 3.7, which indicated primarily an L (large) clothing size and 3.0 for females, which indicated an M (medium) average clothing size. About three-fourth of the participants (72.9%) were Caucasians.

Table 4-1. Demographic information of participants

Characteristics	Male	Female	Overall
Sex (%)	47 (55.3)	38 (44.7)	85 (100)
Age: Mean (σ)	22.5 (5.0)	23.9 (6.5)	23.2 (5.7)
Height: Mean (σ)	70.3 (3.0)	66.3 (2.5)	68.5 (3.4)
Weight: Mean (σ)	163.5 (25.9)	144.6 (36.3)	155.0 (32.2)
BMI: Mean (σ)	23.2 (3.4)	23.6 (6.1)	23.4 (4.8)
Clothing Size: Mean (σ)	L (.88)	M (1.1)	M-L (1.0)

Table 4-2. Additional demographic information of participants

Ethnicity	(%)	Education	(%)	Clothing Size	(%)
African American	4.7	High School	1.2	XS	2.4
Caucasian	72.9	Some College	72.9	S	14.1
Asian	8.2	Bachelor's Degree	5.9	M	41.2
Hispanic/Latino	2.4	Professional Degree	2.4	L	31.8
Multiracial	11.8	Graduate Degree	17.6	XL+	10.6

Table 4-3. Physical profile information of the participants

BMI Category	Sex	N	Overall Percent
Underweight	Male	4	10.6
	Female	5	
Healthy	Male	30	63.5
	Female	24	
Overweight/Obese	Male	13	25.9
	Female	9	

4.3.2 Experimental Design and Procedure

Multi-dimensional methods were used to gain a holistic understanding of the fit and comfort perception of the hospital patient gown among the participants: (a) demographic and preference survey questionnaires, (b) 3D body scanning, (c) scenario activities, and (d) exit interview. Figure 3-1 (refer back to chapter 3) summarizes the data collection procedure.

4.3.2.1 Demographic and Preference Survey Questionnaires

At the lab visit, the participant was asked to fill out a survey questionnaire that consisted of the three main sections including demographic profiles, sensory clothing preferences, and hospital patient gown evaluation, which took approximately 30 minutes to complete. The demographic profiles section asked sex, age, height, weight, ethnicity, education, marital status, and clothing size, along with history of musculoskeletal problems.

The sensory clothing preferences survey consisted of 16 sensory questions, which measured the participants clothing habits and preferences on a 5-point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree). Additionally, 2 of the questions in this survey questionnaire had a multiple-choice option to choose the type of clothing they usually wear during the week and weekend (i.e., casual, business-casual, formal, sports or other). These questions were added in the hope to provide further insights in understanding the discomforts with the hospital patient gown. For instance, if a certain individual does not like wearing loose clothing or is easily bothered by clothing tags, than they are more likely to be bothered by the security or closure system of the hospital patient gown.

The patient gown design preference survey consisted of 23 fit and comfort-related questions on a 5-point Likert scale (1=very uncomfortable, 2=uncomfortable, 3=neutral, 4=comfortable and 5=very comfortable). This survey questionnaire evaluated the users perception of fit and comfort with the hospital patient gown, and the participants were offered to try on the conventional patient gown and freely move, as they desired, prior to the survey. The questions included in the survey questionnaires were framed to identify and evaluate the selected design features for the universal design of hospital patient gown.

4.3.2.2 3D Body Scanning

Following the completion of the demographic and preference surveys, the participants were invited to the 3D body scanning room, and walked through the scanning steps by the researcher. Prior to 3D body scanning, to ensure accurate BMI calculation, the participant's height and weight were measured using a stadiometer (Seca®) and digital weight measurer (Tanita® TBF-310GS). Although the 3D body scanner ($[TC]^2$, KX-16) can extract over 400 measurements, 15 three-dimensional human body measurements were selected for further evaluation: Waist, hips, chest, bust, neck, left knee, right knee, left biceps, right biceps, left elbow, right elbow, left shoulder length and right shoulder length (Figure 4-1). These are the major angle points for flexion of various joints while wearing the hospital patient gown (Cho, 2006) and the most critical body measurements due to the significant differences they pose across gender, age and BMI (body mass index). The 3D body scanner uses non-invasive depth sensors to capture a surface representation of approximately 300,000 spatial data points per scan. There are no known risks associated with the 3D body scanning procedure. Once both parties were ready to begin the process, each participant enabled the scanning trigger by pushing a button located on the handle bar, inside the scanner. The trigger started a suitable music with further instructions how to properly acquire the necessary measurements. Each participant was scanned at two different levels of clothing layers: 1) in undergarments for baseline measurements (i.e., a bra and underpants for females and underpants for males), 2) hospital patient gown with undergarments. The 3D body scanner captured 2 images in each clothing layer, which took on average 15-20 seconds. The scanner automatically averaged the scan data and produced accurate 3D scan images of each participant's body, thus avoiding any outlaying data. The 3D scans can be visually examined on the computer screen in any direction of the body, on the horizontal axis to see the back, side or front, and on the vertical axis to view the body from different angles.

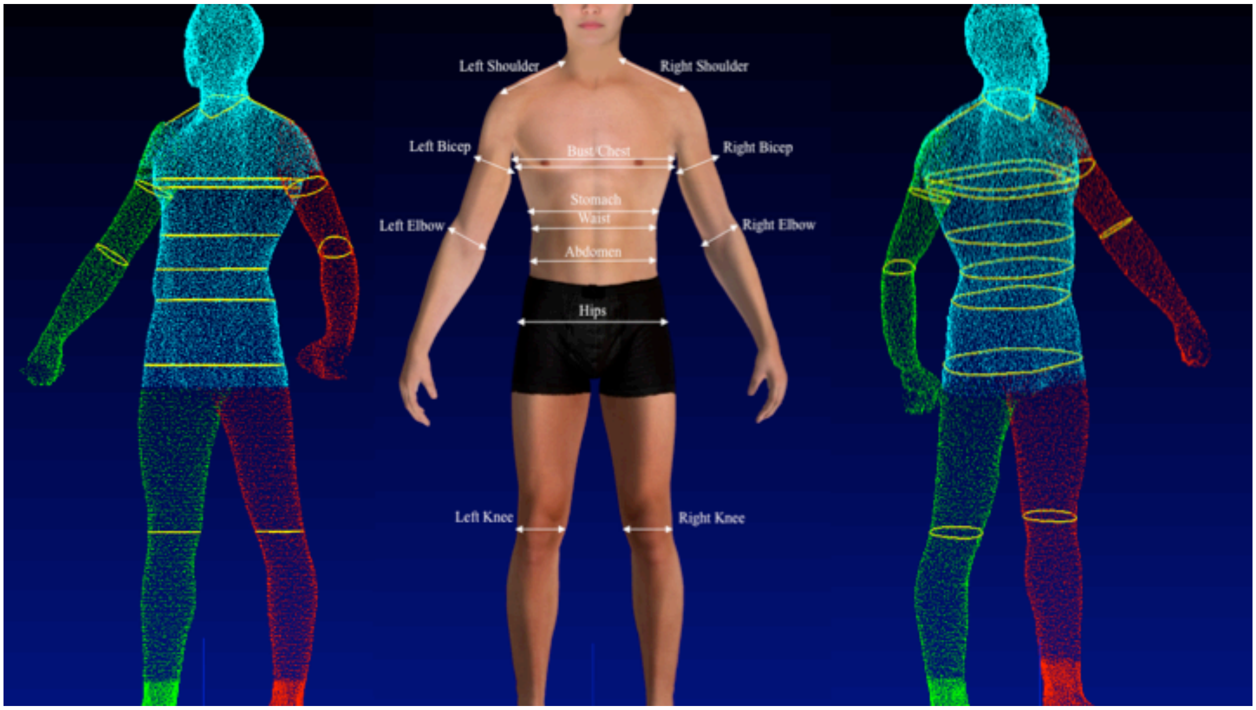


Figure 4-1. Visual Representation of the 15 selected 3D human body measurements

4.3.2.3 Hospital Patient Gown Tie Measurements

The hospital patient gown has 4 ties located on the back of the gown. The upper-back ties (UT) are located around the neckline of the gown (Figure 3-3a) and the lower-back ties (LT) are located near the waist/hip circumference of the gown (Figure 3-3c). The ties can accommodate for size. Because of this size adjustability, each individual tended to tie the gown at various degrees of tightness. In order to obtain this information, the gown tie choices (the UT #1 provides a slightly tighter fit, and UT #2 provides a slightly looser fit as shown on Figure 3-3b; and the same goes for the lower-back ties, see Figure 3-3d) on both upper and lower back were accounted for, as well as the gown tie length, which was measured using a 10cm ruler (Figure 3-3ab; Figure 3-3d). The distance between the UT #1 and UT #2, as well as the distance from LT #1 and LT #2 is 4 inches.

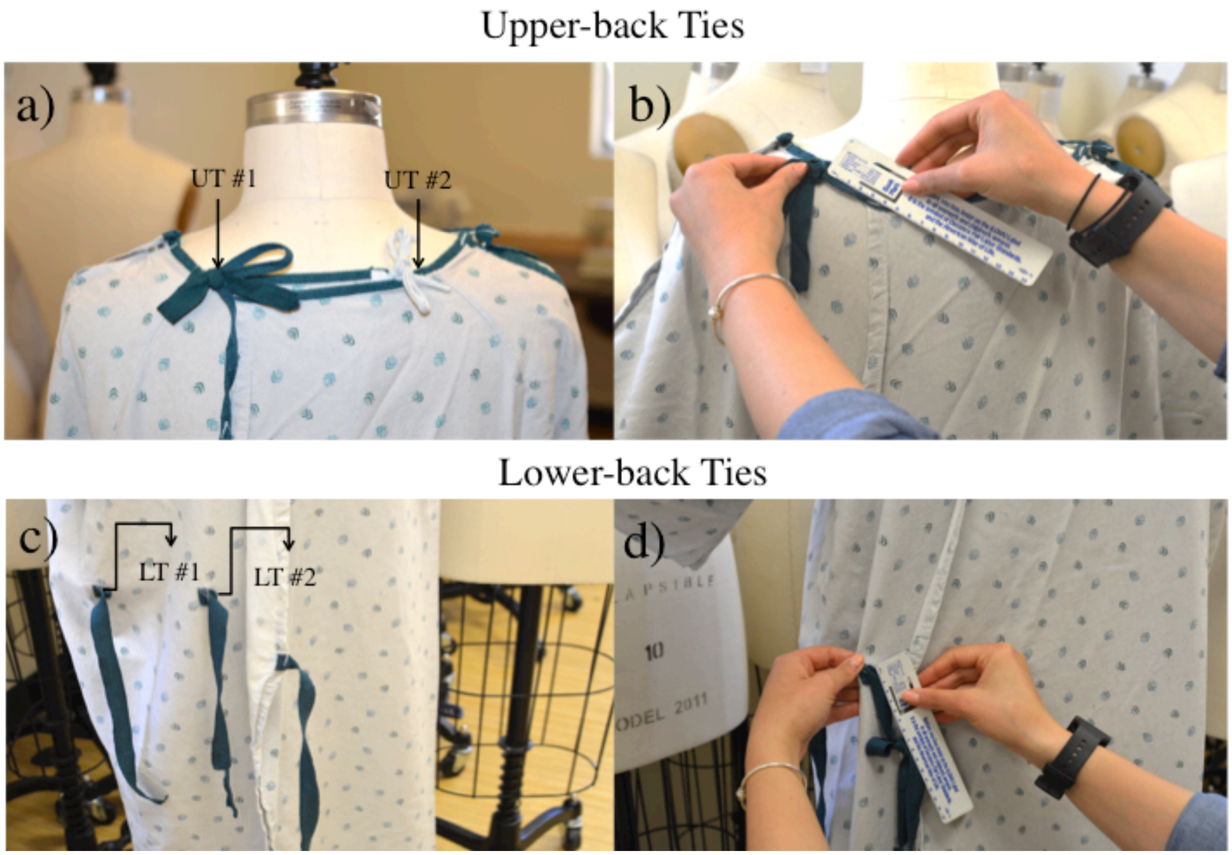


Figure 4-2. Hospital Patient Gown Ties

4.3.2.4 Scenario Activities

The experiment employed a scenario activity exercise in which the researcher mocked a hospital room setting where each participant was exposed to the same circumstances (i.e., room setting, lightning, bed, comfort pillows and blankets, chair and table). The physical level of the five scenario activities was minimal and the activities were selected among those that were commonly performed by hospital patients. The activities selected were 1) walking, 2) lying down, 3) bending, 4) reaching up and 5) sitting (Figure 3-4). In addition, while each activity was performed, the participants were asked to identify some of the most uncomfortable landmark points (Figure 3-5) related to the fit and comfort of the hospital patient gown though a survey questionnaire (See Appendix J for scenario activity survey), rate them on a 5-point Likert scale and provide a brief description stating why they were troublesome. The scenario exercise started with the first physical activity in which the participants were asked to walk around the research room for few minutes, as a means to help them imagine that they were in a real hospital setting. While walking, the researcher asked the participant to identify any problem areas of the hospital patient gown. For the next scenario activity, the participants were asked to lie down on a single-size bed (17.5-inches from the ground) in a lounge position supported by 2 pillows and a blanket (Figure 3-4a). The next activity asked the participants to reach up with both hands (i.e., first with both hands at the same time and second with each hand separately) and touch a marked measurement on the wall (65-inches from the ground) assuming they are picking up an object from the shelf at the simulated height (Figure 3-4b). The next activity asked the participants to bend down and pick up a glass of water from a 16-inch table with each arm separately (Figure 3-4c). The last scenario activity required the participants to identify problem areas of the hospital patient gown while sitting down on a 19.5-inch chair for several minutes (Figure 3-4d). They were encouraged to get up and sit down several times to make sure they fully experience the fit and comfort of the gown while performing this activity. Additional pictures are displayed in the results section.

Figure 4-3. Visual represenation of the 11 hospital patient gown landmark points

4.3.2.5 Exit Interview

Upon the completion of the aforementioned experiments, the participants were offered to openly share comments regarding the fit and comfort of the hospital patient gown, and the participants' comments were digitally recorded and transcribed verbatim. The exit interview took less than 5 minutes on average, and the questions asked were as such: What are some problem areas that need immediate attention?; If you were to change something about the hospital patient gown in terms of sizing, which areas would you change?; Do you have any suggestions regarding the fit of the hospital patient gown?. These open-ended questions provided the participants with the option to further elaborate on certain problem areas of the gown.

4.3.3 Data Analysis

Independent samples t-test, descriptive statistics, ANOVA and regression analyses were performed using the IBM SPSS 22.0 analytical software package to analyze data collected from the experiments: (a) demographic and preferences survey; (b) 3D body scan; (c) scenario activities; and (e) exit interview data. Hypothesis 1 required running independent samples *t*-test adjusted for multiple comparisons using Bonferroni's correction (Dunn, 1961) along with descriptive statistics to highlight specific areas of the participant's demographics, physical characteristics, personal clothing preferences, 3D body scan data and scenario activity of the fit and comfort preferences of the hospital patient gown between males and females. Hypothesis 2 required running regression analysis in order to study the linear relationships of the fit and comfort of the hospital patient gown by age. Hypothesis 3 required running descriptive statistics, independent samples *t*-test adjusted for multiple comparisons, and ANOVA for examining the proposed survey questionnaire data, 3D scan data and scenario activity data among different BMI categories in each gender group. Interview data was transcribed verbatim, organized by common themes identified and was used as supporting argument when certain areas of the survey data, 3D scan data or scenario activity were showing insignificant results yet it yielded essential information related to the overall fit and comfort of the hospital patient gown.

4.4 Results

4.4.1 Sensory Clothing Preferences

4.4.1.1 Gender Comparison

Independent samples *t*-tests were performed to analyze the gender differences in sensory clothing preferences. Gender was the dependent variable and the survey questionnaire contained the independent variables, which measured personal clothing habits and preferences among the recruited participants where each point of agreement is given a numerical value from one (strongly disagree) to five (strongly agree). Table 4-4 displays significant gender differences in sensory clothing preferences at a 95% confidence level. Some of the major gender differences included the comfort of wearing loose-fitting clothing ($\overline{X}_{male}$=3.51, $\overline{X}_{female}$=4.18; p=.001), which demonstrates that females felt significantly more comfortable wearing loose-fitting clothing than males did. Female participants also agreed more that they preferred wearing fabric that hangs well on the body than males ($\overline{X}_{male}$=3.38, $\overline{X}_{female}$=4.08; p=.001). Moreover, female participants had a higher preference in wearing a more drapery look ($\overline{X}_{male}$=2.45, $\overline{X}_{female}$=3.63; p=.000), placed a higher importance on comfort over aesthetics ($\overline{X}_{male}$=3.83, $\overline{X}_{female}$=4.37; p=.006), clothing security ($\overline{X}_{male}$=3.47, $\overline{X}_{female}$=4.16; p=.008), and good clothing coverage ($\overline{X}_{male}$=3.85, $\overline{X}_{female}$=4.45; p=.000) than male participants. On the contrary, male participants had a higher preference for wearing a more structured silhouette ($\overline{X}_{male}$=3.85, $\overline{X}_{female}$=3.37; p=.017), placed a higher importance on clothing comfort over quality ($\overline{X}_{male}$=3.85, $\overline{X}_{female}$=4.45; p=.000) and were less bothered by clothing that might be revealing ($\overline{X}_{male}$=3.17, $\overline{X}_{female}$=2.68; p=.032). Such significant gender differences in clothing preferences may indicate how challenging it is to accommodate universal apparel for various individual's personal clothing preferences.

Table 4-4. Evaluation of Sensory Clothing Preferences

Characteristic	Sex	N	Mean	Std. Deviation	Sig. (2-tailed)
Comfortable Tight Clothing	Male	47	2.787	1.1021	.820
	Female	38	2.842	1.1035	
Comfortable Loose Clothing	Male	47	3.511	1.0188	.001**
	Female	38	4.184	.7299	
Prefer Fabric Hangs Well	Male	47	3.383	.9902	.001**
	Female	38	4.079	.9410	
Prefer Drapery Look	Male	47	2.447	.9958	.000**
	Female	38	3.632	.9979	
Prefer Structured Look	Male	47	3.851	.8335	.017*
	Female	38	3.368	.9979	
Prefer Natural Fabric	Male	47	3.787	.8324	.191

	Female	38	3.553	.7952	
Prefer Synthetic Fabric	Male	47	2.979	.8720	.739
	Female	38	2.921	.6731	
Sensitive Clothing Tags/Seams	Male	47	3.617	1.2257	.456
	Female	38	3.816	1.2048	
Comfort Over Aesthetics	Male	47	3.830	.8678	.006**
	Female	38	4.368	.8829	
Comfort Over Quality	Male	47	3.723	.9714	.016*
	Female	38	3.211	.9346	
Purchase Decision Time	Male	47	3.511	.9058	.931
	Female	38	3.526	.7255	
Clothing Security	Male	47	3.468	1.1200	.008**
	Female	38	4.158	1.1974	
Good Coverage	Male	47	3.851	.7512	.000**
	Female	38	4.447	.6857	
Revealing Clothing	Male	47	3.170	1.0899	.032*
	Female	38	2.684	.9330	

NOTE: This table presents the gender differences between sensory comfort perceptions. The possible mean score for variables ranges from 1 to 5. *p<.05 and **p<.01, indicate significant differences between male and female participants.

4.4.1.2 Relationships between Age and Sensory Preference

Additionally, in order to understand the linear relationships between age (independent variable) and sensory clothing preferences (dependent variables), regression analyses were performed. Results showed that age predicted sensory preference among males considering two items in the sensory clothing questionnaire. (See Table 4-5 for ANOVA demonstrating fit of the data to this model). Moreover, the data indicated that as age increases, sensitivity to clothing tags/seams increases in a statistically significant relationship (B=1.113, t=2.263, F=2.149; df=(1, 14); R^2=.301, p=.027). In addition, male participant data demonstrated a negative linear relationship between age and a sensory item, i.e., wearing a drapery look (B= -1.848, t= -2.279, F=2.077; df=(1, 14); R^2=.476; p=.029). This finding means that as age increased, the male participants negatively rated wearing a more drapery look (i.e. a more confined feel was desirable). These results indicate that age should be considered when optimizing the size for the gown as they may contribute to the overall comfort of the gown.

Table 4-5. ANOVA model summary of sensory clothing preferences

Sex	Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Male	Regression	552.052	14	39.432	2.077	.043*[b]
	Residual	607.650	32	18.989		
	Total	1159.702	46			
Female	Regression	598.763	14	42.769	1.008	.478[b]
	Residual	976.000	23	42.435		
	Total	1574.763	37			

NOTE: This table presents age in men as a predictor of sensory clothing preferences (characteristics).. $*p<.05$ and $**p<.01$, indicates this model of age and sensory preferences fits the data well.

4.4.1.3 BMI Comparison

To understand the relationships between different BMI groups (dependent variables) and sensory clothing preferences (independent variables), ANOVA tests were performed. Overall, the data indicated significant differences in the comfort ($\overline{X}_{total}$= 2.95 out of 5; p=.006) of wearing revealing clothing across different BMI groups ($\overline{X}_{underweight}$= 2.56, $\overline{X}_{healthy}$= 3.22, $\overline{X}_{overweight}$= 2.46) where male and female participants with healthy weight were more comfortable with this idea and underweight and overweight/obese participants were less comfortable. There were no statistical differences between males (p=.071) and females (p=.056) in the comfort of wearing revealing clothing. Additionally, the tightness of the gown approached significance across BMI groups (p=.094). These findings may be interpreted as important considerations for the redesign of the gown. The results call for caution on these aspects of the gown design since underweight and obese patients experience lower satisfaction wearing revealing or tighter fit clothing.

Because individuals have apparel fit and comfort preferences based upon functional and aesthetics expectations, it is ultimately the wearer who determines what is considered to be a good fit (Ashdown & DeLong, 1995). In summary, the results above show that the preferences of patients for certain clothing features differ across gender, age and BMI. The consideration of these factors can help predict the potential fit and comfort issues of the hospital patient gown.

Namely, the significant gender differences regarding the looseness, the look, how it hangs and the level of comfort could potentially present difficulty in finding an identifying fit issues and addressing sizing of the gown that meets the needs of both genders. Additionally, significant associations between age and sensitivity to clothing tags and seams, as well as the comfort of wearing a drapery look are the elements that could contribute to the overall comfort of the gown; and therefore, they should be taken into consideration when optimizing the size of the gown. Furthermore, the results pose an indication that both underweight and obese participants feel lower satisfaction wearing revealing and tighter fit clothing than healthy participants. These sensory clothing preferences elements, as they relate to different BMI groups must be taken into consideration in order to optimize the size and comfort of the hospital patient gown. Li and Wong (2006) state that comfort is a psychological feeling or judgment of a person wearing clothing under certain environmental conditions; hence, the brain will process sensory comfort signals and formulate subjective evaluations. These sensory sensations could have an impact on the overall comfort of the wearer's clothing including the fit and size, and therefore impact our clothing wearing experience and further influence our subjective perception of comfort.

4.4.2 Hospital Patient Gown Design Preferences

4.4.2.1 Gender Comparison

Independent samples *t*-tests were performed to analyze the gender differences in hospital patient gown design preferences. This survey questionnaire measured the design preferences of the conventional hospital patient gown, which the participants had a chance to wear for some time before evaluating. The mean scores for the variables ranged from 1 (strongly disagree) to 5 (strongly agree) and the significant gender differences were noted at a 95% confidence level. Table 4-6 presents some of the significant gender differences in design preferences (7 out of 23) of the hospital patient gown. The gown width was ranked lower for female participants than it was for male ($\overline{X}_{male}$=3.13, $\overline{X}_{female}$=2.53; p=.005), which indicated that the overall comfort of the gown width was perceived significantly different across gender with females being less satisfied than males. Additionally, the perceived comfort for the chest circumference was significantly different across gender where females were less satisfied than males ($\overline{X}_{male}$=3.60, $\overline{X}_{female}$=2.84; p=.001). Moreover, significant gender differences were noted for the overall evaluation of the fit and comfort of the hospital patient gown back opening where females were more uncomfortable than males ($\overline{X}_{male}$=2.09, $\overline{X}_{female}$=1.66; p=.041). That is, although both indicated strong discomfort with the back opening of the hospital patient gown, females were significantly more concerned with revealing body parts than males. Additionally, spiral access (i.e. reaching behind their back for donning or doffing) displayed significant results where females rated this area of the hospital patient gown significantly lower than males ($\overline{X}_{male}$=2.45, $\overline{X}_{female}$=2.00; p=.026), indicating greater discomfort with putting the gown on and taking it off. Although gender differences were present for spiral access, almost none of the participants were successful in accurately putting the gown on and tying it; also, difficulties taking the gown off were present. The overall satisfaction with the size adjustability showed significant gender differences where females showed greater dissatisfaction than males ($\overline{X}_{male}$=2.81, $\overline{X}_{female}$=2.29; p=.016). The means to adjust the size of the hospital patient gown was available via the ties, which were located on the back of the gown where each participant chooses the tightness level (refer back to Image 2). The hospital patient gown was also rated for overall mobility and the results indicated significant gender difference with females being less satisfied with the overall mobility and flexibility of the gown than males ($\overline{X}_{male}$=2.85, $\overline{X}_{female}$=2.16; p=.002). Lastly, significant gender difference was noted in the overall perceived medical practicality of the hospital patient gown, where male participants had stronger agreement than females that the current hospital patient gown is helping with practical medical procedures ($\overline{X}_{male}$=3.45, $\overline{X}_{female}$=2.92; p=.016). The results revealed that the satisfaction with the physical features of the conventional gown vary across gender. Given that the results show a clear biased towards higher males' satisfaction for all features, it may be inferred that the conventional gown is generally more suitable for male patients, or males are more tolerant with the gown than females. When looking at more details, it can also be inferred females on average found the gown to be 'neutral', where medical practicability was ranked the highest with 2.9; however they predominantly ranked 'disagree' and 'strongly disagree' with lowest score of 1.6 for the gown back opening.

Table 4-6. Evaluation of Hospital Patient Gown Design Preferences

Characteristic	Sex	N	Mean	Std. Deviation	Sig. (2-tailed)
Gown Width	Male	47	3.128	1.146	.005**
	Female	38	2.526	.992	
Chest Circumference	Male	47	3.596	.925	.001**
	Female	38	2.842	1.104	
Gown Back Opening	Male	47	2.085	.996	.041*
	Female	38	1.658	.879	
Spiral Access	Male	47	2.447	.974	.026*
	Female	38	2.000	1.040	
Size Adjustability	Male	47	2.809	1.014	.016*
	Female	38	2.289	1.088	
Overall Mobility	Male	47	2.851	1.123	.002**
	Female	38	2.158	.823	
Overall Medical Practicality	Male	47	3.447	.996	.016*
	Female	38	2.921	.969	

NOTE: This table presents only the data that reveal statistically significant gender differences between hospital patient gown design perceptions. The possible mean score for variables ranges from 1 to 5. *p<.05 and **p<.01, indicate significant differences between male and female participants.

4.4.2.2 Relationships between Age and Design Preference

Regression analyses were performed to discover the presence of linear relationships between age and the multiple dependent variables based on the participants' design preferences of the gown. Significant age-related relationships were noted in this questionnaire (Table 4-7).

Specifically, as age increased, the tolerance of the overall comfort with the neckline also increased (B=2.042, t=2.417, F=1.555; df=(1, 23); R^2=.370; p=.019). This finding may be due to the behavioral characteristics of the hospital patient gown neckline. That is, as the open-ended exit interviews also signified, the participants pointed out that while wearing the patient gown, the neckline was often out of place and was difficult to manage as it slipped off the shoulders, and raised too high up in the front but dropped low at the back of the neck, causing a 'choking-like' experience. This finding may signify that the older participants were more tolerant with the confined and often ill-fitting gown neckline than the younger participants. This may also be explained by the baseline neckline measurement as the older participants had narrower neckline circumferences than the younger participants. In general, the findings of the regression analyses show that advancing age is associated with the overall comfort and design elements of the hospital patient gown, in particular with the neckline where, as age increased, the overall satisfactory ratings of the hospital patient gown neckline were less impacted.

Table 4-7. Overall ANOVA model summary for design preferences

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1025.627	23	44.592	1.555	.087[b]
	Residual	1749.385	61	28.678		
	Total	2775.012	84			

NOTE: This table presents age as the predictor of hospital patient gown design preferences. *p<.05 and **p<.01, indicate significant fit of the data to the model.

4.4.2.3 BMI Comparison relative to Design Preferences

Overall, the data analyses revealed statistically significant differences across gender and age, but none across different BMI groups regarding the hospital patient gown design preferences. Although different BMI groups did not display significant differences in this subjective evaluation of the hospital patient gown, gender and age differences must be taken into consideration in order to optimize the size of the conventional gown as they are directly involved with the fit and size of the gown.

4.4.3 3D Body Measurements

3D body scan data included (a) baseline measurements (i.e. undergarments), (b) hospital patient gown measurements (i.e. undergarments and hospital patient gown), and (c) functional ease measurements (hospital patient gown measurements minus baseline measurements). 3D scan data were generated at the 11 previously identified landmarks points (Figure 4-1).

4.4.3.1 Gender Comparison

Independent samples *t*-tests were performed to analyze the gender differences in 3D body scan data. Baseline measurements (i.e. only wearing undergarments) of the participants showed gender differences in the landmark points (Table 4-8). Female participants had smaller waist measurement ($\bar{X}_{male}$= 31.79, $\bar{X}_{female}$= 29.18; p=.003), chest measurement ($\bar{X}_{male}$= 40.01, $\bar{X}_{female}$= 37.44; p=.002), neck measurement ($\bar{X}_{male}$= 16.48, $\bar{X}_{female}$= 14.50; p<.001), left elbow ($\bar{X}_{male}$= 10.82, $\bar{X}_{female}$= 9.95, p<.001), right elbow ($\bar{X}_{male}$= 10.70, $\bar{X}_{female}$= 9.83; p=.001), shoulder left ($\bar{X}_{male}$= 5.08, $\bar{X}_{female}$= 4.43; p=.001) and shoulder right ($\bar{X}_{male}$= 4.91, $\bar{X}_{female}$= 4.43; p=.001), which were all statistically significant at a p<.01. Furthermore, female participants had smaller stomach measurement ($\bar{X}_{male}$= 34.10 $\bar{X}_{female}$= 32.16; p=.032), bust measurements ($\bar{X}_{male}$= 38.78, $\bar{X}_{female}$= 36.97, p=.044), abdomen measurement ($\bar{X}_{male}$= 37.29, $\bar{X}_{female}$= 34.66; p=.022) and right bicep ($\bar{X}_{male}$= 12.84, $\bar{X}_{female}$= 11.98; p=.012), which were all statistically significant at p< .05. It is evident that male and female bodies differ naturally. Typically, the male torso is longer than the female's, where the waist line is lower and does not appear as tapered as it is on the female body. Hence, the hips are not predominant and the pelvis is narrower, unlike for females, where the hips appear more predominant with a waist circumference that is more tapered in relation to the hip circumference. Therefore, regardless of how big the differences is between male and female bodies, poor fit will prevail in both cases.

Table 4-8. 3D Body Scan Data of Baseline Measurements by Gender

Baseline Measurements	Sex	*n*	Mean	Std. Deviation	Sig. (2-tailed)
Waist	Male	47	31.788	3.329	.003**
	Female	38	29.177	4.540	
Hips	Male	47	40.612	2.642	.737
	Female	38	40.871	4.361	
Chest	Male	47	40.007	2.956	.002**
	Female	38	37.438	4.315	
Stomach	Male	47	34.097	3.198	.032*
	Female	38	32.161	4.941	
Bust	Male	47	38.775	3.480	.044*
	Female	38	36.972	4.634	
Abdomen	Male	47	37.291	4.547	.022*
	Female	38	34.658	5.824	
Neck	Male	47	16.475	.973	.001**
	Female	38	14.501	1.913	
Knee Left	Male	47	14.999	.836	.733
	Female	38	15.087	1.499	
Knee Right	Male	47	15.217	.834	.599
	Female	38	15.354	1.514	
Left Biceps	Male	47	12.823	1.217	.086
	Female	38	12.234	1.890	
Left Elbow	Male	47	10.816	.696	.001**
	Female	38	9.952	1.330	
Right Biceps	Male	47	12.841	1.120	.012*
	Female	38	11.982	1.944	
Right Elbow	Male	47	10.697	.834	.001**
	Female	38	9.825	1.421	
Shoulder Left	Male	47	5.082	.596	.001**
	Female	38	4.430	.714	
Shoulder Right	Male	47	4.913	.608	.001**
	Female	38	4.427	.745	

NOTE: This table presents gender differences between the 15-selected 3D body scan measurements. *p<.05 and **p<.01, indicate significant differences between male and female participants.

While the baseline measurements showed significant gender differences, the gown measurements (i.e. undergarments + hospital patient gown) did not show any particular gender differences in the 15-selected 3D body measurements except for the neck measurements ($\overline{X}_{male}$= 16.45, SD_{male}=.966; $\overline{X}_{female}$= 14.11, SD_{female}=.893; p<.001) and the left biceps ($\overline{X}_{male}$= 16.14,

SD_{male}=1.809; $\overline{X}_{female}$= 14.71, SD_{female}=4.418; p=.046). These findings could be due to the fact that the conventional hospital patient gown does not covers up the neckline; hence, creates additional bulk around the neck to change the baseline neck measurements and since these already showed significant gender differences, the results are similar. Additionally, the difference in the left bicep could be due to the gown ties, which are located on the left side of the gown. Overlaps and slits, as well gown ties can contribute to size and fit changes of the garment when movement pulls them (Cho, 2006), such as grabbing the handle bar during the 3D body scanning process. The rest of the hospital patient gown measurements data did not show any significant differences and this finding could be due to the fact that the hospital patient gown has a tube-like shape and is fairly wide and ill-fitting, which contributes to similar measurements regardless of the body shape or proportion.

To evaluate the functional ease of the hospital patient gown, baseline measurements, measured while wearing undergarments only were subtracted from the measurements collected while wearing the hospital patient gown over the undergarments. (See Table 4-9 for numerical representation of functional ease.) Functional ease refers to the needs of the garment to accommodate and adapt to the user's movement and other similar functions (Boorady, 2011). The results showed statistically significant data between males and females in their waist measurements ($\overline{X}_{male}$= 13.50, $\overline{X}_{female}$= 15.84, p=.002), chest measurement ($\overline{X}_{male}$= 4.86, $\overline{X}_{female}$= 6.49, p=.001), stomach measurement ($\overline{X}_{male}$=12.78, $\overline{X}_{female}$= 14.30, p=.024) and abdomen measurement ($\overline{X}_{male}$=9.41, $\overline{X}_{female}$= 12.55, p=.001). These significant differences in the waist, chest, stomach and abdomen measurements indicate that there is rather a large discrepancy in the fit of the hospital patient gown between males and females. These differences contribute to and partially define the overall poor fit of the hospital patient gown, which was especially demonstrated in the scenario activities. The results show that in order to provide the optimal fit for both females and males, the potential problem areas discovered in the existing gowns should be addressed. More specifically, with the high significance, it can be implied that the design of the upper body of the gown is poorly designed and this part fits very differently across gender. Thus, special caution should be applied with the upper portion of the gown when addressing the fit and comfort of the new gown suitable for both genders.

Table 4-9. 3D Body Scan Data of Functional Ease Measurements by Gender

Functional Ease Measurements	Sex	*n*	Mean	Std. Deviation	Sig. (2-tailed)
Waist	Male	44	13.500	2.532	.002**
	Female	34	15.840	3.821	
Hips	Male	47	7.240	2.600	.495
	Female	37	6.830	2.807	
Chest	Male	47	4.860	1.885	.001**
	Female	37	6.490	2.563	
Stomach	Male	47	12.780	2.619	.024*
	Female	37	14.300	3.432	
Bust	Male	47	5.020	2.754	.106
	Female	37	5.980	2.560	
Abdomen	Male	43	9.410	3.779	.001**
	Female	34	12.55	4.192	
Neck	Male	47	-.026	.366	.186
	Female	38	-.390	1.842	
Knee Left	Male	47	13.519	8.757	.425
	Female	38	14.951	7.413	
Knee Right	Male	47	13.008	8.569	.979
	Female	38	13.055	7.035	
Left Biceps	Male	47	3.320	1.475	.206
	Female	38	2.479	4.223	
Left Elbow	Male	47	6.595	2.113	.090
	Female	38	7.362	1.960	
Right Biceps	Male	47	2.848	3.168	.764
	Female	38	2.639	3.190	
Right Elbow	Male	47	6.892	2.976	.728
	Female	38	7.114	2.859	
Shoulder Left	Male	47	.532	1.113	.141
	Female	38	.939	1.411	
Shoulder Right	Male	47	1.385	1.414	.665
	Female	38	1.524	1.512	

NOTE: This table presents data revealing statistically significant gender-based differences among the 15-selected 3D body scan measurements. *p<.05 and **p<.01, indicate significant differences between male and female participants.

Descriptive statistics and independent samples *t*-tests were performed to obtain the results from the gown tie portion of the experiment. The data showed statistically significant differences in the upper-back tie between males and females ($\overline{X}_{male}$=1.05, $\overline{X}_{female}$= 0.83; p=.001, refer to Figure 3-3), where the overall mean of the discrepancy between the hospital patient gown and the tie was 0.95cm (Table 4-9). This means that the upper back tie was tied more loosely for males than it was for females. Although no statistical significance was noted in the lower back tie lengths between males and females ($\overline{X}_{male}$=1.78, $\overline{X}_{female}$= 2.30; p=.065), the participants indicated that the gown ties did not provide sufficient size adjustability. As far the gown tie choices, Table 4-10 indicated that all but six participants chose the 1st tie on the upper back located near the neckline, and only six chose the lower back tie, which provided looser fit of the hospital patient gown at the waist/hip circumference. In addition, 92.9% (n=79) of the participants chose the 1st tie on the lower back, which exhibits a more confined and tight fit. The fact that there were such significant preferences in gown ties, and a gown tie length distance signifies that adjusting for size in the hospital patient gown is necessary across gender and diverse body profiles. This emphasizes the need to consider and evaluate the fit of the hospital patient gown for its diverse wearers in body shapes and sizes.

Table 4-10. Hospital Patient Gown Upper-back and Lower-back Ties

Gown Tie	Sex	*n*	Overall Mean (cm)	Mean (cm)	Std. Deviation	Sig. (2-tailed)
Upper-back Tie	Male	47	0.953	1.053	0.280	.001**
	Female	38		0.829	0.334	
Lower-back Tie	Male	47	2.012	1.777	0.765	.065
	Female	38		2.303	1.707	

NOTE: This table presents the data from the hospital patient gown tie measurement. The possible mean score for variables ranges is displayed in centimeters and it represents the distance between the gown and the tie length. *p<.05 and **p<.01, indicate significant differences between male and female participants.

Table 4-11. Hospital Patient Gown Tie Choice

Sex	Lower Back Gown-Tie Choice		Total
	First Tie	*Second Tie*	
Male	45	2	47
Female	34	4	38
Total (%)	79 (92.9)	6 (7.1)	85

4.4.3.2 Age Association with 3D Body Measurements

Regression analyses were preformed to evaluate the presence of linear relationships between age and 3D body measurements. Overall, the baseline body measurements did not vary with age, except for some specific body areas, such as the left bicep (B=3.103; *t*=2.149; *F*=1.396; *df*=(1, 15); R^2=.233; *p*=.035) and right biceps (B=-3.883; *t*=2.382; *F*=1.396; *df*=(1, 15); R^2=.233; *p*=.020) where the model shows statistical significant results (Table 4-12). This means that the newly designed gown could have potential problems with identifying fit issues and addressing sizing issues of the gown areas around the biceps that would meet the needs for people of different ages. Additionally, significant relationships were noted across gender as age increased, where male functional ease measurements were significantly affected by age in the right shoulder (B=-.688, *t*=-2.829; *F*=.474; *df*=(1, 15); R^2=.215; *p*=.009) and right knee (B=-1.726; *t*=.-2.469; *F*=.474; *df*=(1, 15); R^2=.215; *p*=.020) measurements, as age increased, the right shoulder and right knee 3D measurements were negatively affected. This finding could be due to the deformation of the human body as we age (i.e. we lose muscle mass and that could contribute to decreased body measurements). On the other hand, there were significant gender differences in the functional ease measurements where female waist measurement (B=2.131; *t*=2.118; *F*=.827; *df*=(1, 15); R^2=.422; *p*=.050) increased as age increased.

Table 4-12. Baseline and functional ease 3D body scanning measurements by age

Baseline Measurements	Beta	*t*	Sig.	Functional Ease Measurements	Beta	t	Sig.
Waist	-.106	-.159	.874	Waist	.447	.986	.328
Hips	-.241	-.578	.565	Hips	-.275	-.891	.377
Chest	-.926	-.965	.338	Chest	-.380	-1.209	.232
Stomach	.671	.944	.348	Stomach	-.479	-1.017	.314
Bust	.685	.922	.359	Bust	-.182	-.740	.462
Abdomen	-.081	-.311	.757	Abdomen	.044	.204	.839
Neck	.016	.033	.974	Neck	.062	.142	.887
Knee Left	-1.527	-.507	.614	Knee Left	.060	.360	.720
Knee Right	2.796	1.001	.320	Knee Right	-.265	-1.458	.150
Left Biceps	3.103	2.149	.035*	Left Biceps	-.342	-1.536	.130
Left Elbow	2.022	1.058	.294	Left Elbow	.002	.006	.995
Right Biceps	-3.883	-2.382	.020*	Right Biceps	.046	.216	.830
Right Elbow	-1.543	-.902	.370	Right Elbow	.063	.304	.762
Shoulder Left	.939	.721	.474	Shoulder Left	.154	.243	.808
Shoulder Right	-.049	-.036	.972	Shoulder Right	-1.091	-2.371	.021*

NOTE: This table presents age as a predictor of the 3D body scanning measurements. The presented Beta coefficients are unstandardized. *$p<.05$ and **$p<.01$, indicate significant relationships between age and 3D measurements.

4.4.3.3 BMI Comparison

A one-way ANOVA was performed to understand the differences of 3D body scan baseline measurements by BMI. The results indicated statistical significance across different BMI groups in all of the baseline body measurements (Table 4-13). These differences definitely contributed to the overall poor fit of the hospital patient gown, which was especially demonstrated in the scenario activities. The results show that in order to provide the optimal fit for people with diverse BMI profiles, the significant differences across the selected 3D body scan data should be considered. More specifically, with the high significance, it can be implied that people have all kinds of diverse body profiles and the gown size must be able to accommodate as many individuals as possible. Thus, special caution should be applied to the entire 15-selected baseline measurements of the gown when finding the optimal size of the new gown suitable for as many diverse BMI groups as possible.

Table 4-13. Baseline Measurements by BMI

Baseline Measurements		Sum of Squares	df	Mean Square	F	Sig.
Waist	Between Groups	683.394	2	341.697	38.277	.001**
	Within Groups	732.019	82	8.927		
	Total	1415.413	84			
Hips	Between Groups	397.776	2	198.888	25.951	.001**
	Within Groups	628.458	82	7.664		
	Total	1026.233	84			
Chest	Between Groups	555.574	2	277.787	33.791	.001**
	Within Groups	674.098	82	8.221		
	Total	1229.673	84			
Stomach	Between Groups	740.234	2	370.117	42.607	.001**
	Within Groups	712.313	82	8.687		
	Total	1452.548	84			
Bust	Between Groups	622.634	2	311.317	32.015	.001**
	Within Groups	797.383	82	9.724		
	Total	1420.017	84			
Abdomen	Between Groups	660.409	2	330.205	16.010	.001**
	Within Groups	1691.219	82	20.625		
	Total	2351.628	84			
Neck	Between Groups	26.485	2	13.242	4.634	.012*
	Within Groups	234.323	82	2.858		
	Total	260.807	84			
Left Knee	Between Groups	45.869	2	22.935	27.000	.001**
	Within Groups	69.654	82	.849		
	Total	115.523	84			
Right Knee	Between Groups	45.104	2	22.552	25.662	.001**
	Within Groups	72.062	82	.879		
	Total	117.166	84			
Left Biceps	Between Groups	117.038	2	58.519	52.986	.001**
	Within Groups	90.562	82	1.104		
	Total	207.600	84			
Left Elbow	Between Groups	36.530	2	18.265	22.368	.001**
	Within Groups	66.959	82	.817		
	Total	103.489	84			
Right Biceps	Between Groups	108.239	2	54.120	42.342	.001**
	Within Groups	104.809	82	1.278		
	Total	213.049	84			
Right Elbow	Between Groups	45.062	2	22.531	23.820	.001**
	Within Groups	77.562	82	.946		
	Total	122.624	84			

Left Shoulder	Between Groups	4.719	2	2.359	4.907	.010**
	Within Groups	39.422	82	.481		
	Total	44.141	84			
Right Shoulder	Between Groups	7.842	2	3.921	9.261	<.001**
	Within Groups	34.718	82	.423		
	Total	42.560	84			

NOTE: This table presents 3D body scans measurements differing across BMI. *p<.05 and **p<.01, indicate significant differences.

Additionally, although there was no statistical significant in hospital patient gown measurements across different BMI groups, the results indicate that there were significant differences in the functional ease measurements. As previously noted, one of the reasons why the hospital patient gown measurements may not display significant results was due to the overall fit of the gown which eliminates a particular look for a particular type of body (i.e. individual with a healthy BMI) because it hangs similarly on everyone. The 3D data showed statistical significance in functional ease by different BMI groups. To elaborate, waist, chest, stomach, bust, abdomen, left elbow, right elbow, right bicep and shoulders functional ease measurement were noted to be statistically significant across different BMI groups (Table 4-14). These results show empirical data that prove that there are discrepancies between the body and the hospital patient gown that are significantly different across different BMI groups. Additionally, in order to understand the significant differences between gender-specific BMI data, an ANOVA was preformed where both male and female data also indicated some statistical differences among different BMI groups. Specifically, male data indicated significant differences in waist measurement ($\overline{X}_{underweight}$= 16.08, $\overline{X}_{healthy}$= 13.85, $\overline{X}_{overweight}$= 12.16; F=4.177; df=(2, 83); p=.022) stomach measurement ($\overline{X}_{underweight}$= 16.08, $\overline{X}_{healthy}$= 12.93, $\overline{X}_{overweight}$= 11.42; F=6.087; df=(2, 83); p=.005) and right shoulder length ($\overline{X}_{underweight}$= 2.91, $\overline{X}_{healthy}$= 1.43, $\overline{X}_{overweight}$= .81; F=3.868; df=(2, 83); p=.028) among different male BMI groups. On the other hand, female data also indicated significant differences in waist measurement ($\overline{X}_{underweight}$= 17.87, $\overline{X}_{healthy}$= 16.93,

$\overline{X}_{overweight}$= 11.84; *F*=8.494; *df*=(2, 83); *p*=.001), hip measurement ($\overline{X}_{underweight}$= 10.44, $\overline{X}_{healthy}$= 7.35, $\overline{X}_{overweight}$= 3.84; F=16.429; *df*=(2, 83); p=.000), stomach measurement ($\overline{X}_{underweight}$= 16.68, $\overline{X}_{healthy}$= 15.60, $\overline{X}_{overweight}$= 9.77; F=24.047; *df*=(2, 83); p=.000), bust measurement ($\overline{X}_{underweight}$= 7.12, $\overline{X}_{healthy}$= 6.41, $\overline{X}_{overweight}$= 4.23; F=3.273; *df*=(2, 83); p=.050), abdomen measurement ($\overline{X}_{underweight}$= 16.30, $\overline{X}_{healthy}$= 13.73, $\overline{X}_{overweight}$= 7.09; F=21.765; *df*=(2, 83); p=.000), and right knee measurement ($\overline{X}_{underweight}$= 4.71, $\overline{X}_{healthy}$= 12.83, $\overline{X}_{overweight}$= 18.30; F=8.473; *df*=(2, 83); p=.001) across different female BMI groups. In order to adequately address the fit and sizing issues of the future hospital patient gown, the functional ease measurements must be addressed. These differences were definitely supported during the open-ended exit interviews where individuals with different BMIs had different satisfaction over the fit and sizing of the gown.

Given the strong statistical significance that a majority of the functional ease measurements vary with BMI categories, it can be inferred that patients with different BMIs would likely show varying satisfaction levels with the overall comfort and the fit of the gown. In summary, it can be seen from the model that the upper part of the gown is likely a potential problem for addressing the adequate fit and size issues since the functional ease measurements vary across different BMI groups. The results show that the functional ease around the knees and hips area would probably not deliver varying (dis) satisfaction ratings by patients with different BMI groups for the fit and comfort of the gown.

Table 4-14. Functional Ease Measurements by BMI

Functional Ease Measurement	BMI Category	*n*	Mean	Std. Deviation	Sig.
Waist	Underweight	7	17.10	1.601	.003**
	Healthy	50	15.20	3.175	
	Overweight/Obese	21	12.04	2.775	
	Total	78	14.52	3.347	
Hips	Underweight	8	8.77	3.557	.737
	Healthy	54	7.36	2.309	
	Overweight/Obese	22	5.70	2.741	

	Total	84	7.06	2.684	
Chest	Underweight	9	6.05	2.915	.002**
	Healthy	53	5.92	2.183	
	Overweight/Obese	22	4.56	2.271	
	Total	84	5.58	2.342	
Stomach	Underweight	8	16.38	1.625	.032*
	Healthy	54	14.12	2.545	
	Overweight/Obese	22	10.74	2.855	
	Total	84	13.45	3.080	
Bust	Underweight	9	6.81	2.616	.044*
	Healthy	53	5.73	2.291	
	Overweight/Obese	22	4.17	3.233	
	Total	84	5.44	2.698	
Abdomen	Underweight	8	12.57	5.718	.022*
	Healthy	48	11.54	3.793	
	Overweight/Obese	21	8.42	3.814	
	Total	77	10.80	4.240	
Neck	Underweight	9	.037	.230	.001**
	Healthy	54	-.343	1.55	
	Overweight/Obese	22	.092	.309	
	Total	85	-.190	1.265	
Left Knee	Underweight	9	10.508	8.074	.733
	Healthy	54	15.172	7.327	
	Overweight/Obese	22	13.165	9.854	
	Total	85	14.158	8.167	
Right Knee	Underweight	9	8.889	7.879	.599
	Healthy	54	13.582	7.012	
	Overweight/Obese	22	13.363	9.595	
	Total	85	13.029	7.874	
Left Bicep	Underweight	9	3.286	1.930	.086
	Healthy	54	3.016	3.282	
	Overweight/Obese	22	2.627	2.848	
	Total	85	2.944	3.036	
Left Elbow	Underweight	9	6.962	1.160	.001**
	Healthy	54	6.985	2.187	
	Overweight/Obese	22	6.809	2.126	
	Total	85	6.937	2.069	
Right Bicep	Underweight	9	2.766	1.789	.012*
	Healthy	54	3.045	3.076	
	Overweight/Obese	22	2.035	3.753	
	Total	85	2.754	3.160	
Right Elbow	Underweight	9	8.518	3.320	.001**
	Healthy	54	6.985	3.046	
	Overweight/Obese	22	6.380	2.200	
	Total	85	6.991	2.909	
Left Shoulder	Underweight	9	.479	.6776	.001**

Length	Healthy	54	.799	1.316	
	Overweight/Obese	22	.598	1.334	
	Total	85	.7134	1.263	
Right Shoulder Length	Underweight	9	1.628	1.570	.001**
	Healthy	54	1.607	1.467	
	Overweight/Obese	22	.979	1.318	
	Total	85	1.447	1.451	

NOTE: This table presents differences in 3D body measurements across BMI. *p<.05 and **p<.01, indicate significant differences in 3D measurements across BMI.

4.4.4 Scenario Activities

Descriptive statistics and independent samples *t*-tests were performed to analyze the gender differences in the 5 moderate-level scenario activities, including walking, lying, bending, reaching up, and sitting, that are commonly performed by patients in hospital settings. The participants were asked to identify up to three uncomfortable areas during each scenario activity. Each time they mentioned an area of the hospital patient gown that is troublesome; they rated the fit and comfort of the particular area using a 5-point Likert scale (1=very uncomfortable, 5=very comfortable). The participants were given an image of a person wearing the same hospital patient gown (refer to Figure 4-3) with 11 landmark points to aid them in identifying the uncomfortable areas: Neckline, shoulders, bust/chest, waist, hips, sleeve length/width, back opening, armholes, fabric texture/aesthetics, excess of fabrics and knee circumference.

4.4.4.1 Gender Comparison

Although the scenario activities did not show any statistically significance gender differences, they yielded meaningful information for the further development of this study. Overall female participants showed lower satisfactory rating in all four activities except sitting (Table 4-11). Female participants reported slightly lower ratings in overall fit and comfort with the *Walking* activity ($\overline{X}_{female}$ =3.053) than male participants ($\overline{X}_{male}$ =3.181). Female participants also showed slightly lower scores in perceived overall fit and comfort of the hospital patient gown during the *Laying* activity ($\bar{X}_{female}$ =2.711) than male participants ($\bar{X}_{male}$ =3.043). Female participants showed very similar scores of comfort rating for the *Bending* activity ($\bar{X}_{female}$ =2.658) than male participants ($\bar{X}_{male}$ =2.734). The *Reaching Up* activity was ranked overall most uncomfortable where female participants had a lower score ($\bar{X}_{female}$ = 2.184) than male participants ($\bar{X}_{male}$ =2.426). The *Sitting* activity was the only difference in lower ratings of scores where males reported slightly lower ratings ($\bar{X}_{male}$ =2.394) than females ($\bar{X}_{female}$ =2.421). Figure 4-4 and Table 4-15 summarizes the scenario activity ratings in the fit and comfort of the hospital patient gown between male and female participants.

Table 4-15. Overall ratings of the performance of the 5 scenario activities

Overall Comfort	Sex	*n*	Overall Mean	Mean	Std. Deviation	Sig. (2-tailed)
Walking	Male	47	3.124	3.181	.830	.458
	Female	38		3.053	.733	
Laying	Male	47	2.894	3.043	1.015	.084
	Female	38		2.711	.643	
Bending	Male	47	2.700	2.734	.932	.706
	Female	38		2.658	.909	
Reaching Up	Male	47	2.318	2.426	.847	.161
	Female	38		2.184	.692	
Sitting	Male	47	2.406	2.394	1.037	.895
	Female	38		2.421	.826	

NOTE: The possible mean score for variables ranges from 1 to 5.

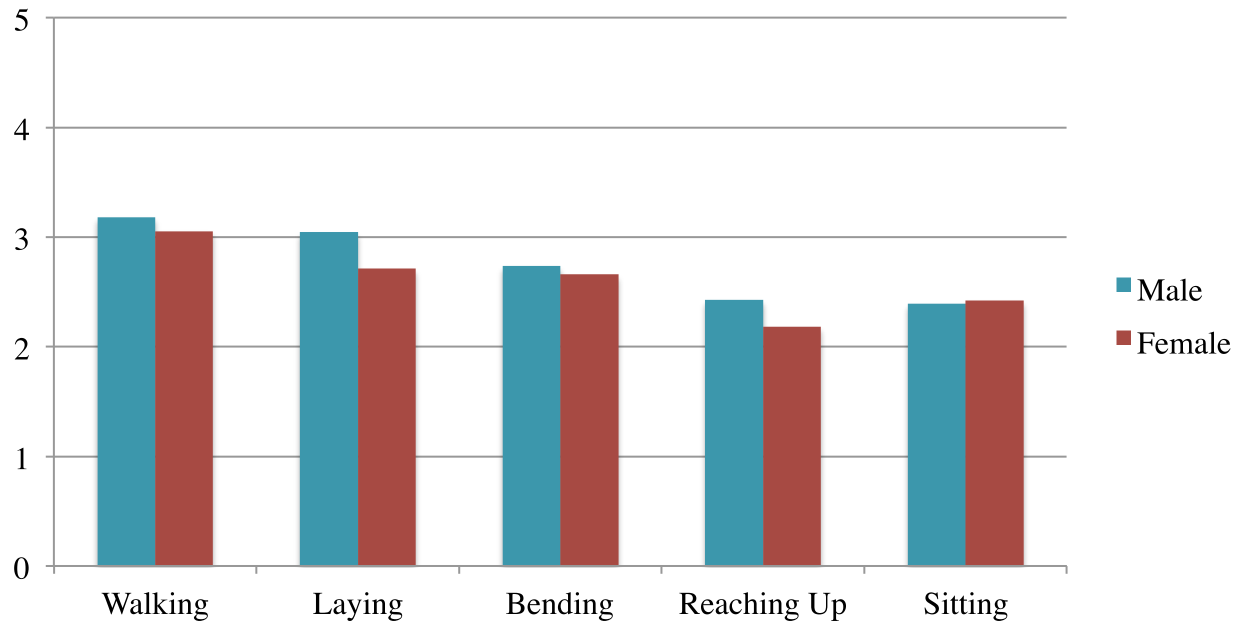


Figure 4-4. Overall rating of the performance of the 5 scenario activities

As for the particular areas that the participants pointed out during the scenarios activities (Table 4-16a) while walking, the following areas were the top five most frequently mentioned: neckline, sleeves, shoulders, back opening, and excess of fabric. Nearly 60% of the participants, i.e., 34 males out of 47 (72.3%) and 16 females out of 38 (42.1%), noted the neck as the cumbersome area of the hospital gown, and it was the most frequently noted area during the walking activity, followed by sleeves, shoulders, back opening, and excess of fabric. Among the aforementioned areas, the gender difference was only found in the ratings of sleeves ($\overline{X}_{male}$=2.11, $\overline{X}_{female}$=2.50; p=.031). That is, male participants rated significantly lower on the sleeves of the hospital gown than females, and their open-ended comments evidenced this trend.

During the lying down scenario activity, the following five areas were most frequently noted: neckline, back opening, shoulders, sleeves and armholes. About 48.2% of the participants, i.e., 18 males (38.3%) and 23 (60.5%) also reported that the neckline is the most troublesome area of the hospital patient gown during the lying activity, closely followed by the back opening, shoulders, sleeves and armholes (Table 4-16b). Although the neckline was often most frequently mentioned as a troublesome area of the hospital patient gown, the complaints were rather similar across most of the participants. Furthermore, the shoulders were also often mentioned as one of the most uncomfortable areas of the hospital patient gown and this could be due to the fact that the males naturally have broader shoulders; hence the hospital patient gown tends to be tighter and more restrictive.

Moreover, the following five areas were most frequently noted during the bending down scenario activity: neckline, back opening, shoulders, hips and sleeves. About 52.9% of the participants, i.e., 28 males (59.6%) and 17 (44.7%), also reported that the neckline was the most cumbersome area of the hospital gown while performing the bending activity, and was closely followed by the back opening, shoulders, hips and sleeves (Table 4-16c).

While performing the reaching up scenario activity, about 80% of the participants featured the back opening of the hospital patient gown as one of the most troublesome areas of the hospital patient gown, where 36 (75%) were males, and 32 (84.2%) were females. and was closely followed by the sleeves, shoulders, neckline and armholes (Table 4-16d). Significant gender differences were noted where females were more concerned with body exposure than males participants ($\overline{X}_{male}$=1.97, $\overline{X}_{female}$=1.47; p=.004).

Furthermore, the particular areas that the participants pointed out during the sitting scenarios activity, the following areas were the top five most frequently mentioned: neckline, back opening, knee circumference, shoulders, and sleeves. Nearly 76.5% of the participants, i.e., 33 males (70.2%) and 32 females (84.2%), noted the neck as the cumbersome area of the hospital gown (Table 4-17e). Among the aforementioned areas was the knee circumference; and although it did not display any gender differences, this trend was more typical for the males then it was for the females. Due to the tunic shape of the hospital patient gown, it may be inferred that males find it more difficult to get accustomed to wearing a gown, especially while sitting. While it is typical for females to keep knees close together and perhaps even cross the legs while performing a sitting position, males tended to keep knees separated and legs more wide spread than females, which contributes to a more tight and restrictive feeling of the gown especially around the knees. This condition of sitting may indicate why males rated lower in the fit and comfort of the hospital patient gown at the sitting position than females. This trend also corresponds with the baseline 3D scan data, in which there are significant differences in baseline knee circumference measurements between males and females.

In conclusion, the data revealed that across all 5-scenario activities, these were the top 5 most uncomfortable landmark areas: Neckline, sleeves, shoulders, back opening and excess of fabrics. The neckline and sleeves have been repetitively reported as the major problem areas for both females and males, where more than 40% of all participants reported having problems performing all activities, except lying and bending. Slightly fewer, but still more than 35% of males reported having neckline problem with lying down, while females reported having sleeves problem with bending. Considering that most patients usually most commonly perform these scenario activities, having such restrictions and tensions in several different body part areas is something that definitely needs to be taken into consideration when presenting solutions for the fit and comfort of the gown as well as exploring the ideal size of the hospital patient gown.

Table 4-16. Top 5 Most Uncomfortable Problem Areas of the Hospital Patient Gown

Scenario Activity	Top 5 Most Uncomfortable Landmarks	Sex	*n*	Mean	Std. Deviation	Sig. (2-tailed)
(a) Walking	Neckline	Male	34	2.235	0.606	.649
		Female	16	2.125	0.719	
	Sleeves	Male	22	2.636	0.581	.337
		Female	20	2.150	0.587	
	Shoulders	Male	18	2.111	0.471	.031*
		Female	16	2.500	0.516	
	Back Opening	Male	12	2.083	0.669	.348
		Female	10	1.800	0.789	
	Excess of Fabric	Male	8	2.125	0.641	.603
		Female	5	1.800	0.447	
(b) Lying	Neckline	Male	18	1.556	0.616	.242
		Female	23	1.789	0.600	
	Back Opening	Male	19	2.211	0.713	.135
		Female	18	1.833	0.786	
	Shoulders	Male	15	2.200	0.561	.326
		Female	15	2.000	0.535	
	Sleeves	Male	16	1.813	0.544	.466
		Female	11	2.000	0.775	
	Armholes	Male	14	2.107	0.626	.243
		Female	9	1.778	0.667	
(c) Bending	Neckline	Male	28	1.893	0.737	.402
		Female	17	1.706	0.686	
	Back Opening	Male	19	2.053	0.621	.626
		Female	14	1.929	0.829	
	Shoulders	Male	14	2.071	0.475	.958
		Female	12	2.083	0.669	
	Hips	Male	18	2.222	0.647	.174
		Female	8	2.625	0.744	
	Sleeves	Male	9	2.333	0.500	.358
		Female	14	2.071	0.730	
(d) Reaching Up	Back Opening	Male	36	1.972	0.736	.004**
		Female	32	1.468	0.621	
	Sleeves	Male	19	2.105	0.809	.359
		Female	17	1.882	0.600	
	Shoulders	Male	13	2.000	0.707	.115
		Female	16	2.437	0.727	
	Neckline	Male	12	1.583	0.669	.347
		Female	9	1.889	0.782	
	Armholes	Male	6	1.500	0.548	.599
		Female	6	1.666	0.516	
(e) Sitting	Neckline	Male	33	1.545	0.564	.348
		Female	32	1.688	0.644	

Back Opening	Male	24	1.875	0.741	.572
	Female	18	1.750	0.647	
Knee Circumference	Male	23	1.913	0.793	.823
	Female	5	2.000	0.707	
Shoulders	Male	7	1.857	0.690	.491
	Female	12	2.083	0.669	
Sleeves	Male	19	1.950	0.762	.561
	Female	9	1.778	0.441	

NOTE: The possible mean score for variables ranges from 1 to 5. *p<.05 and **p<.01, indicate significant differences at the between male and female participants.

Table 4-17. Problem areas by body landmark and activity

Top 5 Most Uncomfortable Landmarks	Neckline		Sleeves		Shoulders		Back Opening		Excess of Fabric	
Sex	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
(a) Walking	72.3%	42.1%	46.8%	52.6%	38.3%	42.1%	25.5%	26.3%	17.0%	13.2%
(b) Lying	38.3%	60.5%	40.4%	47.4%	31.9%	39.5%	34.0%	28.9%	29.8%	23.7%
(c) Bending	59.6%	44.7%	40.4%	36.8%	29.8%	31.6%	38.3%	21.1%	19.1%	36.8%
(d) Reaching up	76.6%	84.2%	40.4%	44.7%	27.7%	42.1%	25.5%	23.7%	12.8%	15.8%
(e) Sitting	70.2%	84.2%	51.1%	47.4%	48.9%	13.2%	14.9%	31.6%	40.4%	23.7%

4.4.4.2 Associations with Age

The subjective evaluation of all participants indicated significant differences between the independent variable age and the five predictors (independent) of overall walking, laying, bending, reaching, and sitting scenario activities (Table 4-18). Overall, regression analyses show significant differences in the gender combined (p=.016) and male (p=.011) data (Table 4-19). As far as the gender combined data, significant results were obtained in the reaching up (p=.021) and sitting (p=.019) scenario activities (Table 4-20). That is, as age increased, regardless of gender, the satisfactory ratings for the reaching up activity decreased and the ratings for the sitting activity increased (i.e. improved). As for the gender-specific regression data, significant differences were also noted in male data. That is, male participants rated lower on the reaching up (p=.001) and higher on sitting (p=.015) scenario activities, as age increased (Table 4-20).

In conclusion, when combined the results show that rating of lying and reaching up activities vary with age. Younger people are likely to report higher rating, i.e. to be more comfortable wearing the gown while reaching up. Also the results show the comfort rating while sitting increases with the patient's age.

Table 4-18. Model summary of overall ratings of the 5 scenario activities

Model	Sex	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate
1	Combined	.398[a]	.158	.105	5.4371
	Male	.542[a]	.294	.208	4.4687
	Female	.446[a]	.199	.074	6.2782

NOTE: This table presents age as a predictor of scenario activities ratings. *p<.05 and **p<.01, indicate significant relationships between age and scenario activities.

Table 4-19. Model summary of overall ratings of the 5 scenario activities

Model	Sex	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	Combined	439.608	5	87.922	2.974	.016[b**]
Residual		2335.404	79	29.562		
Total		2775.012	84			
Regression	Male	340.971	5	68.194	3.415	.011[b**]
Residual		818.732	41	19.969		
Total		1159.702	46			
Regression	Female	313.463	5	62.693	1.591	.191[b]
Residual		1261.300	32	39.416		
Total		1574.763	37			

NOTE: This table presents age as a predictor of scenario activities ratings. *p<.05 and **p<.01, indicate significant relationships between age and scenario activities.

Table 4-20. Model summary of overall ratings of the 5 scenario activities

Sex	Model	Unstandardized Coefficients	Standardized Coefficients		*t*	Sig.
		B	Std. Error	Beta		
Combined	Overall (Walking)	-.752	.903	-.103	-.832	.408
	Overall (Laying)	-.847	.832	-.130	-1.018	.312
	Overall (Bending)	-.454	.828	-.072	-.549	.585
	Overall (Reaching)	-2.137	.909	-.292	-2.350	.021**
	Overall (Sitting)	1.838	.770	.302	2.386	.019**
Male	Overall (Walking)	.573	.989	.095	.579	.566
	Overall (Laying)	-.039	.897	-.008	-.043	.966
	Overall (Bending)	-.924	.965	-.171	-.957	.344
	Overall (Reaching)	-3.585	.976	-.605	-3.674	.001**
	Overall (Sitting)	2.114	.834	.437	2.534	.015*
Female	Overall (Walking)	-2.751	1.589	-.309	-1.731	.093
	Overall (Laying)	-2.714	1.730	-.268	-1.569	.127
	Overall (Bending)	-.196	1.384	-.027	-.141	.888
	Overall (Reaching)	-.137	1.706	-.015	-.080	.937
	Overall (Sitting)	1.414	1.414	.179	1.000	.325

NOTE: This table presents age as dependent predictor of the scenario activities ratings. *p<.05 and **p<.01, indicate significant relationships between age and scenario activities.

4.4.4.3 BMI Comparison

In order to ensure diverse representation of body profiles, the participants' BMI was calculated based on their height and weight. All of the participants wore minimal clothing (i.e. the hospital patient gown) during this process to ensure that their BMI was calculated accurately. By gender, the participants were categorized and placed in one of the following 3 BMI groups: (a) underweight, (b) normal and (c) overweight/obese.

None of the scenario activities showed statistical significance in the results of the ANOVA analysis at $p<.05$. However, overall, the walking activity had the highest best rating ($\bar{X}_{total}$= 3.12) among the different BMI groups ($\bar{X}_{underweight}$= 2.83, $\bar{X}_{healthy}$= 3.20, $\bar{X}_{overweight}$= 3.05) which indicated a neutral satisfaction with the fit and comfort of the hospital patient gown during walking; following, the laying down activity ($\bar{X}_{total}$= 2.89) scored a slightly dissatisfied to neutral across different BMI groups ($\bar{X}_{underweight}$= 3.00, $\bar{X}_{healthy}$= 2.97, $\bar{X}_{overweight}$= 2.66). Next was the bending activity ($\overline{X}_{total}$= 2.70), which scored between slightly uncomfortable and neutral across different BMI groups ($\overline{X}_{underweight}$= 2.83, $\overline{X}_{healthy}$= 2.69, $\overline{X}_{overweight}$= 2.68); the sitting activity received the second worst ratings ($\overline{X}_{total}$= 2.40) across different BMI groups ($\overline{X}_{underweight}$= 2.17, $\overline{X}_{healthy}$= 2.45, $\overline{X}_{overweight}$= 2.39), where the participants indicated that they were uncomfortable performing this activity while wearing the hospital patient gown. The reaching up activity received the worst ratings ($\overline{X}_{total}$= 2.32) across different BMI groups ($\overline{X}_{underweight}$= 2.17, $\overline{X}_{healthy}$= 2.36, $\overline{X}_{overweight}$= 2.27) (Table 4-21). Although the gender combined and male data did not show any significant differences across the 5 scenario activities data, female data did indicate significant differences in the reaching up activity ($\overline{X}_{underweight}$= 1.60, $\overline{X}_{healthy}$= 2.17, $\overline{X}_{overweight}$= 2.57) where underweight female individuals were least comfortable with doing this activity, following by healthy weight female individuals and lastly overweight and obese females (Table 4-22).

Table 4-21. Descriptive Scenario Activity Data by BMI

Scenario Activity	BMI Category	N	Mean	Std. Deviation	Sig.
Walking	Underweight	9	2.833	.6124	.372
	Healthy	54	3.204	.8098	
	Overweight/Obese	22	3.045	.7854	
	Total	85	3.124	.7864	
Laying	Underweight	9	3.000	.8292	.350
	Healthy	54	2.972	.8818	
	Overweight/Obese	22	2.659	.8916	
	Total	85	2.894	.8800	
Bending	Underweight	9	2.833	.8660	.901
	Healthy	54	2.685	.8649	
	Overweight/Obese	22	2.682	1.0861	
	Total	85	2.700	.9168	
Reaching	Underweight	9	2.167	.8660	.757
	Healthy	54	2.361	.7674	
	Overweight/Obese	22	2.273	.8270	
	Total	85	2.318	.7862	
Sitting	Underweight	9	2.167	.5000	.700
	Healthy	54	2.454	1.0473	
	Overweight/Obese	22	2.386	.8155	
	Total	85	2.406	.9433	

NOTE: This table presents BMI as the grouping variable and differences across BMI in the scenario activities ratings.

Table 4-22. Female ANOVA Scenario Activity Data by BMI

Scenario Activities	Female Data	Sum of Squares	*df*	Mean Square	*F*	Sig.
Walking	Between Groups	1.306	2	.653	1.229	.305
	Within Groups	18.589	35	.531		
	Total	19.895	37			
Laying	Between Groups	.469	2	.234	.552	.581
	Within Groups	14.847	35	.424		
	Total	15.316	37			
Bending	Between Groups	.839	2	.419	.494	.614
	Within Groups	29.714	35	.849		
	Total	30.553	37			
Reaching	Between Groups	2.955	2	1.477	3.505	.041*
	Within Groups	14.756	35	.422		
	Total	17.711	37			
Sitting	Between Groups	1.083	2	.541	.784	.465
	Within Groups	24.181	35	.691		
	Total	25.263	37			

NOTE: This table presents differences across female BMI groups in the ratings of scenario activities. *$p<.05$ and **$p<.01$, indicate significant differences among females across BMI groups in scenario activities ratings.

4.4.5 Exit Interview

The exit interview data revealed that there are several major problem areas of the hospital patient gown that must be addressed. Considering that most of the problem areas were supported by multiple quantitative channels (i.e. though the 3D body scan data or the scenario activities), it is essential that these references are reiterated as they are directly associated with the overall comfort, fit and size of the hospital patient gown. Main areas identified as needing improvement included neckline, shoulders, back opening, armholes and sleeves, bust or chest and knee circumference. The results show that in order to provide the optimal fit for both females and males, the potential problem areas discovered in the existing gown should be addressed.

4.4.5.1 Neckline

Neckline was an issue for nearly all of the participants in one way or another, which is why it was also ranked as one of the most uncomfortable areas of the hospital patient gown by both genders, individuals from various ages and BMI groups. Exit interview data identified these issues with the neckline: it was riding up too high in the front and dropping too low in the back; it would not remain centered hence, it would shift with every movement; felt tight and restricting in the front of the neck; posed issues with tying the upper back ties of the gown. Most of the participants indicated that these issues with the gown limited their mobility, increased their frustration, restricted their ability to don and doff the gown and impacted their overall mood, comfort and experience of wearing a hospital patient gown. Cho (2006) argues that if the hospital patient gown is ill fitting and not comfortable to the body that it can impact the recovery state of the patients. Considering how spacious and wide the gown is and can feel to some individuals, having something that tight around the neck when everything else is free-floating might evoke a feeling of unrest and frustration, which is most certainly an issue with patients who are in need of rapid recovery. Figure 4 visually demonstrates the ill-fitting neckline, and the following accounts exemplify the participants' comments on the gown neckline.

ID 17: I think if you just cut it into a V-neck, the fit would be so much better. You would have more room to move around and not feel like you are getting choked (Female, 19 years old, BMI: Healthy).

ID 38: The neckline was pretty uncomfortable and irritating especially at the back when I was sitting down and moving around because it felt too exposed and with any movement it tightens up around your neck. Also, tying it by yourself was pretty much impossible to do (Male, 23 years old, BMI: Healthy).

ID 79: The neck and the shoulders need help. The neckline is just so tight around the neck and it chokes me, haha (Female, 52 years old, BMI: Healthy).

ID 70: The neckline has too big of a gape, it can go really far forward, and it can go really far backward so it shifts the weight of the fabric (Male, 29 years old, BMI: Overweight).

Figure 4-5. Hospital Patient gown neckline during (a) sitting and (b) walking activities

4.4.5.2 Bust, Chest and Stomach

It is evident that male and female bodies differ naturally. Looking at the current hospital patient gown it can be noticed that the bust/chest/stomach are closely interconnected areas of the gown and their fit and sizing have not been accurately taken into consideration. Since most of the weight is located at this part of the body, it is essential that the fit and the size be adequately represented. This front part of the hospital patient gown was mostly an issue for females as they complained the gown was clearly biased in its unisex construction. Some of the major concerns with this part of the hospital patient gown were the following: lack of consideration that females need more room at the bust; restricted movement to the sides especially during the lying activity; lack of size adjustability; tightness and tensions in the bust and chest area and looseness in the stomach area. The participants indicated that these circumstances impacted their psychological state of mind and overall satisfaction with their appearance. Females displayed slightly higher disagreement and dissatisfaction with the comfort of the bust/chest area of the gown. Visual data is unavailable due to lack of consents.

ID 7: It makes me wonder if there is a way to make the gown more unisex applicable, or if it fits better to just have 2 different ones and accommodate for both genders, especially for females because the current gown really does not take into consideration the female upper-body structure. (Female, 25 years old, BMI: Obese)

ID 6: I think the whole chest circumference, neck, back opening and arm area, that's all kind of too tight when I am trying to move, especially the chest because it gives a pretty vivid outline of my chest and reveals my back and I am really not okay with it; mainly when I am trying to reach up or bend down. (Female, ID: 24, 21 years old, BMI: Healthy)

"I do not like the chest and back area of the gown, and how it is meant to fit different sizes

but it really isn't beneficial because it just ends up opening at the back and hanging too loose in the front. (Female, 20 years old, BMI: Underweight)

ID 5: I think really more of a bell shape needs to taper down from the armholes instead of a tube because especially for women with curves in the hips and stomach. Plus, a lot of people carry their weight in the front of their body and it seems that it is assuming equal proportions and so, the back ends up being too big because the stomach/chest pulls it forward…it didn't really seem like the gown was accommodated for my chest, and I have a relatively average size chest and so for me, it completely changed the whole fit of the garment. (Female, 25 years old, BMI: Obese)

4.4.6 Sleeves and Armholes

Male participants rated significantly lower on the sleeves of the hospital gown than females, and their open-ended comments evidenced this trend. Because the sleeve width was noted to be too wide (i.e. the armhole area) for most of the participants in this study, it was often prominent that the sleeves lacked modesty and revealed body parts while walking around and holding an IV. Additionally, most of the participants, including females complained that the length of the gown is odd and suggested that it is shorter (or longer if that is more medically preferable). The participants mentioned that disadvantages of the sleeves are not only its length and width but also the irritation of the cold snaps, the large gap between the snaps and the width of the armholes, which revealed body parts in some cases. Figure 4-6 demonstrates an example of the ill-fitting sleeves and armhole areas of the gown.

ID 1: The sleeve length was definitely too long, especially for women and I think it would be nice to be able to do something about it like, hook it up. Also, it was tight at times like when I was trying to lift things or move around but at the same time if I extend my arm, the *armhole gap became too wide, which exposed my bra and probably other body parts. (Female, 32 years old, BMI: Healthy).*

ID 46: The sleeves are very tight around the bicep area especially if you consider bending down and extending your hand further for a glass of water, but then when you raise your hand up, the sleeve suddenly becomes too wide and sloppy. (Male, 23 years old, BMI: Healthy).

Figure 4-6. Hospital patient gown sleeves and armholes during scenario activities

4.4.6.1 Shoulders

Although both male and female participants indicated that the shoulders posed a restrictive and tight feeling, this design feature of the hospital patient gown was predominant for males mostly. The shoulders were mentioned as one of the most uncomfortable areas of the hospital patient gown and this could be due to the structure of the conventional gown. This poses an issue for males (mostly) due to the fact that the males naturally have broader shoulders and the hospital patient gown tends to be tighter and more restrictive. In order for the gown to adequately address the fit and size issues, the current technical structure of the gown must be adjusted and accommodated accordingly. The shoulders must stand on their own separately from the main body of the gown. Here are some of the comments from the participants.

ID 43: The shoulders limit my movement and to me, it actually feels like that whole area is out of place and will not stay centered (Female, 24 years old, BMI: Healthy).

ID 36: I would concentrate mostly on the neckline and the shoulders. The neckline just creeps up on your throat and the shoulders circumference is just very tight and restrictive (Male, 39 years old, BMI: Obese).

ID 53: The shoulders tighten up when I make any sort of movement especially during the reaching up and lying activities. Because it is so restricting and tight, with any movement the gown rises which is very uncomfortable. (Male, 19 years old, BMI: Healthy)

4.4.6.2 Back Opening

The back opening of the hospital patient gown showed unease in both genders. However, females felt slightly more dissatisfied with this feature of the gown than males, especially during the reaching up activity. Some of the issues associated with the back opening are the following: lack of modesty and security (i.e. revealing body parts); restricted movement; affected emotional state of mind; irritation of lower back ties located at the back opening; and avoidance to perform certain activities due to lack of security and privacy. Figure 4-7 demonstrates visual presentation of some of these issues.

ID 22: The back opening was definitely the most uncomfortable part of the gown because it had such minimal security and felt like it will open up anytime. (Female, 23 years old, BMI: Healthy).

ID 69: It would be nice to try to limit the exposure of the back opening and although I felt fine, it certainly is a problem. (Male, 29 years old, BMI: Overweight).

ID 15: I just really didn't appreciate the back opening, I felt like even if I could have tied it to the possible end of the strait, I would still have parts of my body exposed. (Female, 19 years old, BMI: Obese).

ID 80: Feeling exposed on the back is pretty uncomfortable and not necessarily physically but more like emotionally especially if you are reaching for something; feeling exposed on the back would probably prevent me from doing things necessarily in the hospital that I want to do (Male, 31 years old, BMI: Overweight).

Figure 4-7. Hospital patient gown back opening during scenario activities

4.4.6.3 Knee Circumference

The knee circumference was mostly typical issue for the male participants especially during the sitting and lying activity. Some of the main issues with this feature of the gown were the following: restricted body movement; restricted blood circulation during the sitting activity; body pressure marks; potential flashing (i.e. exposing body parts during the sitting activity); and tightness around the knees. Figure 4-8 demonstrates a visual presentation of some of these issues.

ID 82: When it comes to the lower part of the legs, I can't sit comfortably because the gown rides up in the front and tightens around my knee circumference, which makes it hard for me to maintain my dignity. (Male, 28 years old, BMI: Overweight).

Figure 4-8. Hospital patient gown knee circumference

4.5 Discussion

The purpose of this study was to identify fit issues associated with the hospital patient gown in order to facilitate a better fit and comfort of the hospital patient gown to as many potential patients as possible. To address the research questions, this study adopted a three-dimensional (3D) body scanning technology as a primary body measurement tool. In addition, the study measured sensory clothing preferences and hospital patient gown design preferences through the use of a survey preferences questionnaire. Besides objectively generating body measurement data, this study also employed a multiple scenario activity, which measured and identified fit and comfort issues of the hospital patient gown. As a supplementary method, the study conducted exit interviews, which yielded additional insights into the hospital patient gown. The exploration of the fit and comfort of the hospital patient gown across gender, diverse age, and different BMI categories revealed three major issue that must be taken into consideration in order to achieve an the best fit and size for the hospital patient gown: (a) consideration of sensory clothing preferences and hospital patient gown design preferences, (b) 3D body measurements and (c) accommodation to common daily activities such as, walking, laying, bending, reaching up and sitting during hospitalization.

4.5.1 Sensory Clothing Preferences

The results showed that female participants were more concerned with clothing security and privacy than male participants. The results from the sensory clothing preferences questionnaire indicated statistically significant gender differences in the preference for clothing that has good coverage and better security, where females placed higher importance than males. During the exit interviews, female participants definitely seemed more concerned with the adornen, protection and security that clothing provides. Li & Wang (2006) state that well-fitting and comfortable clothing can enhance the overall satisfaction of the wearer by providing the function of modesty and giving the wearer the mental comfort of having their bodies covered properly. Moreover, significant gender differences were noted in the comfort of wearing loose-fitting clothing, clothing that hangs well on the body and clothing that exhibited a drapery look, where females felt significantly more comfortable than males with these clothing preferences. In addition, females had a significantly higher agreement than males that clothing comfort should be more important than aesthetics, whereas males had a significantly higher agreement than females that clothing comfort should be more important than clothing quality. In both cases, clothing comfort outweighed other clothing attributes indicating that clothing comfort is indeed a fundamental and universal need for all consumers (Li & Wong, 2006). On the other side, male participants had a higher preference for wearing a more structured silhouette than females. Because individuals have apparel fit and comfort preferences based upon functional and aesthetics expectations, it is ultimately the wearer who determines what is considered to be a good fit (Ashdown & DeLong, 1995). The understanding of human sensory perception of clothing is essential in the process of advancing the fit and comfort of any product as these elements are often in direct contact with the human body during the wear, which can stimulate mechanical, visual and thermal sensations (Li & Wong, 2006).

The results reported that there were significant differences in sensory clothing preferences across age. For instance, as age increased, the discomfort with clothing tags and seams also increased. Moreover, the results showed that there was significant difference across age and the hospital patient gown design preferences. As age increased, so did the positive ratings of the neckline, which indicates that the tolerance gets higher for this trait as age progresses. Although a majority of the participants often found the neckline to be a critical body landmark point, which must be addressed in the future design of the hospital patient gown. Although the overall fit, sleeve length and gown width did not have significant relationships wit progressing age, it should be noted that exit interview data were supportive of these being problematic areas. The overall fit satisfaction and comfort of the hospital patient gown seemed to be declining as age increased among the participants and this finding could be due to the exceptional requirement and consideration of flexibility, comfort and mobility. Because the current apparel and textile market is not well suited for people with unusual body dimensions and/or different kinds of functional impairments, many elderly people and people with disabilities do not fit into the current size systems and an adjustment of the garments is usually needed (Thoren, 1994).

Results showed that only one significant BMI related difference was noted in this sensory clothing questionnaire. Overall, the data indicated significant differences in the comfort of wearing revealing clothing across different BMI groups where participants with healthy weight were more comfortable with this idea and underweight and overweight/obese participants were less comfortable. Additionally, the tightness of the gown should be taken into consideration, due to the possibility of its impact on the overall comfort and restricting nature of the hospital patient gown considering activities of daily living. The model results call for caution on these aspects of the gown design since underweight and obese patients feel lower satisfaction wearing revealing or tighter fit clothing.

4.5.2 Hospital Patient Gown Design Preferences

The results revealed that the satisfaction with the physical features of the conventional gown vary across gender, in gown width, chest circumferences, gown back opening, spiral access, size adjustability and overall mobility and medical practicality. Given that the results show a clear bias towards higher males' satisfaction for all features, it may be inferred that the conventional gown is generally more suitable for male patients, or males are more tolerant with the gown than females. These results showed that as we get older, our tolerance in terms of satisfactory ratings improves for the neckline of the hospital patient gown.

4.5.3 3D Body Measurements

The 3D body scanning baseline measurement data revealed major significant differences between the male and female physique in the waist, chest, stomach, bust, abdomen, neck, left elbow, right elbow, right bicep, left shoulder and right shoulder, where males exhibited higher means than females, which signifies that the male physique was on average, bigger than the female one. This indicates that H1 was supported. Measuring the human anthropometry by a conventional tape-measure method is time consuming, and this is why 3D body scanning technology was used for this study to obtain objective high-quality digital information about the human body shape. Male and female bodies differ naturally where typically, the male torso is longer the female's and the waist line is lower and does not appear as trapped with the rest of the body, as it does on the female body. Hence, the hips are not predominant and the pelvis is narrower for males however, for females, the hips are more accentuated and the waist circumference looked more tapered. Although males and females have significant differences in baseline waist measurements, they both reported feeling the same tension at the hip during the bending and sitting scenario activities. Because of the straight (tube-like) and fairly wide silhouette, the hospital patient gown often fits everyone the same. Support of this was found in 3D scan measurements: when the participants were scanned using the 3D body scanner for the second time wearing the hospital patient gown, the body measurements were very similar and did not display any particular gender differences except for the neck and left bicep. The functional ease measurements displayed significant differences between males and females in waist, chest, stomach and abdomen measurements. Although there were significant differences in the male and female physique, most of the participants reported that the hospital patient gown was bulky around the waist, stomach and abdomen. Previous studies have also noted that this finding may be due to the fact that the conventional gown has a straight silhouette, which helps build up space around the waist and stomach area, and the space might contribute to bulkiness (Cho, 2006).

Baseline body measurements did not vary much with age, except for some specific body areas, such as the left bicep and right biceps. This finding could be due to the fact that we tend to lose muscle mass as we age which can negatively impact the measurements size on certain body pats especially around the biceps. Additionally, significant differences were noted across gender as age increased, where male functional ease measurements were significantly affected by age in the right shoulder and right knee measurements. Here, as age increased, the right shoulder and right knee were also negatively affected, which could be similarly explained. Furthermore, there were significant gender differences in the functional ease measurements where female waist measurement increased as age progressed. This indicates that H2 was supported.

The results indicated that there was statistical significance across different BMI groups in all of the baseline body measurements (i.e. waist, hips, chest, bust, neck, left knee, right knee, left biceps, right biceps, left elbow, right elbow, left shoulder length and right shoulder length) as well as some of the functional ease measurements (i.e. waist, chest, stomach, bust, abdomen, left elbow, right elbow, right bicep and shoulders measurement). Additional female data also showed significant results across different BMI groups in the waist, hips, stomach, bust, abdomen and right knee circumferences at the functional ease measurements. On the other hand, male data also showed significant results in the functional ease measurements across different BMI groups and they were the followings: waist, stomach and right shoulder measurements. These differences definitely contributed to the overall poor fit of the hospital patient gown, which can restrict body movement, limit overall comfort and performance, and pose tightness and pressure around certain parts of the human body. The results show that in order to provide the ideal fit for people with diverse BMI profiles, the significant differences across the selected 3D body scan data should be considered. More specifically, with such high significance across baseline and functional ease measurements data, it can be implied that people have all kinds of diverse body profiles and the gown size must be able to accommodate as many such individuals as possible. This indicates that H3 was supported.

4.5.4 Scenario Activities

During the scenario activities, gender differences were noted during the walking activity and the identified body landmark area was shoulder, where males displayed lower ratings than females. Moreover, major gender differences were noted during the reaching up activity, where females had significantly lower ratings associated with the back opening of the hospital patient gown than males. Considering that males have much broader shoulders than females, the comfort ratings of the shoulders were a lot lower and their comment had a stronger voice. This finding may be due to the current construction of the gown, which qualitative and quantitative data have revealed is tight and restricting especially for individuals with wider shoulders. Although there were no significant differences in age for females, there was for males in the same reaching up and sitting activities. Specifically, during the reaching up activity males rated this activity worse than they did the sitting activity, which received positive (better) results.

As for age, the gender-combined results show that rating of lying and reaching up activities vary. Younger people are likely to report higher rating, i.e. to be more comfortable wearing the gown while reaching up. Additionally, the results show the comfort rating while sitting increases with the patient’s age. There were no significant results in scenario activities across different BMI groups except for females in the reaching up activity. It seemed that the underweight individuals were least comfortable performing this activity, followed by the healthy and then overweight/obese individuals. This indicates that H2 was supported.

4.5.5 Exit Interview

The supporting data indicated similar results related to the most troublesome areas of the current hospital patient gown. Some of the major issues identified were the following: neckline, bust/chest and stomach, sleeves and armholes, shoulders, back opening and knee circumference. This clearly supports the major quantitative findings and calls for immediate attention to the previously mentioned problem areas of the gown.

4.6 Conclusion

The hospital patient gown is a simple yet complicated garment that needs to satisfy diverse needs of multiple end users. Considering that almost each and every one of us will be hospitalized at some point in our lives, gown designers need to accommodate the gown to fit many diverse body profiles and satisfy as many of potential individuals as possible. In the contextual situation of using the hospital patient gown, being hospitalized does not mean that the patients do not perform basic daily activities, such as walking, bending, lying, reaching up and sitting or that they are completely isolated from social interactions with other patients, visitors and caregivers. The particular purpose of the study was to identify fit issues associated with the conventional hospital patient gown and to propose insightful solutions for this universally used garment in order to better facilitate the fit and comfort to as many potential patients as possible.

The findings of the study suggest that there are major issues with the conventional hospital patient gown, which must be address adequately in order to adequately address the fit, comfort and sizing of the gown. First, the data indicate that sensory clothing preferences, as well as hospital patient gown preferences are the essential step in the future development of the hospital patient gown and should be carefully considered before the production of the garments is set in place. These features provide subjective preferences of the patients regarding their personal clothing habits and how they foresee their experience with the future hospital patient gown. This initial design scheme will aid with defining the general scope and conceptual design of the future construction of the gown. Key design considerations, identified through this study, are summarized below:

- Allowing for better fit throughout the garment
- Elimination of clothing tags and raw seams lines
- Careful choice of fabrics to where it hangs well on the body and can shape around variety of different body profiles
- Consideration of good coverage with secure closure systems that minimize the exposure of body parts and maximized garment mobility
- Accommodation of size adjustability on both, upper and lower back
- Design features that allow for easier donning and doffing of the garment

The second aspect focuses on the fact that human bodies differ across gender, age and BMI groups and these variables must be considered at the development stage of the hospital patient gown because various body types play significant roles in affecting the fit of the garment. In addition, 3D body (i.e. baseline) measurements indicate strong results that major differences are present in terms of the male and female physique, as well as across various ages and different BMI groups. Specifically, male and female bodes showed significant differences in the waist, chest, neck, elbows, shoulders, stomach and abdomen measurements where females tended to have smaller measurements than males. Not only did the results indicate that there are evident differences between male and female bodies, the data also verified that as we age, our bodies lose muscle mass and body measurements decrease. Additionally, the data indicated that there are significant differences between various BMI groups, which imply that the future design of the hospital patient gown must take into consideration several critical landmark points, such as the waist, shoulders, bust/chest, neckline and abdomen areas. Therefore, it is strongly recommended that diverse anthropometric comparisons of the potential users (e.g., gender, age, and BMI) should be considered during the design stage of the future hospital patient gown. The results from this study identified the following key points, with regards to diverse body anthropometry:

- Waist, chest, stomach, bust, abdomen, neck, elbows, shoulders, and biceps region should be closely considered to fit various body profiles of both genders and different BMI categories
- The functional ease of the garment must be enhanced to where it provides and discrepancies between the body and the garment
- Age impacts clothing fit and comfort and such aspects (i.e. muscle loss and postural differences including pathology) should be considered in the future design of the gown

Third, accommodating to common daily activities, such as walking, laying, bending, reaching up and sitting during hospitalization is one of the most essential parts to consider when solutions on how to optimize the size of the gown are considered and proposed. The following solutions were suggested:

- The size of the neckline needs to be adequately adjusted to where it remains centered on the body and avoids shifting the gown in either direction
- Maximum security of back opening (or any other similar sensitive body parts) during any physical activity, especially the reaching up activity

- Consideration of increased mobility in the shoulders and bicep areas of the gown
- Smaller sleeve width and shorter sleeve length to accommodate irritation at elbow and allow for easy access to IVs bags
- Accommodation at the bust/chest area (i.e. consideration of female upper body)
- Elimination of excess of fabric around stomach and abdomen (i.e. consideration of a wrap style that can be easily maneuvered around the body)

The sources of the data collected for this study are representative of only those community members being involved. Eighty-five (47 males, 38 females) participants from the Midwestern region of the United States participated in this study. Due to a limited samples size, these data may restrict generalization of data for all communities across the United States or globally. Also, considering the exploratory nature of this study, significance levels were not adjusted in the case of multiple *t*-tests, leading to claims made here of significant differences where some (for example with *p* values between .05 and .004) possibly not representing true significant differences. These findings were reported as such to highlight all potential problems in the various areas studied. Further investigations are desired with a larger sample size from several different regions of the county, representing various ages and BMI categories. The mean age of the study participants was 23.2 (SD= 5.7). Thus the age of the participants was skewed toward the younger population. Considering that the main users of the hospital patient gown are much older, additional data collection is highly desired with older participants. Additionally, the recruited participants were mostly healthy with stable physical and mental health, which could contribute to the overall satisfaction and comfort of the gown. Although the use of 3D body scanning technology provided highly accurate anthropometric data of the hospital gown's potential users, given that the gown is often worn when the patients are in motion, wireless motion capture (MoCap) systems should be considered for future studies, along with the evaluation of the scenarios activities. Additionally, other anthropometric measurements, pattern construction and human movement need to investigate the functional change and provide further guidance on functional ease requirements for a universally used garment. Researchers should continue to evaluate specific designs that would accommodate for the identified fit and comfort issues of the hospital patient gown to as many individuals as possible. Lastly, a comparison between the conventional hospital patient gown and a prototype gown with specific design elements and application of the optimization solutions presented through this study should be compared to potential patients with diverse background profiles.

4.7 Insights

Based on the findings of this study, the following suggestions were proposed in order to deliver the best fit and comfort of the gown as well as addressing the sizing issues of the conventional hospital patient gown:

- Make the neckline less wide and more steep in the front (i.e. V-neck)
- Increase shoulder mobility (i.e. curve Reglan sleeves; contour silhouette)
- Adjust length and width of sleeves & armholes (i.e. shorten sleeves – above elbow)
- Introduce a better closure system (i.e. reduce the potential of revealing body parts)
- Accommodate for better fitting bust/chest (i.e. consider the female upper body; add more volume and flexibility)
- Consider allowing for size adjustability in critical points, such as stomach/abdomen/hips
- Allow for more flexibility around the knee circumference
- Consideration of sensory clothing and hospital patient gown preferences

REFERENCES

Apeagyei, P. R. (2010). Application of 3D body scanning technology to human measurement for clothing fit. *International Journal of Digital Content Technology and its Applications, 4*(7), 58-68.

Ashdown, S. P., Loker, S., Adelson, C., Carnrite, E., Lyman-Clarke, L., & Petrova A. (2005). Improved apparel sizing: Fit and anthropometric 3D scan data. *National Textile Center Annual Report*. NTC Project: S04-CR01.

Ashdown, S., Loker, S., & Rucker, M. (2007). Improved apparel sizing: Fit and anthropometric 3-D scan data. *National Textile Center Research Briefs.* NTC Project: S04-CR01. 1-3.

Ashdown, S. P., Loker, S., Schoenfelder, K., & Lyman-Clarke, L. (2004). Using 3D scans for fit analysis. *Journal of Textile and Apparel, Technology and Management*, *4*(1), 1-12.

Ashdown, S. P. (1998). An investigation of the structure of sizing systems: a comparison of three multidimensional optimized sizing systems generated from anthropometric data with the ASTM standard D5585-94. *International Journal of Clothing Science and Technology*, *10*(5), 324-341.

Assessing Your Weight. (2012, July). *Centers for Disease Control and Prevention*. Retrieved from: http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

Black, S., & Torlei, K. (2013). Designing a new type of hospital gown: A user-centered design approach case study. *Fashion Practice: The Journal of Design, Creative Process & The Fashion*, *5*(1), 153-160.

Boothroyd, G. (1994). Product design for manufacture and assembly. *Computer-Aided Design*, *26*(7), 505-520.

Boorady, L. M. (2011). Functional clothing-principles of fit. *Indian Journal of Fibre and Textile Research*, *36*(4), 344.

Bowens, S. (2001). U.S. *Patent No. 6237153 B.* Washington, DC: U.S. Patent and Trademark Office.

Burbidge, N. (2000). U.S. *Patent No. 6012199 A.* Washington, DC: U.S. Patent and Trademark Office.

Cho, K. (2006). Redesigning hospital gowns to enhance end users' satisfaction. *Family and Consumer Sciences Research Journal*, *34*(4), 332-349.

Gupta, D., & Gangadhar, B. R. (2004). A statistical model for developing body size charts for garments. *International Journal of Clothing Science and Technology*, *16*(5), 458-469.

Gordon, L., & Guttmann, S. (2013). A User-centered approach to the redesign of the patient hospital gown. *Fashion Practice*, *5*(1), 137-151.

Istook, C. L., & Hwang, S. J. (2001). 3D body scanning systems with application to the apparel industry. *Journal of Fashion Marketing and Management*, *5*(2), 120-132.

Jha, S. (2009). *Exploring design requirements for a functional patient garment: Hospital caregivers' perspective* (Master's Thesis). Retrieved from North Carolina State University Library: http://www.lib.ncsu.edu/resolver/1840.16/20

Kohn, I. L., & Ashdown, S. P. (1998). Using video capture and image analysis to quantify apparel fit. *Textile research journal*, *68*(1), 17-26.

Lamghabbar, A., Yacout, S., & Ouali, M. S. (2004). Concurrent optimization of the design and manufacturing stages of product development. *International Journal of Production Research*, *42*(21), 4495-4512.

Langseth-Schmidt, K. (2014). *Anthropometric fit evaluation of structural firefighters' protective pants: A gender comparison study* (Unpublished master's thesis). Colorado State University, Fort Collins, CO, USA.

Lu, J. M., & Wang, M. J. J. (2008). Automated anthropometric data collection using 3D whole body scanners. *Expert Systems with Applications*, *35*(1), 407-414.

Li, Y., & Wong, A. S. (2006). *Clothing biosensory engineering*. Woodhead Publishing.

McCulloch, C. E., Paal, B., & Ashdown, S. P. (1998). An optimization approach to apparel sizing. *Journal of the Operational Research Society*, *49*(5), 492-499.

Meunier, P., & Yin, S. (2000). Performance of a 2D image-based anthropometric measurement and clothing sizing system. *Applied Ergonomics*, *31*(5), 445-451.

Mcelroy, E. (1923). U.S. *Patent No. 1962515 A.* Washington, DC: U.S. Patent and Trademark Office.

Palm, C. B. (1955). U.S. *Patent No. 2701364 A.* Washington, DC: U.S. Patent and Trademark Office.

Park, J. (2014). Development of an integrative process model for universal design and an empirical evaluation with hospital patient apparel. *International Journal of Fashion Design, Technology and Education, 7*(3), 1-11.

Park, J., Morris, K., Stannard C., Hamilton, W. (2014). Design for many, design for me: Universal design for apparel products. *The Design Journal*, *17*(2), 267-290.

Park, J., Nam, Y., Lee, E., & Park, S. (2009). Error detection in three-dimensional surface anthropometric data. *International Journal of Industrial Ergonomics*, *39*(1), 277-282.

Paquet, E., Peña, I., & Viktor, H. L. (2011). From anthropometric measurements to three-dimensional shape. *Indian Journal of Fibre and Textile Research*, *36*(4), 336-343.

Perissinotto, E., Pisent, C., Sergi, G., Grigoletto, F., & Enzi, G. (2002). Anthropometric measurements in the elderly: Age and gender differences. *British Journal of Nutrition*, *87*(2), 177-186.

Pheasant, S. (1990). *Anthropometrics-An Introduction*. British Standards Institution: UK.

Price, S. N. (1987). U.S. *Patent No. 4686715 A.* Washington, DC: U.S. Patent and Trademark Office.

Simmons, K. P., & Istook, C. L. (2003). Body measurement techniques: Comparing 3D body-scanning and anthropometric methods for apparel applications. *Journal of Fashion Marketing and Management*, *7*(3), 306-332.

Song, H. K., & Ashdown, S. P. (2013). Female apparel consumers' understanding of body size and shape relationship among body measurements, fit satisfaction, and body cathexis. *Clothing and Textiles Research Journal*, *31*(3), 143-156.

Song, H. K., & Ashdown, S. P. (2010). An exploratory study of the validity of visual fit assessment from three-dimensional scans. *Clothing and Textiles Research Journal*, *28*(4), 263-278.

Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H. B., Choi, Y. S., & Joseph, A. (2008). A review of the research literature on evidence-based healthcare design. *HERD: Health Environments Research & Design Journal*, *1*(3), 61-125.

Xu, B., Huang, Y., Yu, W., & Chen, T. (2002). Body scanning and modeling for custom fit garments. *Journal of Textile and Apparel Technology and Management*, *2*(2), 1-11.

APPENDICIES

APPENDIX A

IRB Approval Letter

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 Fort Collins, CO
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	January 08, 2015	
TO:	Park, Juyeon, 1574 Design and Merchandising Hughes, Amy, 1574 Design and Merchandising, Jankovska, Daniela, 1574 Design and Merchandising, Miller, Nancy, 1574 Design and Merchandising	
FROM:	Swiss, Evelyn, Coordinator, CSU IRB 2	
PROTOCOL TITLE:	Toward commercialization of new patient hospital apparel	
FUNDING SOURCE:	Funding - Grants/Contracts	
PROTOCOL NUMBER:	14-5064H	
APPROVAL PERIOD:	Approval Date: January 07, 2015	Expiration Date: June 09, 2015

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Toward commercialization of new patient hospital apparel. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

IRB Office - (970) 491-1553; RICRO_IRB@mail.Colostate.edu
Evelyn Swiss, IRB Coordinator - (970) 491-1381; Evelyn.Swiss@Colostate.edu

Swiss, Evelyn

Evelyn Swiss

Swiss, Evelyn

Amendment is approved to include the option of providing extra credit, to use the revised consent and recruitment files that include this option, and to use the revised comfort rating survey (addition of questions regarding perceived comfort levels while they perform a series of simulated activities). No change in risk.

Approval Period: January 07, 2015 through June 09, 2015
Review Type: EXPEDITED
IRB Number: 00000202

Funding: CSU Ventures

APPENDIX B

E-mail Script to Participants

Dear ____________________,

My name is Daniela Jankovska and I am a graduate student who is working with Dr. Juyeon Park in the Department of Design and Merchandising at Colorado State University, in Fort Collins. For my thesis, I am conducting a research study on identifying an optimum size for the hospital patient gown, in an effort to identify fit and comfort issues with the current hospital patient gown, which will aid in the further development of a new hospital patient gown with enhanced mobility, performance, and look. We are looking for male and female participants represent a diverse body profile and have no history of musculoskeletal problems.

If you decide to join this study, you will be asked to visit the HBD facility for a lab experiment. First you will be asked to fill out a short demographic and preferences survey. Than, your BMI (body mass index) will be calculated. Following, a three-dimensional body scanning technology ([TC]2, KX-16) will be used to capture body dimensions with over 400 measurement points. You will be asked to take two scans: in your undergarments (for baseline measurement) and in the conventional patient gown (for control measurement). You will be than asked to stand in the scanner for a few seconds while scanning is being processed. Next, you will be asked to perform few light physical scenario activities, which will help evaluate physical movements when the following three activities are applied: walking, laying down, bending, reaching up and sitting. Before you are free to go, you will be given an opportunity to share your thoughts and insights on the hospital patient gown during a 2-5 minute exit interview. The total time asked is approximately 1 hour, and you will be compensated for your time at the rate of $10/hour.

If you are interested in participating in this study, please contact us by email at HumanFactorsLab@colostate.edu or djankovs@gmail.com. Please be sure to include your age, height and weight when you contact us. We will then contact you for scheduling of your lab visit. Thank you very much for your willingness to participate in advance.

Sincerely,

Juyeon Park, Ph.D.
Director, Human Factors Lab
141 Gifford Building
College of Health and Human Sciences
Colorado State University

Daniela Jankovska
Graduate Student and Research Assistant
Department of Design & Merchandising
Colorado State University
Djankovs@gmail.com

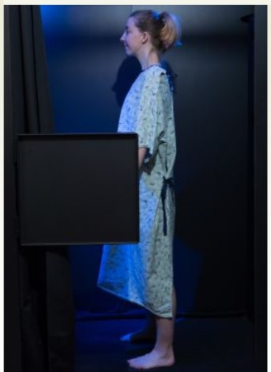
APPENDIX C

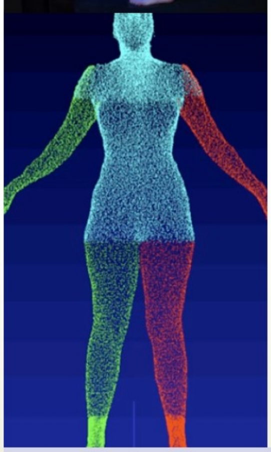
Recruitment Flyer

Colorado State University

College of Health & Human Sciences

Design & Merchandising





WE ARE SEEKING FOR ADULT PARTICIPANTS, BOTH **MALE & FEMALE, WITH DIVERSE BODY PROFILES** WHO ARE INTERESTED IN PARTICIPATING IN OUR STUDY ON IDENTIFYING OPTIMUM SIZE FOR A HOSPITAL PATIENT GOWN.

Research Project: Identifying an optimum size for the one-size-fits all hospital patient gown: An anthropometric approach.

Purpose of the Study: This project aims to identify an optimum size Using 3-Dimensional Body Scanning Technology for a hospital patient gown.

Once you agree to participate in this study, you will be asked to share 1 hour of your time, for which you will be compensated for your time & efforts. Your body will be measured using a 3D-Body Scanning Technology that uses non-invasive depth sensors. During the study you will be asked to do basic physical movements such as, walking, reaching up, sitting, bending and laying down. There are no known risks associated with this study. This study will take place at the Human Factors Lab in **141 Gifford Building, (Colorado State University).**

TOTAL TIME ASKED: 30-45 minutes

COMPENSATION: $5-$10

INCLUSION CRITERIA

1. MALE or FEMALE
2. DIVERSE BODY PROFILES ARE ENCOURAGED
4. HAVE NO HISTORY OF MUSCULOSKELETAL PROBLEMS

IF INTERESTED IN PARTICIPATING

FOR PARTICIPATION PLEASE CONTACT : DJANKOVS@gmail.com

FOR RESEARCH INQUIRIES CONTACT : Daniela.Jankovska@colostate.edu

Human Factors Lab, Gifford—141
DJANKOVS@gmail.com
Daniela.Jankovska@Colostate.edu

Human Factors Lab, Gifford—141
DJANKOVS@gmail.com
Daniela.Jankovska@Colostate.edu

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Human Factors Lab, Gifford—141
DJANKOVS@gmail.com
Daniela.Jankovska@Colostate.edu

Human Factors Lab, Gifford—141
DJANKOVS@gmail.com
Daniela.Jankovska@Colostate.edu

APPENDIX D

Data Collection Protocol

Order of events:

1. Appointment overview
2. Paperwork
    a. Participant consent
    b. Demographic and preferences survey
3. **3D Body Scanning**
    a. 3D body scanning introduction
        i. Baseline measurements (undergarments)
        ii. Hospital patient gown measurements (undergarments + gown)
    b. BMI measurements
        i. Height
        ii. Weight
4. **Scenario Activities**
    a. Walking
    b. Lying
    c. Bending
    d. Reaching Up
    e. Sitting
5. Exit Interview
    a. Recorded participant answers (2-5 minutes)
6. Participant Compensation
    a. Receipt

APPENDIX E

Participant Consent Form A (Extra Credit)

Consent to Participate in a Research Study
Colorado State University

TITLE OF STUDY: Toward Commercialization of New Patient Hospital Apparel

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? You were recruited as a study participant, because you have no history of musculoskeletal problems; and represent a diverse physical body profile.

WHO IS DOING THE STUDY?
Juyeon Park, Ph.D., PI, Department of Design & Merchandising, Colorado State University, Juyeon.Park@colostate.edu.
Daniela Jankovska, Graduate Research Assistant, Department of Design & Merchandising, Colorado State University, daniela.jankovska@colostate.edu.

WHAT IS THE PURPOSE OF THIS STUDY? The overall purpose of the project is to identify an optimum patient gown size for U.S. adults to accommodate the diverse body profiles and clinical needs.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? Data collection will take place in Human Body Dimensioning (HBD) facility, located in 141 Gifford at Colorado State University. The total time expected is approximately 1 hour.

WHAT WILL I BE ASKED TO DO? If you decide to join this study, you will be scheduled for a lab experiment session, which will take place in the Human Body Dimensioning Facility (141 Gifford). As the first step, you will be asked to fill out a short demographic and preferences survey. Then you will be invited to come in the 3D body scanning room. Three-dimensional body scanning technology ([TC]2, KX-16) will be used to capture your body dimensions over 400 measurement points. During the experiment, you will be asked to put on two different garments: undergarments (for baseline measurement), and the conventional patient gown, and stand in the scanner for a few seconds/scan while scanning is processed. Following the scanning, your BMI measurements will be taken specifically, your height and weight using a stadiometer (Seca®) and digital weight (Tanita® TBF-310GS). Next, you will be asked to perform physical movements that hospital patients typically do while being hospitalized such as walking, laying down, bending, reaching up and sitting. Following the experiment, you will be asked to fill out a comfort rating survey. Upon the completion of the lab session, you will be given an opportunity to provide additional insights of fit concerns with the hospital patient gown.

ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY? You should not participate in this study if you do not meet the inclusion criteria or do not feel comfortable with the research procedure described above.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS? You may feel fatigue due to minor physical movement while participating in the study, and you may experience minor psychological discomfort when your body is scanned with the 3D scanner. However, since the 3D scanner uses non-invasive light sensors to measure the dimensions of the human body there will be no known risks associated with the procedures. It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks. If you feel uncomfortable with the experiment procedure, you have a right to stop your study participation at any time.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? There will be no direct benefit to you. However, your study participation may contribute to the development of an optimum size for the new hospital patient gown, which will entail enhanced mobility, performance, and look.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE? We will keep private all research records that identify you, to the extent allowed by law. For this study, we will assign a code to your data (e.g., "Participant 1") so that the only place your name will appear in our records is on the consent and in our data spreadsheet which links you to your code. If necessary, the Colorado State University Institutional Review Board (CSU IRB) and the study investigators may inspect these records. Your 3D scan images may be shared at professional presentations; in such a case, your face or identifiable body parts will be treated blur to keep your confidentiality. All original data will be stored in the PI's research file storage and destroyed after three years of the study completion.

CAN MY TAKING PART IN THE STUDY END EARLY? If, for any reason, you wish to end your participation early, feel free to request the study investigators to make arrangements.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? You will be compensated with extra credits for your participation. Your ID/record of receiving compensation (NOT your data) may be made available to CSU officials for financial audits.

WHAT IF I HAVE QUESTIONS? Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact Juyeon Park, PhD at Juyeon.Park@colostate.edu. If you have any questions about your rights as a volunteer in this study, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; (970) 491-1553. Please take a copy of this consent form with you for your record.

If you are interested in participating in this project, please sign below. Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 3 pages.

____ _____________________
Signature of person agreeing to take part in the study Date

____
Printed name of person agreeing to take part in the study

_______________________________________ _____________________
Name of person providing information to participant Date

____
Signature of Research Staff

APPENDIX F

Participant Consent Form B (Monetary)

Consent to Participate in a Research Study
Colorado State University

TITLE OF STUDY: Toward Commercialization of New Patient Hospital Apparel

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? You were recruited as a study participant, because you have no history of musculoskeletal problems; and represent a diverse physical body profile.

WHO IS DOING THE STUDY?
Juyeon Park, Ph.D., PI, Department of Design & Merchandising, Colorado State University, Juyeon.Park@colostate.edu.
Daniela Jankovska, Graduate Research Assistant, Department of Design & Merchandising, Colorado State University, daniela.jankovska@colostate.edu.

WHAT IS THE PURPOSE OF THIS STUDY? The overall purpose of the project is to identify an optimum patient gown size for U.S. adults to accommodate the diverse body profiles and clinical needs.

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ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY? You should not participate in this study if you do not meet the inclusion criteria or do not feel comfortable with the research procedure described above.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS? You may feel fatigue due to minor physical movement while participating in the study, and you may experience minor psychological discomfort when your body is scanned with the 3D scanner. However, since the 3D scanner uses non-invasive light sensors to measure the dimensions of the human body there will be no known risks associated with the procedures. It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks. If you feel uncomfortable with the experiment procedure, you have a right to stop your study participation at any time.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? There will be no direct benefit to you. However, your study participation may contribute to the development of an optimum size for the new hospital patient gown, which will entail enhanced mobility, performance, and look.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE? We will keep private all research records that identify you, to the extent allowed by law. For this study, we will assign a code to your data (e.g., "Participant 1") so that the only place your name will appear in our records is on the consent and in our data spreadsheet which links you to your code. If necessary, the Colorado State University Institutional Review Board (CSU IRB) and the study investigators may inspect these records. Your 3D scan images may be shared at professional presentations; in such a case, your face or identifiable body parts will be treated blur to keep your confidentiality. All original data will be stored in the PI's research file storage and destroyed after three years of the study completion.

CAN MY TAKING PART IN THE STUDY END EARLY? If, for any reason, you wish to end your participation early, feel free to request the study investigators to make arrangements.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? You will be compensated with $10/hr for your participation. Your ID/record of receiving compensation (NOT your data) may be made available to CSU officials for financial audits.

WHAT IF I HAVE QUESTIONS? Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact Juyeon Park, PhD at Juyeon.Park@colostate.edu. If you have any questions about your rights as a volunteer in this study, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu; (970) 491-1553. Please take a copy of this consent form with you for your record.

If you are interested in participating in this project, please sign below. Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 3 pages.

_______________________________________ _____________________
Signature of person agreeing to take part in the study Date

____
Printed name of person agreeing to take part in the study

_____________________________________ _____________________
Name of person providing information to participant Date

____
Signature of Research Staff

APPENDIX G

Demographic Survey Questionnaire

Health & Human Sciences
Design & Merchandising

Colorado State University

Human Body Dimensioning Lab 141 Gifford

Questionnaire for 3-dimensional Body Scanning – [TC]2, model KX-16

Please take a few minutes to fill out this survey for new participants, prior to 3D scanning.

Background Information

Sex:
☐ Male ☐ Female

Age:
______________________________ years old

Physical Profile:

Height ______ ft ______ in Weight ________ lbs

Clothes size (circle): XS S M L XL 2XL 3XL 4XL _________

Shoe Size (circle): 5 5 ½ 6 6½ 7 7 ½ 8 8 ½ 9 9 ½ 10 10 ½ 11 11 ½ 12 12 ½ 13 13 ½ 14 ________

Marital Status:

☐ Single ☐ Married ☐ Divorced
☐ Widowed

Education:

☐ High school diploma ☐ Some college or currently in school ☐ Bachelor's degree
☐ Professional degree ☐ Graduate degree

Employment Status: (check all that apply)

☐ Employed ☐ Unemployed ☐ Student

Occupation

If you checked "employed" above, please state your occupation:_____________________________
How long have you been in the occupation stated above: __________ year(s) __________ month

Ethnicity: (check all that apply)

☐ Native American ☐ African American ☐ Caucasian
☐ Asian ☐ Hispanic/Latino ☐ Pacific Islander
☐ Multiracial ☐ Prefer not to say

Do you have any postural concerns?:

☐ Yes ☐ No
If you checked "yes" above, please describe your postural concerns. ___________________________________

Please rate the severity of your postural concerns (1 - not significant, 7 – very significant)

1 2 3 4 5 6 7

Thank you for your participation. For office use only: ID# __________________

APPENDIX H

Sensory Clothing Preferences Survey

In regards to your preference of regular clothing, please rate your comfort level of the following questions on a 5-point scale.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

1. I feel comfortable wearing clothing that is tight (e.g., I like the confined feel by wearing tight clothing)	1	2	3	4	5
2. I feel comfortable wearing loose fit (e.g., I like the roomy feel by wearing loose clothing)	1	2	3	4	5
3. I like to wear fabric that hangs well (e.g. silk or jersey)	1	2	3	4	5
4. I like to wear a drapery look	1	2	3	4	5
5. I like to wear a structured look	1	2	3	4	5
6. I prefer to wear natural fabric (e.g., cotton, wool)	1	2	3	4	5
7. I prefer to wear synthetic performance fabric	1	2	3	4	5
8. I am sensitive to clothing tags and seams	1	2	3	4	5
9. I try to express my personality through clothing	1	2	3	4	5
10. I prefer clothing comfort over aesthetics	1	2	3	4	5
11. I prefer clothing quality over aesthetics	1	2	3	4	5
12. I put much thought when I purchase clothing	1	2	3	4	5
13. I feel secure when I wear clothing that provides me with good coverage	1	2	3	4	5
14. I am not bothered by wearing clothing that reveals my body	1	2	3	4	5

APPENDIX I

Hospital Patient Gown Design Preferences Survey

In regards to the hospital patient gown, please rate your comfort level of the following questions on a 5-point scale.

1	2	3	4	5
Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable

1. I feel comfortable with overall gown length	1	2	3	4	5
2. I feel comfortable with overall gown width	1	2	3	4	5
3. I feel comfortable with chest circumference	1	2	3	4	5
4. I feel comfortable with hip circumference	1	2	3	4	5
5. I feel comfortable with waist circumference	1	2	3	4	5
6. I feel comfortable with shoulder circumference	1	2	3	4	5
7. I feel comfortable with sleeve length	1	2	3	4	5
8. I feel comfortable with sleeve width	1	2	3	4	5
9. I feel comfortable with gown opening	1	2	3	4	5
10. I feel comfortable with neckline	1	2	3	4	5
11. I feel comfortable with storage	1	2	3	4	5
12. I feel comfortable with spiral access	1	2	3	4	5
13. I feel comfortable with size adjustability	1	2	3	4	5
14. I feel comfortable/understand how to put on the gown	1	2	3	4	5
15. I feel comfortable/understand how to take off the gown	1	2	3	4	5
16. I feel comfortable with fabric print	1	2	3	4	5
17. I feel comfortable with fabric color	1	2	3	4	5
18. I feel comfortable with aesthetics (overall look)	1	2	3	4	5
19. I feel comfortable with the fit	1	2	3	4	5
20. I feel comfortable with overall look	1	2	3	4	5
21. I feel comfortable with overall comfort	1	2	3	4	5
22. I feel comfortable with overall mobility	1	2	3	4	5
23. I feel comfortable with overall medical practicality	1	2	3	4	5

APPENDIX J

Scenario Activity Survey

In regards to the activities you are asked to do, please rate your comfort level of the following questions on a 5-point scale. Please refer to the **human body diagram** for identifying potential areas of discomfort.

1	2	3	4	5
Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable

1. Please rate your comfort level while walking	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
2. Please rate your comfort level while laying down	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
3. Please rate your comfort level while bending down	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
4. Please rate your comfort level while reaching up	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
5. Please rate your comfort level while sitting	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5
Area of discomfort ____________________________	1	2	3	4	5