THESIS

CUSTOM PARALYMPIC SHOOTING JACKET: A SINGLE-CASE PRODUCT DEVELOPMENT PROJECT

Submitted by

Kayna Hobbs

Department of Design and Merchandising

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Master's Committee:

Advisor: Kristen Morris

Kevin Kissell
Rosemary Kreston

ABSTRACT

CUSTOM PARALYMPIC SHOOTING JACKET: A SINGLE-CASE PRODUCT DEVELOPMENT PROJECT

The goal of this research was to develop a custom regulation jacket for a Paralympic Shooting athlete. A six-step design process was implemented to understand the design needs of a Paralympic shooting athlete in their shooting jacket. Data were collected through qualitative research methods in a single-case study design. The participant's design needs in their shooting jacket were framed through Lamb and Kallal's (1992) FEA (functional, expressive, aesthetic) Consumer Needs Model. Three research questions that guided this study were, RQ1) How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant? RQ2) How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant? And RQ3) How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires? To address these questions, the researcher used anthropometric body measurements, 3D body scanning, virtual garment simulation technology, and half-scale dress forms to develop the custom shooting jacket throughout the design process. Overall, this research contributes to an understanding of factors and processes needed to develop clothing or sportswear for disabled athletes. The main outcomes of this research are a regulation Paralympic shooting jacket and a new model of apparel needs for disabled athletes called the FEA Model for Disabled Athletes.

The model advances theory in the field of apparel design and is a step in the direction of understanding the clothing needs of disabled athletes. This study provides industry and research professionals with best practices when working with these populations and products.

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Paralympic: referring to the Paralympic Games, i.e., Paralympic Shooting or Paralympic athlete

Functional: "…considerations for an apparel product [that] relate to its utility." (Lamb & Kallal, 1992, p. 43)

Expressive: "…considerations [that] relate to the communicative, symbolic aspects of dress." (Lamb & Kallal, 1992, p. 43).

Aesthetic: considerations that "…deal with the human desire for beauty." (Lamb & Kallal, 1992, p. 43)

Needs: the requirements for clothing from the consumer, user, end-user, or clothing wearer

Sportswear: clothing worn during athletic participation or competition

3D body scanning: use of a 3D body scanner to gather a 3D image of a human's body

Virtual garment simulation: use of computer CAD software, such as CLO, to develop a virtual prototype of a garment design

Anthropometrics: body shape and size

CHAPTER 1: INTRODUCTION

For all people, clothing serves many purposes. Clothing can be utilized for adornment, warmth, ceremony, function, and many other things. To be most effective, clothing must serve the wearer's various needs. Lamb and Kallal (1992) summarize clothing needs into three categories: functional, aesthetic, and expressive. While it is reasonably easy for most people to find clothing that meets their various needs, people living with disabilities have their own set of clothing needs, which may not align with those of the able-bodied or non-disabled population. Thus, disabled users may require clothing that is more specialized in development and design, compared to the design and development of clothing for the non-disabled user. In a landmark evaluation of the clothing industry's impact on disabled consumers, Thorén (1996) stated that the clothing market was "not adapted for people with unusual body dimensions and/or different kinds of functional impairments" (p. 389). The industry has since changed, and there are a handful of select clothing companies and collections that focus on people who use wheelchairs and their needs (such as adapted products available at ASOS, Target, and Ralph Lauren). However, the number of these adaptive clothing companies is much smaller than the number of clothing companies that design for the non-disabled population. Furthermore, the clothing currently available for the disabled community, even when specifically designed for the niche, does not seem to satisfy the various needs of every person within this population, such as disabled persons who participate in athletics. Specifically, people who use wheelchairs who participate in athletics (to be referred to as wheelchair athletes) often face struggles when shopping for sportswear (Bragança et al., 2018). That is, there is a shortage in current market offerings for wheelchair athletes, which lends a specific focus of this study.

The goal of this research was to develop custom sportswear, namely a custom jacket, for a single-case study person who uses a wheelchair who is a U.S. Paralympic Shooting athlete. An exploratory single-case study approach was used to investigate and explore the needs and values of the end user in a real-world context (Yin, 2014).

Though Paralympic Shooting is not as widely known as other Paralympic Sports such as swimming or rugby, it is indeed a sport that is growing in numbers. According to World Shooting Para Sport (n.d.), the number of Paralympic Shooting athletes has risen each year since its introduction to the Paralympics in 1976. Paralympic Shooting is a sport requiring intense accuracy and mental discipline. Shooting athletes must control their breathing and heart rate for higher performance and score (International Paralympic Committee, n.d.). The shooting target consists of ten rings, with the bullseye in the center as a score of 10. These rings are further separated into ten parts each, using decimals to indicate higher accuracy. A score of 10.9 is the highest score possible in competition shooting (Paralympic Committee, n.d.). Paralympic Shooting was first seen at the Toronto 1976 Paralympic Games (Paralympic Committee, n.d.). According to the Paralympic Committee (n.d.), over 65 countries now practice and participate in competition shooting.

The components of the Paralympic Shooting uniform for a wheelchair athlete include comfortable base layers, a custom-made jacket, a specialty glove, and a sling to hold their rifle in place (International Shooting Sport Federation, 2017; World Shooting Para Sport, 2017). Athletic performance should be enhanced by the clothing worn by the athlete (Watkins & Dunne, 2015), and the shooting jacket is no different. This garment is highly regulated because of the potential for extreme performance improvement via certain jacket elements, such as a tightly-fitted jacket allowing the athlete to gain artificial body support in competitions (International

Shooting Sport Federation, 2017). Wheelchair and non-wheelchair shooting athletes typically have these jackets custom made to fit them very well while also maintaining compliance of regulations (L. Esparza, personal communication, September 13th, 2018).

Literature

In the London 2012 Paralympic Games, "more than 4,250 athletes from 164 countries" competed in the 503 events (comprised of 20 different sports), breaking previous records of participation (International Paralympic Committee, n.d.). With the clear prominence of disabled athletics and the new rising numbers of athlete participation, it is essential that researchers investigate clothing that serves the unique needs of the disabled athletes, whether they be Paralympians or not. Bragança et al. (2018) researched semi-professional wheelchair rugby athletes and their clothing. They found that many of the wheelchair athletes were often forced to compete in sportswear designed for able bodies because of a lack of wheelchair adapted sportswear options. The sportswear that these wheelchair rugby athletes purchased was commonly made for non-disabled athletes and modified by the wheelchair athlete themselves to better fit their various athletic safety, mobility, and performance needs (Bragança et al., 2018). Consequentially, the wheelchair rugby athletes felt dissatisfied with the current readily made sportswear options that were available on the market (Bragança et al., 2018). In discussion of their study, Bragança et al. (2018) called for more research within this area: "…further studies are needed to enhance the sports experience within the wheelchair users' community" (p. 10).

Not only can a lack of suitable clothing cause dissatisfaction in disabled athletes, it can also cause a lack of participation in sports activities if clothing options are not readily available to people who use wheelchairs. Kabel, Dimka, and McBee-Black (2017) found that in their survey of 113 people who use wheelchairs, 56% of respondents either had difficulty finding athletic apparel or, out of discouragement, made no attempt at all to find athletic apparel that met their needs; in both cases, this caused the person who uses a wheelchair to avoid participation in athletics or exercise altogether. Kabel et al. (2017) also call for more research in the area of adapted clothing to "…investigate the requirements for developing ergonomic design strategies to help people living with mobility challenges" (p. 168).

Furthermore, there are only a limited number of companies that create custom Paralympic Shooting jackets for disabled athletes. The process these companies use to create custom jackets are somewhat monotonous: athletes print a company measurement form, gather the various body measurements that are required, send the measurements in, and receive their jacket in a few months (L. Esparza, personal communication, September 13th, 2018). There is a need for a more in-depth evaluation of the athlete and how their jacket can be rethought, redesigned, and redeveloped (L. Esparza, personal communication, September 13th, 2018). An in-depth look into the user's FEA needs (Lamb & Kallal, 1992; Orzada & Kallal, 2019) may provide a higher-satisfaction Paralympic Shooting jacket. Furthermore, utilizing innovative technologies in garment development, specifically 3D body scanning and virtual garment simulation, may facilitate higher quality in the custom Paralympic Shooting jacket.

Research Gap

Throughout this research, it has become apparent that there is a further need for the design of garments for wheelchair athletes to meet their current clothing needs. Therefore, the goal of this study is to explore the needs of the wheelchair athlete and apply design principles and technologies to meet these needs in the physical form of a shooting jacket. The outcome of this study is expected to help fill the gap in the people who use wheelchairs' sportswear research, as well as provide a practical design case that demonstrates design strategies to customize clothing for people who use wheelchairs.

Methods

For this research, a single-case study approach was chosen due to the custom nature of Paralympic Shooting jackets. Yin (2014) states that single-case study research is appropriate when one of the following five rationales are present: "having a critical, unusual, common, revelatory, or longitudinal case" (p. 51). In the 2016 Paralympic Games, there were 147 Shooting athletes, 50 of whom were female. Because the number of Paralympic Shooting athletes worldwide is comparatively small, this lends rationale to the use of a single-case study due to the "unusual" or unique nature of the sport as well as the unique and personal relationship between each Paralympic Shooting athlete and their jacket.

The International Paralympic Committee's mission includes encouraging and increasing participation in all Paralympic sports, including shooting (International Paralympic Committee, 2017). Members of the Paralympic Shooting team have expressed in personal communications with the researcher that they desire to see more knowledge and growth within the sport as well (L. Esparza, personal communication, September 13th, 2018). Therefore, the rationale for a single-case study in this research is because of the unique nature of both the sport and the custom clothing used in competition. The growing nature of Paralympic Shooting lends even further justification for this study; as the sport expands, there will be an increased need for a model which manufacturers may follow when developing clothing for Paralympic Shooting athletes.

Statement of Purpose

The specific purpose of this research is to investigate the functional, expressive, and aesthetic needs (FEA Consumer Needs Model, Lamb & Kallal, 1992) of the single-case study Paralympic Shooting athlete to develop a high-satisfaction custom Paralympic Shooting jacket. As an athletic representative of the United States of America (USA), the Paralympic athlete's uniform should not only enhance their athletic performance (Watkins & Dunne, 2015), but should also represent their image of themselves and their country. By investigating and weighing not only the functional needs but the expressive and aesthetic needs of the participant as well, the jacket developed in this research may be able to serve the athlete in a multitude of ways. Furthermore, using 3D body scanning and virtual garment simulation in the development of the jacket will allow researchers and industry alike to see the possible impact of these technologies in the garment design and development process.

This research presents an in-depth review of relevant literature in Chapter 2, exploring the research currently available regarding people who use wheelchairs' clothing needs and the current status of 3D body scanning and garment simulation technologies. Chapter 3 discusses the specifics of the methodology of the proposed research. Chapter 4 of this study shares the findings and discussion of this work. And the work is concluded in Chapter 5 with a discussion of key findings and future work. This research benefits researchers and industry alike in navigating the unique and in-depth process of development of high-satisfaction custom sportswear for wheelchair athletes.

Research Questions

The following research questions served as a guide for inquiry throughout the research process:

RQ1: How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant?

RQ2: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant?

RQ3: How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires?

Data Sets

With regard to the research questions delineated above, it is important to identify the various data sets that will be analyzed. The FEA needs of the participant, gathered via interview, will be considered a data set that will aid in understanding the user's clothing preferences and desires. The FEA needs data set will be analyzed and 'weighed' by the researcher (further discussed in Chapter 3) and will inform or affect the creation of high-satisfaction custom sportswear. The data that is gathered from 3D body scanning and gathering of anthropometrics (further discussed in Chapter 3) will be considered another data set and will be considered during the garment development process. Finally, the Evaluation interview data, gathered to understand the single-case participant's satisfaction with the prototyped jacket, will be regarded as a data set. The research questions and data sets explored and analyzed in this research may be utilized by industry and researchers alike to see the potential effects on the design of clothing for disabled athletes. Further research and product development may be conducted to investigate these same data sets in other areas of accessible design for people who use wheelchairs, such as the design of spaces or products.

Conclusions

The findings and discussion of this research led to the following conclusions, or key findings for industry leaders as well as researchers who seek to develop high-satisfaction sportswear for people with disabilities: (a) communication between the designer and the end user is essential in developing a high-satisfaction product, especially when developing niche products for minority or underserved populations; (b) 3D body scanning technology can aid designers and researchers in the design development process. However, it is essential to use physical prototyping and other traditional apparel design methods in tandem to these technologies as much as possible; and (c) developing adapted models or understandings of the user's or users' needs, especially when designing niche products for specific activities (such as athletics), and minority or underserved populations, is an essential factor in understanding current and future users' needs in a more accurate and useful way.

CHAPTER 2: LITERATURE REVIEW

The purpose of this chapter is to review the regulations present for Paralympic Shooting jackets, as well as synthesize and evaluate literature exploring the topics clothing needs for people who use wheelchairs and explore how 3D body scanning and virtual garment simulation technologies may be applied to improve garment design and user satisfaction.

Paralympic Shooting Jacket Regulations

Paralympic Shooting athletes must wear shooting jackets that are compliant with World Shooting Para Sport and International Shooting Sport Federation (ISSF) regulations for every competition (International Shooting Sport Federation, 2017; World Shooting Para Sport, 2017). The regulations for Paralympic Shooting jackets are quite thorough and Paralympic specific, dictating several elements of design and construction: thickness, length, ease, overlap of the front closure, patches, and placement of seams, to name a few. One example of a regulation that exists specifically for Paralympic Shooting jackets (as opposed to Olympic Shooting jackets) is the hem length. For seated athletes, the front jacket must not extend past the lap, and the back jacket must not extend past the top of the chair seat or wheelchair seat (World Shooting Para Sport, 2017). A detailed list and infographics of Paralympic Shooting jacket regulations can be found in Appendix A. Compliance of regulations is subject to voluntary Equipment Control (EC) inspections via several standardized measurement tools. Athletes are responsible for considering potential variances in garment and body measurements due to environmental factors such as humidity and temperature (International Shooting Sport Federation, 2017). Each athlete must register their jacket to be used in all competitions, meaning that athletes must wear only this jacket during competition until a new jacket is registered, replacing the formerly registered jacket (International Shooting Sport Federation, 2017).

Because of these strict regulations, competition shooting jackets are typically custom-made. However, only a small number of companies exist that create or tailor custom regulation-compliant jackets for Paralympic Shooters (Kurt Thune, n.d.; Monard Shooting, n.d.; TenPointNine Tailoring, n.d.). These companies typically provide "worksheets" for athletes to fill out that request several personal anthropometric measurements. The athlete may recruit a family member, coach, or even a professional tailor to take these measurements. Customizable options are available for selection as well, such as color or closure style. Paralympic Shooting athletes are highly encouraged, but not required, to select jacket colors reflecting their nation's colors and emblems (International Shooting Sport Federation, 2017).

Paralympic Shooting athletes' jackets must comply with several regulations, and custom jacket creation is the most effective way to ensure these regulations are met with athlete satisfaction. However, one might question the accuracy of measurements gathered if not done by a professional tailor, which could lead to problems in jacket fit and regulation compliance. Furthermore, although the headquarters of Paralympic jacket companies are located in different areas around the world, it is not likely that all the athletes can be present in the prototyping phase of development. The first time the athlete interacts with their jacket might be when the final product is received, which does not allow for much tolerance for error or athlete input during the development process. The overall satisfaction of the final product could benefit from further designer and end user communication throughout the entire product development process. It could also benefit from using virtual garment simulation technology to prototype garments on a 3D body avatar before completion. Furthermore, investigating the specific needs of the end user before the development and prototyping phase of design could potentially improve the athlete's satisfaction with their custom garment as well as their performance.

Summary of Existing Work

Few published research studies explore sportswear for wheelchair athletes, and very few sportswear products are available specifically for disabled and wheelchair athletes. Research and development needs for improvement in Paralympic Shooting clothing have been proposed and outlined by an expert and long-time Paralympic Shooting athlete (L. Esparza, personal communication, September 13th, 2018). Currently, no published research exists that focuses on serving the clothing needs of Paralympic Shooting athletes. Furthermore, no researchers have examined custom-made sportswear for disabled users utilizing 3D body scanning and virtual garment simulation technologies.

Functional, Expressive, and Aesthetic (FEA) Clothing Needs of People who use Wheelchairs

Lamb and Kallal (1992) state that the user and their culture centrally dictate functional, expressive, and aesthetic (FEA) clothing needs. The FEA Consumer Needs Model was developed by Lamb and Kallal (1992) to reflect the theory that the key clothing needs of people are FEA oriented. The model situates the consumer or end user at the center, surrounded by their culture. The attributes of the consumer and their culture must be fully adhered to during the clothing design process, for any consumer. Once the consumer and their culture are fully understood, the model shows that functional, expressive, and aesthetic needs are the three categories of requirements that future researchers or manufacturers must understand. The outer section of the model, which houses the functional, expressive, and aesthetic categories, has no barriers, meaning that one single need expressed by the consumer/participant could potentially lie within two categories. For example, an end user's desire for brighter color fabrics in a garment could be both an expressive and aesthetic need.

The FEA Consumer Needs Model is utilized throughout Lamb and Kallal's Six-Step Apparel Design Framework, seen in Figure 2.1. This framework seeks to understand the FEA Clothing Needs of the user through a process of problem identification and hopes to understand how the clothing needs are met in a specific product through a process of evaluation (Lamb & Kallal, 1992).

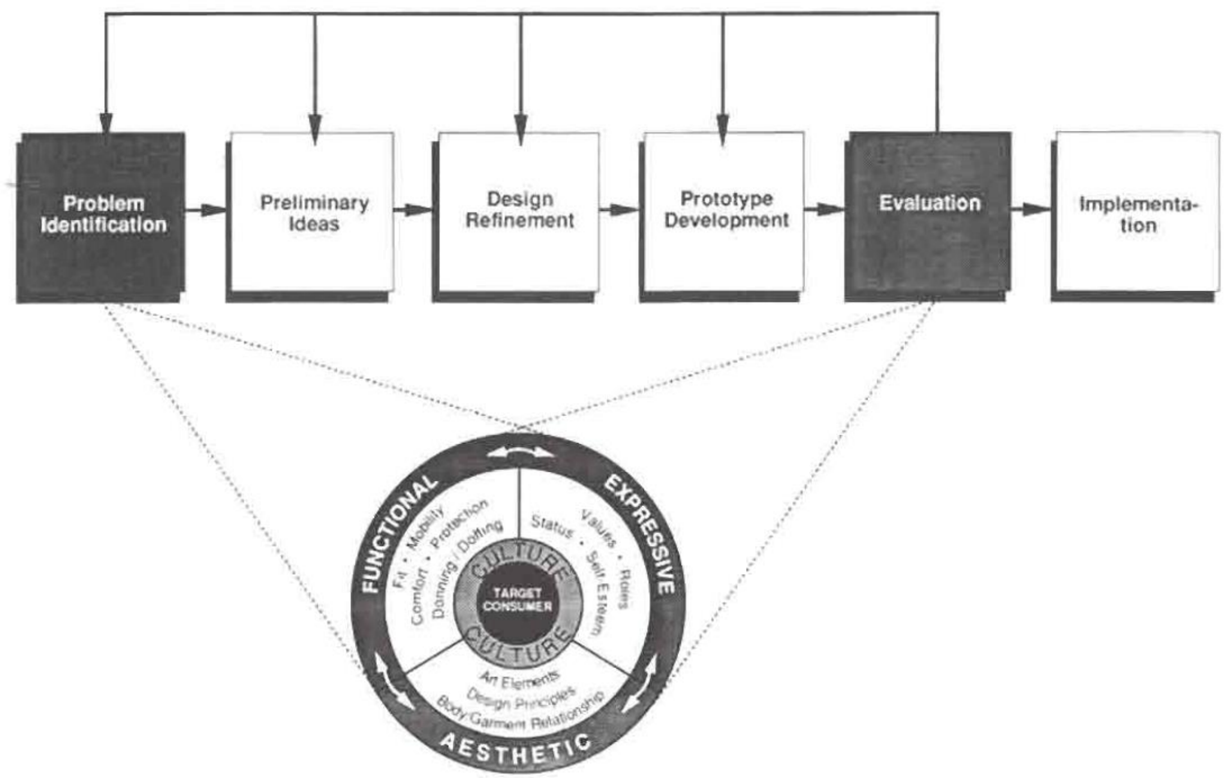


Figure 2.1: Six-Step Framework for Apparel Design, developed by Lamb and Kallal (1992). The functional, aesthetic, and expressive (FEA) Consumer Needs Model is housed within the framework.

Due to differences in functional, expressive, and aesthetic needs, people who use wheelchairs may require clothing that is different than apparel for non-disabled users. This section examines the literature on the functional, expressive, and aesthetic clothing needs of people who use wheelchairs.

Functional clothing needs. Functional needs consider all clothing aspects that have to do with how the garment functions for the user. Lamb and Kallal (1992) describe functional needs as "considerations for an apparel product [that] relate to its utility. Protection, thermal comfort, fit, and ease of movement are examples of functional requirements…" (p. 43). Within this section, the most important functional clothing factors for people who use wheelchairs are discussed as they are found in the literature: anthropometric fit, easy donning and doffing, tactile sensations, and adapted clothing.

Anthropometry, according to Greek definition, literally translates to the "measurement of humans," with "anthro" meaning man, and "pometry" meaning measure (Stack, Ostrom, & Wilhelmsen, 2016, p. 78). Anthropometry is the applied physical branch of anthropology and is thus focused on comparing groups of populations to one another in terms of body size, shape, and measurement (Stack, Ostrom, & Wilhelmsen, 2016; Wilson, 2000). When comparing people who use wheelchairs to their non-disabled counterparts, it is vital to identify the differences in body shape, size, and measurement between these groups to fulfill the anthropometric clothing needs for people who use wheelchairs.

For a person who uses a wheelchair, the following are anthropometric and body posture factors that must be considered in clothing design: the knees are bent majority of the time, the elbows may be bent often, the trunk is bent while seated, the spine may curve forward slightly, and the shoulders may be somewhat forward a majority of the time. Several clothing research studies to date have considered these specific anthropometric factors of people who use wheelchairs (Bragança et al., 2018; Wang et al., 2014; Wu, Wang, & Li, 2011). Most often pattern adjustments are made to remove fabric from inside of knee and elbow joints, add volume to the outside of these joints, lower the front rise in trousers, increase the back rise in trousers, elongate the length of shirt backs, and shorten the front length of shirts. Clothing made for able-bodies will not cater to people who use wheelchairs' specific anthropometrics, as the two groups are different in measure and posture. Considerations of the user's anthropometrics should be the first consideration when developing clothing for people who use wheelchairs, followed by consideration of donning and doffing of clothing.

For people who use wheelchairs, functional clothing can address the tasks performed throughout the day as well as inherent issues that are present with paraplegia or other impairments that result in wheelchair use. For these users, much of the day is spent in a seated position with little to no movement in the lower limbs. Because of this, a critical functional clothing need for people who use wheelchairs is the ease of donning and doffing. Some studies have researched and developed functional garments for people who use wheelchairs that could allow for more comfort in activities of daily living (ADL) dependent on donning and doffing of clothing. The functional garments created in these studies allowed people who use wheelchairs to reduce time and difficulty of donning and doffing, as well as to complete don and doff tasks independently of aid (Wang et al., 2014; Wu et al., 2011). Therefore, ease of donning and doffing activities created through attention to functional clothing needs can allow for more user independence, a factor that can be important for people with disabilities. Another functional need that is essential to the health and wellness of disabled users and people who use wheelchairs is comfort.

Comfort in tactile sensations and body surface temperature are important for all clothing users. For people who use wheelchairs, different areas of the body may require various comfort considerations. Temperature discrepancies between different regions of the body are common for people who use wheelchairs and vary between users, often with the upper body being warmer and the lower body being colder (Antonela, Viorica, Laura, & Marian, 2014). Wu et al. (2011) discovered through interviews with 58 people who use wheelchairs that soft and comfortable fabrics that provided breathability were considered the most essential tactile/temperature related design feature. Breathability was regarded as important to avoid skin wetness via sweat accumulation. Moisture in the seat area can lead to health and safety concerns such as ulcers and infection (Bragança et al., 2018; Wang et al., 2014). Antolena et al. (2014) developed and tested three heating fabric systems using conductive thread that lower body garments could utilize to prevent coldness, but the researchers did not address skin wetness. However, both Antolena et al. (2014) and Wu et al. (2011) suggest that seat areas may benefit from anti-bacterial fabric. An additional safety concern for people who use wheelchairs' clothing includes pressure sores in the seat area caused by thick fabric seams (Bragança et al., 2018). When designing functional clothing for people who use wheelchairs, one must develop thin seaming techniques and incorporate as few seams in the seat area as possible to promote better health for the wearer.

Clothing that is adapted to the wearer not only provides comfort and health to the wearer but also has the potential to allow for better mood and social participation. Kratz et al. (1997) conducted adapted garment research with people who use wheelchairs who participated in athletics. Through wear testing of modified prototypes and several qualitative interview analysis methods, the researchers found that their wheelchair adapted clothing led to higher affect states, defined as better mood and experience with the environment, for the users. This can be attributed to the functional needs of the wearers being met, and thus a positive effect on their mood and experience. Furthermore, the adapted clothing allowed for higher involvement states, defined as the response to task difficulty, coping ability, and concentration (Kratz et al., 1997). Thus, affect state and involvement state can be affected positively by the degree of easiness in performing activities, such as athletics or social participation. In summary, attention to the functional needs of clothing can facilitate increased mobility, capability, comfort, health, participation, and positive mood (affect) states for people who use wheelchairs. The expressive clothing needs of people who use wheelchairs will be discussed next.

Expressive clothing needs. Clothing has several expressive and emotional roles for the user. Lamb and Kallal (1992) define expressive clothing needs as “considerations [that] relate to the communicative, symbolic aspects of dress.” (p. 43). All users require clothing that communicates their personal message accurately and thus makes them feel emotionally and physically confident. This section provides a review of the literature as it relates to the communicative and expressive qualities of clothing for people who use wheelchairs.

Clothing that expresses the correct message about the wearer can allow the wearer to feel more confident (Kratz et al., 1997). However, when a person is unable to find clothing that expresses their message correctly, it can lead to negative impacts on social participation. Kabel et al. (2017) conducted online surveys of 113 people who use wheelchairs or their caretakers to investigate how people who use wheelchairs feel about their clothing and the barriers to social participation it might cause. In their analysis, half of the respondents declined to participate or felt they “missed out” on social participation due to clothing barriers (Kabel et al., 2017). Half the participants were also concerned or frustrated by the lack of appropriate clothing, specifically work attire and winter jackets (Kabel et al., 2017). Over half of the respondents had a tough time finding athletic wear or did not even bother trying to look for athletic wear (Kabel et al., 2017). It is clear from this research that social participation can be hindered by the lack of available and appropriate clothing for people who use wheelchairs that do not meet their expressive needs.

As discussed in functional clothing needs, there are characteristic differences in body shape and proportions of people who use wheelchairs' bodies compared to typical bodies. For people who use wheelchairs, commonly the functioning upper body is stronger and larger than average, and the non-functioning or low-functioning lower body is smaller than average. Previous studies have developed clothing adaptions that would serve to visually "even out" atypical proportions in disabled users (Carvalho, Duarte, Heinrich, Souto, & Woltz, 2009; Chang, Zhao, Guo, Wang, & Gu, 2009). While communicating more average proportions may be an important expressive clothing need for some, it should be noted that not every disabled consumer or person who uses a wheelchair will desire designs that provide them with a more typically proportionate appearance. When working with disabled consumers or people who use wheelchairs, it is essential to investigate the clothing needs of the end user or users via interviews, focus groups, questionnaires- all methods that ask the end user about their specific needs. If the researcher assumes that an end user has the expressive need for communicating more average proportions, but the user does not have that need, they may face offending the user. It is important in any work to understand the specific FEA clothing needs of the user, as these needs differ from person to person. In the case of clothing, expressing personal ideals of beauty and style, expressive and aesthetic needs can be closely related.

Aesthetic clothing needs. Aesthetic clothing needs "deal with the human desire for beauty" (p. 43). Each person has a different idea of beauty and aesthetics, and clothing should outwardly express the wearer's aesthetic and, thus sense of self. Chang et al. (2009) claimed that although functional clothing for people who use wheelchairs has been addressed in research, rarely have aesthetic requirements and desires such as beauty and "embellishment of the body" been addressed for this population (p. 62). There is indeed a lack of research in the specific area of aesthetic clothing needs for people who use wheelchairs. This is not to say that the body of knowledge is lacking- all people, disabled or not, have different aesthetic preferences for their clothing. However, the majority of the work in the field of clothing for people with disabilities focuses heavily on the functional needs of the wearer being met, with little consideration given to the aesthetic needs of the wearer. We have found through this review that lack of clothing deemed appropriate or aesthetically correct by the wearer can cause negative impacts in affect and involvement states. Thus, it is important that the aesthetic clothing needs of the wearer are being investigated just as thoroughly as functional and expressive requirements. Clothing that meets the entirety of the user's needs can result in high-satisfaction, better health, increased social participation, increased affect state or mood, and many other positive outcomes.

It is easy to see how functional, expressive, and aesthetic clothing needs can comingle and overlap for each user in each context. Lamb and Kallal state that "the three types of considerations for apparel product[s] are not mutually exclusive but are interrelated in different ways for different target consumers." (p. 43). From this review of the literature, it is clear that people who use wheelchairs have clothing needs in more than one of the FEA categories. It is also clear that most of the clothing needs of people who use wheelchairs are not being met in the readily available clothing market. Next, a discussion of factors surrounding product availability of adapted clothing for people who use wheelchairs and wheelchair athletes will be had.

Product availability. Most people choose what clothing to buy or wear based on how accurately it expresses their idea of themselves to others. For "typical" bodies that are proportionate, shopping is as simple as going to the store and buying clothing that the wearer finds to express their self and style. For disabled people and people who use wheelchairs, fewer options for well-fitting and appropriate clothing are readily available. A landmark study by

Thorén (1996) navigates the then-current and potential clothing markets for disabled users. From 65 interviews, Thorén (1996) discovered most disabled consumers desired to shop in clothing stores and be able to buy what is available to every other shopper. However, factors including store accessibility, staff and employee knowledge, and clothing appropriateness typically made shopping very difficult (Thorén, 1996). Thorén (1996) concludes the study by examining the market of clothing for disabled users and proposing a potential model of manufacturing for custom adapted clothing that puts the user in the center of development focus. Today, though areas of the apparel industry are working towards the goal of mass customization, this is still not widely available on the ready-made market. Though users may desire custom-made clothing, these goods often have a higher price tag that not all users can afford (Bragança et al., 2018).

When considering wheelchair athletes specifically, meeting various needs can facilitate better athletic performance. Bragança et al. (2018) developed designs for a set of wheelchair rugby garments using insight from a focus group of three wheelchair athletes and questionnaires from 61 wheelchair athletes. The researchers found that the athletes had difficulty finding clothing that was suitable for their athletics, and commonly they would modify sportswear made for able bodies to meet their needs (Bragança et al., 2018). The wheelchair athletes expressed dissatisfaction with their sportswear due to fit and temperature, and often their inappropriate sportswear affected their athletic performance (Bragança et al., 2018). Furthermore, safety was a concern for the athletes when discussing their sportswear, with issues relating to impediments of movement and lack of directional movement control caused by their clothing (Bragança et al., 2018). The designs proposed by the researchers address all the outlined needs and concerns as identified by the qualitative interview and questionnaire data (Bragança et al., 2018). In their conclusion, Bragança et al. (2018) propose several future implications in their research, one of which being a call for more research on sportswear for wheelchair athletes.

It can be concluded from the analysis of FEA clothing needs and product availability that appropriate clothing is essential for people who use wheelchairs. Yet, that clothing is not readily available, and appropriate sportswear for wheelchair athletes is a nearly non-existent market. In the clothing industry, the steps that a company or designer takes to get from the first thoughts of a garment to the garment being made and manufactured previously took months of work and several iterations of prototypes and fittings. Modern-day technologies in the clothing industry have eliminated several of these time-consuming steps, thus making it possible to create clothing for many different users.

3D Body Model Methods and Garment Simulation

With recent and ever-improving technology in the field of apparel product development, computer programs such as Modaris 3D Fit (Lectra), VstitcherTM (Browzwear), 3D Suite (OptiTex), and Clo3D (CLO Virtual Fashion Inc., to be called CLO) allow for prototype development and virtual garment simulation on a personalized 3D body avatar. A review and analysis of 3D body avatars for atypical bodies and virtual garment simulation follow.

3D body avatars of atypical bodies. Anthropometrics of the body must be considered before and during garment design and development. With 3D body scanning technologies now available, a 3D body avatar can be used in testing garment fit and style in the virtual realm, eliminating the traditional physical prototyping step of garment development. Researchers have explored several methods of gathering and developing accurate 3D body avatars since the emergence of these technologies. For this review, 3D body scanning and 3D body avatars of atypical body types will be explored.

3D body scanners that synthesize an exact 3D body avatar of the user, also to be called a 3D body scan, have been a recent technological focus for gathering anthropometric data. 3D body scans can be utilized to collect basic anthropometric data fairly quickly for typical bodies. Because the software systems of 3D body scanners are only programmed to understand and identify anthropometric data for typical bodies, gathering anthropometric data from atypical 3D body scans requires a more substantial amount of technical knowledge as well as creative solutions. For example, previous researchers used mesh reconstruction to repair “holes” in scan data or merged multiple incomplete body scans to create suitable avatars from atypical 3D body scans (Bruniaux, Cichocka, & Frydrych, 2016; Rudolf, Cupar, Kozar, & Stjepanović, 2015). Other researchers have developed methods to create “water-tight” body scan avatars with kinematic skeletons, allowing the avatars to be moved into any pose desired. However, areas of the body such as the armpits or elbows, proved to be ineffective in representing real bodies (Kozar et al., 2014a; Kozar, Rudolf, Cupar, Jevšnik, & Stjepanović, 2014b). Most apparel research that explores 3D body avatars for people who use wheelchairs tends to use typical bodies in a seated position to represent the body of a person who uses a wheelchair. However, as discussed earlier in this chapter, the anthropometrics of typical bodies and people who use wheelchairs are quite different, and the former cannot accurately represent the latter, thus making research that implements these strategies ineffective in that manner. Rudolf et al. (2015) justify the use of able bodies in a seated position in their 3D body avatar research, stating that involving people who use wheelchairs in preliminary research may cause an “unnecessary burden” (p. 1179, 1190). For someone with limited lower body movement, the process of navigating a small body scanning room may indeed pose difficulties.

Another method of creating an individualized 3D body avatar is through customization or personalization of generic avatars in Computer-Aided Design (CAD) systems, such as Optitex and CLO. Several anthropometrics of these generic avatars can be adjusted, including lengths, widths, and circumferences (CLO3d, n.d.; Optitex, n.d.) A list of avatar poses is also available for selection; however, there is yet to be a pose developed in the seated position in the most common CAD programs, such as Optitex and CLO (CLO3D, n.d.; Optitex, n.d.; Optitex Support, personal communication, November 19th, 2018). A recent study by Lin, Johnson, and Kang (2018) compares garment simulation on 3D body scan avatars and personalized Optitex avatars (all non-disabled), finding that industry professionals prefer the personalized avatars in the categories of appearance, smoothness, and fit. However, the professionals were clear in recognizing that the 3D body scan avatars presented a more accurate model of the wearer (Lin et al., 2018). Sayem (2017) conducted research analyzing the avatar "morphing," or personalization, qualities of two CAD systems. The study by Sayem (2017) found that Optitex had some limitations in providing complete customization of the avatars, because landmark anthropometrics, such as chest/bust circumference, only allowed a specific range of morphing capabilities for nearby anthropometrics (such as underchest/underbust using the previous example).

Recent developments in affordable, mobile body scanning devices have provided several new options for researchers and professionals alike to gather 3D information in a more attainable and convenient way. In 2013, a technology company called Occipital launched a device named the Structure Sensor (Occipital, 2018). The wire-free tool uses non-invasive sensors attached to an iPad. It works through an application to gather three-dimensional data of an object, human, or environment as the iPad user moves freely around the subject to capture the data (Occipital, n.d.). Researchers have tested the accuracy of the Structure Sensor compared to similarly priced devices, such as Microsoft Kinect (versions 1 and 2) and Rodin4D O&P Scan (Guidi, Gonizzi, & Micoli, 2016; Redaelli et al., 2018). Redaelli et al. (2018) conducted research to test the effectiveness and accuracy of the four aforementioned 3D scanning devices in scanning stationary objects, using a more expensive and high-quality scanning system called Minolta Vivid 9i as a quality reference. The researchers used the four low-priced scanners to gather 3D data of a mannequin hand, thigh, and chest (Redaelli et al., 2018). According to the discussion of their findings, "The best device, among the others we tested in this project, resulted to be the Structure Sensor, not only for the low deviation from the reference models but also for the possibility to move around the objects without any wire and without the need of an additional tracking system" (Redaelli et al., 2018, p. 958).

With this in mind, the Structure Sensor device could open up a new frontier for 3D body scanning of people who use wheelchairs. To date, no researchers have tested the effectiveness of the Structure Sensor for gathering 3D body scan data for people who use wheelchairs. Because of the Structure Sensor's mobility, the subject or target of the scan process does not need to maneuver into a small scanning room, as is common in most of the current research on 3D body scanning in the apparel design field. As stated, most research in the apparel product design field has omitted the use of actual people who use wheelchairs to generate a 3D body scan of a person who uses a wheelchair in efforts to not cause an "unnecessary burden" (Rudolf et al., 2015, p. 1179, 1190). When the barrier of the small scanning room is eliminated, as it is with the Structure Sensor, new possibilities open up, such as gathering 3D body avatars from actual people who use wheelchairs, resulting in more accurate body representations of this population compared to what the current research provides. Apparel scholars have been working on validating the results of the Structure Sensor with other common body scanning devices. However, no research to date has tested the accuracy of anthropometrics gathered from body scan data of wheelchair users.

It can be concluded that there are several significant elements to consider for both 3D body avatars and personalized generic avatars when used for garment simulation and that the designer or developer might consider these elements when deciding which is most suitable for their process. For people who use wheelchairs, an effective and anthropometrically accurate solution to 3D body avatars has not yet been found. However, the Structure Sensor by Occipital may hold a promising future in this area. A realistic 3D body scan may be used as a mannequin to simulate garment prototypes virtually.

Garment simulation. Though fabric is a difficult material to simulate, technological advancements of virtual garment simulation continue to provide more accuracy in the appearance of these simulations when compared to actual garments. Kim and LaBat (2013) conducted user research measuring the reliability of realism in a virtually simulated garment compared to the actual physical garment. While the overall silhouette of the simulated and real garments was similar, there were some discrepancies in fabric properties such as the representation of wrinkles and textures (Kim & LaBat, 2013). When considering technological advancements, some of these discrepancies may have been addressed by developers of virtual garment simulation technology since the time this research was conducted. Rudolf et al. (2015) developed garments adapted for a 3D scanned and reconstructed seated body avatar (non-disabled) and compared the garments at the virtual simulation and physical prototyping stages, from the wearer and researcher perspective. Both parties concluded that the virtual simulation of the garment was visually accurate to the physical prototype, and the seated wearer expressed greater comfort in the seat-adapted garments when compared to non-seat-adapted garments of the same style (Rudolf et al., 2015).

Garment simulation on atypical body models is a growing research area. As discussed, researchers are working to develop accurate 3D body avatars of people with atypical bodies to include this population in the newest technology of virtual garment simulation. A notable development in this area is a set of programmatic studies that examine virtual garment simulation methods on a reconstructed 3D body avatar of a participant with severe scoliosis (Bruniax, Cichocka, & Frydrych, 2016; Hong et al. 2018a; Hong, Bruniax, Zeng, Curteza, & Liu, 2018b; Hong, Zeng, Bruniaux, & Liu, 2017). The research consists of virtual garment simulation from two-dimensional pattern pieces. It examines the possibilities of advanced three-dimensional draping in a virtual setting, finding in all cases that virtual garment simulation eliminated several physical prototyping steps with sufficient accuracy (Bruniax et al., 2016; Hong et al., 2017; Hong et al. 2018a; Hong et al., 2018b).

One specific software that is gaining the attention of researchers and designers is CLO. CLO's website features tutorials that demonstrate the accuracy of materials and drape in the garment simulation, leading to a more streamlined design process (CLO3D, n.d.). Wang and Lui (2020) stated in an overview of CLO that the program's virtual garment simulation, specifically the fabric texture properties, were "very close to reality" (p. 47). CLO also provides subscription options to individuals versus only to institutions and organizations, making it more accessible for small-scale designers and independent researchers (CLO3D, n.d.).

From the research, it can be concluded that virtual garment simulation on an accurate 3D body avatar can serve as a useful tool for evaluating a garment before or in place of physical prototyping. Designers and researchers focused on developing clothing for wheelchair athletes can potentially utilize these technologies to create clothing with better and more accurate fit on the body, and more specific attention paid to expressive and aesthetic properties of the clothing. Some conclusions about the existing work presented in this literature are discussed next.

Conclusions About Existing Work

Critical Evaluation of Existing Work

Strengths and weaknesses are found in the presented literature. There is a wealth of research exploring functional clothing needs for people who use wheelchairs and developing adaptive garments for this population based on the knowledge gained. These studies have indicated the differences in anthropometrics of non-disabled people and people who use wheelchairs. Furthermore, there is programmatic research regarding clothing creation for disabled users that investigates innovative technology-based solutions to the current challenges. However, despite the wealth of research, everyday clothing for people who use wheelchairs is not as readily available on the market as is clothing for non-disabled people. Sportswear for wheelchair athletes is a nearly non-existent market, and there is minimal research present that investigates the sportswear needs of wheelchair athletes. No research to date has explored Paralympic Shooting jackets or clothing. Another weakness in the literature is the frequent use of manipulated non-disabled avatars to create 3D body avatars and develop clothing designs for people who use wheelchairs. Although justification is present, the research will not be completely accurate in anthropometric data until researchers create a 3D body avatar that is true to people who use wheelchairs' anthropometrics.

Directions for Future Work

There are several areas with a strong need and potential for future research to be conducted within the topics addressed in this review. Bragança et al. (2018) call for more research to be undertaken to investigate and develop sportswear for wheelchair athletes who participate in all types of recreation or competition sports. The researchers also call for clothing companies to address how to provide readily available sportswear to wheelchair athletes (Bragança et al., 2018). Within the topic of 3D body avatars, research needs to be conducted that examines the proven differences in anthropometrics through comparing accurate 3D body avatars of people who use wheelchairs and non-disabled people, versus the use of seated or manipulated non-disabled avatars to represent the wheelchair-using population. Although there is a body of research regarding physically prototyped adaptive clothing for people who use wheelchairs, research is also needed to demonstrate virtual garment simulation and prototyping of adaptive clothing using accurate 3D body avatars for people who use a wheelchairs. More work must be done to include people who use wheelchairs in the benefits of virtual garment simulation and prototyping to develop both daily garments and high-satisfaction sportswear.

Justification of Proposed Objectives

The objective of this research is to create a custom regulation-compliant competition jacket for a Paralympic Shooting athlete who uses a wheelchair. No previous research has been done to explore the topic of competition jackets for Paralympic Shooting athletes. Attention to the single-case participant’s FEA needs can result in higher overall user satisfaction while maintaining compliance with World Para Shooting Sport and ISSF jacket regulations. Several research studies have been conducted regarding people who use wheelchairs and their day-to-day clothing needs. Still, very little research has evaluated the needs of wheelchair athletes and created sportswear based on those needs. As stated in the discussion of weaknesses in the existing work, sportswear for wheelchair athletes is a nearly non-existent market.

Furthermore, there is a gap in the literature regarding accurate 3D body avatars of people who use wheelchairs, as the whole of the research presented in this area has reconstructed or manipulated non-disabled 3D avatars into a seated position. There was no research found in the apparel product development body of knowledge that utilized people who use wheelchairs as participants for 3D body scanning in research that sought to benefit said population. Development of an accurate 3D body avatar to allow for virtual garment simulation and prototyping could (a) facilitate higher user satisfaction in sportswear for wheelchair athletes, as compared to companies that develop and produce sportswear using manual measurements alone, and (b) make advancements in the field of accurate 3D body scanning for people who use wheelchairs.

This thesis research may serve as a model for how to develop adaptive sportswear for people who use wheelchairs that considers their unique needs and anthropometrics. Wheelchair athletes' are likely to experience greater motive to participate in sports, enhanced athletic performance, higher clothing satisfaction, and a positive effect on mood states when their FEA needs are met in their sportswear.

CHAPTER 3: METHODS

The goal of this research was to develop a high-satisfaction custom regulation jacket for a Paralympic Shooting wheelchair athlete. This study adopted a single-case study approach, which is a suitable methodology when the situations and participants in the research are unique (Yin, 2014). Because Paralympic Shooting jackets are typically custom-made for each athlete and are heavily regulated, a single-case study approach also allowed for a high-satisfaction custom end product in this research. This chapter will discuss the specifics of Paralympic Shooting jacket regulations, recruiting the single-case study participant, the framework for data collection, and the details of data analysis.

Single-Case Participant

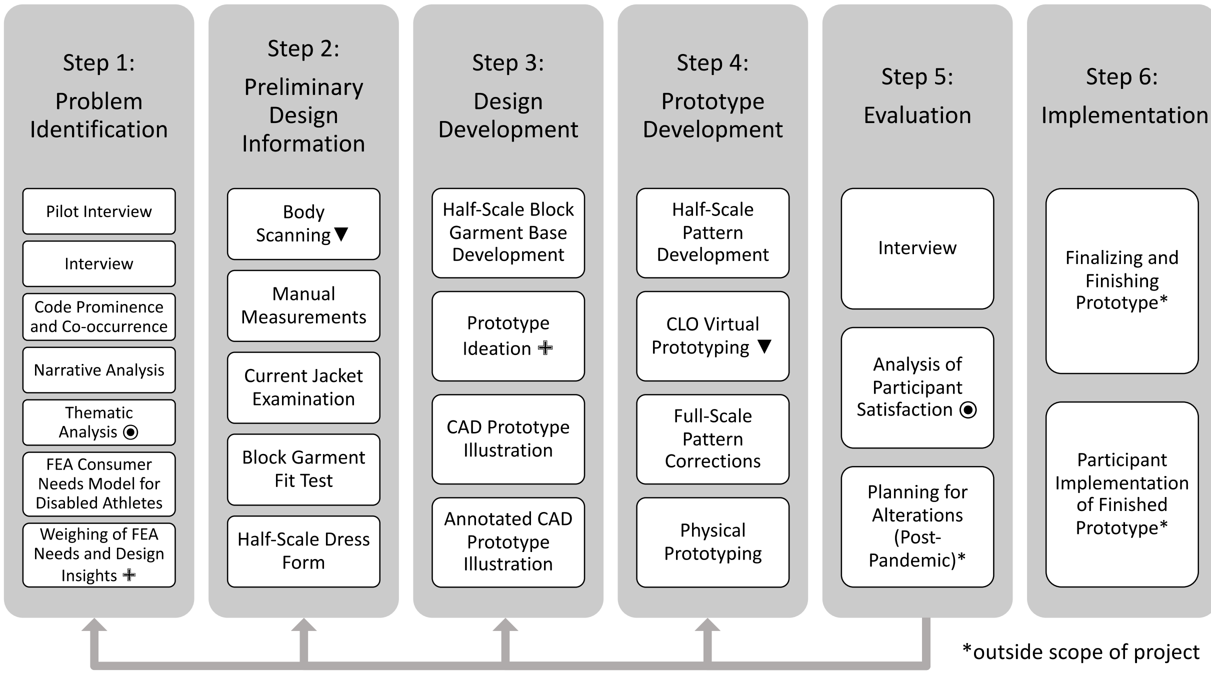
A vital aspect of this research was the recruitment of a Paralympic Shooting athlete willing to participate in this single-case study. The researcher's previous advisor had a pre-established network with the U.S. Paralympic Shooting Team, and a contact from the shooting team helped the researcher with the participant identification and recruitment. The connection is a male shooting athlete in his fifties who is a long-time athlete and committee member of the U.S. Paralympic Shooting Team. During a preliminary conversation, the researcher in partnership with the Paralympic Shooting contact, developed a list of participant inclusion criteria. The ideal participant for this research was to be a competition shooter who was female, over age 18, a person who uses a wheelchair, and residing somewhere within reasonable distance to the researcher. A female participant was preferred over a male participant because the feminine body shape requires more expertise in fitting clothing. Women tend to have more curves and rounded body shapes, and the bodies of people who use wheelchairs tend to be different in anthropometrics than non-disabled persons. Having a female athlete who uses a wheelchair as the participant for this research was expected to unveil more undiscovered and unique clothing needs than other, more common demographics of disabled athletes (i.e., male or ambulatory athletes).

The Paralympic Shooting contact introduced the researcher to a potential participant who fit all criteria, and who was interested in participating in the research: a young female Paralympic Shooting athlete with the potential to qualify for the 2020 Paralympics in Tokyo. Contact was made with the potential participant to allow for preliminary questions from both parties. After a brief discussion of the research methods and goals, the young female Paralympic Shooting athlete who uses a wheelchair agreed to be the single-case study participant for this research. This athlete is 22 years old. She has been on the U.S. Paralympic Team for around two years but has been practicing competition shooting for five years. The athlete practices Paralympic Shooting as her career, with a typical Monday through Friday, 40 hours/week training schedule. Because there are only a few American female Paralympic Shooting athletes, the identity of this research participant must be protected. The single-case participant in this research will furthermore be referred to as Hannah.

Hannah resides at the Paralympic Training Center, approximately a three-hour drive from the researcher's institution- a trip that the researcher made when needed throughout the research method processes. As a pilot effort, the researcher attended a competition shooting event in February 2019 at the Paralympic Training Center to become more familiarized with the sport of shooting, to see EC processes in person, and to physically meet Hannah. Prior to this pilot effort, the researcher reviewed the World Para Shooting Sport and ISSF handbooks that outline regulations of Paralympic Shooting jackets. During the pilot effort visit, the Paralympic Shooting university contact, as well as the EC staff aided in any clarifications of jacket regulations that were needed whilst demonstrating standard EC processes. The final research prototype of the Paralympic Shooting jacket was offered to Hannah as an incentive for participating in this research.

Data Collection Procedures

For this research, an adapted version of Lamb and Kallal's (1992) Six-Step Framework for Apparel Design (Figure 2.1) was used as a guide throughout the methodology process. The framework for methods used for this research will be referred to as the Adapted Six-Step Framework. The steps of the framework process are as follows: 1) Problem Identification, 2) Preliminary Design Information, 3) Design Development, 4) Prototype Development, 5) Evaluation, and 6) Implementation. A visual representation of the Adapted Six-Step Framework, along with a key linking each research question to a process of these research methods, is illustrated in Figure 3.1. It should be noted that certain aspects of this work, originally intended to be within the scope of this project, were affected by the COVID-19 pandemic and stay-at-home orders, and as a result, were pushed outside the scope of this project. The following sections will provide an overview of each step of the Adapted Six-Step Framework as they apply to the methods of this research.



✚ Relates to the answering of RQ1: How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant?

▼ Relates to the answering of RQ2: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant?

◉ Relates to the answering of RQ3: How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires?

Figure 3.1: Adapted Six-Step Framework for this research, including research questions.

Step 1: Problem Identification

The first stage of the design process framework sought to identify the problems that exist currently for Hannah regarding her competition shooting jacket. A pilot interview was completed with the Paralympic Shooting contact, followed by a Problem Identification interview with Hannah to gather and analyze these data. The researcher analyzed the interview data using narrative and thematic analyses. Based on these analyses, an FEA Model for Disabled Athletes was developed. Finally, weighing of FEA needs and defining design insights were done to provide tangible outcomes for the following steps.

Pilot Interview

A pilot interview was completed with the Paralympic Shooting contact early in this research to examine the clarity, flow, logic, and relevance of the interview questions. A final set of interview questions were developed based on the pilot interviewee's feedback. The final interview protocol for this research can be found in Appendix B.

A brief analysis of the pilot interview data, as well as knowledge picked up during visits to the Paralympic Training Center, investigation of literature, and understanding of the regulations surrounding Paralympic Shooting jackets allowed the researcher to develop an adapted FEA model for data analysis. For example, reviewing of sources mentioned above revealed that Paralympic Shooting athletes can experience psychological or 'emotional' comfort as a functional feature of their clothing. Therefore, the adapted FEA model for data analysis was developed by the researcher and was utilized for Problem Identification interview analysis. Lamb and Kallal's (1992) original FEA Consumer Needs Model is seen with the adapted FEA model for data analysis, for comparison, in Figure 3.2.

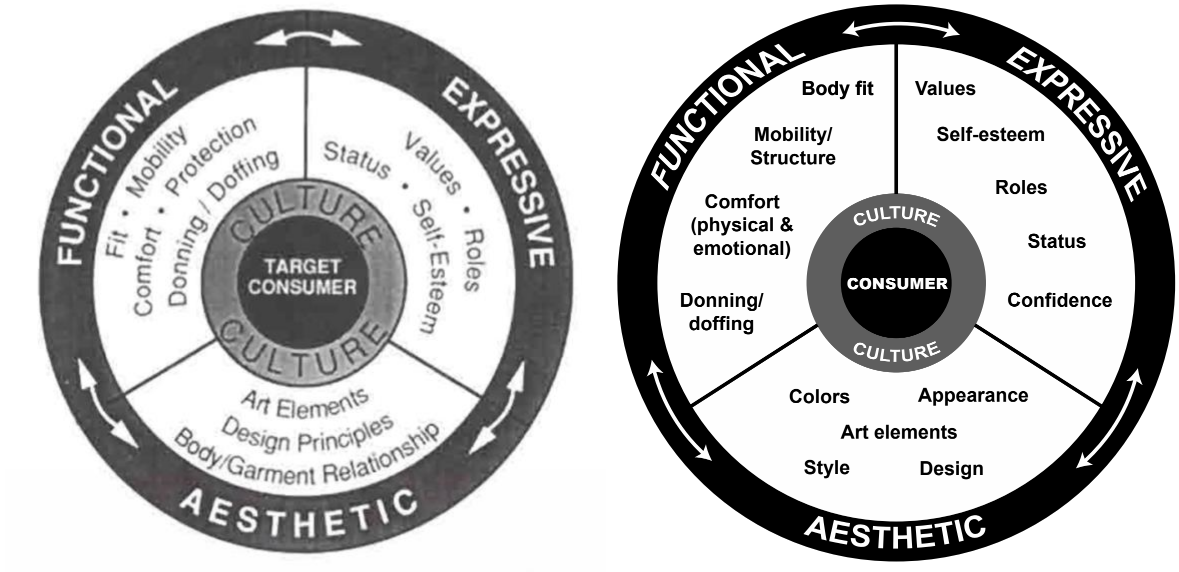


Figure 3.2: FEA Consumer Needs Model (Lamb & Kallal, 1992, left) and adapted FEA model for data analysis (right).

Interview

The semi-structured interview protocol followed a set of predetermined questions that, as previously mentioned, were tested in the pilot interview with the Paralympic Shooting contact. The interview protocol inquired about the following categories: (a) participant background as it relates to how they got involved in Paralympic Shooting; (b) daily activities for training or culture; (c) jacket performance or functional needs; (d) jacket aesthetics or aesthetic needs; (e) jacket meaning or expressive needs; and (f) questions about current jacket to better understand the current shooting jacket manufacturers and industry. Follow up questions were asked if the meaning of Hannah's words were not clear during the interview. The researcher read the items in the order they appeared in the interview protocol. If Hannah's responses included answers to future questions, the question was revisited later in the interview to allow for extended responses to each question individually. The data set gathered from the interview with Hannah was subjected to analysis using Lamb and Kallal's original FEA Consumer Needs Model, as well as the adapted FEA model for data analysis (Figure 3.2).

Coded Data Reliability

The interview data were imported to a qualitative analysis software called Dedoose (Dedoose, n.d.). The code list (to be discussed in Chapter 4) was transferred to this software, and the interview data were coded within the software.

Qualitative research is a process of analysis in which the researcher must stay very close to the data (Bazeley, 2013). The researcher typically knows the participants, understands the context of the interview, and has specific views or knowledge that impact how the data is coded (Bazeley, 2013). Therefore, to ensure the reliability of the data analysis, the researcher worked with their advisor to check the code applications and employ member checking (Bazeley, 2013). The data were coded in several iterations and verified by the researcher's advisor for good quality, proper code development, and good code application before being finalized, as a means of providing a form of outside reliability to the data. The research advisor had a proper amount of knowledge about Paralympic Shooting to be able to give feedback and suggestions for coding the data. Hannah was then asked to member check the codes by reviewing a researcher-made document that defined each code using her direct quotes. Hannah found the codes to be 100% accurate to the quoted definitions, providing further reliability and validity to the code applications and findings within this research.

In this research, it was unreasonable to ask another researcher to learn about Paralympic Shooting, the Paralympic Shooting jacket regulations, the construction details of the jackets, and understand the nuances between the athlete and their jacket. Therefore, inter-coder reliability was not employed in this research. Had the data been more explicit in outlining this highly important background information, it may have been possible to go through inter-coder reliability processes. Similarly, had this research been conducted in a team setting, with several researchers having this previous knowledge, inter-coder reliability would have been an important process. However, in this research, the learning of the aforementioned information was achieved through a rigorous review of documents, interactions with athletes, visits to training centers, and communication with EC professionals. For these reasons, inter-coder reliability was not employed in this research. The limitations of this research regarding reliability is discussed further in Chapter 5.

Problem Identification Interview Data Analysis

Narrative analysis. Narrative analysis was utilized in this work to allow for Hannah's voice and statements about the relationship she has with her shooting jacket to set the stage for subsequent forms of data analysis. Differing slightly from Riessman's (2008) approach to narrative analysis, the narrative in this research was constructed by the researcher, using the separate excerpts from the data to more thoroughly illustrate Hannah's feelings about her jacket. The excerpts in this narrative are presented in sequential order, with researcher input and off-topic data omitted. This narrative analysis presents the data as separated into lines to promote understanding of the meaning and impact of what is being said (Faulkner, 2018). This narrative analysis is presented first within the findings of this research to lay the foundation of the unique athlete/clothing relationship that is essential to understanding the thematic analysis of Hannah's FEA needs.

Thematic analysis. Thematic analysis was utilized in this research to analyze Hannah's interview data. Thematic analysis is a flexible method of qualitative data analysis that allows the researcher to examine data for themes and patterns (Braun & Clark, 2006). Hannah's interview data were analyzed using a priori themes developed from the original FEA Consumer Needs Model and the adapted FEA model for data analysis (Figure 3.2). Familiarization of the data was done by reading through the transcribed interview minutes several times. Initial coding was then done by separating the data into excerpts and applying preliminary codes to these excerpts. Based on what was found in the data, a more focused coding list was developed and finalized, and the data were coded again. The full finalized coding is discussed in Chapter 4.

Post-analysis Discussion of Problem Identification Interview

FEA Model for Disabled Athletes. Based on the Problem Identification interview data analysis, the researcher developed the FEA Model for Disabled Athletes to attempt to continue to advance theory in the field of apparel design (Bye, 2010). This model stays true to the meaning of the original FEA Consumer Needs Model while considering information used in the adapted FEA model for data analysis. The new (updated) model, as an outcome of this research, provides useful information regarding the differences between Hannah's needs and the original FEA Consumer Needs Model. The newly updated model is a step in the direction of understanding the clothing needs of disabled athletes. More research should be done to understand the clothing needs of disabled athletes and advance the FEA Model for Disabled Athletes presented in Chapter 4 of this research.

Weighing of FEA needs and design insights. When evaluating a consumer's needs, sometimes specific needs contradict each other and must be considered by the researcher for hierarchy regarding which need is more important and must be met in the final prototyped product (Lamb & Kallal, 1992; Orzada & Kallal, 2019). According to Watkins and Dunne (2015), "Skilled designers have what might be called *design insight.* This is the unique ability to extract from what is sometimes a very large body of information the important details that will lead to an innovative… approach to a solution." (pp. 3-4). For this work, design insights were objective statements gathered from interview data analysis regarding the requirements of the jacket design, separate from the jacket regulations. The practices of weighing needs and defining design insights are tactics that can help a designer sort out data and create a new understanding of a design problem (Watkins & Dunne, 2015). Weighing FEA Needs as well as eliciting design insights from the analysis of the Problem Identification interview aided in answering Research Question 1: How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant (Hannah)? The outcome of RQ1 are presented in Chapter 4.

Step 2: Preliminary Design Information

After Hannah's FEA needs were identified and analyzed in Step 1, Step 2: Preliminary Design Information involved gathering data about Hannah's body anthropometrics (shape and size). These data were gathered through 3D body scanning using the Structure Sensor Mark II (by Occipital) and manual gathering of measurements. Data about Hannah's current shooting jacket were also gathered in this step via an examination of the physical jacket. Also, in this step, a block garment was developed to test the fit of a standard jacket on Hannah's body. Finally, a half-scale dress form of Hannah's body was created as a tool and reference for further jacket development. The specifics of each process within Step 2 are outlined below.

Body Scanning

As discussed in Chapter 2, 3D body scanning is a method of gathering an accurate 3D body avatar, or 3D body scan, of a human subject. This 3D body scan can be utilized in CAD patternmaking programs, such as CLO, to allow for virtual garment simulation. For this research, the hand-held 3D body scanning Structure Sensor, version Mark II by Occipital, was used to acquire Hannah’s body model for the creation of a 3D avatar. This 3D body avatar was also used for virtual garment simulation (described in Step 4), which together sought to answer Research Question 2: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant (Hannah)? The outcomes and insights relevant to RQ2 are addressed in Chapter 4.

Although the portability of the scanner offers a great benefit to this research, the accuracy of the body measurement data gathered by the Structure Sensor Mark II and corresponding iPad application has not yet been validated in the literature, especially for the wheelchair-using population. Therefore, a manual collection of Hannah’s body measurements using a tape measure was done to gather a comprehensive understanding of Hannah’s anthropometrics.

Manual Measurements

Before gathering of manual measurements, a list of required measurements was developed based on ASTM standard body measurements (ASTM International, 2011), custom Paralympic jacket measurement charts from companies Kurt Thune (Kurt Thune, n.d.) and Monard Shooting (Monard Shooting, n.d.), and the QVC jacket measurement guide for apparel vendors (QVC, 2009). The researcher identified critical body landmarks based on key patternmaking landmarks relevant for Paralympic Shooting jacket development and construction.

The researcher also practiced taking manual body measurements on friends and family to be sure that the measurement process was both accurate and efficient. A worksheet with descriptions of each measurement, as well as line drawings illustrating key body landmarks which are referred to for each measurement description can be found in Appendix C.

Current Jacket Examination

The current jacket used by Hannah was analyzed to consider all factors of Hannah's competition shooting jacket experience. First, the researcher gathered a series of pictures annotated with measurements of the current jacket to be able to collect replica of the two-dimensional pattern. Because Hannah was continually and actively training during all research phases, annotated pictures of her current jacket were the most effective way to gain important fit and anthropometric data from the jacket in an efficient and transportable form. The jacket fabrics and seaming methods in Hannah's current jacket were also be analyzed. Analysis of these methods provided baseline reference data regarding the durability of Paralympic Shooting jackets. The fabrics and construction methods were documented via notes and pictures. Other design features, such as any buckles, buttons, and reinforcements were noted. All examined features of Hannah's current competition shooting jacket helped ensure the jacket prototype developed in this research was of high quality.

Block Garment Fit Test

The researcher developed a very basic jacket block (a pattern with very minimal details and stylelines) using Hannah's body measurements as well as a "rub-off" pattern replica of a used shooting jacket purchased from eBay. The block garment was sewn in an inexpensive fabric of appropriate jacket weight. This block jacket was the fit on Hannah during a fit test. During this fit test, areas of issue were noted and marked, which provided further context for Hannah's body size in relation to a jacket pattern.

Half-Scale Dress Form

As an extra tactic to ensure proper fit in the developed prototype, a half-scale dress form of Hannah was created using Hannah's body scan. Vuruskan and Ashdown (2015) outline the processes for creating half-scale dress forms, which this research followed closely. Hannah's body scan was edited and cleaned in Meshmixer (Meshmixer, n.d.) and Fusion 360 (Autodesk, n.d.), sliced into half-inch horizontal layers using Fusion 360 Slicer, and laser cut from half-inch open-cell foam. After the laser cutting was complete, the layers of foam were stacked in order and secured with dowels running through the form's interior. Lastly, the form was covered in stretch fabric and important body landmarks such as waistline, bustline, and princess lines were placed on the form using style tape.

By constructing a half-scale form of Hannah, the researcher was able to develop further fit test garments to a model that was anthropometrically similar to Hannah. The patterns produced through the use of the half-scale dress form allowed the researcher to scale the patterns up by twice the size, and have a garment fitted to Hannah's body as a result. Use of this half-scale dress form allowed for tactile design strategies to be implemented as needed during Step 3: Design Development.

Step 3: Design Development

Using data gathered from Steps 1 and 2, the third step of Design Development included the development of several creative solutions. These solutions included a half-scale block garment base, prototype ideation, and finalized CAD prototype illustrations (with and without annotations). The goals of Step 2: Design Development were to develop all the design information needed to be able to move onto prototyping the final jacket. Design work often involves spending a great deal of time and energy on ideating solutions (Watkins & Dunne, 2015). Below, each creative solution for developing the final jacket design is outlined.

Half-Scale Block Garment Base Development

Using the half-scale dress form of Hannah's body, a base garment pattern without style or design details was draped and developed into a rough fitted garment in half-scale. When developing any garment pattern, fit is essential. One limitation of developing garment patterns in a virtual CAD program such as CLO is that fit is often difficult to interpret. Draping fabric directly onto a form is often the best way to achieve optimal fit of a garment. Because Hannah's location for living and training, the Paralympic Training Center, was about a three-hour drive from the researcher, it was not feasible to drape a base garment directly on Hannah's body. Draping a jacket base on the half-scale dress form allowed for the most accurate and efficient method of pattern development possible in this research. For the researcher, developing a base garment aided in sparking ideas and inspiration during prototype ideation.

Prototype Ideation

Prototype ideation is often the most crucial phase of any design project (Lamb & Kallal, 1992; Watkins & Dunne, 2015). Ideation was done in the form of sketches and illustrations made by the researcher that aimed to meet the needs and solve the problems that Hannah expressed during Step 1, whilst also maintaining compliance with competition shooting jacket regulations. As Lamb and Kallal (1992) state, weighing of the FEA needs must happen to create a feasible and effective product, because often the meeting of all requirements is not possible in a single product. Hannah's FEA needs were weighed in Step 1, however, it is valuable to present design ideas to the end user before prototyping, to ensure the highest satisfaction possible. Therefore, frequent consultation with Hannah was helpful in this stage to advance the jacket design through the ideation process. Hannah had access to the final round of sketches to give input and feedback on design features. When a satisfactory final prototype ideation sketch was complete, this sketch was rendered as a CAD prototype illustration.

CAD Prototype Illustration (with and without Annotations)

A set of final technical drawings of the finalized ideation sketch, both with and without annotations, were made using the 2D CAD software Adobe Illustrator (Adobe, n.d.). Technical drawings or technical flats often aid the designer or researcher in understanding the specific details of a garment, allowing for less confusion during prototype construction. The final CAD illustration was shown to Hannah for her review, and subsequent rounds of further editing were done based on feedback. Once Hannah was satisfied with the final design of the jacket, this research entered Step 4: Prototype Development.

Step 4: Prototype Development

During Step 4, the final design was prototyped. The process the researcher underwent to develop the final jacket prototype was: finalize the half-scale pattern, virtually prototype the jacket pattern in CLO, and complete a final fit test on Hannah to correct any pattern issues at full-scale. Following these steps, the final jacket prototyping was then completed. The sections below walk through these phases of Step 4: Prototype Development.

Half Scale Pattern Development

A more completed half-scale pattern was developed with style-lines, design details, and feature placement locations using the half-scale base garment created in Step 2. This was done by using style tape and pencil to indicate important placements directly onto the base garment. By marking the base garment with these placements, the jacket pattern pieces were able to be edited in half-scale and subsequently sewn into a half-scale version of the final jacket (in test fabrics) to ensure proper fit, placement, and details. Once a finalized half-scale pattern was completed, the pattern pieces were imported to Adobe Illustrator, where they were made into vector files. The researcher then imported the vector files of the finalized pattern pieces into CLO for virtual prototyping.

CLO Virtual Prototyping

As reviewed in Chapter 2, virtual garment prototyping can be a way to streamline the garment development process (CLO3D, n.d.). After considering the small selection of virtual garment prototyping software available on the design market, CLO was chosen due to the program's accessibility to individuals (versus institutions or organizations), quality of fabric simulation, and ease of use. Therefore, after the finalized half-scale pattern was developed, the pattern itself was made into a vector file and imported into CLO. The jacket was then simulated on Hannah's 3D body scan (gathered Step 2: Preliminary Design Information). CLO's fabric editing features were utilized to simulate the virtual jacket in true-to-life fabric weights and qualities, on an exact virtual copy of Hannah's body, ideally allowing for the best virtual prediction of style and fit. Front, back, and side images of the virtual garment, as well as videos of the virtual garment, were shared with Hannah to gather design input and feedback. Any style or design changes requested by Hannah were made in the CLO patternmaking software. Using tension and tightness maps in CLO, the general fit of the jacket pattern was ascertained. However, a full-scale garment was sewn to allow for a final iteration of physical prototyping and fitting.

Full-Scale Pattern Corrections

The full-scale CLO pattern was printed and sewn together in test canvas materials for full-scale pattern corrections. Often virtual prototype CAD software can streamline the garment fitting process in design work. However, a final fitting in real fabrics on an actual body is often needed to confirm garment fit, as virtual garments cannot give information about garment factors such as mobility, donning and doffing, etc. For these reasons, a full-scale test garment was sewn in test canvas fabrics and fitted on Hannah directly. All required fit changes were noted, and the pattern was corrected in full-scale prior to the start of final physical prototyping. When comparing the full-scale test garment to the CLO prototype, it was possible to answer Research Question 2: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant?

Physical Prototyping

Physical prototyping allowed the researcher to synthesize all of the information from all previous steps in the construction of the Paralympic Shooting jacket design. The pattern pieces were cut from the final fabrics and constructed according to researcher-determined steps, incorporating seaming and finishing techniques seen in Hannah's current shooting jacket during Step 2: Preliminary Design Information. Photos of the prototyping process were sent to Hannah at regular intervals to allow for feedback. Upon completing the construction of the physical prototype, the researcher did a quality check to confirm that the prototype was accurate in measurement to both the final patterns and Hannah's measurements.

Due to the global pandemic surrounding COVID-19 during the completion of this research, Hannah relocated to her home state before the jacket was completed. Because of this, as well as stay-at-home orders, the researcher delivered the completed shooting jacket via USPS mail. Once Hannah received the jacket, Step 5: Evaluation was able to take place.

Step 5: Evaluation

The original intent for Step 5: Evaluation in this research was a protocol of delivering the jacket to Hannah, doing a final jacket fitting to understand any remaining fit issues, and finally, conducting a final Evaluation interview. Due to the COVID-19 pandemic, this protocol required serious modification. As stated, the final prototyped jacket was mailed to Hannah. Upon her receiving the jacket, she was able to try it on, take pictures, and make a note of fit or other issues remaining. An Evaluation interview was held via FaceTime with Hannah to understand her satisfaction with the jacket. The Evaluation interview protocol was developed in parallel to the Problem Identification interview and sought to understand Hannah's satisfaction based directly from the analysis of the Problem Identification interview data. The Evaluation interview protocol is seen in Appendix D.

Evaluation Interview Data Analysis

The Evaluation interview was transcribed verbatim and imported to the same qualitative data analysis software, Dedoose, used in the Problem Identification interview data analysis. Utilizing similar coding schema developed during the Problem Identification interview data analysis, the data from the Evaluation interview was subjected to thematic analysis (Braun & Clark, 2006) to understand the satisfaction that Hannah had with the final jacket prototype. Specifics of the final coding schema are discussed in Chapter 4.

The researcher first separated the data into excerpts, and relevant codes were applied to each excerpt. As in the Problem Identification interview analysis, the researcher's advisor provided insights, suggestions, and feedback to the final coding of the interview data. Member checking of the Evaluation interview was done by sending Hannah a written 'report' of her stated satisfaction. Hannah found the report to be 100% accurate, thus lending credibility to the findings of the Evaluation interview data analysis. Using the analysis of the Evaluation interview, it was possible to reflect on the entire process of this design research to answer Research Question 3: How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires?

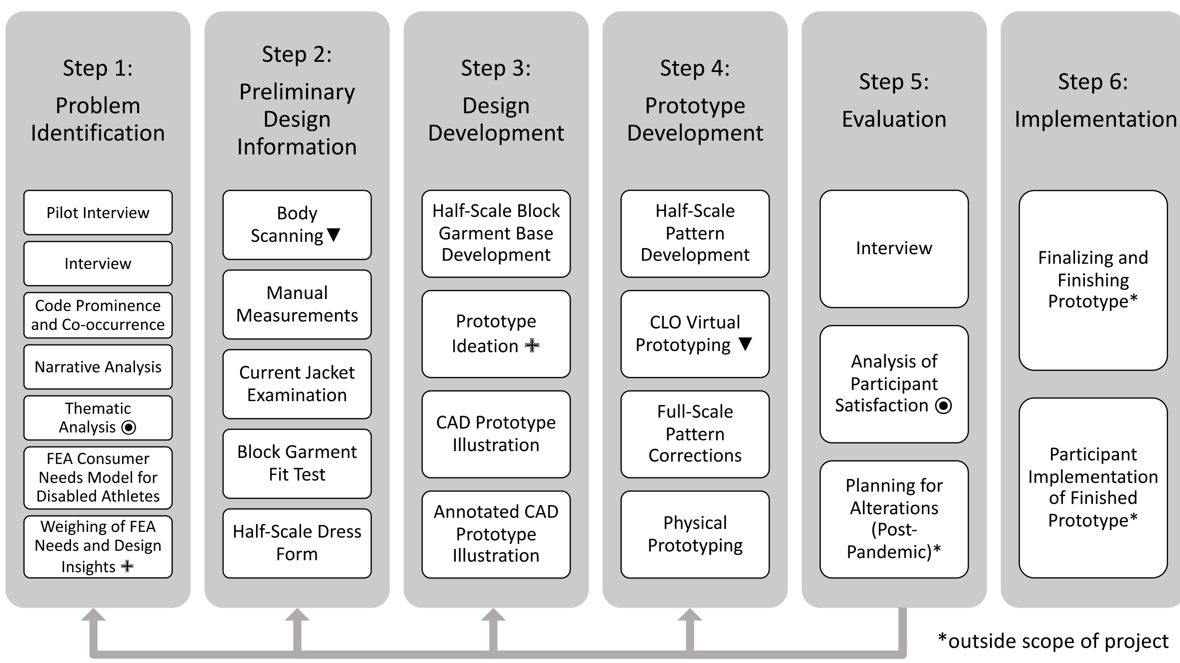
In the original plan for this work, the researcher included feedback from the previous steps in the Adapted Six-Step Framework (Figure 3.1), in the event that Hannah's satisfaction with the jacket was not to a high degree. However, due to time and distance limitations, further jacket modifications were pushed outside the scope of this work.

Step 6: Implementation

For this research, Step 6: Implementation was planned to include the following: any finalizing or finishing details of the final prototyped jacket being implemented, and Hannah implementing the jacket into her competition shooting routine and competition. Implementation of the shooting jacket was also pushed outside the scope of this work because of COVID-19 social distancing limitations. Hannah relocated to her home state while the pandemic was in effect, and the finalized jacket was in her possession until the presentation of this thesis work. Completing the jacket based on Hannah's stated dissatisfactions will be done at a future date when she is back at the Paralympic Training Center. Until then, Hannah will not be able to implement the prototyped jacket into her training routine. The effects of COVID-19 is a limitation on this work. More limitations are discussed in Chapter 5: Conclusion. What implementation may look like at a future date will be discussed in Chapter 4: Findings and Discussion. To allow for this work to be meaningful on a larger scale, implementation also considers what effects the insights gained from each step in the design process used in this research may have on a larger scale within the clothing industry. The findings and discussion of each step within this work are discussed next in Chapter 4: Findings and Discussion.

CHAPTER 4: FINDINGS AND DISCUSSION

This chapter will walk through the findings of each step of the Adapted Six-Step Framework (Figure 4.1) used as the method for gathering data in this research. Each section reports the findings of the methods outlined in Chapter 3, as well as provides a discussion of each result. Findings and discussion are reported together in this chapter to allow for better continuity and readability. The research questions for this work are reflected upon at the end of this chapter, so as to consider all the information gathered and the process completed throughout the scope of this thesis.



✚ Relates to the answering of RQ1: How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant?

▼ Relates to the answering of RQ2: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant?

◉ Relates to the answering of RQ3: How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires?

Figure 4.1: Adapted Six-Step Framework for this research, including research questions.

Step 1: Problem Identification

The first step in this research was Problem Identification. Within discussion of the Problem Identification interview findings, code development and code co-occurrence are discussed. This is followed by a narrative analysis (Faulkner, 2018; Riessman, 2008) and thematic analysis (Braun & Clark, 2006) of the interview data. Following these analyses, an FEA Model for Disabled Athletes is presented based on the Problem Identification interview findings and analysis. Weighing of FEA needs and design insights will conclude this section.

Problem Identification Interview Analysis Codes

For this research, the Problem Identification interview was conducted with Hannah, as noted in Chapter 3, to understand her FEA needs and potential areas for improvement regarding her Paralympic Shooting jacket. A single semi-structured interview was held with Hannah in a location of her choosing: a local coffee shop. The interview was expected to be approximately one to two hours in length. The interview lasted about 38 minutes. After the interview, Hannah was given the list of interview questions to keep and examine. Hannah was invited to contact the researcher within the next week if she had more data to provide regarding any given interview question. Hannah did not make contact or offer any additional responses within the timeframe of one week. The interview was video recorded to capture any physical referencing to the jacket done by Hannah during the interview. Audio from the interview recording was transcribed by the researcher with pauses and paralinguistic cues included in the transcript.

Hannah's interview data were analyzed using a priori themes from the adapted FEA model for data analysis, seen in Figure 3.2. Table 4.1 shows the finalized code list developed for the Problem Identification interview analysis.

Table 4.1

Code list for Problem Identification interview thematic analysis.

Parent Theme Code	Child Code	Description
Consumer/Athlete	History of Shooting	Path to and beginning of involvement in Paralympic Shooting
	Disability	Information and history about disability
	History of jacket	Regarding the past of the current or previous shooting jackets
	Comments about jacket manufacturer	Comments regarding Hannah's interactions with and impressions of the manufacturer of her current shooting jacket
	Connection to jacket	Mental and emotional connection towards jacket
Culture	Training	Daily training activities, i.e. shooting or other training activities
	Lifestyle outside training	Regarding Hannah's weekends or free time
	Peers	Interactions or mentions of other Paralympic Shooting athletes
	Jacket regulations	Information related to ISSF and World Para Shooting Sport Equipment Control guidelines
Functional	Body fit	How the jacket fits on Hannah's body
	Mobility	How Hannah is able to move when needed in her jacket
	Structure	Jacket providing physical support and stability to the athlete
	Physical comfort	Tactile comfort of the jacket on the body
	Donning and doffing	Putting the jacket on and taking the jacket off
	Temperature	How warm or cold Hannah feels in her jacket
	Emotional comfort	Comfort of the jacket to Hannah's mental/emotional state
Expressive	Values	Jacket elements that express Hannah's values
	Self-esteem	Jacket elements that affect Hannah's self esteem
	Roles	Jacket as an expression or understanding of role as a Paralympic athlete
	Status	Rank or status held by Hannah as it is expressed through the jacket
	Confidence	Jacket affecting Hannah's confidence
	Emotional comfort	Comfort of the jacket to Hannah's mental/emotional state
	Connection to jacket	Mental and emotional connection towards jacket
Aesthetic	Appearance	General visual aesthetics of the jacket
	Design	More in-depth visual and technical elements of the jacket
	Style	Elements of the jacket that reflect the personal style of Hannah
	Colors	Comments about the color of the jacket
Improvements	Participant identified	Improvements to the jacket that Hannah suggested
	Researcher identified	Potential areas of improvement within the data, identified by the researcher

The FEA needs of the consumer (Hannah) are what this research sought to understand, to develop a shooting jacket design and further develop the FEA Consumer Needs Model to be better suited to understand the needs of disabled athletes. Because of the unique relationship between Paralympic Shooting athletes and their jackets, *Emotional comfort* was determined to be both a Functional need as well as an Expressive need after initial coding of the data. This emotional comfort can both aid performance as a psychological factor and can impact the athlete's expression of themselves as a Paralympian through feeling comforted by their jacket. Thus, *Emotional comfort* as a child code under Expressive needs was an emergent code.

The parent code theme of Aesthetic needs originally housed a child code of body/garment relationship in Lamb and Kallal's (1992) FEA Consumer Needs Model (Figure 3.2). In the adapted FEA model for data analysis, the body/garment relationship was removed due to these factors being more embedded in key aspects of Functional needs that aid the athlete in their shooting performance.

Often in qualitative research, a parent code theme is created to place excerpts that the researcher feels will be valuable to highlight and display in the findings section of their study (Bazeley, 2013). For this research, a parent code theme of Improvements was made to house indications of potential areas of improvement in the jacket that were *Participant identified*: improvements to the jacket that Hannah suggested, and *Researcher identified*: potential areas of improvement within the data, determined by the researcher. It was valuable to pull excerpts that related directly to the design and of the jacket, especially when Hannah identified areas for improvement. These excerpts that identified areas needing improvement can help jacket manufacturers and industry leaders understand the needs that are not being met in their product.

These suggestions provide direct and readily identifiable features that can be re-designed by manufacturers and ensure higher satisfaction to the athlete/consumer.

Code Co-occurrences

Examining how child codes co-occurred, and at what frequency, allowed the researcher to understand more about how certain Paralympic Shooting jacket elements relate to each other for the participant, Hannah. Any co-occurrence over the count of three was given attention. Two out of the top three co-occurrences had the same child code under different parent code themes (*Connection to jacket* and *Connection to jacket* had 12 co-occurrences; *Emotional comfort* and *Emotional comfort* had six co-occurrences). This was to be expected when using one child code under two parent code themes, and thus these data are not especially valuable. Table 4.2 shows all of the co-occurrence relationships; these two cases have been highlighted in gray, indicating that they do not provide new information.

Other code co-occurrences provided more interesting insight. For example, *Emotional comfort* co-occurred with *Connection to jacket* four times. Similarly, *Confidence* co-occurred with *Connection to jacket* also four times. In this same vein, *Connection to jacket* co-occurred with *History of jacket* four times. Based on this evidence, there is suspected to be a deep relationship that the participant has with her jacket, which is also part of the jacket's history. This relationship aids in both emotional comfort and confidence of the athlete, which are both functional aspects. There is evidence, thus, to suggest that the connection that Hannah feels to her jacket can be a functional, performance-aiding relationship. Though each mentioned connection only had four co-occurrences, when considered as a whole, these co-occurrences present significant meaning.

More prominent and less informative co-occurrences found in the analysis include *Colors* and *Appearance* co-occurring 12 times, *Comments about jacket manufacturer* and *History of jacket/s* co-occurring five times, and *Body fit* and *Structure* co-occurring four times. However, because *Appearance* and *Roles* co-occurred four times, and *Colors* and *Appearance* co-occurred 12 times, there is a relationship between the colors of the jacket and the role of the participant as an athlete representing the USA. Narrative and thematic analyses of the Problem Identification interview provided further insights to Hannah's FEA needs regarding her Paralympic Shooting jacket.

Table 4.2:

Problem Identification interview co-occurrences.

First code theme	First code	Second code theme	Second code	Co-occurrence rate
Expressive	Connection to jacket	Consumer	Connection to jacket	13
Aesthetic	Colors	Aesthetic	Appearance	12
Expressive	Emotional comfort	Functional	Emotional comfort	6
Consumer	Comments about jacket manufacturer	Consumer	History of jacket	5
Functional	Body fit	Consumer	History of jacket	5
Functional	Body fit	Functional	Structure	4
Functional and Expressive	Emotional comfort	Consumer and Expressive	Connection to jacket	4
Expressive	Confidence	Consumer and Expressive	Connection to jacket	4
Expressive	Connection to jacket	Consumer	History of jacket	4
Aesthetic	Appearance	Expressive	Roles	4

Narrative Analysis

The narrative analysis is presented here before the thematic analysis, so as to lay the foundation of the unique athlete/clothing relationship that is essential to understanding the thematic analysis of Hannah's FEA needs. Below is a constructed narrative gathered from Hannah's interview data. After the narrative, an analysis is presented, followed by the thematic analysis of Hannah's interview data.

It's Helping You Grow:

I would say more

if you didn't have it,

it would hurt it.

If you didn't use it,

it would hurt it.

I mean, it's for the benefit, I think.

I like it because it's thick

and it's very form-fitting...

it keeps you… like, in a

stationary position that you need to be.

There's not much movement that can be made.

I mean the jacket, it's a jacket.

Like... I could change 50 million things

about the jacket and probably

still not be happy, after all.

But like, it's knowing that like…

knowing that this jacket could like potentially, like, win you the Paralympics.

I guess knowing that the fact
that a jacket can do so much
to help you,
and knowing that you're using a specific jacket
to help you shoot.

I guess it's like a two and two thing…
I guess it's me and partially the jacket…

So it's kinda like water
and like a plant.
It's small, but like,
the more that you water it,
the more it's gonna grow.
But it's still the same plant.
So like the jacket is kinda like…
the water, per say?

And the human is more or less the plant
and the jacket helps the human grow.

Like the more you wear the jacket,
the more that you're gonna grow
because it's helping you grow.

In this constructed narrative, Hannah explores her feelings and relationship with her Paralympic Shooting jacket. Immediately she sets the stage by orienting the jacket as being "for the benefit", thus, likely more helpful than harmful. There is more clarity when she describes that the jacket is structured and form-fitting (while still following the EC regulations), putting her in a stationary position that allows her to gain stability and thus shoot better. The beginning of this story orients the jacket as very important and helpful for Hannah and other Paralympic Shooting athletes.

Next, thinking beyond the obvious importance of the jacket, Hannah digs deeper into her feelings about how the jacket looks and perhaps certain design elements of the jacket. Hannah is an athlete who spends nearly everyday training for her sport and thus, wearing her jacket. The relationship between athlete and jacket is a close one. Hannah states that she could change "50 million things about the jacket and probably still not be happy after all". However, although there is room for improvement and changes, she recognizes that the jacket, even as is, has the potential to "win [her] the Paralympics". Hannah does not say that the jacket can *help* her win the Paralympics. She says that the jacket would win the Paralympics for her. This orients the jacket as a powerful garment to which the athlete has a deep and powerful respect and connection.

Hannah orients the jacket further in this constructed narrative by saying that a "specific jacket" is used: her custom-made jacket made by a company called Kurt Thune. Hannah values that her jacket is "specific" or custom for her, and the specificity and accuracy of fit to her body helps her shooting performance. Again, Hannah orients the jacket as one of the main factors in helping her shooting performance. Hannah then evaluates her jacket's impact on her performance as well as her skill as an athlete, saying that it's a "two and two thing", "[her] and partially the jacket". The relationship is somewhat symbiotic. She describes the athlete as a small plant and the jacket as the water. "The more you water it, the more it's gonna grow", she says. Hannah clarifies this abstract passage by defining that the human is "more or less" the plant, and "the more you wear the jacket, the more you're going to grow because it's helping you grow." The more the athlete wears the jacket, the more the athlete will grow.

At the end of the day, the jacket is a beneficial tool for Hannah and can help her grow and become a better athlete. She values her jacket to a high degree. Within this narrative, there are indications of themes revolving around Hannah's connection to the jacket as well as psychological or emotional comfort provided to Hannah by the jacket. Hannah's psychological connection and comfort relating to her jacket is something that is not present in neither the original FEA Consumer Needs Model (Lamb and Kallal, 1992) nor the adapted FEA model for data analysis (Figure 3.2), thus *Emotional comfort* was an emergent code in this data analysis. These complex aspects of Hannah's Paralympic Shooting jacket needs are further explored through a thematic analysis of each major theme in this data.

Thematic Analysis

The thematic analysis of this interview data is presented below in sequential order to the interview protocol.

Consumer/athlete attributes. The theme of Consumer/Athlete houses the essential information for the clothing designer or manufacturer to understand. The consumer must be understood before any design process, or investigation of needs can move forward (Lamb & Kallal, 1992; Orzada & Kallal, 2019). *History of jacket* was the most prominent code within the Consumer/Athlete theme. *Comments about jacket manufacturer* (Consumer/Athlete) and *Body Fit* needs (Functional) co-occurred with *History of jacket* five and four times, respectively.

Where these codes co-occur, there are rich excerpts. In one excerpt, Hannah shared information about how and why she chose a specific manufacturer for her jacket:

> Researcher (R): Yeah, did you pick that brand [Kurt Thune] for a reason?
>
> Hannah (H): Um, no... well, yeah and no. Not by choice, but they did, they had... so this is a Para jacket. Specifically, it's not an able-bodied [non-disabled] jacket. So, Kurt Thune had a measuring scale for Para, versus just able-bodied [non-disabled].
>
> R: Ok.
>
> H: So, we're like "yeah, hey let's try it" because like every jacket or like the jacket I had previous to that, fit like... it was terrible. The sides would like flare. Like it was a straitjacket, and then the sides would just like flare out. So, then we had to get the jacket [altered]... well, we had to kind of do the same thing with this [jacket], but it wasn't that extreme.
>
> R: So, you picked it because they were one of the only people that had the Para [measuring scale]?
>
> H: At the time.

Hannah states that only minor alterations were made to her Kurt Thune jacket after it arrived. She has had trouble in the past with jackets fitting correctly, which prompted her to try purchasing a jacket from a manufacturer that offered jacket options for disabled athletes specifically. The fit issues of her previous jacket were directly related to her disability. Body shape and size (anthropometrics) of disabled people and athletes are not the same as the anthropometrics of non-disabled or able-bodied people. Hannah understands this crucial difference and how her body position and use of a wheelchair affect her clothing:

> R: So, obviously this jacket is custom made. Did you... I've seen the forms that they [use]... basically, can you talk a little bit about like what the process was, like did somebody take your measurements? Or...

> H: Somebody took measurements of me sitting in a wheelchair versus standing because if you get... if you go from standing and using it for sitting, it's gonna be a complete... like the other way around. So, if you're gonna use it for in a chair, sit in a chair. And get measured.

Hannah recognizes here that her disability plays a large part in how she interacts with clothing. She understands that her seated body is different from her standing body. Hannah uses a wheelchair as her primary means of mobility, and thus she recognizes that it is imperative to be measured for a custom jacket while she is sitting in her chair. Just as non-disabled people often see their bodies as a part of their identity, so do disabled people often see their body as a part of their identity. When one understands and identifies with their body, they can also understand how the clothing will or should fit on their bodies. Hannah knows that "if you're gonna use [the jacket] in a chair, sit in a chair. And get measured [in a chair]."

Through examining the attributes of the Consumer/Athlete, it is clear that disability affects body fit of clothing and interactions with clothing. Manufacturers need to understand that the consumer and disability are tied together, and the design and fit of clothing should reflect and understand that inseparable tie. Clothing designed for disabled athletes should, as Hannah stated, be measured and constructed with respect for the athlete's disability and body anthropometrics. These anthropometrics may differ from the anthropometrics of non-disabled persons, even when in a seated position. The athlete's disability and anthropometrics need to be understood first and foremost by manufacturers, followed by any cultural influences of the consumer that directly affect their clothing needs.

Culture. The culture of the consumer most often is made up of their lifestyles and passions. Because Hannah is a career athlete, the most prominent topic within the theme of Culture was *Training*. Hannah practices her sport as a full-time job:

R: …so can you... like... it's, just imagine it's like an average weekday, and you have, ya know, your agenda... what does that look like for you?

H: Um, we usually start at 8:30 in the morning until about 11:30/12, then we go to lunch… we'll go to lunch for about an hour, and then we'll come back at 1:00, and we'll shoot from around like 1:20 to like 3:30, and that's pretty much a day for us, so…

Training for Hannah and other Paralympic Shooting athletes is not only about shooting to hit a target, but also includes training the mind to be focused on shooting despite any outside distractions. For example, every competition has some background music that is chosen by the announcer at the event. Hannah found it valuable to practice with a wide variety of music playing:

H: It's... it's good because you don't know what you're ever gonna run into... at a competition. So, prepare for it now, versus not be prepared and really screw yourself over.

R: Yeah, that's crazy.

H: Yeah. You kinda start laughing to yourself, but you gotta... keep it in.

Equipment control (EC) and *Jacket regulations* are something that a shooting athlete must know well, and must keep in mind before every competition, and thus are a part of the athlete's Culture. There is a regulation regarding how tight the jacket can be on the athlete. Human anthropometrics can change with time, such as gaining or losing weight, or with the climate, such as the body swelling in hotter climates. Manufacturers recognize this, and most shooting jackets have a feature of removable buttons that can be moved in or out on the jacket to accommodate for any change in body shape or size:

R: Have you ever like come close and had to move a button?

H: Yeah, I've had to move a button in... Korea. At world championships last May.

R: Wow, and they let you do that, they just are like "go move that button"?

H: Yeah. They'll let you do it during EC, but if it's during the match and you get caught, you're kind of just screwed. Because I mean, at any point you could have changed [it] so they're like, "yeah, you're done."

Jacket regulations also dictate the thickness of the shooting jacket. Even during brainstorming of design solutions, in this instance for underarm ventilation, Hannah immediately mentally references EC regulations:

R: You were saying last time that ... thinking about the armpits, putting like a...

H: A zipper?

R: Or like something, yeah. A zipper or something where you could have like a breathable material.

H: Yeah, that'd be cool, but I don't... I don't know if that would be legal though, at the same time. 'Cuz I mean that could technically be artificial support.

R: Oh yeah.

H: Because of the thickness of the zipper, if it's not open, ya know. I mean the thickness of the zipper, but the thickness of it all together would be enclosed too with the material underneath it as well.

From these excerpts, it's clear that the Culture of Hannah is focused around her sport. Hannah knows how to train herself to concentrate on shooting and mentally block out distractions. She also has direct knowledge of the shooting *Jacket regulations*, which is indeed a part of her culture because it dictates the design of her jacket. The FEA needs of Hannah and other Paralympic Shooting athletes cannot overstep these jacket regulations, and thus the Culture of the athlete defines the FEA needs of the athlete.

Functional needs. Within the theme of Functional needs, *Body Fit* was the most prominent need, and most commonly was brought up with *History of jacket* and *Comments about jacket manufacturer* (both child codes of Consumer/Athlete). Within Functional needs alone, *Body Fit* co-occurred with *Structure* most often. The 'job' of the shooting jacket is to essentially constrict movement as much as possible, to help the athlete stay in a stationary position, which in turn helps the athlete to hit their small shooting target easier. Hannah defines the ‘job’ of the shooting jacket in a very concise way:

> R: Does your current jacket, this one, like... how does it aid your shooting performance, if it does in any way...
>
> H: Stability, mainly.
>
> R: Because it’s nice and tight?
>
> H: Mhmm [affirmative].

In the narrative analysis presented in an earlier section, there are ties between the Functional aspects of *Body fit* and *Emotional comfort*. Shown here is an elaboration of an excerpt that was seen in the narrative analysis:

> H: I mean the jacket, it’s a jacket. Like... I could change 50 million things about the jacket and probably still not be happy after all. But like, it’s knowing that like... I mean not every jacket is the same (inaudible) so like knowing that this jacket could be like...
>
> R: whatever, any other thing?
>
> H: No, knowing that this jacket could like potentially, like win you the Paralympics...
>
> R: Yeah, yeah!
>
> H: You know what I mean?
>
> R: Ok I get it. Yeah. And because it’s made for you, right?
>
> H: Yeah.

Emotional comfort is not at all present in Lamb and Kallal’s (1992) original FEA Consumer Needs Model (Figure 3.2). For Hannah, *Emotional comfort* is tied to feeling *Confidence* as a result of her clothing. Kratz et al. (1997) referred to that level of inner confidence as affect state. They understood clothing’s role in affect state for disabled consumers, as well as the importance of having a highly confident affect state. Having high internal confidence can allow the athlete to have a better performance in their sport (Kratz et al., 1997). *Emotional comfort* is therefore both a Functional need and an Expressive need for Hannah. The overlap between confidence, emotional comfort, and connection to jacket will be further explored within the following analysis of Expressive needs.

Expressive needs. As understood through both the analysis of Functional needs and the narrative analysis, there is an inherent *Connection to jacket* that Hannah has, and that relationship provides *Emotional comfort* and *Confidence*. *Connection to jacket* was the most prominently coded Expressive need, followed by *Emotional comfort*. An elaboration on an excerpt seen in the narrative analysis is presented here for demonstration:

> R: When you're wearing this jacket, does it make you feel like empowered in any way? Or... anything like that?
>
> H: I don't know. I've never thought about that before. Um...... I guess it's like a two and two thing. I guess it's me and partially the jacket. Like, it's... ok so say like.... we'll use this analogy, which is probably gonna be way off, but like... so like imagine two things. So, it's kinda like water... and like a plant. It's small, but like, the more that you water it, the more it's gonna grow. But it's still the same plant. So, like the jacket is kinda like... the water, per say?
>
> R: Yeah, I get where you're going.
>
> H: And the human is more or less the plant, and the jacket helps the human grow.

Emotional comfort and *Connection to jacket* co-occurred four times within the data. *Confidence* and *Connection to jacket* also co-occurred four times. There is a clear linkage between *Emotional comfort*, *Connection to jacket*, and *Confidence*. All three are Expressive needs, but can also be placed within the consumer's identity (Consumer/Athlete) as well as the Functional needs of the athlete due to the strong relationship between the athlete and the jacket as well as the 'job' of the jacket (providing body support and stability).

Lamb and Kallal's (1992) FEA Consumer Needs Model also identifies Expressive needs as those that influence interactions with and perceptions from other people. The shooting jacket is not a common-looking garment, and Hannah navigates that in the following excerpt:

> R: Um, can you talk a little bit about how your jacket affects your self-esteem? Like does it help with that when you're... um, shooting, or on camera even?
>
> H: I wouldn't say that it does. I mean, it's not... it's not all about the jacket. It's more of... I mean... somebody's perception of the jacket is obviously gonna be much different than your own. So, at that point, I don't even know... I mean there's really no point of even putting it out there because it's not like it's really gonna matter.

The outside perceptions of Hannah's jacket do not affect or dictate her Expressive needs, because she feels that the value of the jacket is within its ability to do its job. For Hannah, it does not matter what others may think of her jacket, and those outside opinions do not affect her self-esteem. Hannah was more interested in how the jacket expresses or could express her *Roles* as an athletic representative of the USA:

> R: Did you get this [jacket] because you started on the national team?
>
> H: Uh yeah.
>
> R: They want you to have like…
>
> H: Red, white, and blue.
>
> R: Yeah.
>
> H: Yup. Might not match everyone else, don't be the oddball (laugh).

Hannah also demonstrated how her *Style* must be put aside to continue to respect the role of being an athlete representing the USA:

> R: Um... so without considering [regulations], if you could wear whatever you wanted and your jacket could look however... you wanted it to, what would it look like?
>
> H: I would say cheetah print pattern. That's a little extreme though.

How Hannah understands that her role as an athlete dictates her clothing is an excellent example of how the culture of the athlete dictates the needs of the athlete. Hannah's culture is fully embedded in the fact that jacket regulations exist. In this case, we see that the *Roles* of the athlete are directly related to the <u>Aesthetic</u> needs of her jacket.

Aesthetic needs. *Appearance* and *Color* were two <u>Aesthetic</u> needs that were most frequently coded within this entire data set. The *Appearance* of the jacket co-occurred with *Roles* (<u>Expressive</u>) four times. Hannah perhaps has sacrificed some of her personal aesthetic preferences because of her current culture and roles as a Paralympic athlete. Although she would like a jacket that is cheetah printed, she recognizes that her aesthetic needs must more closely follow what is expected of her: having a jacket that reflects the USA, the country she is an athletic representative for.

Within these culturally- and role-based aesthetics, Hannah had further concerns and ideas about how the aesthetics of her jacket could be improved, specifically related to the *Colors* of her jacket being faded from wear:

> R: Do you feel like your, the appearance of this jacket kind of reflects what you want it to when you're like in the media, and like as somebody who's moving like, growing...
>
> H: Um... I don't know. I feel like if the jacket, like if the colors could be more like vibrant, it would be better.

Out of all the codes applied to the interview data, *Colors* was the third most prominent code. The athlete mentions the faded colors of her jacket more than once:

H: Um… so I got [my Kurt Thune jacket] October 11th of '17 (shows a picture of a new jacket from that date).

R: Wow, it looks so fresh!

H: Yeah, compared to now.

R: It doesn't look bad now.

H: It's not vibrant; it's just dull.

The appearance of the jacket is important to Hannah. Whether this is based on her values or outsider perceptions of the jacket is unclear. However, it is certain that the role of being an athletic representative of the USA heavily influences her aesthetic needs for her jacket. Creating more vibrant colors with less potential for fading is a design feature that manufacturers could seek to improve upon. More improvements for Paralympic Shooting jackets will be discussed in the next section.

Identified improvements. As mentioned, the theme of Improvements was added to the coding list as a place to house suggestions for improvements identified by both Hannah as well as the researcher. Eight excerpts were coded as *Participant identified* improvements, and five as *Researcher identified*. These identified improvements housed suggestions within all three FEA needs, which indicates that Hannah's clothing needs are not being adequately met in her current shooting jacket. Hannah spoke mainly about three areas of potential improvement: the lack of communication from the jacket manufacturer, the colors of her jacket, and the materials used to make the jacket.

The jacket Hannah currently uses was custom manufactured for her, based on measurements taken by a salesperson from Kurt Thune. Kurt Thune allows customers to customize their jacket colors online during the ordering process. After this, Hannah indicated that it was a "silent seven months" while she waited for her jacket to arrive, with no communication from the manufacturer:

> R: Really? Seven months??... that sounds a little frustrating.
>
> H: Yeah. I mean seven months without a jacket and I'm like "help! I don't know what to do!" like I want this jacket, I need the jacket, and I don't know where it's at. I don't know if it's been started if it's done if it's on its way... if it's being held in customs... like, I don't know.

Hannah was without updates from the manufacturer, and that caused her to feel helpless and very concerned about where the jacket was and when she would be receiving it. It is important for any industry leaders that wishes to manufacture custom sportswear, specifically for people with disabilities whom already face struggles finding proper sportswear, to note that interaction with the athletes themselves is important. These custom garments are often expensive; when the athlete invests financially, they invest emotionally as well.

Hannah's connection to her jacket is not only due to the jacket being custom made to her measurements but also to the level of personalization she was able to have regarding the colors and specific design features of the jacket. Of course, sometimes decisions made by the consumer are later the ones they regret. For instance, Hannah was able to choose what colors her jacket would be, and she has since decided that her choice of the color white for some areas of her jacket was not ideal:

> H: White, don't ever do it; it's a bad idea. As you can see, white.... literally, it's terrible. Go black, don't go white.

Hannah is referring to the dirt her jacket has collected when she says, "as you can see". The accumulated dirt that has embedded itself in the white canvas of the jacket is visible, and Hannah does not like the way that the white becomes dirty. These jackets cannot easily be washed or dry cleaned due to suede and plastic components. Although she suggests that black would be a better option, Hannah also indicated would like to have USA flag print, to be referred to as American flag print for ease, on her jacket:

> R: I remember last time we talked [casually], we were asking Equipment Control if... print was ok. Like a printed... material. And they said it was ok. Is that like... do you want something like that?
>
> H: American flag print would be really cool.

Perhaps the inclusion of an American flag print textile could be incorporated into an area that is less likely to gather and hold on to dirt, such as one or both sleeves. Hannah had identified that perhaps the upper back yoke area could be a good place for an American flag printed textile, but backtracked on that statement based on another identified improvement of including a more breathable material somewhere in her jacket:

> R: So, if you could add or take away, like, any of those things that we just talked about, or even like different things that would make your jacket more functional and make you… feel like it is... more comfortable for you...
>
> H: I feel like the top, like right in [here]… Like if this top [upper back yoke] could be like, breathable material, like... not like fishnet material, but like... like kinda like UnderArmour material… Yeah, the upper half. Because this does really nothing for you. It's mainly the back and the arms and the sides [that provide stability]. So, I mean if this could be breathable, then your back wouldn't be so warm.

Paralympic Shooting jackets are meant to provide artificial body support to the athlete. The jacket bodies are typically made of canvas and either faux or real suede, which does provide structure, but also causes the athlete to retain a great deal of their body heat. According to Hannah, this can be a problem in warmer climates or shooting sites without air conditioning:

> R: Do you feel too warm when you're wearing it? Or too cold sometimes?
>
> H: …well when you go out in the heat in Georgia, in the middle of June or July, it's brutal. It's literally brutal. You literally take a shower in that jacket. It is terrible. It's definitely not a breathable material, by far.

Temperature, a child code under the theme of Functional needs, was coded ten times within this data set. Hannah provided a reasonable suggestion for improvement: to incorporate a sweat-wicking material in the upper back yoke area. It would also be possible to integrate underarm gussets to provide ventilation to the underarm area, as was touched upon in Consumer/Athlete. Still, jacket regulations would need to be closely monitored and adhered to. The jacket, most importantly, must provide structure to the athlete, and thus thinner fabrics should not be placed in key areas that provide body support, such as the area around the torso. Hannah indicated that the canvas material was far more supportive than the suede material on her jacket in this excerpt that was also partially seen in the narrative analysis:

> R: Do you like this [canvas] fabric, or do you like the other [suede material]?
>
> H: I like [the canvas] because it's thick, and it's very form-fitting, not form-fitting, but it's very… it's form-fitting, but it keeps you... like, in a stationary position that you need to be. There's not much movement that can be made. Unlike this [suede] material.

Manufacturers should be attentive to what the function of the jacket is (to provide structure), as well as how the jacket effects the athlete's body heat when making decisions regarding textiles and materials to be used.

Hannah provided excellent suggestions for changes she would like to see made on her jacket, and the data coded as *Researcher identified* improvements indicated only one area that Hannah did not bring up herself: *Mobility*. When asked if her jacket is comfortable to wear, Hannah had valuable feedback:

R: Is your jacket... do you find it to be like, comfortable? Not just during competition, but also like.... ya know, when you're in between shooting?

H: Like what do you mean...

R: Like, is it comfortable to wear? Do you like wearing it?

H: I'm not a fan of it because [the extent of the range of motion] is like, here… you can't really move your arms any further than that. And you try to push a wheelchair with it on. It's nearly impossible.

The sleeves of Paralympic Shooting jackets are typically designed and patterned with a 45-degree bend in the elbow, and flexible material in the inner elbow area to allow for comfortable elbow bending and more structure to the arms. While this is a valuable design feature for a Paralympic Shooting athlete's performance, it causes Hannah to have limited mobility when trying to push her wheelchair. Providing more mobility to Hannah and other shooting athletes who use wheelchairs through the use of engineered gussets in the elbow area would be a possible way to improve comfort and mobility levels while wearing the jacket. Because both Hannah's and other Paralympic Shooting athletes' shooting performance is the most important outcome of wearing the jacket, it is essential not to sacrifice structural design features for more mobility. A good designer should instead search for design solutions that accomplish both mobility and structure.

Using the identified improvements, the narrative illustrating Hannah's connection to her jacket, and the thematic analysis of Hannah's FEA needs, it is possible to see the unique ways in which Hannah interacts with her Paralympic Shooting jacket. In the next section, these multiple methods of data analysis will be used to develop an FEA Consumer Needs Model more specific for disabled athletes, that shall be referred to as the FEA Model for Disabled Athletes.

FEA Model for Disabled Athletes

Based on the Problem Identification interview with Hannah and narrative and thematic data analyses, an FEA Model for Disabled Athletes was developed. Unlike the adapted FEA model for data analysis, the FEA Model for Disabled Athletes is an outcome of the data analysis and intended to aid in the advancement of theory in the apparel field (Bye, 2010). The FEA Model for Disabled Athletes stays true to the form and meanings of the original FEA Consumer Needs Model while providing useful information that relates to what was learned through data analysis in this research. The FEA Model for Disabled Athletes is seen in Figure 4.2 alongside the adapted FEA model for data analysis that was utilized earlier in this work.

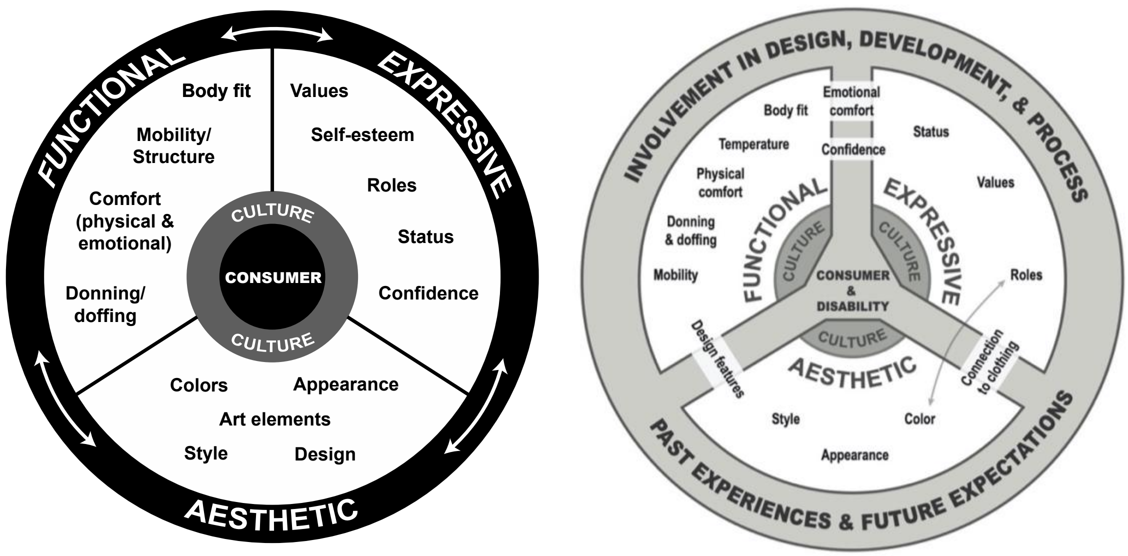


Figure 4.2: The adapted FEA model for data analysis (left) and the FEA Model for Disabled Athletes, developed from Hannah's Problem Identification interview data analysis insights (right).

The consumer remains at the center of the FEA Model for Disabled Athletes, as in the original FEA Consumer Needs Model, however, in this final iteration of the model, disability has been added because it is also a central part of the consumer's identity. Just as Lamb and Kallal (1992) indicated that the consumer and their culture should be fully adhered to during the development of clothing and investigation of needs, so should an understanding of disability be given this central importance when working with and for disabled athletes. Again, following the form of the original FEA Consumer Needs Model, the culture of the consumer is situated close to the center of the FEA Model for Disabled Athletes. For Paralympic Shooting athletes, the culture of shooting includes the jacket regulations that are mandatory and must be followed. Understanding of culture is a means of understanding what needs the consumer may have and how those needs can and cannot be met. Culture indeed dictates the functional, expressive, and aesthetic needs of the consumer.

The functional, expressive, and aesthetic needs of the consumer are placed as they are in the original model, with requirements specific to athletes with disabilities, organized by each FEA theme. These needs, again, are subject to change for each consumer/athlete based on their disability, sport, and culture. What was found to be true for Hannah is that *Color* and *Roles* were linked. Perhaps this linkage is more valid for athletes who compete in a team setting or as representatives of a country, as Paralympic athletes do.

Lamb and Kallal's (1992) FEA Consumer Needs Model acknowledged that functional, expressive, and aesthetic needs exist on a continuum, with one specific need, such as *Design Features*, being able to be both an <u>Aesthetic</u> and a <u>Functional</u> need. In this model for disabled athletes, needs that are explicitly able to be placed in more than one theme (based on the data analysis) are placed in the middle of the two themes. For example, *Confidence* and *Emotional comfort* are both <u>Expressive</u> as well as <u>Functional</u> needs, as they relate to how the athlete portrays themselves to others as well as their shooting performance quality.

Perhaps the most significant deviation from the original FEA Consumer Needs Model is the recognition that the consumer strongly wishes to be directly connected and involved in the clothing manufacturer's design, development, and process. As indicated by Hannah, it is concerning for a consumer when they do not know the outcome of their purchase, and they are unsure of things like where their clothing is, when it will arrive, and how it will look or fit, amongst other things. Past experiences with manufacturers influence the future expectations of the consumer/athlete when dealing with clothing manufacturers again. Kabel, Dimka, and McBee-Black (2017) found that the majority of people who use wheelchairs involved in their research had such poor experiences when shopping for certain sportswear items that they did not bother to try shopping for these items again. Thus, future sportswear shopping expectations of disabled consumers could exist on a spectrum, from doubtful, to hopeful, to expectant of exemplary findings. Manufacturers should be aware of these expectations and strive for excellent relations with their consumers.

Certain needs criteria overlap not only between several themes (such as Functional and Expressive housing both *Emotional comfort* and *Confidence*) but with the consumer and their need to be involved with and in communication with the manufacturer of their sportswear. For example, situated between the themes of Aesthetic and Functional is *Design features*, which relate not only to both themes, but also to the consumer and their need for involvement in the manufacturer's design, development, and process of their clothing. In essence, specific needs within this FEA Model for Disabled Athletes are not only related to more than one FEA need, but also related to the consumer and their expectations for relations with the clothing manufacturer. These needs are the most critical needs for any manufacturer or industry leader to understand. In this model, these specific needs are *Emotional comfort*, *Confidence*, *Design features*, and *Connection to clothing*. These four critical needs are not present in the original FEA Consumer Needs Model, but all relate directly back to the consumer and their disability. Not being attentive to these needs is perhaps where industry leaders who are looking to develop high-satisfaction sportswear for disabled athletes have previously fallen short of the athlete/consumer's expectations. The FEA Model for Disabled Athletes presents a potential guide for industry leaders and design researchers alike. Throughout this research, the FEA Model for Disabled Athletes was referred to for accuracy in a method of constant comparison and was found to remain valid throughout the remainder of method processes and analyses.

Weighing of FEA Needs

When evaluating a consumer's needs, sometimes particular needs contradict each other and must be weighed by the researcher for hierarchy regarding which need is more important and must be met in the final prototyped product (Lamb & Kallal, 1992; Orzada & Kallal, 2019). For example, within this research, Hannah stated that she did not like the white color on her jacket, but also indicated that she would like to see the incorporation of American flag print (of which white is a color involved) within her jacket. To weigh these two contradicting needs, we must consider the positive outcomes of each design decision. Not including any white on Hannah's custom shooting jacket reduces the chances of seeing dirt on her jacket, something she explicitly stated as bothersome to her. However, when considering implementation of an American flag printed area on her jacket, there are a list of positive outcomes. First, having a unique and unseen element when compared to most current shooting jackets is a positive outcome. Second, having the jacket and athlete be easily distinguishable from other countries with red, white, and blue national colors is a positive outcome. Third, having an element of the jacket that outwardly expresses Hannah's role as an athlete representing the USA is a positive outcome. Figure 4.3 illustrates the process of weighing these two conflicting needs. As there are more positive outcomes via the inclusion of American flag printed areas on Hannah's shooting jacket, it weighs more heavily than no inclusion of white color on her jacket.

Figure 4.3: Weighing of two conflicting FEA Needs from Problem Identification interview data (#1).

Consumer needs that appear to be conflicting are sometimes a test of the designer's innovativeness and design abilities to meet both seemingly conflicting requirements. For example, Hannah stated that if her jacket could appear in any way, she would have cheetah print incorporated into her jacket design. Assuming that both cheetah print and American flag print cannot simultaneously be incorporated into the design of Hannah's jacket, it is useful to weigh the positive outcomes of each. Figure 4.4 illustrates this weighing process. Cheetah print incorporated into Hannah's jacket would allow her to express her style directly. American flag and USA colors (red, white, blue, and black) follow suggestions given to athletes by ISSF and World Shooting Para Sport regarding jacket appearance. Usage of these national colors also sits in line with the culture of Paralympic athletes and the roles of an athlete representing the USA. Thus, at face value, it would seem that the jacket must only include USA colors. However, the interior of the jacket is not seen by the public or media and could possibly incorporate elements that are more in line with Hannah's style (i.e., cheetah print and other colors). Thus, sometimes seemingly conflicting or contradicting FEA needs may require ideation and contemplation from the designer, in efforts to meet as many consumer needs as possible, creating the highest satisfaction possible out of the end product.

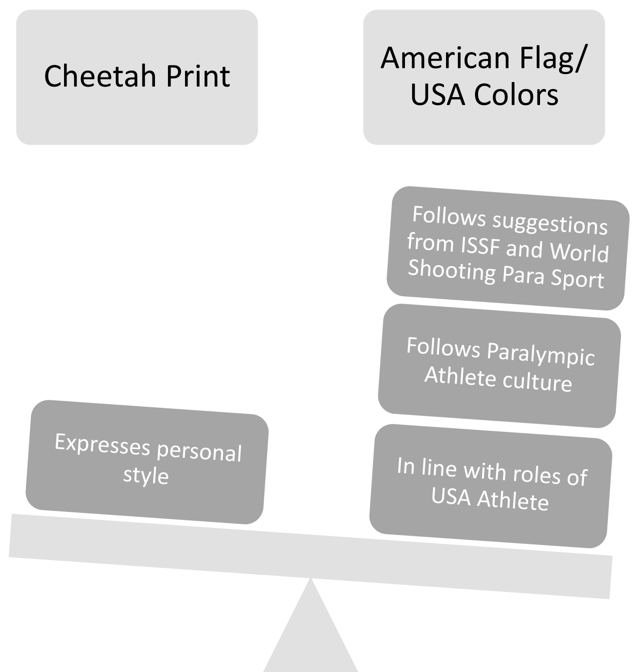


Figure 4.4: Weighing of two conflicting FEA Needs from Problem Identification interview data (#2).

The final example of weighing FEA needs of the consumer is illustrated in Figure 4.5. Hannah expressed that pushing her wheelchair is difficult when wearing her jacket. Though she did not say specifically what jacket elements make this task difficult for her, it is most logical to assume that the curved sleeve design and thickness of material present in the jacket does not allow for the full range of motion in Hannah's arm. Therefore, the need for a non-bent sleeve and need for a bent sleeve must be weighed. A sleeve without an engineered bend would allow for better mobility for Hannah when pushing her wheelchair. However, a sleeve with a bend, as is standard for most shooting jackets, has more positive outcomes: support for arms while the athlete is in shooting position, which causes less fatigue for the athlete while competing or practicing. Thus, a bent sleeve design outweighs a non-bent sleeve design. However, as mentioned previously, design innovations may be realized through ideation (in Step 3: Design Development) that allow for a bent sleeve design in Hannah's prototyped custom jacket as well as better mobility when compared to her current shooting jacket. Usage of gussets, attention to textile placement, and innovative design lines may allow for both of Hannah's needs to be met within the final product. Having a list or image for reference to these important weighing processes is helpful to a designer when summarizing information gathered and analyzed during the investigation and identification of the consumer's FEA needs.

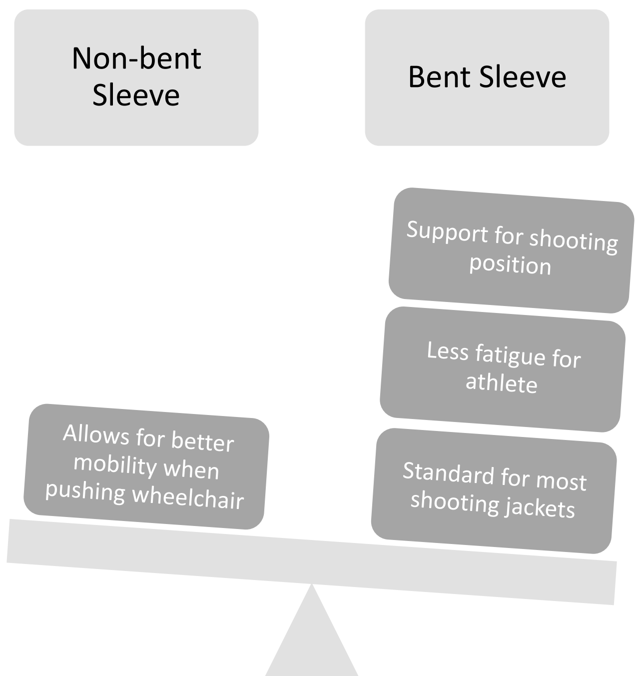


Figure 4.5: Weighing of two conflicting FEA Needs from Problem Identification data (#3)

Design Insights

Development of design insights summarize the findings of Step 1: Problem Identification and guide the upcoming design development process. The design insights that are relevant within this research are present in Figure 4.6.

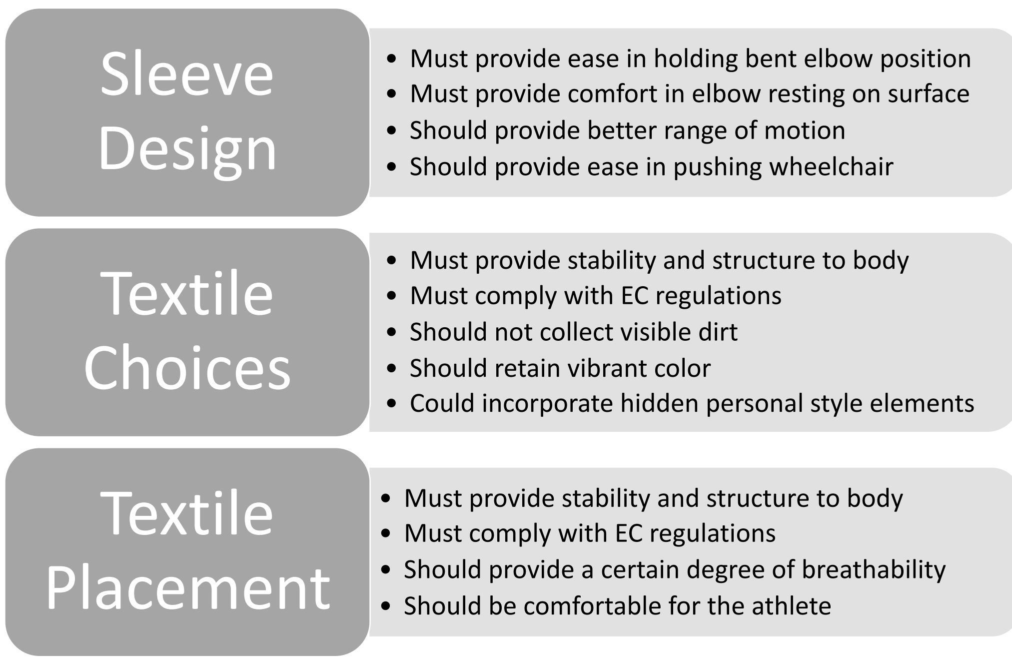


Figure 4.6: Design insights for jacket prototype based on Problem Identification interview data.

The sleeve design in the prototyped shooting jacket needed to provide Hannah ease in holding her elbow in a bent position. As is standard for all shooting jackets, the sleeve must provide comfort when resting on a surface by using a rubber-based gripping and cushioning fabric called Top Grip. The jacket sleeve should also be designed to provide a better range of motion than Hannah's current jacket, subsequently providing Hannah with more ease when pushing her wheelchair.

Textile choices within the jacket design, first and foremost, must provide stability and structure to Hannah's body when shooting, and must simultaneously follow EC regulations.

Beyond this, Hannah's prototyped jacket should somehow not collect visible dirt, should retain vibrant color, and possibly could incorporate hidden elements of Hannah's style (i.e., cheetah print interior, as discussed in weighing of FEA needs).

Lastly, textile placement is an important design consideration. Insights gained from the Problem Identification interview include, again, textiles providing stability and structure to the body. Hannah expressed that the suede in her jacket body does not provide stability and structure she desires. Thus, within the design of the prototype for this research, the functional need for stability or structure will need to be addressed. Also, again, EC regulations must be addressed. Overall, the prototyped jacket should be more comfortable for Hannah. These design insights summarize what was learned within the Problem Identification interview (as applies to the jacket design process) and guided the design of the shooting jacket prototype within Step 3: Design Development. Before Step 3, Step 2: Preliminary Design Information sought to understand Hannah's anthropometrics.

Step 2: Preliminary Design Information

The second step of this research method was gathering Preliminary Design Information. For this research, Preliminary Design Information was collected to understand Hannah's anthropometrics as well as how clothing interacted with her body. The planned methods included 3D body scanning, taking manual measurements, examining Hannah's current jacket, fit testing a block garment, and constructing a half-scale dress form within this step. The application of each of these tasks is discussed and analyzed in the following sections.

Body Scanning

For the scanning process, Hannah was asked to sit in a backless chair with hand grips on her sides, wearing all clothing worn under her competition shooting jacket, while the Structure

Sensor Mark II was moved by the researcher around Hannah and gather her 3D scan data. This process was repeated until a complete 3D body model was generated. Hannah's body scan data were imported to software called Meshmixer to process the body scan (Figure 4.7). First, extra data, such as the stool she was sitting on, were removed. Next, holes on the surface of Hannah's body scan were repaired using both auto repair and manual repair functions. Hannah's underarms were edited as best as possible in Meshmixer to remove excess surface area (webbing) created by both the Structure Sensor Mark II in scanning as well as the t-shirt she was wearing during the scan process. As much editing was done as Meshmixer allowed, however, not all the drape of the t-shirt in the underarm area could be removed; thus, the underarms on Hannah's edited 3D avatar are not true-to-size of Hannah's actual body.

Areas of Hannah's body not needed for fitting nor structure of the half-scale form were removed (head, hands, feet). The left half of Hannah's body was reflected to create a more symmetrical 3D avatar, and the right side deleted. Figure 4.8 shows the final edited 3D body scan of Hannah. The 3D body scan provided a fine basis for future processes, such as creating a half-scale dress form and virtual prototyping (to be discussed in Step 4: Prototype Development).

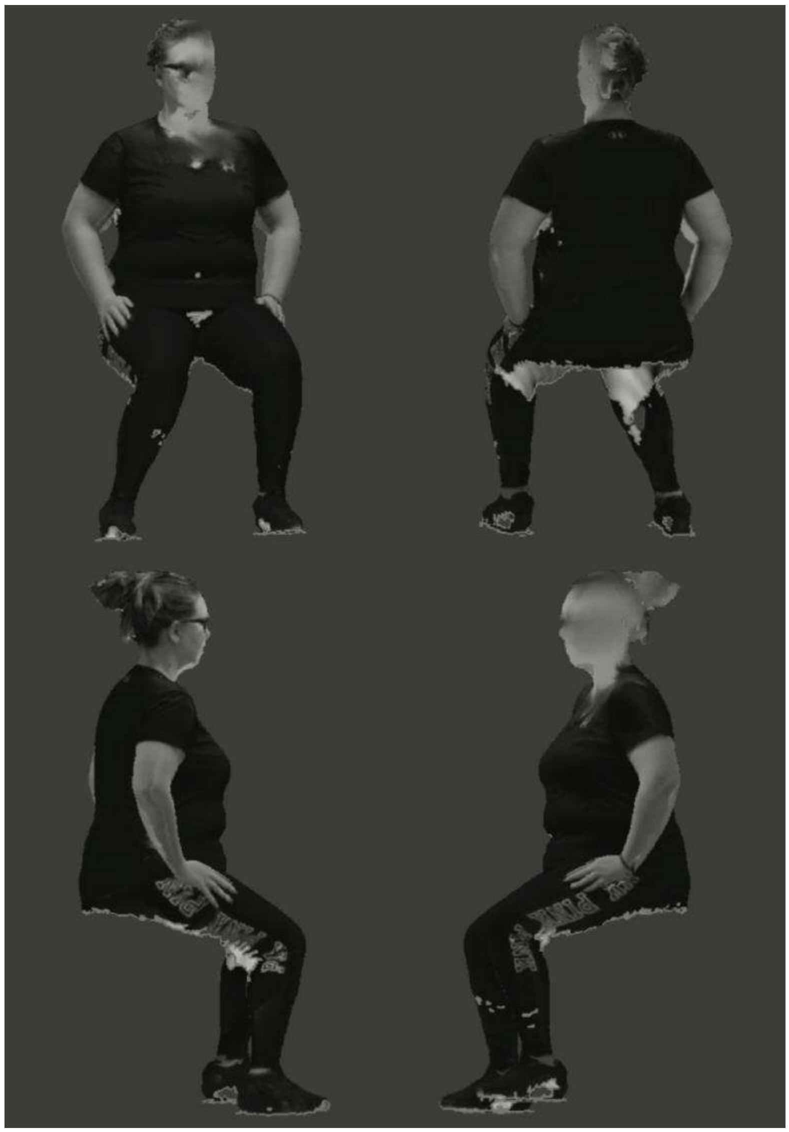


Figure 4.7: Unedited Hannah 3D body scan, gathered using Occipital Structure Sensor Mark II.

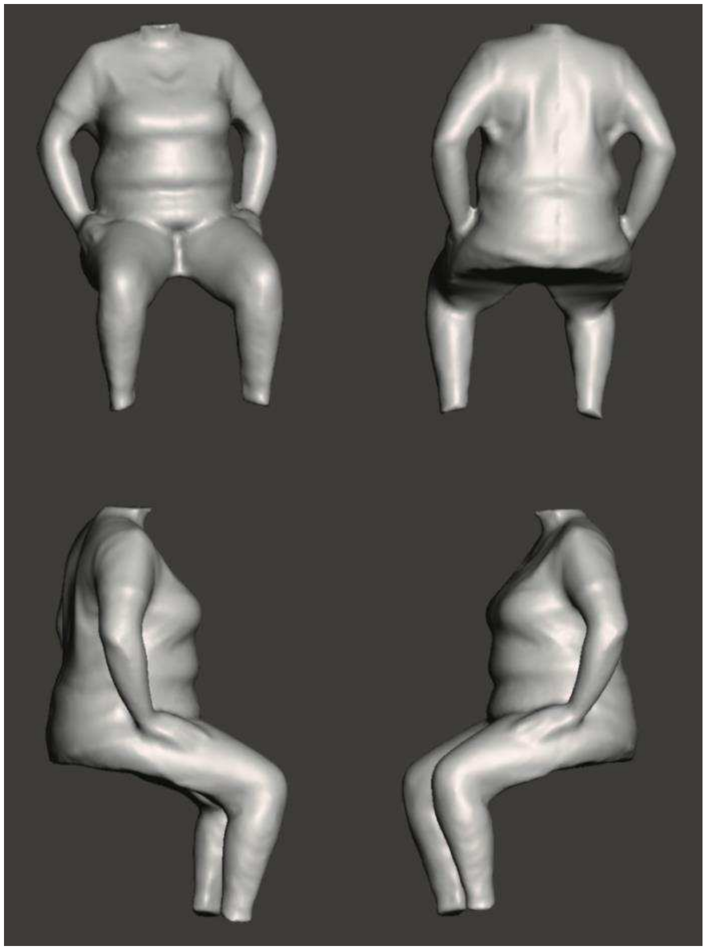


Figure 4.8: Hannah 3D body scan, edited and cleaned using Meshmixer.

Manual Measurements

Next, the researcher took manual measurements of Hannah, and these provided more information regarding Hannah's anthropometrics. For the measurement process, Hannah was again asked to wear her base layers that are typically worn under her competition shooting jacket. The researcher then measured each specified location on Hannah three times and later averaged these three for a final measurement in each location. Manual measurements were collected from Hannah by the researcher based on critical body landmarks discussed in Chapter 3: Methods and displayed as well as described in Appendix C. Table 4.3 shows each measurement's location and final dimension in inches. By gathering Hannah's measurements, the researcher was able to understand Hannah's anthropometrics. Further investigation into Hannah's anthropometrics included an examination of Hannah's current shooting jacket, as well as a block garment fit test.

Table 4.3:

Manual measurements of Hannah gathered via tape measure.

Circumferences

Ref. #	Measurement Location	Final Measure
1	Neck Base Circumference	14.75"
2	Front Shoulder Circumference	20.5"
3	Back Shoulder Circumference	24.5"
4	Front Bust Circumference	22.75"
5	Back Bust Circumference	21"
6	Full Bust Circumference	43.5"
7	Front Underbust Circumference	19.75"
8	Back Underbust Circumference	21.75"
9	Full Underbust Circumference	40.5"
10	Front Waist Circumference	21.5"
11	Back Waist Circumference	21"
12	Full Waist Circumference	42"
13	Full Lower Waist Circumference	49.5"
14	Full Modified Hip Circumference	52"
15	Armscye Circumference	20.5"
16	Full Bicep Circumference	14.25"
17	Full Elbow Circumference	12.25"
18	Full Forearm Circumference	10.75"
19	Full Wrist Circumference	7.25"

Lengths

Ref. #	Measurement Location	Final Measure
20	Front Neck Base to Waist	15.5"
21	Front Neck Base to Front Lap	17.5"
22	Back Neck Base to Waist	16.25"
23	Back Neck Base to Seat	28.5"
24	Underarm to Side Waist	7.5"
25	Underarm to Seat	18.25"
26	Left HPS to Shoulder Tip	5.75"
27	HPS to Apex	13.5"
28	HPS to Front Waist	19.5"
29	HPS to Front Lap	20"
30	Upper Front Width	13.75"
31	Upper Back Width	16.5"
32	Shoulder Tip to Wrist	21"
33	Shoulder Tip to Elbow	13.5"
34	Elbow to Wrist	9.5"

Current Jacket Examination

Several measurements of Hannah's current shooting jacket were taken, including lengths and widths of the jacket body, sleeves, and key design features (side front panel, side back panel, etc.). The researcher also took pictures of the jacket to capture details about the garment construction and details such as suede piping and topstitching, canvas edge binding on hems, and interior construction of the jacket. Unique shapes of jacket pattern pieces were noted, such as the armhole having a sharp angle (See Figure 4.9 image in the center row, far right). Most importantly, it was captured that the buttons on Hannah's jacket indicated that the jacket shape was not adequately fitted to her body (far left, top two images). The adjustable buttons have been moved to areas that indicate that the curves in the jacket seams are not fitted to her body, but that the button placement is creating the shape she needs for her jacket to fit correctly. For example, the button on the horizontal plane of the bust is on the body of the left-center front jacket, but the two buttons below this are very near to the edge of the jacket and are placed on the edge trim. This placement indicates that the jacket is barely fitting Hannah; if Hannah were to gain weight or retain water due to travel/climate, she might not have enough fabric on the body of her jacket to be able to move the button further outwards below the bust.

Figure 4.9: Current jacket examination photos with annotations.

Block Garment Fit Test

The block garment developed by the researcher from a used shooting jacket rub off pattern is seen in Figure 4.10. The block garment did not close properly at center front, was too large in the armhole and shoulders, and too long and wide in the sleeves. These fit issues were marked and recorded.

Figure 4.10: Photos of block garment on Hannah for a fit test at the Paralympic Training Center.

As is common in clothing creation, especially for atypical bodies, fitting a garment is not an easy task. Furthermore, people's bodies change from day to day, depending on their diet, health, and mood. The information gathered from this block garment fit test was valuable and further exemplified that a shooting jacket is a unique garment, and Hannah's body anthropometrics are equally unique. Development of a half-scale dress form allowed for more opportunity to explore unique design factors.

Half-Scale Dress Form

Using Hannah's 3D body scan, it was possible to create a half-scale dress form of her body to create an anthropometrically similar model. This half-scale form allowed for further understanding of Hannah's anthropometrics, pattern development, fitting, and design development in this research, due to the physical distance between Hannah and the researcher. Below is a detailed outline of how the half-scale form of Hannah was developed and constructed.

Development. Hannah's cleaned and processed 3D body scan was exported from Mexhmixer and imported into Fusion 360. In this software, her 3D body scan was reduced to 50% scale (half-scale) and exported to a Fusion 360 extension called Slicer. Slicer allows the operator to slice their 3D object into layers in any orientation to create a 3D model using a 2D substrate (i.e., cardboard, foam, Plexiglas, etc.). Furthermore, the thickness of each layer can be edited as well as the placement of support beams (most commonly wooden dowels) throughout the model. Figure 4.11 shows Hannah's half-scale body sliced into horizontal layers, each ½ inch thick. Dowel placement is indicated by the dashed lines running through the form.

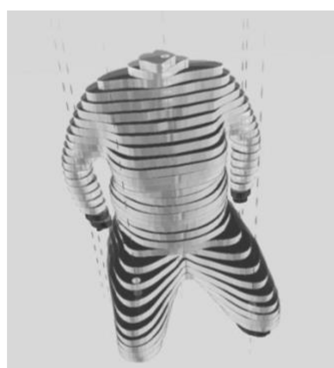


Figure 4.11: Sliced half-scale body scan from Fusion 360.

After finalizing the layers and support placement, Slicer generates a plan for cutting the material to the exact size of each layer. The cut plan for Hannah's half-scale form can be seen below in Figure 4.12.

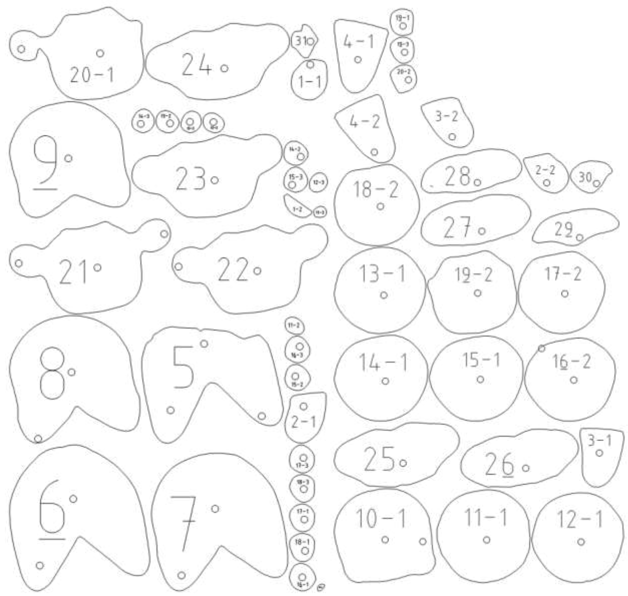


Figure 4.12: Cut plan for the half-scale dress form.

The files for the cut plan were exported to a laser cutter and cut from ½ inch open-cell foam. Each outer line and internal circle were cut. The guide numbers on each layer were etched into each layer as a guide for construction. After the layers were finished being cut, they were stacked by the researcher to ensure placement. Wooden dowels were cut to precise lengths to provide internal support to the half-scale form. After the layers were aligned and dowels were cut to exact lengths, a small amount of glue was used to attach the layers to each other in the correct order. The stacked and glued layers of Hannah's half-scale form can be seen in Figure 4.13.

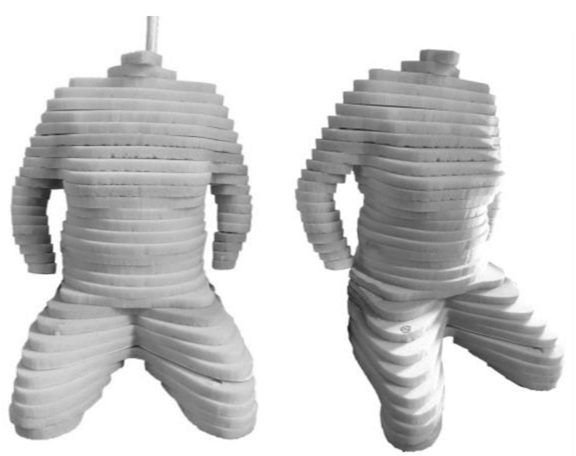


Figure 4.13: Stacked and glued half-scale dress form layers.

The foam layers were covered with knit material and sewn together to create a smoother and more durable model. Important body landmarks and lines were transferred to the half-scale dress form using thin elastic tacked down via hand sewing using a curved needle. These landmarks included neckline, armscyes, center front, center back, princess seams, bustline, waistline, and side seam. The completed half-scale dress form based on Hannah's 3D body scan can be seen in Figure 4.14.

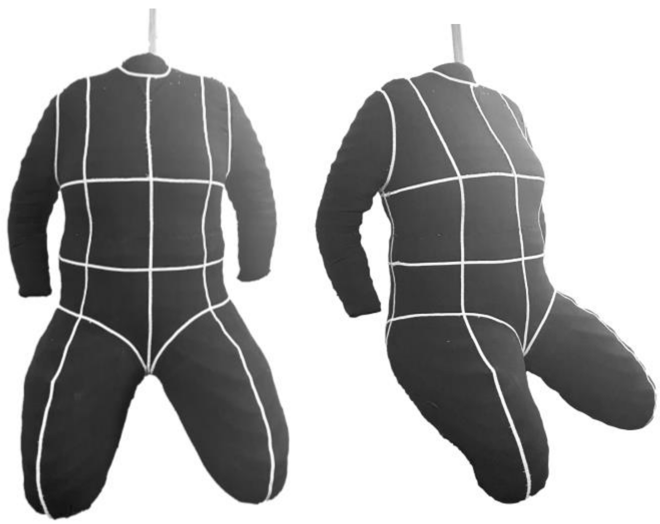


Figure 4.14: Finished half-scale dress form based on Hannah 3D body scan.

Deviations between manual and half-scale measurements. In order to understand how similar or dissimilar the half-scale dress form of Hannah's body was compared to her manually gathered measurements, the half-scale form was measured at the same landmarks used to measure her body earlier in Step 2: Preliminary Design Information. The half-scale form measurements were recorded and compared to the manual measurements (divided by two). The deviation between these measurements in half-scale was recorded for each measurement location. Lastly, the half-scale deviation was sized back up to full-scale by doubling the measurement. A chart of these measurement data can be seen in Table 4.4. Recording and understanding this data allows the researcher to be mindful of potential problem areas when using the half-scale form to develop fitting base patterns and designs using the half-scale form.

Table 4.4

Deviations in manual and half-scale dress form measurements, areas with high deviations highlighted.

Half Scale Form Circumferences

Ref. #	Measurement Location	Form Measure	Half of Final Body Measure	Form Measure Deviation	Real-Scale Deviation
1	Neck Base Circumference	7.5″	7.375″	+ 0.125″	+ 0.25″
2	Front Shoulder Circumference	10.25″	10.25″	0	0
3	Back Shoulder Circumference	11″	12.25″	- 1.25″	- 2.5″
4	Front Bust Circumference	12.75″	11.375″	*+ 1.375″*	*+ 2.75″*
5	Back Bust Circumference	9.5″	10.5″	*- 1″*	*- 2″*
6	Full Bust Circumference	22.25″	21.75″	+ 0.5″	+ 1″
7	Front Underbust Circumference	12″	9.875″	*+ 2.125″*	*+ 4.25″*
8	Back Underbust Circumference	9.25″	10.875″	*- 1.625″*	*- 3.25″*
9	Full Underbust Circumference	21.25″	20.25″	+ 1″	+ 2″
10	Front Waist Circumference	12.5″	10.75″	*+ 1.75″*	*+ 3.5″*
11	Back Waist Circumference	10″	10.5″	*- 0.5″*	*- 1″*
12	Full Waist Circumference	22.5″	21″	+ 1.5″	+ 3″
13	Full Lower Waist Circumference	23.75″	24.75″	- 1″	- 2″
14	Full Modified Hip Circumference	25″	21″	*+ 4″*	*+ 8″*
15	Armscye Circumference	11.5″	10.25″	+ 1.25″	+ 2.5″
16	Full Bicep Circumference	7″	7.125″	- 0.125″	- 0.25″
17	Full Elbow Circumference	6″	6.125″	- 0.125″	- 0.25″
18	Full Forearm Circumference	5.5″	5.375″	+ 0.125″	+ 0.25″
19	Full Wrist Circumference	3.75″	3.625″	+ 0.125″	+ 0.25″

Half Scale Form Lengths

Ref. #	Measurement Location	Form Measure	Half of Final Body Measure	Form Measure Deviation	Real-Scale Deviation
20	Front Neck Base to Waist	8.5″	7.75″	+ 0.75″	+ 1.5″
21	Front Neck Base to Front Lap	10.5″	8.75″	+ 1.75″	+ 3.5″
22	Back Neck Base to Waist	8.75″	8.125″	+ 0.625″	+ 1.25″
23	Back Neck Base to Seat	12.75″	14.25″	*- 1.5″*	*- 3″*
24	Underarm to Side Waist	3.25″	3.75″	- 0.5″	- 1″
25	Underarm to Seat	8″	9.125″	*- 1.125″*	*- 2.25″*
26	Left HPS to Shoulder Tip	2.75″	2.875″	- 0.125″	- 0.25″
27	HPS to Apex	6.25″	6.75″	- 0.5″	- 1″
28	HPS to Front Waist	9.25″	9.75″	- 0.5	- 1″
29	HPS to Front Lap	11.25″	10″	+ 1.25″	+ 2.5″
30	Upper Front Width	7.5″	6.875″	+ 0.625″	+ 1.25″
31	Upper Back Width	6.75″	8.25″	- 1.5″	- 3″
32	Shoulder Tip to Wrist	10.5″	10.5″	0″	0″
33	Shoulder Tip to Elbow	6.25″	6.75″	- 0.5″	- 1″
34	Elbow to Wrist	4.25″	4.75″	- 0.5″	- 1″

Deviations requiring attention are highlighted in the figure above. As described in development, Hannah’s half-scale form was made by mirroring half of the body scan and reflecting. This strategy could have caused some deviations, as no human body is fully symmetrical. Another potential cause of variations is due to Hannah’s manual measurements being taken by the researcher in September, and the body scan was done in November. Hannah’s body may have changed in those few months.

Furthermore, the measurements taken by the researcher could potentially be inaccurate in some areas, based on posture differences. For example, the body scan demonstrates a longer length between the neck base and the waist than the measurements taken; this could be because of a sloped or more hunched posture during manual measurements and a more upright posture during body scanning. Hunching posture could also have caused deviations in measurements between the half-scale form and Hannah's body measurements, due to the body compressing and landmarks being in slightly different locations. For example, the full waist circumference of the body scan deviated from the manual measurements by three inches, with the body scan being larger. The location of the waist could potentially be different than what it was during the manual measurements, due to posture. It is impossible to explain exactly why the manual measurements and body scan measurements deviate in some areas. However, these variations in measurements are indeed reflective of the human body's tendency to change over time, even a short amount of time. Because the Paralympic Shooting jacket is a garment that must be used by the athlete nearly every day, often for at least a year and more often longer, it is valuable to have some deviation in certain measurements such as the bust, underbust, and waist circumferences. The shooting jacket created in this research needs to be adjustable for Hannah to be able to use during different times of the year and in different climates. Throughout the use of this jacket, Hannah will most likely have deviations in her body measurements, similar to the variations seen between the body scan measurements and manual measurements. Other deviations, such as back shoulder circumference and upper back width, also possibly caused by hunching, needed more attention during the development of the prototyped jacket. Areas such as these are less able to be adjusted for in a garment, therefore creating a prototype that is too large versus too small was important: making a garment larger is more complicated than making it smaller by taking fabric in. What was learned during Step 2: Preliminary Design Information provided further insights that led to Step 3: Design Development.

Step 3: Design Development

The goal of Step 3: Design Development was to develop all the design information needed to be able to move onto prototyping of the finalized jacket. The activities in this step included the development of a half-scale block pattern, prototype ideation, and CAD prototype illustrations (with and without annotations). The outcome of Step 3 was a finalized jacket design.

Half Scale Block Garment Development

Developing a half-scale block garment in this research allowed for two outcomes: a base to continue to make pattern changes on, and an idea of proportions for design ideation. Basic draping techniques were utilized to make a block garment with princess seams and a bent sleeve design. Ideation of stylelines was preliminarily done on this block garment to help spark inspiration for prototype design ideation. The half-scale block garment with inspiration style lines can be seen in Figure 4.15.

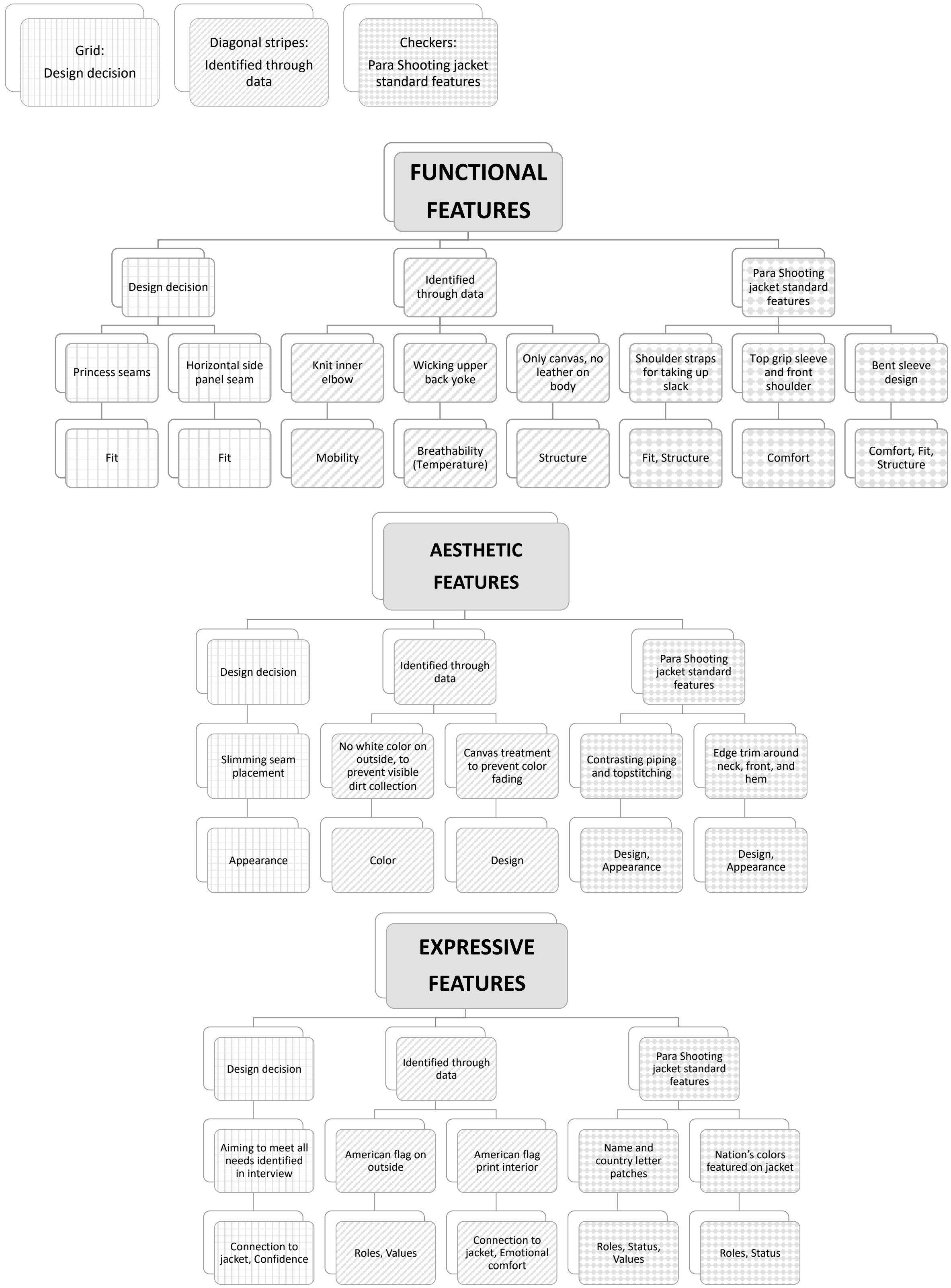
Figure 4.15: Half-scale block garment with design inspiration stylelines.

Prototype Ideation

Prototype design ideation is often a process that is difficult for experienced designers and design researchers to define and explain (Bye, 2010). As a result, many design research projects do not explicitly explain the ideation process in an effective way that can promote both learning and understanding from novice designers and researchers in other fields. Bye (2010) suggests that “reflection on the process” of design decisions made during ideation can “uncover the knowledge resulting from the practice.” (p. 208). Thus, an outline of key design features, organized by FEA needs, can be seen in Table 4.5. The goal of this practice is to disclose as much information about the seemingly indefinable process of design ideation, so as to promote learning and understanding of design ideation considerations that experienced designers and design researchers make.

Table 4.5

Outline and brainstorm of prototype design features categorized by FEA needs.



Using the FEA needs considerations tables above, the researcher was able to sketch the final jacket prototype that took into consideration jacket regulations, the weighing of FEA needs, design insights, and the design features in Table 4.5. This sketch can be seen in Figure 4.16.

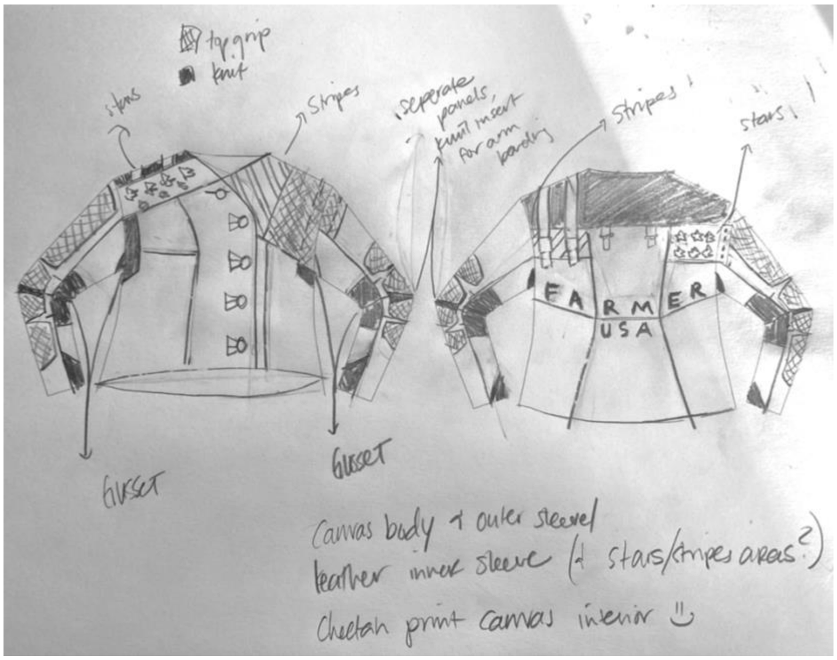


Figure 4.16: Ideation sketch of jacket prototype.

This sketch was sent to Hannah via text message and met with approval. The final ideation, having been approved by Hannah, was able to be moved forward as a rough final design for the CAD prototype illustration.

CAD Prototype Illustration (with and without Annotations)

A more finalized set of CAD prototype illustrations were made using the prototype ideation sketch. Figures 4.17 and 4.18 show the first and second CAD prototype illustrations. These illustrations were developed using Adobe Illustrator.

Figure 4.17: First CAD jacket prototype iteration.

Figure 4.18: Second CAD jacket prototype iteration.

Hannah was sent the illustration seen in Figure 4.17 and asked for her opinions. After a few days, Hannah decided she would rather have American flag print as opposed to cheetah print in the lining. Hence, in Figure 4.18, the lining of the jacket has been edited to have American flag print.

Upon sourcing and testing materials, some of the features of the jacket design were forced to change. A finalized illustration for the jacket prototype design is seen in Figure 4.19. An annotated version of this illustration is seen in Figure 4.20.

Figure 4.19: Final jacket CAD prototype illustration.

Figure 4.20: Annotated Final jacket CAD prototype illustration.

Step 4: Prototype Development

Prototype development sought to take the jacket prototype from design to reality. A half-scale version of the jacket was developed, which was utilized to create a virtual jacket prototype in CLO. The full-scale pattern was then sewn and fitted to allow for final pattern editing. Lastly, the final jacket prototype was cut and sewn. Each of these prototyping tasks are discussed below.

Half Scale Pattern Development

As described in Chapter 3, a more completed half-scale pattern was developed based on the half-scale block garment and the finalized jacket design. The block garment was marked with relevant lines, and the pattern was edited. The result was a half-scale pattern of the final jacket design, sewn in test fabrics to fit on the half-scale dress form. The final half-scale jacket is seen in Figure 4.21.

Figure 4.21: Half-scale jacket prototype.

Small fit changes to the back and sides of the final half-scale garment were pinned and edited on the pattern pieces. The result of this process was a finalized set of patterns for Hannah's shooting jacket. These paper half-scale patterns were imported to Adobe Illustrator, where their shapes were traced and made into vector images. A selection of the vector pattern pieces in half-scale are seen in Figure 4.22. These pieces and the remainder of the jacket pieces were imported to CLO and sized to full-scale for virtual prototyping.

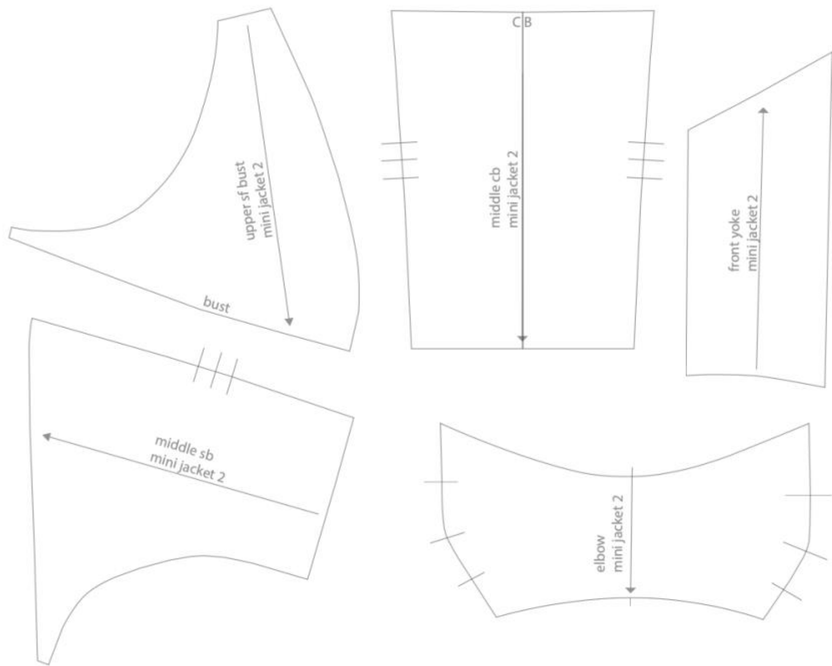


Figure 4.22: Half-scale vector pattern pieces.

CLO Virtual Prototyping

Using full-scale digital pattern pieces and Hannah's cleaned full-scale 3D body scan (Figure 4.8), it was possible to use CLO to develop a virtual garment prototype. This virtual prototype was used to check fit, textures, appearance, design, and more. To develop the virtual prototype, each seamline was established, all fabric textures and properties were set, arrangements of piece locations were set, and other general tactics were executed to allow for a finished-looking virtual garment. Hannah was sent images of the virtual prototype via text message and allowed to give design feedback, of which she had a minimal amount. However, though Hannah had minimal design feedback, the response to the CLO virtual prototype was generally positive. Figure 4.23 shows the finalized CLO virtual jacket prototype. Figure 4.24 shows a detailed close up of the elbow area of the jacket.

Figure 4.23: Final CLO virtual jacket prototype; front, side, and back views.

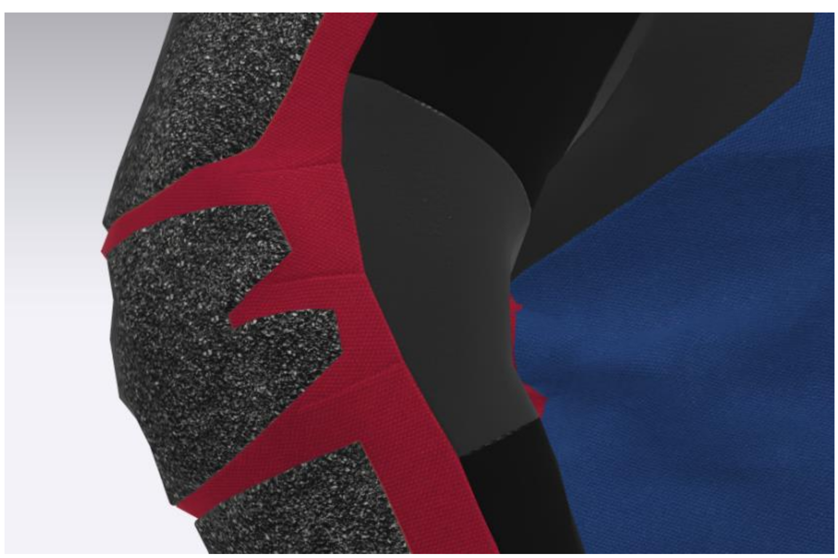


Figure 4.24: Detail close-up of CLO virtual jacket prototype, elbow area.

Discerning how a virtual garment fits on a virtual body can sometimes be difficult, thus, CLO has a tension mapping feature that allows the designer to see where the tightest fit of the garment is, indicated by a red color. Figure 4.25 shows the tension map for the prototyped jacket. The underarm was the only area where the fit was too tight on the 3D avatar. As mentioned previously, the underarm area on Hannah's edited and cleaned 3D body scan was not able to be edited to accuracy, and drape of the t-shirt worn during scanning remained (Figure 4.7).

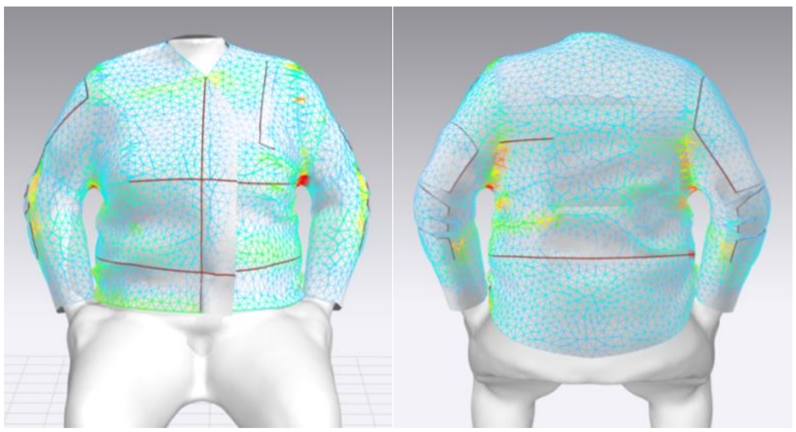


Figure 4.25: Tension map of CLO virtual jacket prototype.

The CLO virtual prototype of the final shooting jacket design was a useful tool to be able to see small design detail changes that needed to happen. Very few pattern changes were made in CLO, as it is easy in digital patternmaking to overcorrect. CLO was used to create internal lines in certain pattern pieces, such as the sleeve, to add lines for separation between sleeve and gusset. These pattern changes were not related to fit, because fittings are better done on a human body. A final fitting of the jacket was done in order to complete full-scale pattern corrections. This is discussed in the next section.

Full-Scale Pattern Corrections

The final patterns from CLO were exported and printed full-scale. Figure 4.26 shows these full-scale pattern pieces. These pieces were cut from thick muslin fabric, with important style lines marked. The cut pieces were sewn, and a full-scale jacket made in test fabrics was sent to Hannah via USPS mail.

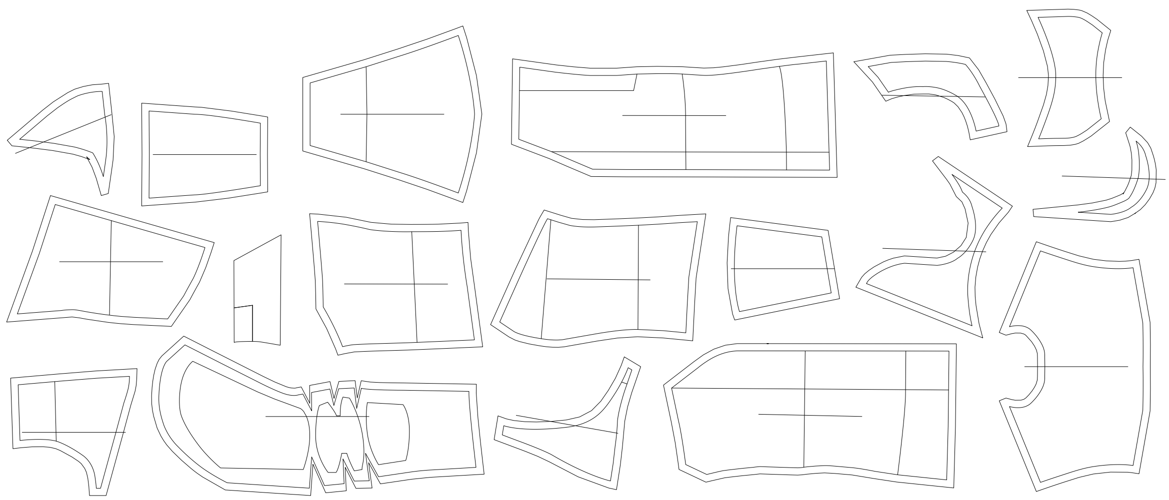


Figure 4.26: Full-scale jacket prototype pattern pieces.

Upon Hannah's receipt of the final test jacket, she made contact regarding fit: the jacket was too small in the sleeves and body. This fitting error could be attributed to improper editing of the 3D body scan in Step 2: Preliminary Design Information. Because the physical prototype of the virtual CLO garment was too small on Hannah's actual body, another fitting was completed in person. The researcher made a quick weekend trip to the Paralympic Training Center (a six-hour round trip) to fit the jacket in person. A fitting was done on a Friday evening to check what areas of the jacket were too tight. The researcher then took the jacket, and changes were made overnight: the researcher added panels for width for a better fit, as well as rotated the sleeves to allow for the elbow bend to be more towards the front. The second fitting of this test jacket was done Saturday morning. Pictures from that fitting of the edited full-scale test garment are seen in Figure 4.27.

Figure 4.27: Final test garment for jacket prototype

The fit changes included inserting width at the side seam and sleeve. The sleeve of the jacket was also rotated back, so as to place the elbow bend correctly. All fit changes made to the muslin test garment seen in Figure 4.27 were transferred to the paper full-scale jacket pattern. The final version of the jacket prototype pattern was the result of Step 4: Prototype Development. With a finalized pattern, the final physical jacket prototype was able to be constructed.

Physical Prototyping

Physical prototyping was the step during which all previous information gathered in these research methods were brought together to create one final prototype. The goal of this research was to develop a high-satisfaction jacket, through investigation of Hannah's FEA needs and anthropometrics. It was expected that the prototyped jacket in this work would incorporate several novel features, to allow for the prototype to be different than what companies producing

Paralympic Shooting jackets (i.e., Kurt Thune) are manufacturing. Thus, it was necessary in this work to track information regarding all the features of the jacket, from textile and trim components to construction techniques. Table 4.6 showcases all the features seen within the jacket prototype developed in this research, with features that are novel for Paralympic Shooting jackets indicated.

Table 4.6

Final jacket prototype list of features with purpose, novelty, and notes about each.

Feature	Purpose	Novelty	Notes
American flag lining	Fulfill expressive and aesthetic needs	High	Achieved through sewing lining canvas pieces together, then applying printed iron-ons with home iron
American flag print appliques and lettering	Fulfill expressive and aesthetic needs	High	See above
Knit, moisture wicking back yoke	Fulfill functional need of temperature regulation	High	Constructed with double layer to allow for enough structure to support canvas body
Canvas body	Provide structure to body of jacket	Low	Canvas was 1mm thick, face layer had interfacing applied prior to construction, total jacket thickness was 2.2mm
Top Grip sleeve and shoulder appliques	To provide resistance and padding	Low	2mm thick, cut edges were lacquered black, backed with 4mm closed cell neoprene applied to inside of sleeve
Flexible inner sleeve	Fulfill functional need of mobility	Low	Fused leather with knit inner elbow inserts, common for shooting jackets
Leather piping with topstitching	Decorative, standard for shooting jackets	Low	'Bone' piping color, white topstitch create with decorative stitch setting on home machine
Trim tape with embroidery thread stitching	Sturdy, thin edge finish	Low	Twill tape was fused and pressed in half, embroidery stitch was done by hand
Take-up shoulder straps	Bunch excess shoulder fabric for less body movement	Low	Specialty coated nylon for straps and clamp base, plastic fold-down claps adhered with grommets
Knit underarm gussets	Provide least amount of resistance for shoulders rolled forward	Low	Moisture-wicking fabric used to prevent sweat accumulation
Adjustable buttons with leather buttonholes	Allow for adjustment of jacket fit	Low	Adjustable buttons purchased from shooting supplier, leather buttonholes stitched with embroidery thread

As is expected to be common in many research endeavors done around early 2020 and even likely into 2021, the COVID-19 pandemic affected the execution of this research. It was expected that the researcher's institution would allow for the use of several tools, such as industrial sewing machines, laser cutters, UV printers, and industrial heat press machines. However, the textiles and trims for the jacket prototype were not entirely sourced until mid-March 2020, when most places in the United States, including universities, decided to temporarily close doors and ask people to stay home. Thus, the construction process for the jacket prototype was affected, however, solutions were found. Materials for fabricating and sewing the jacket were purchased by the researcher. The jacket prototype was constructed on domestic sewing equipment, which could be a limitation in this work. Images of the final jacket prototype for this research can be seen in Figures 4.28 through 4.33. The final jacket prototype textiles were cut with a rotary cutter. The American flag prints were accomplished using dark color iron-on sheets on canvas, using a home iron as the heat press. The jacket itself was sewn on a domestic Heavy-Duty Singer machine from Walmart. These factors may have affected Hannah's satisfaction with the final prototype of the shooting jacket. More about Hannah's satisfaction with the prototype will be discussed in Step 5: Evaluation.

Figure 4.28: Finished jacket prototype, back view.

Figure 4.29: Finished jacket prototype, front view.

Figure 4.30: Finished jacket prototype, detail views #1.

Figure 4.31: Finished jacket prototype, detail views #2.

Figure 4.32: Finished jacket prototype, elbow, and sleeve views.

Figure 4.34: Finished jacket prototype, lettering, and flag detail views.

Step 5: Evaluation

Evaluation of Hannah's satisfaction with the completed jacket prototype was discerned through analysis of an Evaluation interview. This section will outline the Evaluation interview coding schema, applied code co-occurrences, thematic analysis of the Evaluation interview, and a discussion of Hannah's satisfaction.

Evaluation Interview Codes

The interview with Hannah was done via FaceTime, with audio recorded. The interview lasted approximately 25 minutes. The Evaluation interview data were transcribed by the researcher with pauses and paralinguistic cues included. Using the coding schema from Step 1: Problem Identification (Table 4.1), codes were applied to the data while simultaneously, new codes were developed to analyze the Evaluation interview. Most codes used in the Problem Identification interview were used in the analysis of the Evaluation interview as well, with minor changes: (a) the parent code of Improvements was removed from the coding schema, as it intended in the Problem Identification interview to gather excerpts that related to the new jacket design, and thus this code was no longer needed; and (b) two new codes were added to the coding schema for the Evaluation interview: Alterations and Process. Descriptions of all codes used during the thematic analysis in the Evaluation interview are found in Table 4.7 (codes from Step 1 that were not applied are omitted). After coding of the interview was completed, with the researcher's advisor having checked the code application for quality, the code co-occurrences were analyzed.

Table 4.7

Code list for Evaluation interview analysis.

Parent Theme Code	Child Code	Description
Consumer/Athlete	Comments about jacket manufacturer	Comments regarding Hannah's interactions with and impressions of the manufacturer of her current shooting jacket
	Connection to jacket	Mental and emotional connection towards jacket
Culture	Peers	Interactions or mentions of other Paralympic Shooting athletes
	Jacket regulations	Information related to ISSF and World Para Shooting Sport Equipment Control guidelines
Functional	Body fit	How the jacket fits on Hannah's body
	Mobility	How Hannah is able to move when needed in her jacket
	Structure	Jacket providing physical support and stability to the athlete
	Physical comfort	Tactile comfort of the jacket on the body
	Donning and doffing	Putting the jacket on and taking the jacket off
	Temperature	How warm or cold Hannah feels in her jacket
Expressive	Values	Jacket elements that express Hannah's values
	Self-esteem	Jacket elements that affect Hannah's self esteem
	Roles	Jacket as an expression or understanding of role as a Paralympic athlete
	Status	Rank or status held by Hannah as it is expressed through the jacket
	Confidence	Jacket affecting Hannah's confidence
	Emotional comfort	Comfort of the jacket to Hannah's mental/emotional state
	Connection to jacket	Mental and emotional connection towards jacket
Aesthetic	Appearance	General visual aesthetics of the jacket
	Design	More in-depth visual and technical elements of the jacket
	Style	Elements of the jacket that reflect the personal style of Hannah
	Colors	Comments about the color of the jacket
Alterations		Alterations that need to be done to the final jacket
	Future Plans	Information regarding planning for alterations (post-COVID 19 pandemic planning)
Process		Hannah's opinions/feedback regarding the process of the research (communications, clarity, etc.)

Code Co-occurrences

Examining the co-occurrences of codes applied to the Evaluation interview data allows for some insight into factors affecting Hannah's satisfaction with her shooting jacket. Table 4.8

shows a table of code co-occurrences for the Evaluation interview. Just as in the Problem Identification interview, any co-occurrence over the count of three was given attention. Insight into why these codes co-occurred are discussed in the following section.

Table 4.8:
Evaluation Interview code co-occurrences

First code theme	First code	Second code theme	Second code	Co-occurrence rate
Alterations	Alterations	Functional	Body Fit	8
Functional	Structure	Culture	Jacket Regulations	5
Aesthetics	Color	Aesthetics	Appearance	5
Alterations	Alterations	Functional	Structure	4

Analysis of Participant Satisfaction

Thematic analysis (Braun & Clark, 2006) was used to analyze the Evaluation interview data, to discern Hannah's areas of high-satisfaction and low satisfaction regarding the final prototyped jacket, as well as her satisfaction with the design process.

Areas of high-satisfaction. One feature of the final jacket that Hannah was satisfied with was the general appearance and colors in the design. The code *Colors* was applied to the data six times, *Appearance* was applied five times, and these two codes co-occurred five times. Hannah had mentioned in the Problem Identification interview that she found the colors of her current shooting jacket to be faded and dull. In contrast, she found the prototype to be vibrant and pleasing:

> R: … Do you think, like based on like the colors and like, how it looks, do you like that aspect of it?
>
> H: Yeah, I like that aspect of it. It looks good…. The colors are good. They're bright, they're not like a dull color.

R: Ok cool. Do you feel like.... do like the American flags? Do you feel like other people might like that if they see that too?

H: Yeah.

When considering the American flag print lining implemented in the jacket prototype, it is worth reflecting upon the original design for the jacket (Figure 4.17) that incorporated cheetah print as the lining pattern. This original design decision was made to try to incorporate some of Hannah's style into the jacket. However, she provided feedback that she would prefer an American flag print as a lining motif.

R: Um, originally, if you remember, I had put cheetah print on the inside, that was part of the [original] design, I never actually did it, but... then you had said to change it to American flags.... what kind of things affected that decision or why did you choose American flags for the lining versus that cheetah print? It was totally fine that you did that.

H: Uh, I.. I don't know, I felt like, I mean... I have a really bad problem with colors, not matching.

R: Yeah.

H: And that would throw me off so badly with red white and blue on top and cheetah print inside, so... and like I thought it, I thought like the American flags did that [matched] a little bit better. Because then it's red white and blue on the outside, so I mean adding the American flags on the inside kind of gives it like... I don't know... it kind of... it's kind of like your flag travels with you if you understand.

R: Totally, and I like that we put it on the inside versus the cheetah print. I think you're right. It would've been a little bit weird.

H: Like if the jacket was just pure black... great. But it was red, white, and blue…

R: Yeah, so it's best to do a red white and blue lining.

H: Mhmm.

Implementation of this feedback into the final prototype design allowed for higher satisfaction. The colors and appearance of the jacket were the features met with the most positive feedback and thus assumed to be the main factors of high-satisfaction. Other features that were met with positive feedback included the breathable upper back yoke:

> R: Ok. Um... what about the stretchy back area? Do you think it was a good addition?
>
> H: That was good.

Because this excerpt provides little clarity as to why Hannah felt satisfied with this feature of the final jacket, contact was made with her via text message to inquire. Hannah stated that she liked the upper back yoke because, "It's more of a stretchy fabric that moves with you instead of [being] tight". Whereas this feature of the jacket was meant to allow for better temperature regulation, Hannah found that physical comfort was positively affected by the incorporation of a knit fabric in an area that does not require stiffness nor structure. With areas of high-satisfaction outlined, it is appropriate to move onto analyzing areas of low satisfaction.

Areas of low satisfaction. As is common in both apparel design and design research, participants are rarely fully satisfied with a product. In the analysis of the Evaluation interview, Alterations was the most prominent code with 12 applications. In the event that Hannah's satisfaction with the jacket was not to a high degree, the researcher planned to complete one last set of alterations to the final jacket prototype. However, due to the COVID-19 pandemic, further jacket modifications are now outside the scope of this work. Alterations as a parent code held all the plans and needs for jacket alterations, that will be done at a later date when Hannah can return to the Paralympic Training base, post COVID-19 pandemic. When considering Hannah's satisfaction with the jacket, it is the intention to understand the factors causing low satisfaction in the prototype so that they may be remedied. Thus, each area of low satisfaction for the jacket is outlined as measures for future improvements.

Body fit had nine applications, and this co-occurred with *Alterations* eight times. Hannah found the fit of the jacket to be improper in the upper arm and armhole area:

H: Uh, the arms up in here (the upper arm/armhole) like they're really tight up in here like you can't like flex like this, and you can't completely bend your arm because it's so tight like up in the upper arm area here...

The improper fit of the finalized jacket prototype is likely the result of too much reliance on apparel design technologies and not enough focus placed on physical prototype fittings, due to the distance between Hannah and the researcher (a three-hour drive). Furthermore, the pose that Hannah was asked to use for the body scanning process (Figures 4.7 and 4.8) may have caused the width of her arm to be reduced, thus affecting the fit of the jacket developed in both half scale and CLO. Improper fit may also be the result of construction flaws, pattern editing flaws, variations in body shape and size, and many other potential factors. More about using virtual prototypes versus physical prototypes in the design prototyping process, both in this work and future works, will be discussed in addressing the research questions later in this chapter, as well as in Chapter 5.

Another area of the jacket that received low satisfaction from Hannah was the overall structure of the jacket. As a code, *Structure* had eight applications in this data analysis. It co-occurred with *Jacket regulations* five times, and Alterations four times. Hannah found that the stiffness of the jacket, the feature that could help provide jacket structure, was not on the mark:

R: …other than the fit problems, do you feel like it'll pass equipment control?

H: It'll probably pass, but the only problem I see with it, the material isn't... stiff enough.

R: It's not stiff enough?

H: Like... no, it's not stiff enough. Like it's like... It's pretty loose like that's... Like a jacket's never like, that flexible.

When considering why and how this design feature resulted in negative feedback, it is essential to consider multiple perspectives. It is common for companies selling specialty fabrics (such as very stiff canvas) to require a minimum order amount. This was true in the case of this research. The retail options for canvas textiles for individual researchers were not as varied as wholesale options for large companies. Therefore, the researcher procured the stiffest canvas available to them for this jacket prototype. Hannah was given swatches of this canvas and told that interfacing would provide enhanced stiffness. However, there may have been a lack of knowledge and clarity regarding how much rigidity the interfacing would provide. Thus, it would've been beneficial to give Hannah a sample swatch of the canvas with the interfacing already adhered. Furthermore, the swatches provided to Hannah were not very large (approximately a three inch square), perhaps making it difficult to understand how the textile would function in the jacket design. Lastly, there was no tool for the researcher to be able to measure the stiffness of the jacket throughout the prototyping phase. Only thickness was able to be measured. The canvas that was sourced for the final prototype was at the maximum thickness per the regulation limit when constructed in the jacket prototype.

When reflecting upon the structure of the jacket and the design insights from Step 1, it should be noted that Hannah suggested no suede be included in the body of the prototyped jacket. She found the canvas on her Kurt Thune jacket to be stiffer and more structured, which are important traits for the shooting jacket. However, given the lack of proper stiffness in the prototyped jacket, Hannah decided that perhaps suede would have been a helpful inclusion in this design:

> R: …you had said about your other jacket that the canvas was kind of more sturdy than the suede... um, so I didn't put any suede in the body, I only used canvas... do you think that was a good decision? Or would you have preferred to have some suede in there too?
>
> H: Um, I think suede would have been a little... I think that would've helped with like the thickness, and like... I don't wanna say the durability, but um... Like if it had the suede, it might help with like...

> how, because it’s so flexible now, that if it had the suede on it, like, that would help the stiffness of the jacket. I think that’s what I’m trying to say.

Overall, most design work is not without areas of low satisfaction that researchers and apparel companies seek to improve in subsequent apparel products. Design research aims to bring to light the many nuances and difficulties of the design process, including the designer’s decisions and how they affect the user’s satisfaction. For example, the decision-making process behind not incorporating suede into the body of the jacket was laid out clearly in this work. It was thought to be the correct decision that would lead to high-satisfaction. Once the final jacket prototype was completed, this seemingly straightforward design decision was something that resulted in lower satisfaction. Though the end-product in this research did not achieve full satisfaction, alterations will be done in the future to hopefully allow for the jacket’s low satisfaction features to be remedied.

Satisfaction with process. The data analysis in Step 1 found that Hannah considered communication from the maker of her jacket to be an important factor in her satisfaction with the product. Therefore, understanding her satisfaction with the process of this work was an essential factor in understanding her overall satisfaction, as well as understanding the accuracy of the FEA Model for Disabled Athletes developed in this work (Figure 4.2). *Process* was coded three times in the analysis of this data. Hannah was satisfied with the communication between researcher and user:

> R: So, how do you feel about how much I communicated with you during this time... was it too much or too little compared to what they did?
>
> H: It was very good, I mean you kinda like kept me up to date on like what was going on, what the next process you were doing with [the jacket], and like where you were at on it... and, it was good communication between both of us, I thought.

R: Good, I'm glad. That's what I wanted. Is there anything you would've wanted me to do differently?

H: I don't think so…. It was really fun. I was really happy to get to volunteer my time to help you with it.

Throughout the design process, the researcher visited the Paralympic Training Center four times, had text communications with Hannah for ten separate purposes, and had six phone calls relating to this research. A summary of all of the interactions with Hannah can be seen in Table 4.9. Aside from these communications, time was spent with Hannah outside of research purposes; for example, Hannah and the researcher communicated via text, visited a local shopping mall two times, and generally kept in contact with one another due to a good relationship. It is likely that the high amount of communication between Hannah and the researcher, as well as the time spent with Hannah doing non-research activities, positively affected her satisfaction with the design process. As a design researcher, hearing that the participant enjoyed the process, even if the product was not entirely without flaw, is always the goal. Open communication between the researcher and the end user allowed Hannah to be satisfied and even happy that she participated in this work. Open communication between the designer and the user is a common tactic in user-centered design methodologies (Watkins & Dunne, 2015). Future researchers, as well as industry leaders, should consider user-centered design strategies that focus on communication throughout the design process to be an important factor of overall satisfaction.

Table 4.9

List of communications and visits had with Hannah throughout this research, with the method of communication indicated.

REASON FOR COMMUNICATION OR VISIT	In person	Phone	Text
Participation interest and project overlook		X	
Speak with EC and watch shooting competition	X		
Planning and scheduling for next visit			X
Problem Identification interview and manual measurements	X		
Member checking Problem Identification interview			X
Planning and scheduling for next visit			X
Body scanning, block garment fit test, current jacket examination	X		
Check-in about process, half-scale dress form		X	
Prototype ideation feedback			X
CAD prototype illustration feedback		X	X
CLO virtual prototype feedback		X	X
Full-scale pattern fitting	X		
Check-ins (multiple) with pictures of prototype process			X
Scheduling for Evaluation interview		X	X
Evaluation interview		X	
Member checking, follow up questions			X

Step 6: Implementation

As mentioned in Chapter 3 and depicted in the Adapted Six-Step Framework for this research (Figure 4.1), implementation originally sought to finalize and finish prototyped jacket and thus allow for participant implementation of the prototype. However, due to the COVID-19 pandemic, alterations of the prototyped jacket had to be put on a temporary hold.

Regarding implementation of a design, Lamb and Kallal (1992) state, “When mass production [of a design] is planned, the marketing and merchandising functions might influence revisions of the product design. Information from clients influences custom design revisions…” (p. 45). One very practical limitation of design research is that it is often individuals or teams of researchers behind the work. Researchers do not have all the same resources as larger companies, though sometimes researchers may work with companies to develop design solutions.

Implementation thus is quite different for a product in a company setting with a broader variety of resources than it is for an individual researcher, as in the case in this work. Had this research been done in conjunction with a company or industry partner, it may perhaps be easier to develop yet another, more finalized prototype of this jacket design. If the company intended to produce more Paralympic Shooting jackets, they could incorporate certain factors into their production process that would allow for an even higher satisfaction end product at the end of the design framework. These factors could include ordering of more specialty fabrics and utilization of more specialized sewing labor.

The regulations placed on Paralympic Shooting jackets by ISSF and World Shooting Para Sport affect the implementation of the jacket prototype as well. Finalizing and finishing of the prototype, when working with a larger company or industry partner, could mean trying out new fabrics, editing fit by doing further pattern alterations, and working with EC staff. These extra processes could aid in development of higher satisfaction design prototypes. Furthermore, working with an industry partner could allow for more comprehensive testing of the jacket construction and materials against EC regulations throughout the prototyping process. Developing a jacket that is of high-satisfaction and within the EC regulations was one of the goals of this research, which were partially met. Future work could be done to continue to develop prototype design, materials, and fit of Paralympic Shooting jackets.

Researchers that partner with companies may also be able to focus more on improving the design features and design process, as opposed to focusing on the entire apparel design framework process. As Lamb and Kallal (1992) state, “The design process is critically linked to product development for target markets.” (p. 45). Had this research been done with an industry partner, it would perhaps have been possible to focus on not just one participant, but several, and thus gather more insight into the optimal design process. In this research, the FEA Model for Disabled Athletes (Figure 4.2) was presented, which brought knowledge of the design process into the clothing needs of the user. Thus, the design process used in this work, which was met with satisfaction from Hannah, could be implemented into future Paralympic Shooting jacket design processes, with a larger number of users or Paralympic Shooting athletes.

Research Questions

With the findings and discussion of all the methods involved in the Adapted Six-Step Framework (Figure 4.1) laid out above, it is possible to answer the research questions in this study. Each research question is presented, with the outcomes that apply to both academia and industry outlined for each.

Research Question 1

Research Question 1 asked the following: How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant?

Weighing of FEA needs. In this study, the researcher observed that there are often conflicting user needs that cannot be addressed in one design, just as Lamb and Kallal (1992) stated. Weighing of FEA needs was, in this research, a valuable tool to understand the values and reasons for implementation behind each potential design decision, specifically conflicting design decisions. Weighing of FEA needs did, in this research, affect the final prototype design. For example, in Figure 4.4, the choice between using American flag print or cheetah print as a lining motif was decided by using the weighing process. In this weighing, it was determined that using American flag print was weighted more heavily based on the researcher’s understanding of the participant’s FEA needs surrounding color and role. However, cheetah print was incorporated into the first iteration of the prototype design, because it was determined that perhaps Hannah would like some ‘personal style’ incorporated into her jacket design. However, in the end, Hannah preferred to keep the American flag print consistent throughout, proving that the weighing done in this process was indeed correct.

Based on this study, the researcher suggests that future researchers and industry leaders utilize a visual aid or list for weighing of FEA or consumer needs, as it can be challenging to weigh needs without seeing the factors behind each design outcome directly. When a visual aid is utilized, the reasons to implement each of the design outcomes should be listed beneath each design outcome or each conflicting need; a ‘pro and con’ list of each design outcome could easily become confusing for the designer. In the same vein of keeping the design decision-making process as simplified and transparent as possible, design insights were utilized as a tool in this work to allow for clear intentions and decision making during the ideation and design phase of this research.

Defining design insights. Defining design insights in this research allowed for a more clear-cut idea of how to proceed with the design ideation and brainstorming. Bye (2010) calls for design research to be outlined clearly, in an attempt to help educate design students more effectively, versus design being solely an intangible, purely cerebral skill. Design insights may help teach new designers what is essential to consider during the design process. Design insights also help the designer/researcher themselves clarify what the most important features of the design will need to be, before any design ideation is done. Watkins and Dunne (2015) describe a similar task, “creating a concise problem definition,” as one of the vital steps in their user-centered design framework (p. 15). Communication can be had between the designer and the end user to help define design insights.

Communication between designer and end user. Communication between the designer/researcher and the end user is a focal point in many user-centered, universal, and inclusive design strategies. Designing *for* a user is always done better when you can design *with* a user. In this work, the communication between the researcher and participant allowed for higher satisfaction in the design process. Several design decisions, such as the lining of the jacket, were directly affected by communication with the end user, which likely produced a higher satisfaction product than would have been otherwise provided.

For industry leaders and sportswear companies seeking to help begin to provide high-satisfaction sportswear to the disabled community, it is essential to utilize some strategies that this research explores and implements. For example, in the design phase of product development, working with users to understand their needs is an essential procedure. Utilizing a design framework such as the FEA Consumer Needs Model (Lamb & Kallal, 1992) can aid in understanding user needs more clearly, thus allowing for accurate design insights to be gleaned. Industry leaders should continue communication with the user in many ways throughout the design process. Asking the user for feedback on design ideas and allowing time for user wear testing of prototypes are just two examples of ways in which communication with the user can facilitate a better understanding of user needs. Understanding of needs ultimately allows the product produced to be of high-satisfaction. Thus, this research suggests that communication with the end-user is one of the most important factors in creating high-satisfaction in a design product.

Research Question 2

Research Question 2 asked the following: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant?

3D body scanning. In this work, 3D body scanning did improve the custom sportswear development process, due to physical distance between the researcher and participant. However, because of some technical difficulties in body scan cleaning and processing the half-scale dress form, it is not possible to state that the utilization of technology in this work unequivocally allowed for higher satisfaction in the end prototype than physical wear testing and multiple fit garments would have allowed. The Structure Sensor iPad application would benefit from many improvements, as the researcher had many difficulties in gathering a 3D body scan- what should be a somewhat straightforward process and is for most able-body scanning procedures. App developers need to improve the Structure Sensor's accessibility and usability, and also need to develop solutions for 3D body scanning people with all variations of disability. Programs such as Meshmixer and Fusion 360 (used to clean and scale the body scan) could also benefit from improved navigation and usability developments.

Virtual garment simulation. Virtual garment simulation was a beneficial tool in this work in allowing the user to see the product before any physical prototyping. The researcher also benefitted from being able to virtually simulate seamlines, textiles, and fit of the jacket design: many design, fit, and construction details were better understood because of simulation. Thus, the development process was again improved by the use of technology. How virtual garment simulation affected the participant's satisfaction with the end product is more difficult to predict. The researcher shared images of the virtual garment with Hannah, and she provided feedback.

Hannah responded positively to the images of the virtual garment prototype. It is possible that visually seeing the jacket design prototyped onto her virtual body allowed for more familiarity with the design and thus, higher satisfaction. While virtual garment simulation is an excellent tool to be able to see garment style and consider specific garment details, it cannot be fully used as a tool to understand fit. Though CLO garment simulations are amongst the most realistic in the industry, virtual simulations can never give the same information that a real, physical garment prototype can (CLO, n.d.). Researchers, educators, and industry leaders may find that use of 3D body scanning and virtual garment simulation can aid their development process, even cut down on time and resources. However, creating high-satisfaction clothing still requires physical wear testing and prototyping to ensure fit, mobility, comfort, and several other factors that virtual simulations are currently not able to predict effectively.

Research Question 3

Research Question 3 asked the following: How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires?

When considering the needs of the end user, adapted models for data analysis may be valuable to have for each specific group of end users. For instance, in this work, an adapted FEA model for data analysis was developed based on knowledge of Paralympic Shooting and the specifics of the clothing involved. While the researcher developed this model through understanding the experiences of the Paralympic Shooting contact, EC regulations, and visits to the Paralympic Training Center, the adapted FEA model for data analysis in this research may or may not be applicable in other research with Paralympic Shooting athletes. Future interviews with Paralympic Shooting athletes could potentially improve this adapted model.

The adapted FEA model for data analysis allowed for the more natural development of an a priori code list in the thematic analysis of the Problem Identification interview data. Thus, Hannah's FEA needs surrounding her Paralympic Shooting jacket preferences and desires were more readily understood through the use of this adapted model.

By understanding how Hannah's FEA needs inform her Paralympic Shooting jacket preferences and desires through narrative and thematic analyses, it was possible to develop an FEA Model for Disabled Athletes. This model was discussed in Step 1: Problem Identification Interview. The FEA Model for Disabled Athletes can help future researchers and industry leaders understand how the clothing needs of disabled athletes may differ from the original FEA Consumer Needs Model. However, the researcher acknowledges that it is not possible to determine what factors of the FEA Model for Disabled Athletes relate to disability separately from which factors relate to Hannah's position of being an athlete. This is because the data were collected simultaneously, with questions that asked about both athleticism and disability together. The FEA Model for Disabled Athletes thus can only perhaps help researchers understand the FEA needs of disabled athletes, as opposed to the needs of people with disabilities only or athletes only. The FEA Model for Disabled Athletes offers a more specific understanding of how Hannah's FEA needs informed her Paralympic Shooting jacket preferences and desires and may apply to other disabled athletes' FEA needs as well. However, additional data should be analyzed to test the reliability and validity of this model, as well as develop models that consider disability and participation in athletics separately. All three FEA models described throughout this research are seen in Figure 4.34.

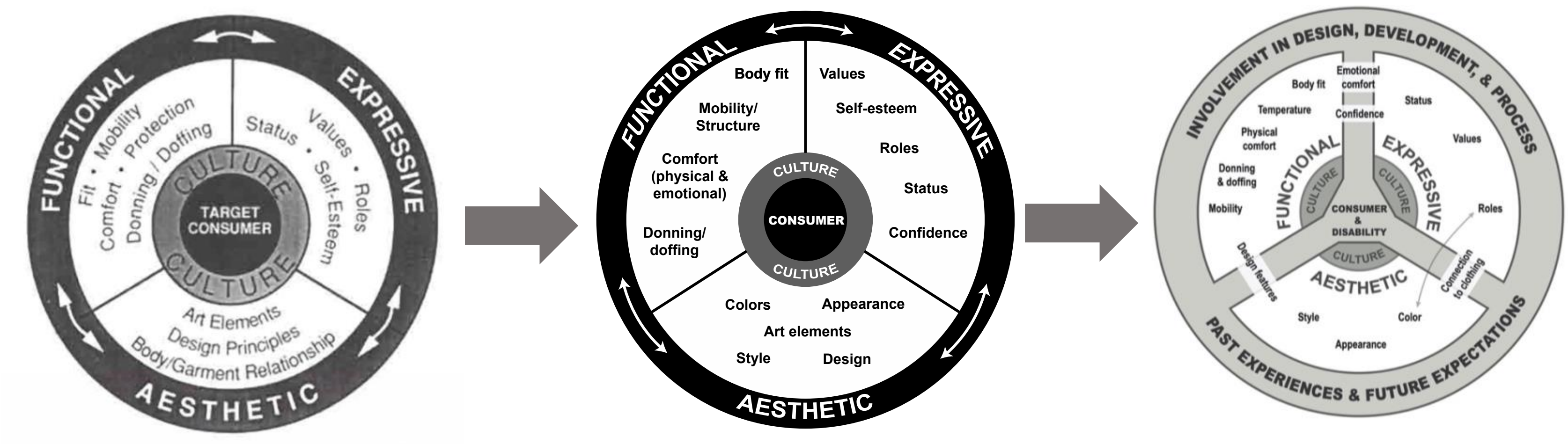


Figure 4.34: All FEA Models utilized in this research: Lamb and Kallal original FEA Consumer Needs Model (left), adapted FEA model for data analysis (center), and FEA Model for Disabled Athletes (right).

The research questions in this work were developed before any data collection or design efforts, and thus partially guided the execution of all methods in this work. By understanding how weighing of FEA needs, defining of design insights, communication between user and designer, use of technology, and adaptations of the FEA model affected the data collection, analyses, and design processes, it is possible to gather specific key findings from this work that will be applicable to future researchers, industry leaders, and educators alike. These key findings are discussed in Chapter 5: Conclusions.

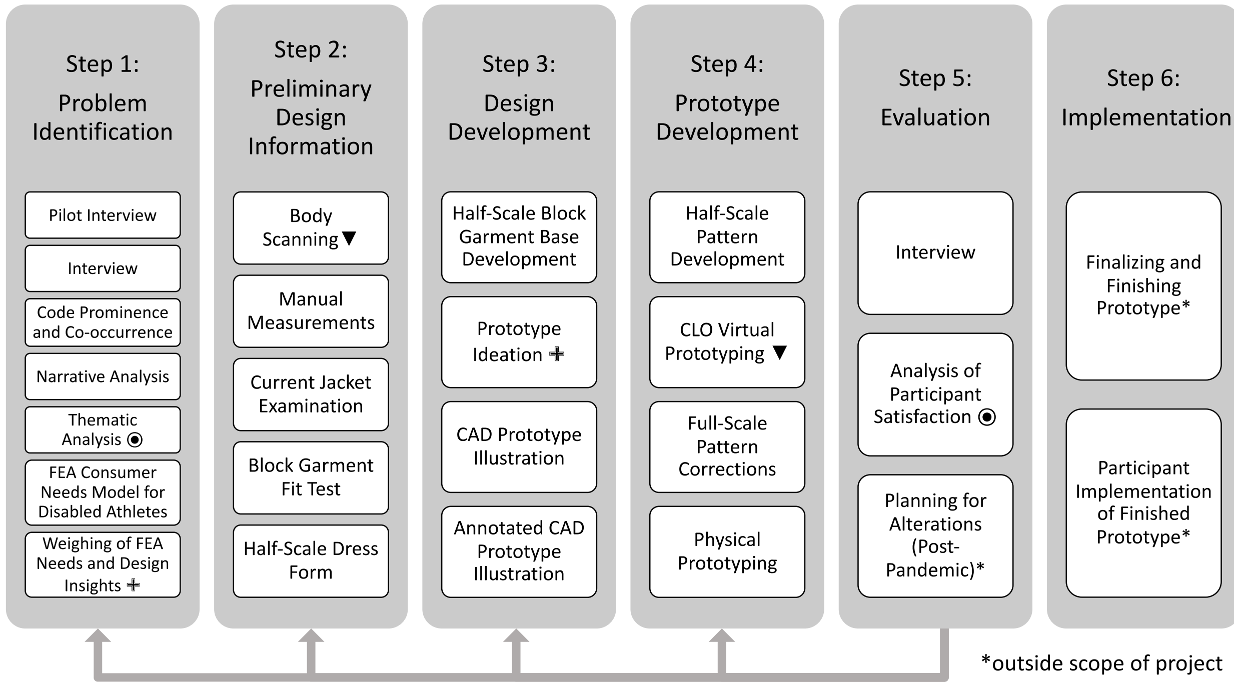
CHAPTER 5: CONCLUSIONS

This research sought to create a high-satisfaction custom Paralympic Shooting jacket for a single-case Paralympic Shooting athlete through an Adapted Six-Step Framework (Figure 5.1) based on work by Lamb and Kallal (1992). To understand the athlete's Paralympic Shooting jacket needs, this work utilized qualitative research and design research methods with a focus on Lamb and Kallal's (1992) FEA Consumer Needs Model and subsequently developed models (Figure 4.36). Apparel design technology was utilized to understand the athlete's body anthropometrics. The following three research questions guided this work:

RQ1: How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant?

RQ2: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant?

RQ3: How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires?



✚ Relates to the answering of RQ1: How can weighing of FEA needs, defining design insights, and communication between designer and end user aid in creating high-satisfaction custom sportswear for the single-case participant?

▼ Relates to the answering of RQ2: How can utilization of 3D body scanning and virtual garment simulation technology improve the custom sportswear development process and create high-satisfaction in the end product for the single-case participant?

◉ Relates to the answering of RQ3: How do functional, expressive, and aesthetic needs (FEA needs) inform the single-case participant's Paralympic Shooting jacket preferences and desires?

Figure 5.1: Adapted Six-Step Framework used for this research, with research questions included.

Key Findings

The broader scope of this research intended to understand how the clothing industry can start to more efficiently and effectively meet the clothing and sportswear needs of disabled athletes. The researcher makes several recommendations throughout the discussion in this section by answering the research questions. The key findings of this research are described below.

High-Satisfaction Apparel Products

Currently, there are very few sportswear options available on the ready-made market for disabled athletes (Bragança, et al., 2018). It is not only imperative for clothing industry leaders to start producing more sportswear for this demographic, but it is also likely profitable due to the rising number of disabled athletes participating in the Paralympics each year (International Paralympic Committee, n.d.). In making clothing, specifically clothing utilized for a mostly functional purpose such as athletics, it is essential for consumers, or an athlete, in this case, to be highly satisfied with the product. By creating high-satisfaction, these consumers are more likely to shop at the same brand multiple times. This research examined how weighing of FEA needs, defining design insights, and communication between designer and end user aided in the creation of high-satisfaction for the end user. This work found that communication between the designer and the end user was the most critical of these three factors, as the end user may sometimes change their mind on what their design needs are. For example, in this work, the participant, Hannah, gave insight on several design factors, including textiles, colors, and fit. Without communication with the end user throughout the process of apparel design and development, mistakes could be made that could be easily prevented.

Communication with the end user is a valuable take-away for industry leaders, educators, and future design researchers alike. In a small scale, single-case study, custom design project such as this one, communication can lead to direct adjustments in the design of a product. In a larger-scale industry or research project, there may be more end users' design needs to consider. Check-in communication points may benefit from being planned into the design framework or methodology, as frequent meetings may not be feasible. Many researchers and designers agree that communication with the end user is becoming more and more of a necessary factor in design, especially when working on specialty/niche clothing for minority populations. This work has also found communication between the designer and the end user to be a crucial factor in design work.

Use of Apparel Technology

In the modern-day, technology has come to a point where it can potentially help designers and researchers understand bodies and clothing fit in a different way. Through 3D body scanning and virtual garment simulations, it is possible to prototype apparel designs multiple times before ever cutting a piece of fabric or making one stitch. Though showing virtual models to the end user is one potential benefit of these technologies, 3D body scanning and virtual garment simulation are primarily tools for the designer to be able to cut down the time from ideation to product. Furthermore, a third party who has access to and proper training on these 3D technologies could act as a "middleman" between the consumer and the clothing designer or manufacturer. They could capture and process a 3D body scan of the consumer for the clothing design company to help them understand the consumers' anthropometrics. The 3D body scan has a substantial amount of information for the designer and is a lasting tool that the designer can reference throughout their design process.

In this research, the researcher utilized 3D body scanning to develop a half-scale dress form for draping, as well as a 3D avatar to use for virtual garment simulation. Because of the physical distance between the researcher and participant, these technologic tools were utilized quite heavily in the development of the Paralympic Shooting jacket. Regarding how technology can aid the apparel design process, it was gathered from this specialty custom work that when physical distance is a factor, these technologies can be a time-saving aid. The programs that these technologies utilize (Structure Sensor iPad application and Meshmixer) could benefit from more engineering and troubleshooting, ideally allowing for better functioning and usability. The fit issues that were present in the final prototype version of the custom Paralympic Shooting jacket were likely attributed to the extreme specialty factors of the garment, the pose used for the 3D body scanning process, and the inconsistencies and errors in the 3D body scan processing and editing. Thus, this work suggests that caution is taken when using the same programs used in this work for 3D body scanning and editing.

CLO and other similar virtual garment simulation programs are utilized throughout the clothing industry and in apparel design education, often with a standard program avatar as the fit model. The capabilities of this program and others have to shorten the time from design ideation to prototype is evident. However, caution is recommended in that virtual garments can never predict the exact properties of the real, physical garment. Thus, while the technology for virtual garment simulation is indeed user-friendly and helpful, the researcher suggests that physical prototypes be made in conjunction with virtual prototypes, especially for niche or specialty products and unique bodies. Furthermore, it is recommended that CLO and other virtual garment simulation programs offer a standard avatar in the seated position. A seated avatar could aid in more easily allowing companies to design for people who use wheelchairs, as well as other populations that often sit throughout the day (elderly, office workers, etc.). These populations should be included in the idea of a standard clothing consumer and target markets worth designing for.

In summary, 3D body scanning technology and virtual garment simulation technology should continue to be utilized and explored in industry, education, and research, however, all parties should be mindful that: (a) virtual clothing can never fully mimic physical clothing; (b) the more niche of a clothing item and more unique or atypical of a body, the less likely that these technologies are to be beneficial; and (c) all the technologies used in this research could benefit from engineering and usability improvements.

FEA Consumer Needs Model Adaptations

All designers have a method for understanding their consumers' needs, no matter the consumer, the product, the designer, the company, the institution, etc. Good design understands what people want and need, and tries to make products that fulfill those wants and needs. There are many ways that designers attempt to understand what consumers or end users need from their products. For this work, the researcher used the FEA Consumer Needs Model (Lamb & Kallal, 1992) to understand the single-case participant's needs. Adaptations were made to the model after the researcher learned more about the sport of Paralympic Shooting, the standard features seen in Paralympic Shooting jackets, the relationship between the shooting athlete and the shooting jacket, and more. This is to say that the adapted FEA model for data analysis (Figure 5.3) was adapted specially for the product and end user in this work, as a direct result of the designer/researcher gaining background knowledge. Adapted models for specific products or consumers can provide a more manageable process of analyses, weighing of FEA needs, and defining of design insights, due to the nature of the user's relationship to their clothing being defined before analysis.

Industry leaders typically do not utilize academic models in their design work; however, most companies do have a general understanding of their consumer's preferences and desires. This work suggests that understanding the consumer's needs must include understanding the context of those needs as well. When designing sportswear, it is important to understand the nature of the sport to understand what clothing properties are beneficial. If any rules or regulations are surrounding the clothing worn during a sport, these must be followed. When designing for the disabled community, it is essential to make efforts to understand how their clothing needs differ from the non-disabled community's clothing needs.

The original FEA Consumer Needs Model is generally scalable and can be used to understand the clothing needs of many end users. One outcome of this research was an adapted FEA Model for Disabled Athletes (Figure 5.2). In the case of this research, the original FEA Consumer Needs Model was flexible enough to provide a framework for this study and, with modifications, reflect the needs of the single-case study participant in this research. The emergent model (the FEA Model for Disabled Athletes) can now be scaled-up in larger studies and tested with a new set of consumers: disabled athletes. The FEA Model for Disabled Athletes could help future researchers and industry leaders understand the clothing needs of disabled athletes more efficiently and effectively. Future research should test the validity and reliability of this model and continue to develop it further towards accuracy. Researchers and industry leaders could benefit from developing adapted models, more specifically towards populations that they are seeking to design for, to continue to understand the needs of minority populations as well as how to meet these needs through solving design problems.

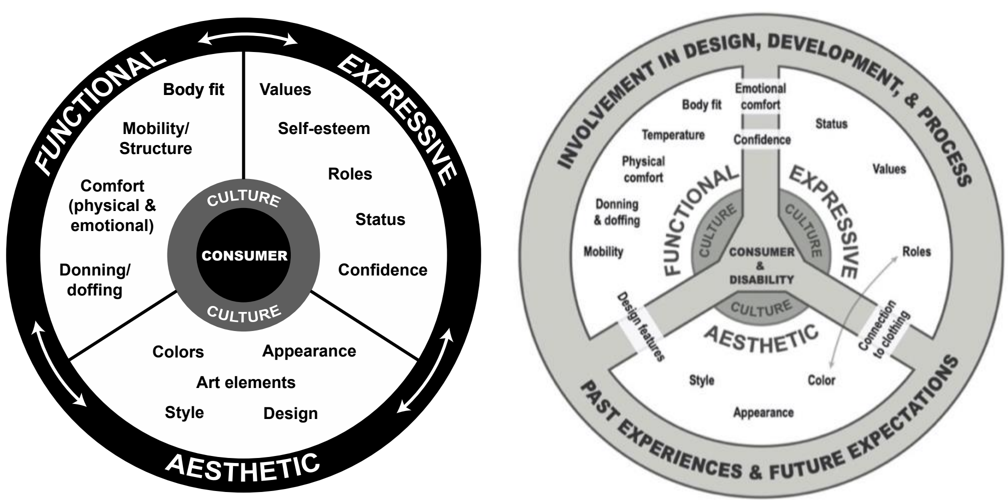


Figure 5.2: Adapted FEA model for data analysis (left) and FEA Model for Disabled Athletes (right). Both models above were created within this research.

Limitations and Future Research

As with all research, limitations exist in this thesis and must be addressed. The limitations of this research were eliminated to the best of the researcher's abilities. Because the single-case study involved in this research was the sole participant, a bias may have been created in which the participant tells the researcher what she thinks is desired or 'correct.' To minimize the effects of this bias, Hannah was ensured that she would receive the compensation for participation in this research, no matter her feedback at any step within the research methods.

This research involves a very small sample of only one female participant and possibly could be strengthened by adding more participants, both male and female. However, due to time constraints and the need for a high-quality and custom end-product, including more participants in the research was not a feasible solution. Instead, an in-depth analysis of a single-case study was chosen. This research is also limited in geographical location due to the researcher's availability and resources. Thus, a single-case study participant within reasonable travel distance for occasional and essential in-person visits was chosen. However, the COVID-19 pandemic significantly increased the distance between the researcher and participant near the final steps of this work. Future research, where the researcher or designer can have more constant meetings and contact with the athlete/user, should be done to study competition shooting gear for many physically disabled athletes in all areas of the world (including outside the USA).

The findings and theoretical contributions of this study may not be generalizable or present external validity in other design scenarios, due to the single-case study nature of this research design. Although essential contributions to product development processes for disabled athletes have been made through this research, future studies should continue to develop the generalizability of the models and stated contributions of this work.

This research utilized apparel design technology in a substantial way both before and after the COVID-19 pandemic. While the technology used in this work did allow for fewer in-person visits with the participant, it may be necessary to do another study that does not include these technologies but instead utilizes more physical prototyping to compare the end user's satisfaction levels in both cases.

The product developed in this study could also benefit from partnerships with industry leaders. Design partnerships between researchers and industry leaders can allow for better product development and higher-satisfaction end products due to sharing of knowledge and resources amongst both parties. Future research, similar to the work presented in this thesis, should be done with industry partnerships to make the best of each party's resources.

The primary focus of this research was a competition shooting jacket for one Paralympic Shooting athlete. Much work has been done to understand the functional, expressive, aesthetic, cultural, and emotional needs of a Paralympic Shooting athlete for the design of the final jacket prototype. However, there remain other categories of athletic apparel/equipment used by Paralympic Shooting athletes that require attention from designers. For example, Hannah wears base layers and gloves designed for non-disabled athletes and not optimized to her needs to perfect her skills as a Paralympic shooter. Future research should focus on other components of the Paralympic Shooting specialty clothing and gear.

Furthermore, there are many other sporting events in which a wide variety of disabled athletes require specially designed clothing that does not yet exist in the mainstream clothing market or could be significantly improved upon. Future researchers need to continue to study and develop sportswear for all types of physically disabled athletes for a variety of sports. If we are to become a community where inequality for people with disabilities is entirely a part of the past, we must look to even the most seemingly niche areas and solve the problems that still exist. There is much work to be done regarding equality in the design of products for disabled users. This research only briefly touches on the wide-ranging and imminent problems of accessible and adaptable design solutions for the disabled population. Through thoughtfully designed and developed adaptive sportswear, we may begin to serve wheelchair athletes who are dissatisfied with the clothing options available to them, and therefore possibly further increase participation and performance in wheelchair athletics worldwide. This research is just a start to the much larger design potential that should be tapped into to meet the needs of people with disabilities throughout the world.

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APPENDICES

APPENDIX A:

JACKET REGULATIONS FROM ISSF AND WORLD SHOOTING PARA SPORT

General Properties

- Any flexible material that does not change characteristics is allowed
- Voluntary inspections of clothing must be allowed
- Athletes must make allowances for measurement variations due to temperature, humidity, environment conditions (simply by jacket compliance being a good amount above regulation standards in thickness, stiffness, ease, and length)
- No quilting, cross-stitch, glue, or other to affix lining to outer layer other than at normal tailoring points
- Clothing should promote name, country, and any sponsorships (whilst following event-specific rules surrounding branding on clothing)
- Clothing should be television friendly, as the Paralympics are a televised event
- For Paralympic athletes who do not use specially made pants, pants cannot be denim or camouflage
- No velcro, sticky substance, liquid, or spray may be applied to any part of jacket, pads, shoes, floor equipment
- Buckles should be affixed on back panel of jacket to hold paper competitor information for competitions

Extra Features

- Loose area on shoulder pad permits (to take up loose material on trigger-pulling arm):
    - 1 zipper or
    - Max 2 straps
- Jacket may also have 1 hook, loop, button, or similar device fastened to outside of sleeve or shoulder seam to prevent sling from sliding

Thickness (Figure A.1)

A. Body and lining must not exceed thicknesses of:
   - 2.5mm in single thickness
   - 5.0mm in double thickness

B. Pockets and name decals are exempt from above thickness requirements

C. Area around buttonhole may be up to 12mm thickness max

D. Reinforcement patches must not exceed thickness of:
   - 10mm in single thickness
   - 20mm in double thickness

Stiffness (Figure A.2)

A. Stiffness minimum of 3.0mm is required

B. Exempt from stiffness
   - Buttonhole area
   - Reinforcement patches
   - Pocket area

Ease (Figure A.3)

A. Fit loosely enough to be overlapped beyond normal closure by 70mm
   - Measurement is taken with overlap gauge with tension of 6.0 to 8.0 kg.

B. Must be able to completely straighten both arms

Length (Figure A.4)

A. Front closure must not overlap more than 100mm when closed

B. Jacket front must not extend past lap

C. Jacket back must not extend past seat cushion, and sitting on any part of jacket is not allowed

D. Sleeve hem must not extend beyond wrist bone on trigger-pulling arm

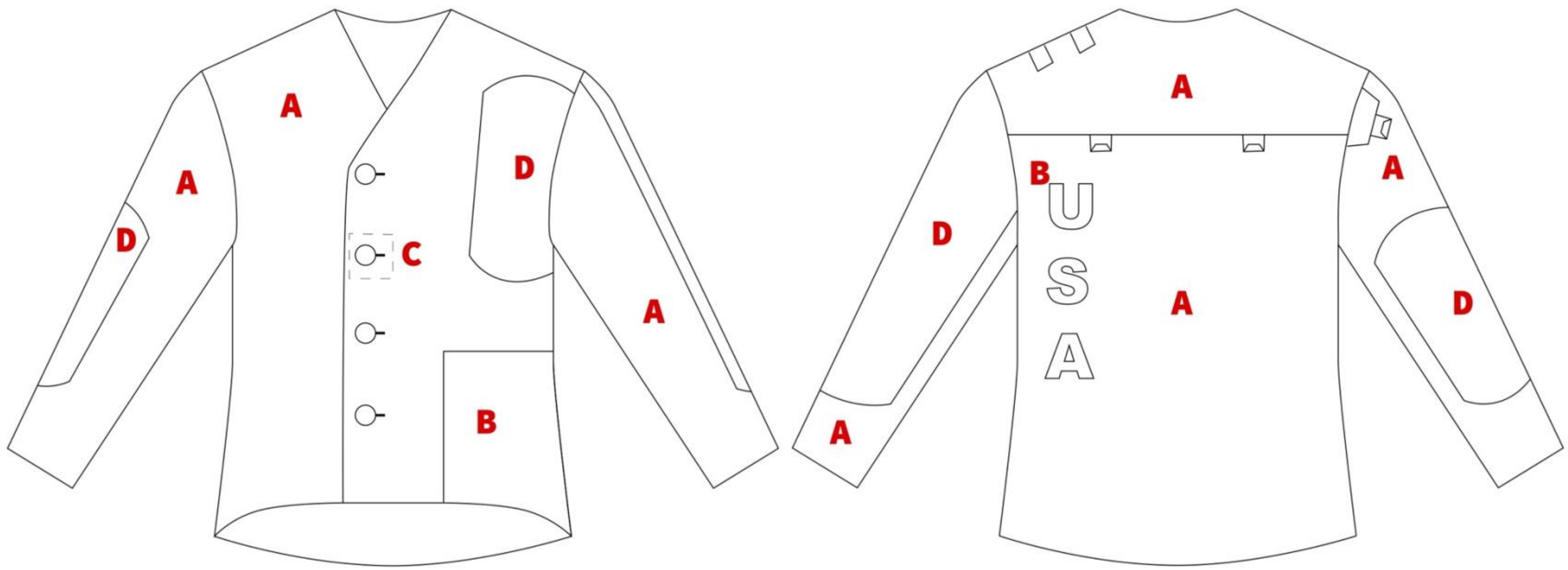
E. When athlete is resting elbow on body, seam free zone on body of the jacket is:
   - 70mm above tip of elbow
   - 20mm below tip of elbow

F. No inside pockets permitted, but one outside pocket:
   - Right side front for right-handed athletes, left side front for left handed athletes
   - Max size: 250mm high from lower edge of jacket and 200mm wide

G. Reinforcement patches must comply with the following:
   - Sling arm: full sleeve, up to 100mm from sleeve hem
   - Opposite arm: 300mm total in length, typically focused around elbow
   - Shoulder where butt plate rests: must not be longer than 300mm in longest dimension

H. Reinforcement patches must not extend more than half the circumference of sleeve

Figure A.1
Thickness Regulations



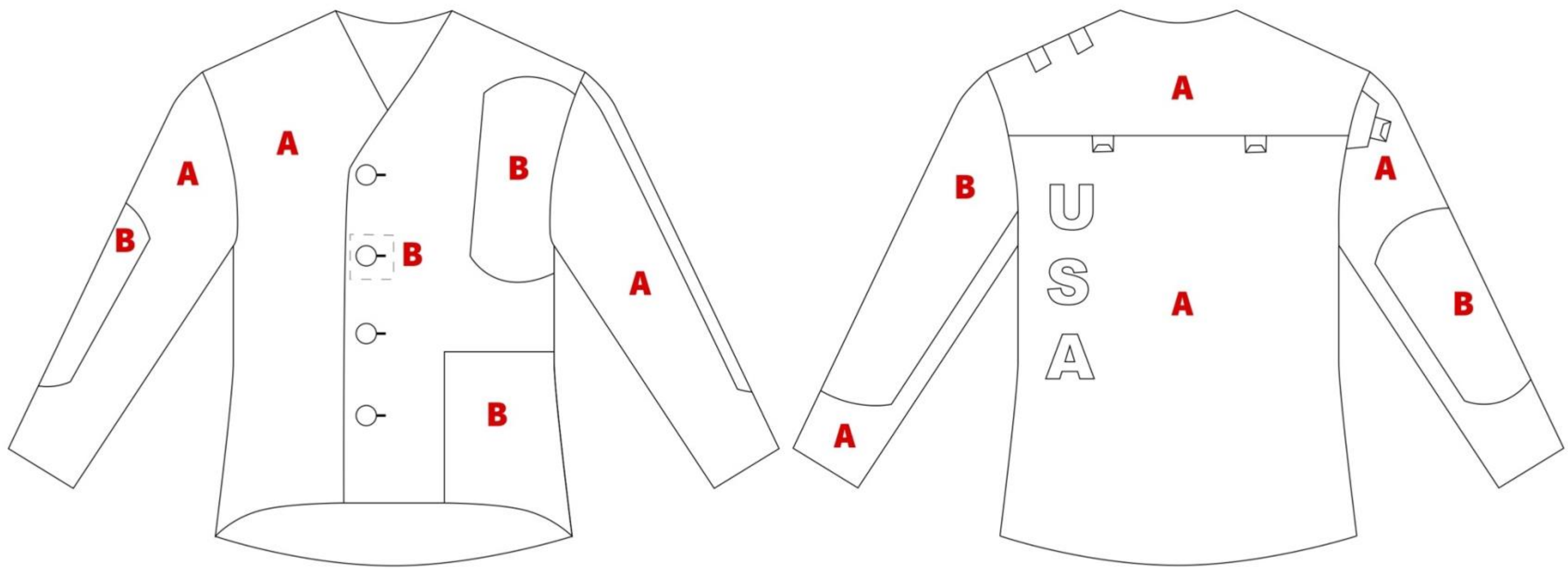
A. Body and lining must not exceed thicknesses of:
- 2.5mm in single thickness
- 5.0mm in double thickness

B. Pocket and name decals are exempt from above thickeness requirements

C. Area around buttonhole may be up to 12mm thickness max

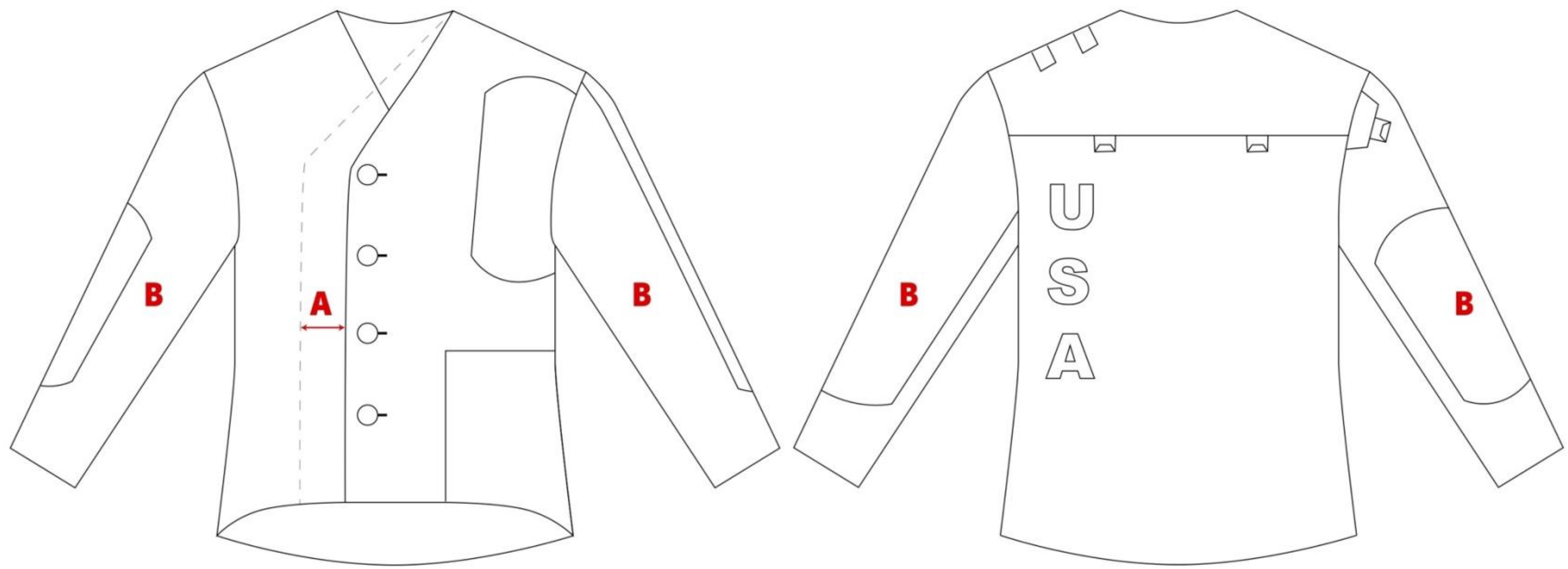
D. Reinforcement patches must not exceed thickness of:
- 10mm in single thickness
- 20mm in double thickness

Figure A.2
Stiffness Regulations



A. Stiffness minimum of 3.0mm is required
B. Exempt from stiffness
- Buttonhole area
- Reinforcement patches
- Pocket area

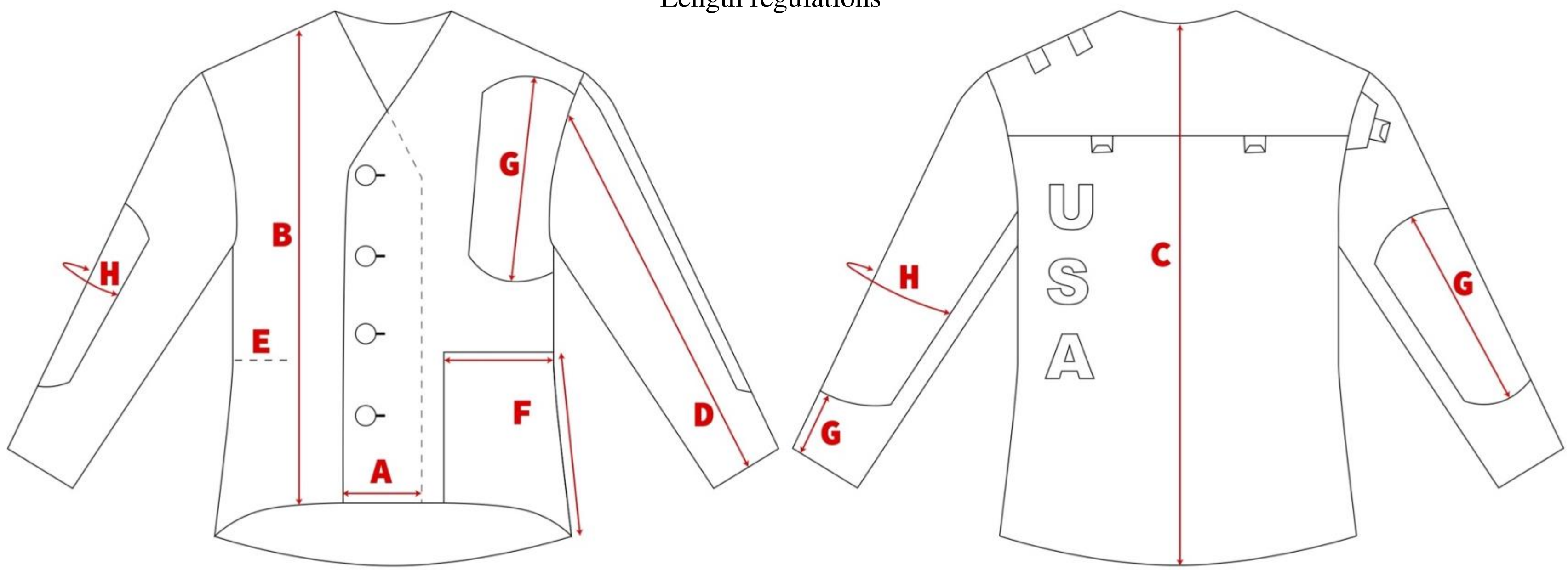
Figure A.3
Ease Regulations



A. Fit loosely enough to be overlapped beyond normal closure by 70mm
- **Measurement is taken with overlap gauge with tension of 6.0 to 8.0 kg.**

B. Must be able to completely straighten both arms

Figure A.4
Length regulations



A. Front closure must not overlap more than:
- 100mm when closed

B. Jacket front must not extend past lap

C. Jacket back must not extend past seat cushion

D. Sleeve hem must not extend beyond wrist bone on trigger-pulling arm

E. When athlete is resting elbow on body, seam free zone on body of the jacket is:
- 70mm above tip of elbow
- 20mm below tip of elbow

F. No inside pockets permitted, but one outside pocket:
- Right side front for right handed athletes
- Left side front for left handed athletes
- Max size: 250mm high from lower edge of jacket and 200mm wide

G. Reinforcement patches must comply with the following:
- Sling arm: full sleeve, up to 100mm from sleeve hem
- Opposite arm: 300mm total in length
- Shoulder: must not be longer than 300mm

H. Reinforcement patches must not extend more than half the circumference of sleeve

APPENDIX B:

PROBLEM IDENTIFICATION INTERVIEW

Pilot Interview with Paralympic Shooting Contact

1. Background Questions (Target Consumer)
    a. Where did you grow up?

    b. Would you be willing to talk about how long you have been using a wheelchair and how often you use it?

    c. How did you get involved in competitive air rifle shooting?

2. Daily Activities Questions (Culture)
    a. Can you give me a rundown of your daily routine? What does an average weekday look like for you?

    b. What does an average weekend day look like for you?

    c. How much time do you spend training?

    d. What kinds of activities does your training involve?

3. Jacket Performance (Functional Needs)
    a. Does your current jacket aid in your shooting performance in any way? If so, how?

    b. Is your jacket comfortable? Both in competition and when you are wearing it otherwise?

    c. Is the jacket easy to take on and off and to adjust?

    d. Does your jacket allow you the ability to move in ways that you need?

    e. With all the layers underneath, does your jacket cause you to feel too warm?

f. What are some functional features that you wish were different about your jacket, if any?

4. Jacket Aesthetics (Aesthetic Needs)
   a. Do you like the colors of your current jacket?

   b. Without considering regulations, what would your ideal shooting jacket look like? Feel like on you?

5. Jacket Meaning (Expressive Needs)
   a. Does your jacket aid in your self-esteem as a competitive shooter?

   b. What does your competition shooting jacket mean to you as far as the status you hold? Does it make you feel empowered, important, etc?

   c. Do you feel like your current jacket appearance reflects what you want it to reflect as a professional competition shooter who is moving towards competing in the Paralympics?

6. Questions about Current Jacket
   a. Did you pick Kurt Thune for your jacket for a certain reason?

   b. When you had this jacket custom-made, did you fill out a sheet with all your measurements? If so, who took the measurements?

   c. Did the people making your jacket communicate with you throughout the process?

   d. When you received your jacket, was it what you were expecting?

   e. Did you have to do any modifications to your jacket when you received it?

   f. Does your jacket have any features to make it adjustable to meet regulations in different climates?

   g. If you don't mind disclosing to me, how much did your jacket cost?

Single-Case Interview with Participant

1. Background Questions (Target Consumer)
    a. How did you get involved in competitive air rifle shooting? How long have you been doing it?

    b. (PRIOR TO QUESTION: Ask about what term the participant prefers- is disability the word they prefer?)

        i. Would you be willing to talk about how long you have been using a wheelchair and how often you use it?

2. Daily Activities Questions (Culture)
    a. Can you give me a rundown of your daily routine? What does an average weekday look like for you?

    b. What does an average weekend day look like for you?

    c. How much time do you spend training?

    d. What kinds of activities does your training involve?

3. Jacket Performance (Functional Needs)
    a. Does your current jacket aid in your shooting performance in any way? If so, how?

    b. Does your current jacket hinder your shooting performance in any way? If so, how?

    c. Did you make any changes to your jacket since you've had it?

    d. Is your jacket comfortable? Both in competition and when you are wearing it otherwise?

    e. Is the jacket easy to take on and off and to adjust? Please explain.

f. Does your jacket allow you the ability to move in ways that you feel you need to?

g. With all the layers underneath, does your jacket cause you to feel too warm?

h. What are some functional features that you wish were different about your jacket, if any?

4. Jacket Aesthetics (Aesthetic Needs)
   a. How do you feel about the colors of your jacket?

   b. Without considering regulations, what would your ideal shooting jacket look like? How would it feel on you? (show picture)

5. Jacket Meaning (Expressive Needs)
   a. Can you talk a little bit about how your jacket affects your self-esteem as an athlete?

   b. What does your competition shooting jacket mean to you as far as the status you hold? Does it make you feel empowered, important, etc?

   c. Do you feel like your current jacket appearance reflects what you want it to reflect as a professional competition shooter who is moving towards competing in the Paralympics? If not, what kind of changes would need to be made for your jacket to reflect that status?

6. Questions about Current Jacket
   a. Did you pick Kurt Thune for your jacket for a certain reason?

   b. You had your current jacket custom-made. Can you talk a little bit about that process? Did you fill out a sheet with all your measurements? If so, who took the measurements?

   c. Did the people making your jacket communicate with you throughout the process? If so, what kinds of communication? If not, do you wish that they would have and in what way?

d. When you received your jacket, was it what you were expecting? Please elaborate.

e. Did you have to do any modifications to your jacket when you received it? Please explain.

f. Does your jacket have any features to make it adjustable to meet regulations in different climates?

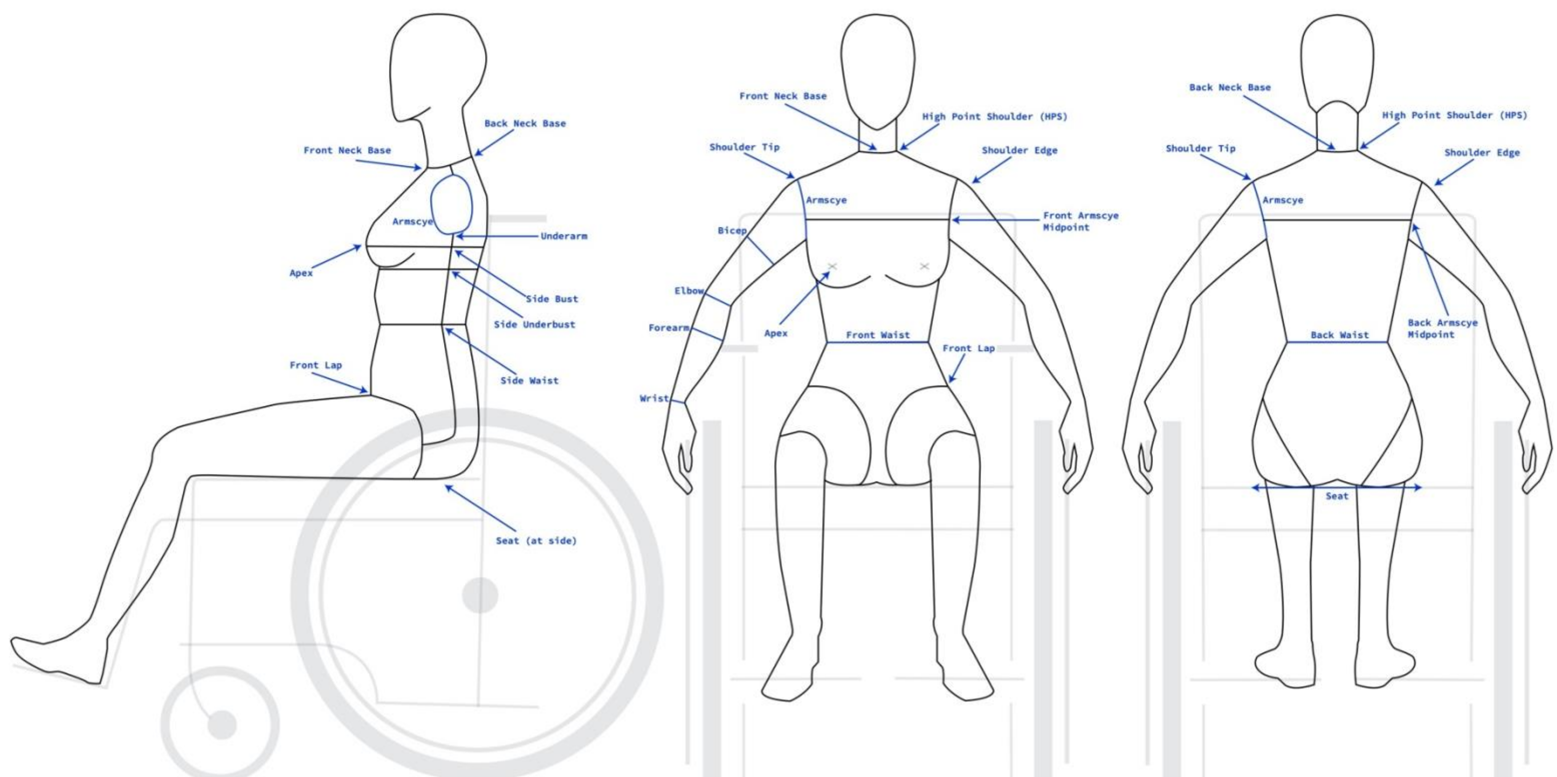
g. Do you have a spare jacket in case this jacket gets lost?

h. If you don't mind disclosing to me, how much did your jacket cost? Do you feel it is worth what you paid?

APPENDIX C:

MANUAL MEASUREMENT GUIDES

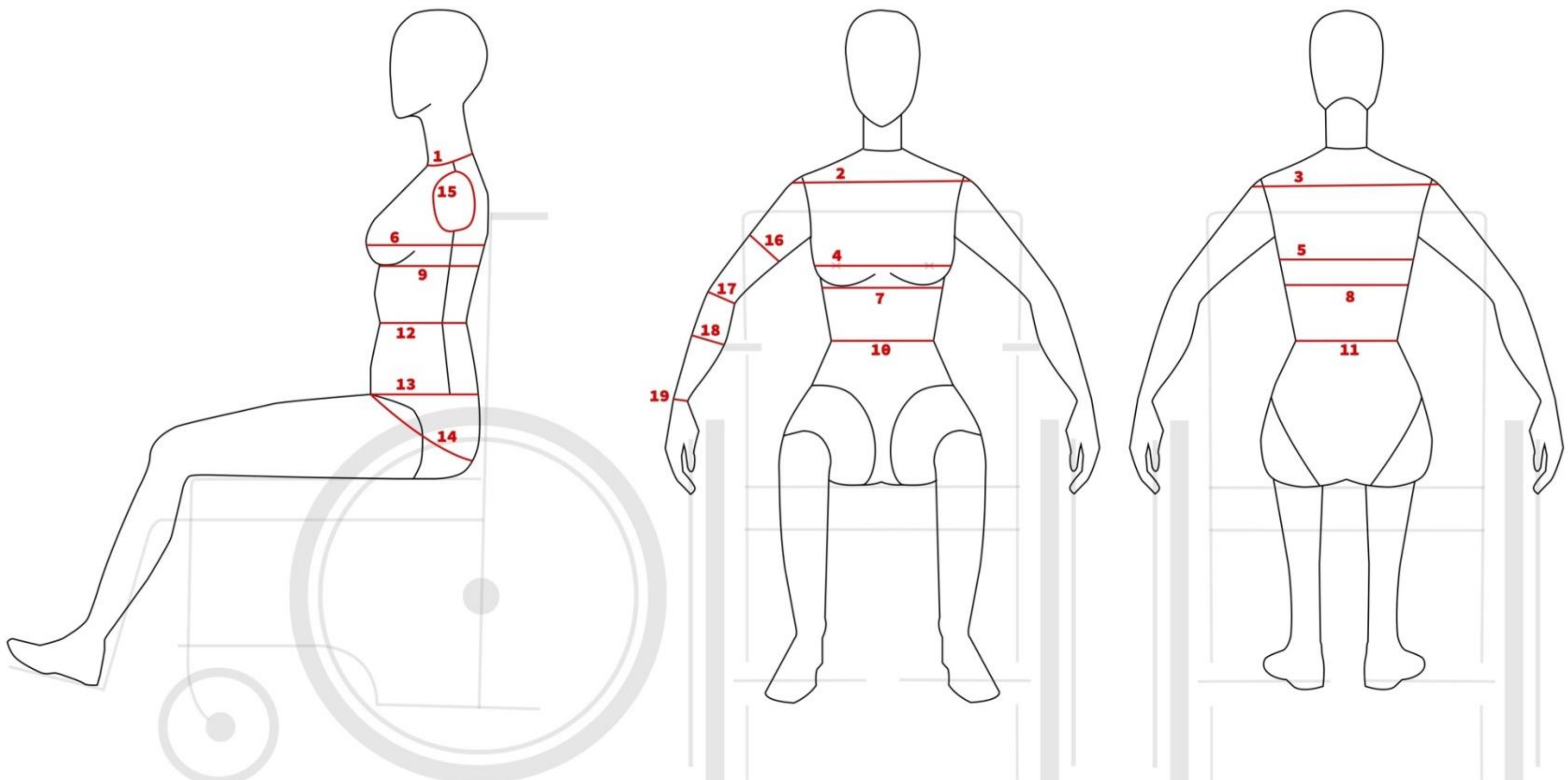
Key Body Landmarks



Participant Measurement Form: Circumferences

Ref. #	Location	Description	Measure 1	Measure 2	Measure 3
1	Neck Base Circumference	Front Neck Base to Front Neck Base Full Measure			
2	Front Shoulder Circumference	Left Shoulder Edge to Right Shoulder Edge in Front			
3	Back Shoulder Circumference	Left Shoulder Edge to Right Shoulder Edge in Back			
4	Front Bust Circumference	Left Side Bust to Right Side Bust in Front			
5	Back Bust Circumference	Left Side Bust to Right Side Bust in Back			
6	Full Bust Circumference	Side Bust to Side Bust Full Measurement			
7	Front Underbust Circumference	Left Side Underbust to Right Side Underbust in Front			
8	Back Underbust Circumference	Left Side Underbust to Right Side Underbust in Back			
9	Full Underbust Circumference	Side Underbust to Side Underbust Full Measure			
10	Front Waist Circumference	Left Side Waist to Right Side Waist in Front			
11	Back Waist Circumference	Left Side Waist to Right Side Waist in Back			
12	Full Waist Circumference	Side Waist to Side Waist Full Measure			
13	Full Lower Waist Circumference	Front Lap to Front Lap Full Measure			
14	Full Modified Hip Circumference	Front Lap to Seat to Front Lap Full Measure			
15	Armscye Circumference	Shoulder Tip to Shoulder Tip Full Armsyce Measure			
16	Full Bicep Circumference	Full Measure around Bicep, not flexed			
17	Full Elbow Circumference	Full Measure around Elbow, mild bend			
18	Full Forearm Circumference	Full Measure around Forearm, not flexed			
19	Full Wrist Circumference	Full Measure around Wrist, relaxed			

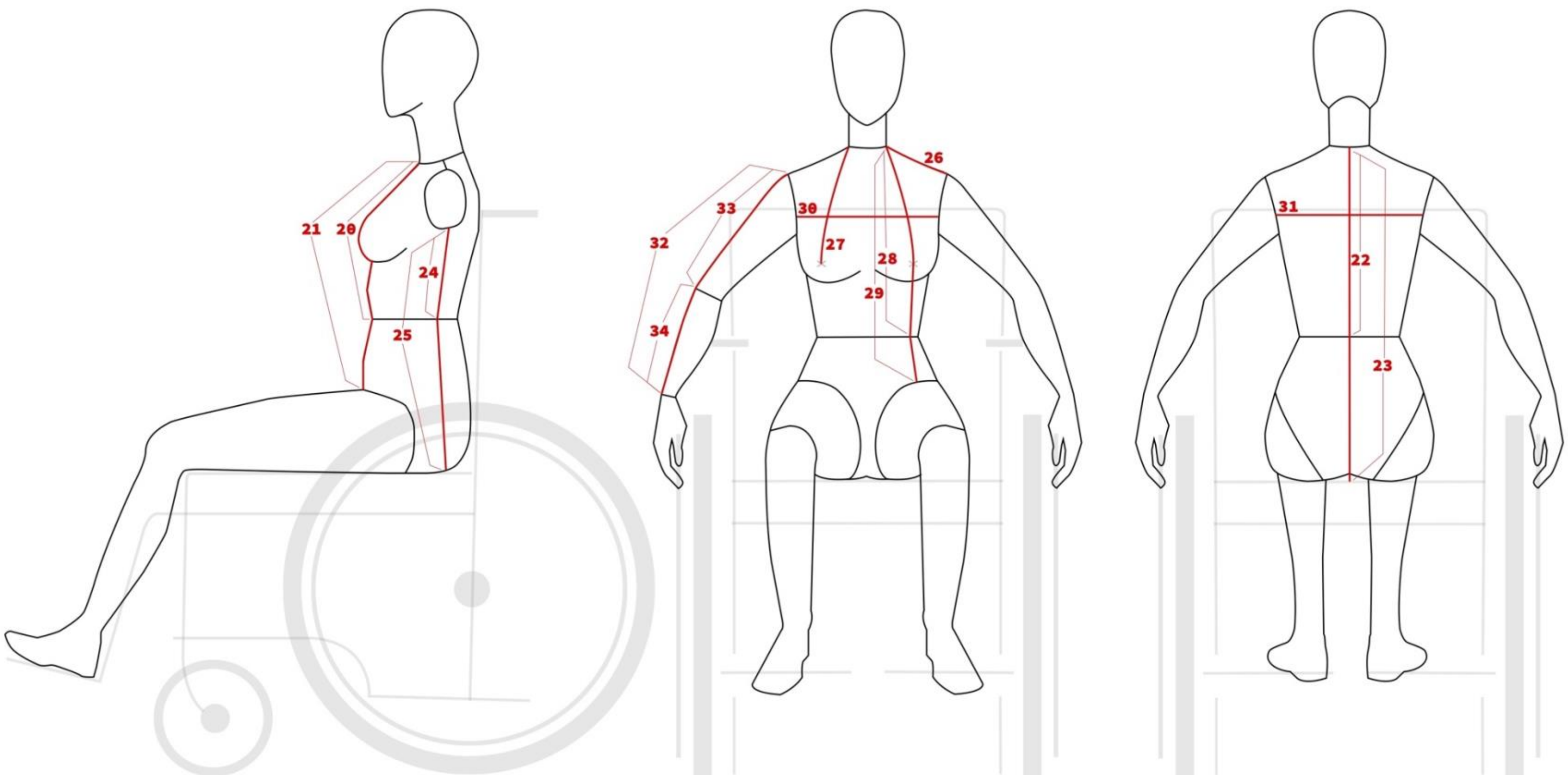
Circumference Measurements



Participant Measurement Form: Lengths

Ref #	Location	Description	Measure 1	Measure 2	Measure 3
20	Front Neck Base to Waist	Front Neck Base to Front Waist, measure at Center Front			
21	Front Neck Base to Front Lap	Front Neck Base to Front Lap, measure at Center Front			
22	Back Neck Base to Waist	Back Neck Base to Back Waist, measure at Center Back			
23	Back Neck Base to Seat	Back Neck Base to Seat, measure at Center Back			
24	Underarm to Side Waist	Underarm to Side Waist			
25	Underarm to Seat	Underarm to Seat (at side), measure over Side Waist			
26	Left HPS to Shoulder Tip	Left High Point Shoulder to Left Shoulder Tip			
27	HPS to Apex	High Point Shoulder to Apex			
28	HPS to Front Waist	High Point Shoulder to Front Waist, measure over Apex			
29	HPS to Front Lap	High Point Shoulder to Front Lap, measure over Apex			
30	Upper Front Width	Left Front Armscye Midpoint to Right Front Armscye Midpoint			
31	Upper Back Width	Left Back Armscye Midpoint to Right Back Armscye Midpoint			
32	Shoulder Tip to Wrist	Shoulder Tip to Wrist, measure with arm straight			
33	Shoulder Tip to Elbow	Shoulder Tip to Elbow, measure with arm straight			
34	Elbow to Wrist	Elbow to Wrist, measure with arm straight			

Length Measurements



APPENDIX D:

EVALUATION INTERVIEW

1. Alterations/Issues
   a. What alterations need to be done to the jacket?

   b. What would be the best way to get those alterations done, in your opinion (should I do the alterations, would you want someone locally to do the alterations, etc.)?

   c. What kind of issues or problems does the jacket still have? How could those be fixed/improved?

   d. Do you think that this jacket will pass the Equipment Control? If no, why not?

2. Self and Culture
   a. How do you like this new jacket? Elaborate as much as you'd like!

   b. After alterations, could you see yourself wearing this jacket for training and competitions?

   c. What kinds of opinions do you think other Paralympic and Olympic shooters will have of this jacket?

3. Questions about New Jacket and the Process
   a. You had mentioned in your first interview that when you ordered your Kurt Thune jacket, they didn't communicate a timeline for delivery to you. How do you feel about how often I communicated with you during this process? Was it too much, too little?

   b. If we could do this whole process again (imagine there is no pandemic), what kinds of things might you want me to do differently?

   c. Do you have anything else you'd like to say about the process that we went through together to get this jacket completed?

4. Jacket Performance (Functional Needs)
    a. Do you feel as though this new jacket could aid your performance in any way that your other jacket does not? If yes, how?
    b. Do you find this new jacket to be comfortable to wear?
    c. Is this jacket easy to take on and off?
    d. Once broken in a bit, does seem like it will be easy to adjust the buttons and shoulder take-ups on the jacket?
    e. Just from trying it on, do you think this new jacket will provide the stability you need for shooting?
    f. You had said that the canvas in your other jacket does a better job at keeping you stationary than the suede. Do you feel like because this jacket has only canvas in the body, that it may provide better stability?
    g. Do you think it will be easier to push your wheelchair in this jacket as compared to your other jacket? If yes, why? If no, why? What could be added to make pushing your wheelchair easier?
    h. Because of the upper back area being made from a moisture-wicking fabric, do you think this jacket will allow more breathability than your previous jacket?
5. Jacket Meaning (Expressive Needs)
    a. Do you feel as though this new jacket might give you the same sense of self confidence in your shooting performance that your other jacket does?
    b. Do you think you will feel confident on camera or in pictures while wearing this jacket?
    c. Do you think this jacket expresses your personality?

6. Jacket Aesthetics (Aesthetic Needs)
    a. Do you like the colors of your new jacket? Is there anything about the colors that you don't like? (I've sprayed this jacket with UV protection spray, so hopefully the colors don't fade as quickly as they did on your previous jacket, and stay vibrant for longer)

    b. We originally had some cheetah print planned for the lining of your jacket, and then you requested changing that to American flags. What affected that decision?

    c. How do you feel about the American flag print in the lining and on the outside of your jacket?

7. Is there anything else you want to add about the jacket, the process of this jacket being made, or anything else?

LIST OF ABBREVIATIONS

EC: Equipment Control

ISSF: International Shooting Sport Federation

FEA: Functional, expressive, and aesthetic

CAD: Computer-Aided Design

USA: United States of America