PERFORMANCE APPAREL FOR DRUMMERS: AN EXPLORATION OF USER NEEDS AND VIRTUAL PRODUCT DEVELOPMENT

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THESIS: PERFORMANCE APPAREL FOR DRUMMERS: AN EXPLORATION OF USER NEEDS AND VIRTUAL PRODUCT DEVELOPMENT

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ABSTRACT

Drumming, a popular activity for musical purposes, is a high-intensity physical activity that involves strenuous levels of physical demand. Due to its intense requirements and full range of associated health benefits, this activity has gained interest as an alternative means for physical activity; however, there is currently no apparel commercially available specifically designed for drummers to alleviate the extreme body temperatures experienced while drumming and no studies focusing on assessing their user needs despite the overall increased levels of physical demand. Thus, the purpose of this study was to assess the user needs of drummers to determine design factors and criteria for developing effective functional drumming apparel. User needs were assessed through a series of research, including an investigation of prior arts regarding musicians’ performance apparel, observations of drummers at concert type events, and in-depth interviews with professional drummers. Drumming apparel was developed through a series of virtual design activities, including the identification of design factors and criteria, development of preliminary design ideas, and virtual prototyping and fit evaluations. The results from the study revealed that musician performance apparel commercially available is limited and possesses three problem areas for drummers, body movement restriction, increased heat insulation, and decreased moisture transfer. Observations also revealed that increased muscular movement, heat production, and perspiration occurs at strenuous levels specifically at drummers’ upper body. Drumming apparel needs and preferences were identified through in-depth interviews and mobility, fit comfort, thermal balance, aesthetic, versatility, and ease of care were determined as
key design factors of drumming based on the user needs determined. Three drumming
tops were virtually prototyped and evaluated for garment fit to satisfy drummers’ needs
and design factors. The proposed design solutions met drummers’ needs and had
acceptable fit, as no areas of high pressure and tension were found, based on a final
design evaluation; thus, successfully addressing the problem areas of commercially
available apparel for drummers. This study has practical and theoretical implications for
designers, researchers, and manufacturers since it provides an efficient virtual design and
product development approach heavily guided thorough user research to develop
functional apparel solutions for understudied musicians and/or vulnerable groups facing
apparel problems, as well as contributes to the limited knowledge of musicians’
performance apparel in the apparel discipline and industry.
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While performing at Manchester’s Hard Rock Café, rock and roll hall of famer and drummer of The Faces and The Who, Kenney Jones, was rushed to the hospital to be treated for heat exhaustion after collapsing on stage (Neill, 2016). 25 minutes into the performance, Jones exerted himself during a drum solo due to a combination of vigorous physical activity, increased body temperature, and the extreme environmental heat being experienced on stage at the indoor venue, causing the collapse. Similarly, metal drummer Phil Taylor from Motörhead collapsed on stage three quarters into a performance at Irving Plaza in New York also due to heat exhaustion (Kozak, 1981). These instances reflect the increased levels of body temperature that are commonly experienced by drummers while performing due to the vigorous and high-intensity level of physical demands required.

Due to these intense requirements, aside from its musical purposes, drumming has further gained interest as an alternative means for physical activity. Approximately 2.5 million Americans have participated in some form of drumming and in 2020, an estimated 106,000 drum kit units were sold in the United States alone (Fortuna, 2018; National Association of Music Merchants, 2021). Studies have associated drumming with a full range of health benefits, including improved immune functions, reduced blood pressure, and boosts in cardio and mood (Fancourt et al., 2016; Mungas & Silverman, 2014; Smith et al., 2014). However, physical activity is a main disruptor of the body’s
temperature and thermoregulation system as it increases heat production and body temperature beyond the normal range (Gavin, 2003; Nagashima et al., 2012). In addition, prolonged and/or vigorous physical activity can rapidly increase body temperature to extreme and dangerous levels which can lead to various impairing health conditions, such as heat exhaustion and exertional heat illness, as experienced by famous drummers Jones and Taylor (Casa et al., 2015; Périard et al., 2021).

**Statement of Problem**

Drumming requires prolonged and vigorous amounts of physical activity which cause an extreme increase in body temperature due to the constant mobility and intense physical demands (De La Rue et al., 2013; Romero et al., 2016; Vellers et al., 2015). Body temperature must be properly regulated in drummers to avoid prolonged heat increases which can negatively affect the body and performance. Apparel can aid the body regulate these increases since it directly interacts with the body, serves as a cushion between the body and external environment, and maintains thermal balance depending on the wearers’ heat production or heat lost (Watkins & Dunne, 2015). During any type of physical activity, apparel must properly transfer the increased volumes of heat, as well as the moisture produced, to the external environment to maintain the body cool, dry, and comfortable (Gavin, 2003). However, there is currently no apparel that is specifically designed for drummers to alleviate these extreme temperatures and no studies addressing drummers’ need of performance apparel despite the overall increased levels of physical activity.
demand. Thus, this study aimed to assess the user needs of drummers to determine effective functional apparel designs for drumming.

Statement of Purpose

The purpose of this study was to identify the key physiological effects of drumming and assess the user needs of drummers to determine design factors and criteria for developing effective functional drumming apparel. A three-stage design process by LaBat and Sokolowski (1999) was utilized and adopted as the theoretical framework to systemize the user research and design process.

Objectives

Objective 1: To identify the physiological effects experienced while drumming that can affect the design and development of drumming apparel.

Objective 2: To determine the user needs of drummers in relation to apparel that must be addressed in drumming apparel for the upper body while performing.

Objective 3: To identify the design factors of drumming based on the identified physiological effects of drumming and user needs of drummers.

Objective 4: To develop design criteria for functional drumming apparel based on the identified design factors of drumming.

Objective 5: To virtually design drumming apparel that incorporates the identified design criteria and satisfies drummers’ needs.
**Objective 6**: To virtually prototype drumming apparel and evaluate garment fit to assess the pressure and tension of the developed drumming apparel.

**Significance of Study**

Drummers are an important group that enable society to experience music through their musical performances. Multiple health benefits have been associated with music, including the strengthening of social bonds, reduced anxiety and depression, boosts in exercise performance, and a decrease in fatigue and pain (Cakmak et al., 2017; Huang et al., 2021; Karow et al., 2020; MacDonald, 2013). Furthermore, multiple studies have examined and identified drumming as an important type of physical activity that can provide multiple health benefits, as well as therapeutical and emotional effects (Bensimon et al., 2008; Dickerson et al., 2012; Ho et al., 2011; Winkelman, 2003). Yet a limited number of studies have focused on designing apparel for musicians to aid their overall performance (Birringer & Danjoux, 2013; Brunzetti, 2015; Sokolowski, 2020; Sokolowski & Lang, 2017). Further studies are needed to assess the specific user and apparel needs of this group to properly develop functional apparel products to potentially provide improved levels of thermal balance and comfort while performing. This study can assist future designers develop functional apparel for drummers, as well as other vulnerable or at-risk musicians and groups, that may experience increased levels of body temperature and physical demands. Moreover, this study can contribute to the increasing body of knowledge regarding drumming, specifically in the apparel discipline as it
expands the application of LaBat and Sokolowski’s (1999) framework into the apparel assessment of musicians’ needs and virtual design development and implementation.

**Definition of Terms**

**Design Factor:** factors that contribute functional benefits to a product to obtain the desired performance (Min et al., 2019).

**Drummer:** an individual who makes a series of strokes on a drum and/or drums that result in sound (Oxford English Dictionary, 2021).

**Drumming:** the action of making a series of strokes on a drum and/or drum kit that result in sound (Oxford English Dictionary, 2021).

**Functional apparel design:** a user-centered apparel design process used for developing functional garments based on the specific needs of the end user (Gupta, 2011; Lamb & Kallal, 1992; Watkins & Dunne, 2015).

**Thermoregulation:** an internal process that allows the human body to function properly by maintaining a normal core temperature near 37°C independent from the changes of the external environment (Cheshire, 2016; Gavin, 2003; Nagashima et al., 2012; Wendt et al., 2007).

**User Needs:** expressive, functional, and aesthetic criteria that a user requires from an apparel product to optimally perform a desired activity and/or function without limitations (Gupta, 2011; LaBat & Sokolowski, 1999; Lamb & Kallal, 1992; Watkins & Dunne, 2015).
Virtual Prototyping: the 3D development and simulation of a virtual garment that requires a 2D pattern, material type, and measurements and/or shape of a virtual avatar or model (Jhanji, 2018).
CHAPTER TWO: LITERATURE REVIEW

A review of the literature was conducted to provide a thorough background for the study. The review is structured under two themes: drumming and functional apparel design. The drumming theme includes three topics: 1) history of drumming, 2) drumming styles, and 3) physiological effects of drumming. The functional apparel design theme includes three topics: 1) functional design process, 2) design factors in functional design, and 3) 3D virtual prototyping technology in functional design.

Drumming

The action of making a series of strokes on a drum and/or drums that result in sound is referred to as drumming (Oxford English Dictionary, 2021). A drum is a musical instrument that generates sound through the vibration of a stretched membrane, also known as the drumhead, which covers one or both ends of the shell, a hollow cylindrical body. This instrument is classified as a membranophone, an instrument that primarily produces sound through a vibrating stretched membrane, such as bongos and tambourines (von Hornbostel & Sachs, 1961). However, drummers commonly use a combination of drums, cymbals, and other percussion instruments for this musical activity. Idiophones are instruments that produce sound through the vibration of the instrument itself, such as cymbals, cowbells, and woodblocks (von Hornbostel & Sachs, 1961).

A standard drum kit, shown in Figure 1, consists of a combination of such instruments and is commonly used in bands and/or ensembles for musical purposes
(Nicholls, 2003). The majority of drum kits in modern western music are designed to be played by striking the drums and/or cymbals with different devices known as beaters. These include hardwood sticks which are often used to play smaller drums, such as snare drums, and cushioned wooden mallets, which are typically used to play larger drums, such as bass drums (Lamb, 2018). To generate a distinct sound, drums are sometimes stroked with wire brushes or other types of beaters. However, other drums, such as the djembe, bongos, and congas drums, are meant to be played directly with the hands.

**Figure 1**

*Standard Drum Kit*

![Standard Drum Kit](image)

*Note.* 5-piece drum kit consisting of 1) bass, 2) snare, 3) tom-toms, and 4) floor tom drums with 5) hi-hat and 6) crash cymbals.

**History of Drumming**

Drumming is found to be the earliest known form of musical performance to mankind, tracing back to as early as 5500 B.C. where both hands and beaters were used
to perform on alligator drums (Liu, 2004; Thomas et al., 2011). In early civilizations, drumming was utilized for rather practical purposes such as religious ceremonies and cultural gatherings where ancient drummers were seen to perform in varying and organic positions but utilized minimal clothing (Burkhart, 2011; Catlin, 1844; Winwood Reade, 1864). Thus, early drummers were susceptible to multiple environmental conditions without proper apparel protection. However, by the 19th century drumming evolved into communication purposes for the military where drummers mainly performed in a standing position in large groups and wore apparel representative of their group association, such as military uniforms (Bensimon et al., 2008; Remington, 1889; Thompson, 1811). By the 20th century, drumming evolved into entertainment purposes and became a musical art form which further impacted drummers’ apparel to be an expressive form representative of their self and identity (Curran, 1996). Furthermore, drumming became a one-person operation with the development of the first drum kit by Ludwig Company which consequently changed drummers’ performance position from standing to sitting and raised the popularity of the activity (Ludwig, 2022; McCabe, 2018).

**Drumming Styles**

Drumming revolves around the classification of styles. This drumming classification is mainly driven by the different styles of music genres that exist, such as jazz, pop, rock, heavy metal, and punk (Curran, 1996). However, many of these styles are combined into larger categories based on the nature of their basic rhythm, tempo, and/or beat. Drumming styles can cause varying levels of body mechanisms and responses
among drummers due to the differentiating speed used to play each style of song (Romero et al., 2016). Although multiple drumming styles exist, this section focuses on the two main styles commonly found in the United States, jazz drumming and rock drumming, as well as the different body techniques and tempos used to perform each style as it correlates to drummers’ physical demands.

**Jazz Drumming**

The basic jazz drum beat is typically performed on the ride cymbal and consists of a cymbal sticking pattern of swinging triplets (Curran, 1996; Korall, 2000). The bass drum plays the one and three count and the snare drum plays the two and four count, while the hi-hat cymbals are closed, an operation done by the hi-hat pedal on the two and four count as well. The different variants within jazz, such as bebop, big band, Dixieland, and fusion, alter this beat’s speed and main application (Curran, 1996). Bebop, for example, uses a faster beat speed where the drummer plays multiple fills and solos which pushes muscular movement and endurance. Big band, also known as swing, has a slower jazz beat than bebop; however, this variant applies a swinging rhythm and technique where the drummer plays loud and with a lot of force which involves grip control and strength (Curran, 1996).

**Rock Drumming**

The basic rock drum beat consists of a straight eight note on the hi-hat or ride cymbal (Curran, 1996). The bass drum plays the one and three count and the snare drum plays the two and four count. Similar to jazz drumming, the different variants within
rock, such as punk, speed metal, progressive rock, and heavy metal, modify this beat’s speed and main application. Punk, for example, uses a double-time rock beat, meaning double the speed, with a straight quarter note on the cymbal, typically the hi-hats, to intensify the rock rhythm (Curran, 1996). As a result, drummers maintain a fast and continuous beat which pushes muscular movement and endurance twice as much as jazz drumming. Speed metal has a faster rock beat than punk with eighth to sixteenth note rolls where the drummer plays substantial amounts of fills and solos; the length of the songs can be considerably long (Curran, 1996; Romero et al., 2016). Thus, requiring prolonged and vigorous levels of physical activity.

**Physiological Effects of Drumming**

Drumming is considered a high-intensity physical activity that involves muscular movement which induces heat production and perspiration (De La Rue et al., 2013; Romero et al., 2016; Vellers, 2015). These body mechanisms and responses happen at strenuous levels mainly at drummers’ upper body as most of the body movement involved is found at the upper area. Thus, this section focuses on the key physiological effects experienced on drummers’ upper body and contributing factors which can further affect the intensity of such effects while drumming.

**Muscular Movement**

Four upper body areas are predominately involved in drumming in terms of muscular movement: a) the hand, b) forearm, c) upper arm, and d) shoulder. The hand is one of the highest used areas in drumming as it provides drummers the capabilities to
hold, maneuver, and control a drumstick, which is used to strike the desired drum and/or cymbal through finger and wrist movements (Lamb, 2018). The fingers and wrist are controlled by various muscles which begin at the forearm and extend through the wrist into the base of the fingers, Figure 2. Several studies have been conducted on drummers’ hand movements (Beveridge et al., 2020; Chong et al., 2015; Dahl, 2004; Dahl & Altenmüller, 2008; Fujii et al., 2009; Fujisawa & Miura, 2010). These studies have predominately examined how the muscles in the hand area affect drummers’ grips and strokes.

**Figure 2**

*Muscles of the Hand*

As previously stated, many of the muscles controlling the hand area begin at the forearm, Figure 3; hence, the forearm is also among the highest used areas in drumming.
Aside from aiding in wrist and finger movements, the forearm muscles provide grip strength. Grip strength is the maximum force produced by the forearm muscles (Nicolay & Walker, 2005). In terms of drumming, the various muscles in the forearm allow drummers to securely hold and grip a drumstick with strength (Chong et al., 2015; Lamb, 2018). Since the forearm plays a major role in hand movement, most studies that have focused on drummers’ forearm movements are in relation to hand movement and have similarly examined its effects on drummers’ grips and strokes (Dahl, 2004; Forman et al., 2019; Fujisawa & Miura, 2010; Goislard de Monsabert et al., 2012).

**Figure 3**

*Muscles of the Forearm*

![Muscles of the Forearm](https://www.britannica.com/science/arm#/media/1/35010/111229). CC BY 4.0.
The upper arm, similarly, is actively engaged in drumming. This body area allows drummers to extend and flex their arms through the elbow joint to reach and strike a desired drum and/or cymbal (Lamb, 2018). The upper arm is controlled by various muscles, as shown in Figure 4, including the commonly known tricep and bicep brachii muscles, which extend along the front and back portion of the upper arm (Lamb, 2018). The upper arm muscles act as a holder for the forearm through the elbow joint. Drummers’ upper arm movement has been examined mainly in relation to hand coordination and stroke intensity (Chong et al., 2016; Dahl, 2004; Golec et al., 2020).

**Figure 4**

*Muscles of the Posterior Upper Arm*

![Muscles of the Posterior Upper Arm](https://www.britannica.com/science/arm#/media/1/35010/121137). CC BY 4.0.

The shoulder, also known as the deltoid, plays an essential function in drumming. The shoulder is formed by three muscle heads, the anterior deltoïd, lateral deltoïd, and
poster deltoid, Figure 5 (Sakoma et al., 2011). These muscles aid in arm elevation, a process called glenohumeral elevation, which is an integral role in the mobility and stability of the shoulder joints and upper arm (Lawrence et al., 2017). In drumming, the shoulder allows drummers to lift their arms to reach for the desired drum and/or cymbal, as well as move their arms left to right for the same purpose. Drummers’ shoulder movements have been analyzed when motion or motor patterns of drumming strokes are examined (Altenmüller et al., 2020; Dahl & Altenmüller, 2008; Eriksen et al., 2018).

Figure 5

Muscles of the Shoulder

Note. From muscles of the shoulder; human muscle system [Image], by Encyclopædia Britannica, 2022 (https://www.britannica.com/science/shoulder#/media/1/541915/119225). CC BY 4.0.
Heat Production

Drumming, similar to other high-intensity and prolonged physical activities, produces significant amounts of metabolic heat (Wendt et al., 2007). This heat is produced by muscle contractions caused by the continuous muscular movements involved in physical activity (Nagashima et al., 2012). As a result, heat production and body temperature increase to extreme and dangerous levels beyond the normal range (Gavin, 2003; Nagashima et al., 2012). To control and alleviate this increase, the body uses various thermoregulation responses to dissipate heat and avoid heat stress. When temperature increases or heat stress is detected, the hypothalamus, a forebrain region whose main function is to maintain the body in homeostasis, sends a message to the nervous system to dilate the blood vessels near the skin’s surface, a process known as vasodilation, to maximize blood flow and move the heat from the body to the environment through the skin’s surface (Romanovsky, 2018; Watkins & Dunne, 2015; Wendt et al., 2007).

Several factors can further contribute to increases in body temperature and heat production while drumming. A study conducted by Romero et al. (2016) showed that the metabolic demands of heavy metal drumming were at higher levels when compared to pop and rock drumming (De La Rue et al., 2013). This was due to the differentiating muscles, techniques, and speed used to play the different tempo songs. Thus, drumming style and techniques, as well as the muscles used, can cause varying levels of heat production among drummers. González-Alonso et al. (1999) demonstrated that performing physical activities over a prolonged period in extreme hot environments causes fatigue and limits cardiac functions in cyclists. Similarly, a study conducted by
Özgünen et al. (2010) concluded that physical performance in football players in extreme heat conditions can decrease their performance due to heat stress. Concert events and performances for drummers can vary in locations, including outside and inside venues, halls, and festivals; hence, exposure to extreme environmental heat conditions, similar to other physical activities, is highly possible among drummers which can further affect thermoregulation responses and heat production.

**Perspiration**

To further dissipate the heat produced while drumming, the body utilizes evaporative cooling to transfer increased heat levels through perspiration, specifically insensible and sensible perspiration (Watkins & Dunne, 2015). Insensible perspiration refers to perspiration that evaporates from the skin’s surface without the creation of visible moisture droplets; thus, the body is unable to sense it is perspiring (Felsher & Rothman, 1945). Sensible perspiration refers to perspiration emitted to the skin’s surface in sufficient quantities that creates visible moisture droplets allowing the body to sense it is perspiring. Perspiration is activated when blood and skin temperature rise beyond the normal range (Felsher & Rothman, 1945). Sweat glands are then triggered by the hypothalamus to produce moisture droplets to further remove the excess heat from the skin’s surface and evaporate (Watkins & Dunne, 2015). During drumming, the increased levels of heat production and body temperature require perspiration to occur at excessive levels, which can affect comfort and further negatively impact and affect performance (Nagashima et al., 2012; Périard et al., 2021).
Several factors can further contribute to excessive perspiration while drumming. Studies have shown that anxiety causes perspiration (Dixon et al., 2017; Schneier et al., 2012; Wheaton et al., 2011). Musicians in particular are highly susceptible to and can experience performance anxiety throughout their careers (Braden et al., 2015; Kenny & Holmes, 2015). Kenny et al. (2012) found multiple patterns of anxiety including social, trait, and performance anxiety in orchestral musicians derived from their musical performances. Similarly, drummers can also experience anxiety, in relation to performing, which can influence their level of perspiration. Studies have also shown that apparel can act as a barrier for moisture transfer specifically during physical activity (Davis et al., 2017; De Sousa et al., 2013; Gavin, 2003; Wendt et al., 2007). In addition, the apparel worn while engaging in physical activity in extreme environmental conditions can further affect perspiration evaporation. Apparel can prevent drummers from properly dissipating the increased heat levels experienced through evaporation; hence, causing prolonged and excessive levels of perspiration which can affect their overall comfort and performance.

**Functional Apparel Design**

Functional apparel design, also known as functional product development, is a user-centered design process used for developing functional garments based on the specific needs of the user (Watkins & Dunne, 2015). This type of design relies heavily on user involvement in the early stages of the process to investigate, evaluate, and gather data regarding the users and their needs. Various studies have proposed different
functional design frameworks to facilitate the evaluation process of the wearers’ needs and establish design requirements and criteria (DeJonge, 1984; LaBat & Sokolowski, 1999; Lamb & Kallal, 1992). Consequently, multiple sources were evaluated to determine effective functional design processes to assess drummers’ needs and identify design criteria.

**Functional Design Process**

DeJonge (1984) introduced a design process specifically for functional design and proposed a framework to be used in an array of functional design projects. This seven-stage framework focuses heavily on the initial stage of the design process which entails an extensive investigation and exploration of multiple outlets and directions to clearly understand the design problem. Upon the completion of this stage, design criteria are identified to proceed with the development and evaluation of the product. DeJonge’s (1984) framework has been applied to different functional design projects including dance practicewear (Mitchka et al., 2009), firefighting coveralls (Huck & Kim, 1997), and cooling vests (Guo et al., 2017). The advantage of this framework lies on the emphasis placed at the initial stage, which facilitates the development of goals, design criteria selection, and product evaluation. However, the framework does not offer any further guidance towards the implementation of the final product to the market, which is a vital part in the overall product development process.

Lamb and Kallal (1992) extended the functional design process by proposing a framework that incorporated functional, expressive, and aesthetic (FEA) considerations. This six-stage framework focused particularly on the cultural context that is involved in
identifying and defining the specific needs of the user as it influences what consumers consider acceptable and appropriate to wear. This addition allows the framework to identify and cater to the needs of a variety of consumers such as athletes (Michaelson et al., 2018), plus-size women (Christel & O’Donnell, 2016), and adolescents with disabilities (Stokes & Black, 2012), which is highly advantageous. Lamb and Kallal’s (1992) framework further incorporated an implementation stage to the design process to involve manufacturing and production practices. However, the framework does not offer any further guidance for further product refinement that may be needed at this stage of the product development process.

LaBat and Sokolowski (1999) later developed a three-stage design framework based on the similarities found among other design processes in the architecture, environment, and industrial design disciplines. Based on their analysis, three common areas were identified and used for the framework: a) problem definition and research, b) creative exploration, and c) implementation. LaBat and Sokolowski’s (1999) framework extends the functional design process by including a redesign phase during the implementation stage where further suggestions from the users are explored in attempts to refine and improve the product. The addition of this phase is highly beneficial as it leads designers to reassess user needs, design criteria, and the design problem. Various functional garments have been developed using this design process, including body armor (Tung, 2008), a posture correcting shapewear (Lyu & LaBat, 2016), and liquid cooling hood (Kim & LaBat, 2010). Consequently, this design process was chosen for this study as it has been established as a framework for functional apparel design that includes the
critical and necessary design phases for the assessment of user needs and the development of effective functional apparel.

**Design Factors in Functional Design**

The use of design factors in functional design allows designers to interpret the needs of the user into concise dimensions to ensure all needs are satisfied upon the development of a user-centered product. Design factors are defined as factors that contribute functional benefits to a product to obtain the desired performance (Min et al., 2019). These factors are commonly defined through an extensive series of user research, including literature reviews, interviews, and surveys. The determined key design factors are then used as guidelines to properly meet user needs. Furthermore, the identification of design factors has been explored for the development of varying functional apparel, including protective gardening gloves (Koo et al., 2016), transformable party dresses (Ma & Koo, 2016), and horticulture (Min et al., 2019) and gait assistive (Koo et al., 2020) garments.

Based on the target user group, a wide range of design factors can be identified from user research. Koo et al. (2016) determined skin cut and protection, dirt and insect protection, ultraviolet (UV) ray protection, water resistance, dexterity, comfort in movement, breathability, ease of donning and doffing, durability, and ease of care as key factors for gardeners using gloves through interviews and surveys. Whereas, Ma and Koo (2016) identified style and occasion, dress length, size and fit, silhouette, color and pattern, neckline type, sleeve length, sleeve type, and pocket type as important factors for female party dress consumers through a literature review and surveys. Studies have
shown that the design development of functional apparel which is guided by such design factors has led to overall user satisfaction, indicating its importance in the functional design process (Koo et al., 2020; Park et al., 2021). In this study, the identification of design factors was similarly used to guide the development of functional drumming apparel to ensure drummers’ needs were properly satisfied.

3D Virtual Prototyping Technology in Functional Design

To further facilitate the functional design process, the use of 3D virtual prototyping for the development of functional apparel has been implemented due to its rapid visualization attributes and fit evaluation capabilities. Virtual prototyping enables the exploration of a design through 3D computerized software prior to the physical production of a garment (Jhanji, 2018). A 3D simulation of a virtual prototype or garment requires a 2D pattern, material type, and measurements and/or shape of an avatar or model. The simulation involves the stitching or sewing of the pattern pieces inside a 3D environment and material drape to achieve a realistic representation of a garment. To evaluate the fit of a virtual prototype, pressure and tension maps are used to depict the amount of contact area between the garment and avatar based on the properties of the material (Jhanji, 2018). Hence, enabling designers to further experiment and evaluate fit prior to physically producing a garment.

In functional apparel design, it is important to provide and achieve comfort in relation to physiological demands as it leads to user satisfaction and optimal performance (McCann, 2009). Pressure and tension maps in 3D virtual prototyping can potentially indicate such comfort levels as freedom of movement and strain-free compression can be
assessed through a color scale (Jolly et al., 2019; Teyeme et al., 2022). Commonly, a white color indicates no pressure and/or tension and a red color indicates high pressure and/or tension, transparent areas mean no contact. This evaluation provides designers with a rapid visualization of a garment’s tension, how stretched the garment is on the body, and pressure, how much the garment is pressing on the body, as well as potential areas of further improvement to enhance comfort and functionality.

Several studies aimed at designing functional apparel for specific target groups have used 3D virtual prototyping for its described capabilities. Hwang and Sanders (2018) successfully designed and evaluated activewear specifically for female boomer consumers for indoor physical activities virtually to aid with the design and evaluation process. Similarly, Teyeme et al. (2016) used 3D virtual prototyping to develop, evaluate, and improve the functionality of a tight-fitted shirt for cyclists to provide enhanced levels of compression for the user. Jolly et al. (2019) efficiently designed and evaluated a jacket and trouser for motorcyclists virtually to rapidly make pattern revisions and evaluate fit based on the complex positions involved in motorcycle riding. Furthermore, Hong et al. (2017) used a similar virtual approach to develop and evaluate garment blocks for consumers with atypical morphology for the design of custom and functional apparel. Based on its proven efficiency and success for functional design, this study used 3D virtual prototyping technology to facilitate the design process of drumming apparel.
CHAPTER THREE: METHOD

In this qualitative study with the objectives to assess drummers’ needs to determine effective functional apparel designs, a three-stage design process by LaBat and Sokolowski (1999) was utilized to systemize the needs assessment and design process. The theoretical framework consists of the following stages: 1) problem definition and research, 2) creative exploration, and 3) implementation. However, certain stages of the framework were modified to align with the objectives of this study. Due to the lack of theoretical background regarding drumming apparel, the current study mainly focused on exploring the design factors and criteria associated with drummers’ needs and potential apparel solutions to address such needs.

In stage one, a review of the literature, investigation of prior arts, observations, and interviews were conducted to obtain a comprehensive understanding of drummers’ needs and apparel problems faced. In stage two, design factor identification, preliminary design ideas, design criteria selection, and virtual design development were completed to adequately address their user needs and provide potential apparel solutions. In stage three, virtual prototyping and fit evaluations were completed to visualize and properly assess the proposed apparel design solutions. A flowchart of the design process for this study is presented in Figure 6.
Figure 6

Flowchart of the Design Process

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Stage One: Problem Definition and Research

The first stage of the design process, as outlined by LaBat and Sokolowski (1999), is to define the preliminary problem and initiate research to further define the working problem. The problem is commonly reinterpreted as research proceeds and requires user involvement. Additionally, the working problem is used to launch the creative exploration stage (LaBat & Sokolowski, 1999).

Problem Identification

To identify the preliminary problem, a literature review was conducted. Literature reviews provide valid means to identify potential gaps and problems in research since it draws from both quantitative and qualitative studies (Werkmeister Rozas & Klein, 2010).
In this study, the review of literature indicated that drumming causes multiple physiological effects, primarily muscular movement, heat production, and perspiration, which affect drummers’ ability to properly regulate their body temperature and achieve thermal balance. It was also revealed that several factors, including drumming style and techniques, environmental conditions, apparel, and psychological conditions, can further influence the intensity levels of such effects which can also affect drummers’ thermoregulation. Hence, there is a need for effective drumming apparel to aid and achieve both thermal balance and comfort for drummers.

**Working Problem Definition**

To define the working problem, an investigation of prior arts, including an academic, patent, and market search, for musicians’ performance apparel was conducted due to the lack of drumming apparel commercially available and studies aimed at designing apparel for drummers. The purpose of the investigation was to determine research and development that may influence the design of drumming apparel, as well as the scope, advantages, and disadvantages of performance products specifically targeted towards musicians. An online search was conducted using keywords “musician,” “performance,” and “clothing” in search engines Google and Google Scholar. Three areas were documented for the investigation: a) name of author and/or product, b) website and/or location of the thesis or product, and c) the main functions and any unique design elements and features of the product. The data were recorded and compiled into a list form in a word document.
The academic and patent search resulted in a limited number of studies designing apparel for musicians to aid their performance (see Appendix A). Sokolowski and Lang (2017) designed a correctional device for brass musicians in attempts to alleviate the symptoms experienced by pharyngoceles, a common condition caused by performing. Birringer and Danjoux (2013) explored the possibilities of designing apparel with audio wearable technologies for performing musicians to emphasize the importance of aesthetics and metaphysics of performance and audience involvement. Sokolowski (2020) also developed a jacket for musical conductors in attempts to improve mobility while performing based on the knowledge of the sport performance apparel market. Brunzetti (2015) designed a dress shirt for guitarists with openings for instrument straps to prevent wear and burn-off on the shoulder.

The market search also resulted in minimal companies focusing on apparel for musicians to aid their performance (see Appendix B); Coregami, Southeastern Performance Apparel, and Black Dress Code. These companies mainly offer formal wear for orchestral musicians. Similarly, minimal musician performance products were found; The Edward Shirt©, The Bernie Short Sleeve©, and Blank Performance Tee (see Appendix C). These evaluated products mainly claim enhanced mobility and cooling effects for musicians through the use of stretchable and smart materials with quick-drying and moisture-wicking capabilities. However, several design aspects of these products can be limiting and not suitable for drumming, including the garment fit and overall style.

Based on the literature review and prior arts investigation, a working problem was defined. Commercially available apparel poses three main problems for drummers: a) body movement restriction, b) increased heat insulation, and c) decreased moisture
transfer. Such problems arise mainly from the garment’s fit, fabrication, and style or design. Hence, to further understand the severity of the working problem, user research was conducted in attempts to provide apparel solutions for drummers and potentially aid their overall performance through apparel.

**User Research**

A series of research, observations and interviews, regarding the user were conducted to identify and comprehend drummers’ needs and apparel behavior and the physiological effects of the activity that affect such needs.

**Observations.** Naturalistic observations were conducted to assess and analyze drummers’ apparel and drumming behavior in natural surroundings. Observations are an advantageous method which provides additional insight of the interest group and their daily behaviors which cannot be obtained through any other type of method (Leedy & Ormrd, 2010). Furthermore, when understanding the needs of a user, observations may provide valuable insight which can aid in the interpretation of the collected data (Watkins, 1995). Drummers were observed while performing at nine public concert type events as it resembled a natural and common environment for drumming. Observed drummers were assigned a number and detailed field notes were recorded during the performances regarding the key body movements, body mechanisms and responses experienced, and common apparel used. A data summary table was created using Excel to systematically categorize and analyze the data. The drummer’s number was listed on the vertical axis and the date, event location, set duration, drumming style, and aspects
being observed were on the horizontal axis. Field notes were converted into a word
document where common characteristics were identified.

**Interviews.** To determine the user needs of drummers, qualitative one-on-one
interviews were conducted. A qualitative approach was ideal since limited information
was known about the topic and it provided an opportunity to gain new insight, develop
initial concepts, and discover problems within the phenomenon of interest (Leedy &
Ormrod, 2010). Convenience and snowball sampling were used to recruit participants
through word of mouth using the researcher’s personal contacts in the Southern
California area. A total of 10 interview participants were sampled purposively to fit the
given criteria regarding lifestyle and drumming habits. According to Creswell (2005), an
effective sample size for these types of interviews range between five to 25 subjects who
have direct experience with the phenomenon of interest. The criteria were as follows: a)
be a male as the majority of drummers in the music field are males (Smith, 2016), b) be
between the ages of 30 to 40 years as peak physical performance and maturity is achieved
at this age range for endurance activities (Stiefel et al., 2013), and c) have 17 years of
drumming experience performing with a band and/or ensemble to possess a professional
drummer status (Schlaffke, 2019). No additional data was found at the 10th interview;
thus, data saturation was reached (Saunders et al., 2018).

Interview participants received an email stating the purpose of the study and
confidentially information (see Appendix D). A consent form was included in the email
where participants were asked to sign the consent form prior to the interview (see
Appendix E). Institutional Review Board (IRB) approval was received (see Appendix F)
and one-on-one interview sessions were conducted online via Zoom Meeting™.
Transcribed interviews, informed consent forms, and data files regarding all participants in the study were stored in a password protected computer. Participants were designated a number to assure confidentiality during the data analysis process. A $15 gift card was provided as compensation to each participant. The interview consisted of 20 open-ended questions regarding drumming apparel behavior and needs, as well as five questions regarding the participant’s background information (see Appendix G), and followed a semi-structured format. This type of format was selected as it is an effective method intended to elicit additional responses and rich data (Bearman, 2019). The interview questions were developed based on similar studies that have focused on identifying the user needs of specific target groups and developing functional apparel designs based on identified design criteria (Bye & Hakala, 2005; Michaelson et al., 2018; Min et al., 2019; Steinhardt, 2010).

Thematic analysis was utilized to analyze the qualitative data from the interviews. This type of analysis is commonly used to analyze classifications and present themes related to data in a systematic way (Alhojailan, 2012). Moreover, thematic analysis can be used to detect and identify factors and/or variables that influence any problems raised by participants. Participant interviews were transcribed to text to analyze the data thorough coding. To become familiar with the data, transcriptions were read carefully several times as it assisted in the analysis and coding process (Braun & Clarke, 2012). To identify significant concepts related to drumming apparel among the transcriptions, open coding was used. Concepts were highlighted among the text in a word document and then categorized according to common characteristics and themes in Excel. A data summary table was also created in Excel to track the themes and further refine them into the
apparel needs and preferences of the participants. The table included participants’
important needs listed on the vertical axis and the transcribed interview responses on the
horizontal axis.

**Stage Two: Creative Exploration**

The second stage of the design process is the creative exploration stage which is
used to generate preliminary design ideas and impose constrains in the process of design
refinement (LaBat & Sokolowski, 1999). The data obtained from the first stage is
commonly utilized as a development guide to ensure user needs are met through the
development of viable prototypes.

**Design Factor Identification**

Based on the user needs and physiological effects determined, the key design
factors in drumming were identified for drummers to guide the design process and solve
the working the problem. This process was completed through an analysis of prior arts,
observation, and interview data which were translated into design factors. A visual
diagram was developed to reflect the association between the physiological effects
experienced by drummers and the design factors which influence the design and
development of drumming apparel. The physiological effects were positioned in an inner
circle and the design factors in an outer circle.
Design Criteria Selection

The key design factors determined led the identification of specific design criteria to properly fulfill and address the needs of the population. This process was completed through an analysis of the key design factors and physiological effects of drumming which were used as parameters to select design criteria which met drummers’ needs. The selected design criteria were used in the design development of drumming apparel. An interaction design matrix was generated in Excel to identify potential conflicts within the design criteria (Watkins, 1995). An expert in apparel design with 12 years of experience also analyzed and reviewed the design criteria for potential conflicts to ensure inter-rater reliability was present due to the subjectivity of the design criteria. Percent-agreement was used to calculate the agreement between the two raters by adding the number of criteria that received the same rating by both raters and dividing that number by the total number of criteria rated by the two raters. To interpret the percentage-agreement score, an agreement level of 70% or more was chosen based on literature as it indicates acceptable and good inter-rater reliability (Stemler, 2004).

Preliminary Design Ideas

Based on the determined design factors and criteria, preliminary design ideas were generated for drumming apparel that addressed the working problem and met drummers’ needs. A free-flow approach was adopted to brainstorm and generate functional possibilities and features for the development of drumming apparel. Preliminary design features were listed and explored through a review of literature for their potential advantages and capabilities to meet the identified design factors and design
criteria. All design ideas and features were considered and further refined in the
development stage.

**Design Development**

After the design criteria selection and exploration of design ideas, three drumming
top designs were developed virtually based on drummers’ needs. This process consisted
of creating 2D technical flat drawings to accurately illustrate the designs and
communicate all elements, construction, and specification aspects of the garments. In
apparel design, technical flat drawings are a universal detail-oriented and specialized
drawing that provides accurate and precise scaled information about a design to apparel
companies and manufacturers for pattern and physical prototype development (Lee &
Steen, 2014; Morris & Ashdown, 2018). A front and back view, as well as a detail view
of any special functional features, were developed of each design using Adobe
Illustrator™. All technical flat drawings were drawn to scale using a 1:8 scale.

**Stage Three: Virtual Implementation**

The last stage of the design process is the implementation stage where the focus is
narrowed to the actual process of producing a garment for marketing, sales, and usage by
the consumer (LaBat & Sokolowski, 1999). At the end of the stage, the working problem
should be solved or further improvements should be made to continue working towards
solving the problem. Based on the application of virtual technology in functional design,
in particular virtual prototyping, the implementation stage of LaBat and Sokolowski’s
(1999) framework was adapted to a virtual context.
Simulation of Prototypes

Based on the 2D technical flat drawings, virtual prototypes were developed to provide a detailed visual representation of the three developed designs on a male virtual avatar. All designs were simulated using 3D software Browzwear VStitcher™. The simulation process consisted of selecting an avatar, developing the 2D garment patterns of all designs in a 3D environment, selecting the proper material for the garments which accurately reflected the structure, weight, and fiber content, positioning the pattern pieces of each garment on the avatar, sewing each garment virtually by stitching and joining all seams together, and simulating the drape of each garment. Once the simulation was complete, digital renders, also known as images, of the front, side, and back view of the prototypes were captured.

Fit Evaluation

To assess the potential comfort level, in relation to the pressure and tension of the prototypes, a fit evaluation of each garment was conducted. The 3D software’s pressure and tension map tool were used for the evaluation. The pressure and tension evaluation process consisted of a 360° visual assessment of all areas of the prototypes, neck, shoulders, arms, and torso, to identify any high pressure and tension areas which could be problematic for the user. The analysis was completed on multiple poses on the avatar to replicate drummers’ common movements. These included 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting. To interpret the fit, a yellow color was chosen as the threshold for indicating acceptable pressure and tension based on the 3D software’s own color scale, white, through light blue, green, yellow, and orange to red,
and the identified specific needs and preferences of the user (Ailabouni, 2022). Digital renders of the front and back view of the prototypes in each pose using the pressure and tension mode were captured.

**Working Problem Evaluation**

To verify the working problem was resolved, an overall evaluation of the virtual prototypes was conducted in relation to the design element and features, as well as garment fit of the virtual prototypes. The process consisted of analyzing the problem areas identified and evaluating how the design solutions fulfilled each problem area. Upon the completion of the evaluation, the proposed solutions should provide effective drumming apparel that meets drummer’s needs and resolves the working problem.

**Validity and Reliability**

An aim of research is to develop studies with high internal and external validity, reliability, and low risk of potential biases (Leedy & Ormrd, 2010). Using triangulation methods increases the validity, strength, and interpretation potential of a study, reduces biases, and provides various viewpoints (Thurmond, 2001). In qualitative research specifically, triangulation is an essential concept as it aids in establishing the rigor, validity, and reliability of a study (Richards, 2015). Consequently, validity and reliability in this study was enhanced through the triangulation of data collection methods, including: 1) investigation of prior arts, 2) observations, and 3) interviews, as shown in

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1 Researcher has 4 years of experience in product development and technical design, specializing in garment fit and functionality.
Figure 7. Furthermore, using different methods to collect data results in a more complete understanding of a phenomenon (Carter et al., 2014). Hence, ensuring credibility as it provides an extensive understanding of the research problem and objectives of the study.

**Figure 7**

*Triangulation of Data Collection Methods*

*Note.* Approach used to analyze results using different methods of data collection.
CHAPTER FOUR: RESULTS AND DISCUSSION

A report and discussion of the results related to the analysis of each stage of the research process in this study is presented in this chapter. The results and discussion consists of three sections: 1) user research, 2) creative exploration, and 3) virtual implementation. The first section is divided into two parts: 1) observations and 2) interviews. The second section is divided into four parts: 1) design factor identification, 2) design criteria selection, 3) preliminary design ideas, and 4) design development. The third section is divided into three parts: 1) 3D simulation of prototypes, 2) 3D fit evaluation, and 3) working problem evaluation.

User Research

A series of user research was conducted to identify and determine the user needs of drummers and the physiological effects of drumming which influence such needs. User data were collected through observations and in-depth interviews and further utilized to gain a comprehensive and thorough understanding of drummer’ needs and successfully determine the important design factors and criteria of drumming apparel.

Observations

A total of 23 drummers were observed from December 9, 2021 to February 3, 2022 at nine events in both indoor (56.5%) and outdoor (43.5%) venue locations (see Appendix H). The average drumming performance was 42 minutes (M = 42.13, SD =
and the majority of the observed drummers used a rock drumming style (56.5%). Drummers using a rock drumming style on average performed for 40 minutes ($M = 40.23, \text{SD} = 9.58$) and those using a jazz drumming style performed for an average of 45 minutes ($M = 44.60, \text{SD} = 10.79$).

**Physiological Effects**

Three key physiological effects were observed to occur at strenuous levels specifically at drummers’ upper body. These included increased 1) muscular movement, 2) heat production, and 3) perspiration. Based on these observations, the corresponding body mechanisms and responses were translated into preliminary apparel needs to support the identified physiological effects of drumming, as shown in Table 1.

Increased muscular movement was observed at the arms, hands, neck, shoulders, wrists, and torso. The key body movements while performing consisted of lifting the arms, swinging the arms, bending the arms, crossing the arms, twisting the torso, bending the torso, wrist rotations, hand grips, and neck rotations. The concentration of muscular movement observed further confirmed the main body areas predominately used while drumming and justified why previous research has mostly focused on examining drummers’ specific movements at these areas, including the hand, forearm, upper arm, and shoulder, and its impact on performance, such as muscle cramping, loss of motor control, and tremor (Altenmüller et al., 2020, Beveridge et al., 2020; Chong et al., 2016, Fujisawa & Miura, 2010).

Due to the constant muscle contractions and movement involved in the performances, increased heat production was seen at the upper body which led to
perspiration and flushing of the face, an apparent redding of the skin combined with a warm sensation commonly caused by changes in blood flow due to physical activity (Izikson et al., 2006). Increased perspiration was observed at the face, neck, underarms, chest, and arms, while other specific areas were not visible due to the dark color apparel worn by the drummers and low lighting at the venue location. Additionally, drummers commonly used a small towel to wipe excessive perspiration from these areas; however, when not available, the sleeves from the garment worn were used to wipe the excessive perspiration in between songs.

The observed body responses in drummers may be signals of a state of dehydration. Dehydration is caused from the loss of excessive body water commonly due to increased perspiration in athletes while engaging in high-intensity and prolonged physical activity (Armstrong et al., 2007). Furthermore, one common symptom of dehydration is flushing, along with thirst, weakness, and fatigue. To avoid such state, drummers should attempt to replenish their fluids whenever possible as it can aid reduce body temperature, perspiration, and potential muscle cramping (Rothenberg & Panagos, 2008). Additionally, apparel worn for performances should be considered carefully as it can contribute to the retention of excessive heat.
Table 1

Observation Analysis of Drum Performances

<table>
<thead>
<tr>
<th>Body Mechanisms/Responses</th>
<th>Action</th>
<th>Apparel needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flailing of arms</td>
<td>Reach and strike desired drum and/or cymbal</td>
<td>Unrestricted movement of arms and shoulders</td>
</tr>
<tr>
<td>Twisting and bending torso</td>
<td>Coordinates and allows movement across all drums and cymbals</td>
<td>Ease of movement without clinging and riding up on body</td>
</tr>
<tr>
<td>Wrist rotations</td>
<td>Hold, maneuver, and control drumstick</td>
<td>Unrestricted movement of hands and wrists</td>
</tr>
<tr>
<td>Neck rotations</td>
<td>Hand-eye coordination to reach and strike desired drum and/or cymbal</td>
<td>Ease of movement without chafing and clinging on body</td>
</tr>
<tr>
<td>Flushing of face</td>
<td>Heat produced by constant muscle contractions involved in drumming</td>
<td>Facilitate heat transfer from body to environment to maintain body cool</td>
</tr>
<tr>
<td>Perspiration</td>
<td>High body temperature due to heat produced while drumming</td>
<td>Facilitate evaporation of moisture from body to maintain body dry</td>
</tr>
</tbody>
</table>

*Note:* Based on rock and jazz drummers at indoor and outdoor performances.

Common Apparel Used

A variety of garments were worn by drummers at the upper body which consisted of a range of different styles of multiple colors, patterns, and artwork. Additionally, the garment fit, sleeve length, and layering of garments, which can affect drummers’ body mechanisms and responses, varied considerably, resulting in dissimilarities among the apparel worn by drummers. Due to these inconsistencies, interview data was further needed to define their needs and preferences toward drumming apparel.

**Style.** Six garment styles were observed on drummers: t-shirt, vest, polo shirt, dress shirt, sport jersey, sweater, and no top worn. The majority of the drummers either wore some type of t-shirt (60%) or a button-down dress shirt (16%), shown in Figure 8. Different elements and characteristics of these styles can potentially affect comfort for drummers. The use of t-shirts for physical activity is highly common as they can be lightweight, comfortable, breathable, and absorbent, depending on the characteristics and
properties of the material used. For example, t-shirts made from cotton can retain high quantities of moisture while engaging in physical activity but lack quick drying capabilities, resulting in wet garments for extended periods of time; however, t-shirts made from polyester can wick away moisture which enable faster drying time, but are more prone to retain odor and microbial growth (Callewaert et al., 2014; Hooper et al., 2015). Furthermore, the use of button-down dress shirts for physical activity can be restricting in terms of mobility since woven materials with limited stretchability are commonly used and multiple seams, pieces, and fusibles are added for structure. Hence, affecting the surface roughness of the garment which can cause potential abrasion to the skin.

**Figure 8**

*Common Garment Styles Used for Drumming*

![Common Garment Styles Used for Drumming](image)

*Note.* n = 25.
**Fit.** Four types of garment fit were observed: regular, fitted, loose, and no fit, as no garment was worn. The majority of the drummers wore regular fitted (56%) garments, which refers to relaxed and straight cut garments with standard ease around the upper body; however, fitted (32%) garments, were also among the majority, as shown in Figure 9. Garment fit should be considered while engaging in any type of physical activity, including drumming, as it can affect thermal comfort based on the air gap thickness and the degree to which apparel encounters the body (Mert et al., 2017). Studies have associated the use of fitted garment with cooling effects due to their low air gap thickness and high contact area (Chen et al., 2014; Lee et al., 2020). However, if a garment is too tight or fitted to the body, the wearer can feel a sense of suffocation particularly while engaging in physical activity due to heat and perspiration production. Similarly, regular and loose fitted garments can also provide cooling effects but mainly through ventilation methods which are commonly achieved by openings on the garments, such as the neck and armhole, when they are larger in size and perforated fabrics, such as athletic mesh (Ho et al., 2016; Lee et al., 2007). Air gap thickness should also be considered in garments with more ease or looser fit as high air gap thickness can result in thermal insulation which can increase body temperature rapidly.
Sleeve Length. Four sleeve lengths were observed on drummers’ garments: short sleeve, sleeveless, long sleeve, and no top worn. The majority of the garments worn had short sleeves (48%) followed by sleeveless garments (34%), and garments with long sleeves (16%), shown in Figure 10. Freedom of movement is essential for drummers as they use complex movement patterns while drumming. However, different sleeve types can interfere and restrict mobility particularly in the arms. For example, the use of long sleeve formal uniforms by flight attendants restricts their mobility, such as extending the arms to reach for overhead compartments on aircraft, which hinders their ability to perform their job duties compared to casual uniforms consisting of a short sleeve t-shirt (Adomaitis & Johnson, 2005). Similarly, the use of raglan sleeves in full body swimsuits provide better freedom of movement at shoulders and arms for swimmers compared to dropped sleeves (Osiani et al., 2020). Sleeve length can also affect cooling effects since
the use of openings in garments increase air circulation. Hence, using sleeveless garments for drumming is beneficial as no additional material obstructs or covers the armhole opening, providing ventilation, and the use of short rather than long sleeves is preferred due to less material coverage at the armhole.

**Figure 10**

*Common Garment Sleeve Length Used for Drumming*

![Pie chart showing sleeve length distribution for drumming](chart.png)

*Note.* n = 25.

**Color.** Garments worn by drummers were in seven colors: black, white, gray, brown, tan, blue, and no color, as no garment was worn. More than half of the garments worn were black (60%), but other colors were also worn in lower quantities, as shown in Figure 11. Color may be an important factor to conceal and camouflage perspiration or self-body image issues while engaging in physical activities, including drumming. For example, dark color and patterned materials are preferred by men suffering from hyperhidrosis, abnormal excessive perspiration, as they conceal and make perspiration
stains less visible (Shayesteh et al., 2019). Similarly, black colored apparel has been worn to disguise and create slimming illusions (Finney, 2006; Lee, 2018). However, the use of certain colored apparel can impact the material’s temperature which may be transferred to the wearer’s skin. Studies have demonstrated that dark color apparel, in particular black, gain and absorb higher amounts of heat when exposed to solar radiation than light colored apparel, such as white (Kenny et al., 2008; Shimazakia et al., 2017). Hence, further contributing to increases in body temperature and affecting thermal comfort.

Figure 11

*Common Garment Color Used for Drumming*

Note. n = 25.

**Artwork.** Five artwork and embellishment types were observed on drummers’ garments: solid, graphic, motif, and no top worn. The majority of the garments were a solid color with no artwork or embellishment, shown in Figure 12, followed by garments with some type of graphic (28%), such as a band logo, lettering, and image. In drumming,
the use of solid garments may represent a similar meaning to orchestral musicians’ adoption of a concert black dress code, formal wear in a solid black color, for musical performances (Urbaniak & Mitchell, 2022). The main purpose is to provide uniformity between the orchestra ensemble and ensure the audience’s attention is on the music rather than on the visual appearance of the musician (Hagberg, 2003). However, the incorporation of artwork and embellishments on garments serves for decorative purposes and visual aesthetics. For drummers, this may be a sense of self-expression or self-identity. Studies have associated graphics on apparel, specifically on t-shirts, as a means of self-expression, such as ideological beliefs, sense of humor, and likes or dislikes; hence, becoming a symbol of their own identity (Cornwell, 1990; Darden & Worden, 1991). Yet musicians’ identities can be influenced by a specific music genre and its characteristics, such as beliefs, content, and aesthetic (Grossman, 1996).
Interviews

A total of 10 participants were interviewed with the use of purposive sampling in reference to the selection criteria. All participants were males between the ages of 30 to 40 years (M = 35.50, SD = 3.54) with music, management, and artist occupations and 17 years or more (M = 23.60, SD = 5.44) of drumming experience performing with a band and/or ensemble. The majority of the participants were of Hispanic (40%) descent and used a rock (70%) drumming style. Table 2 shows the demographic characteristics of the sample.
Table 2

Demographic Characteristics of Drummers

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Age</th>
<th>Occupation</th>
<th>Drumming style</th>
<th>Years drumming</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Caucasian</td>
<td>31</td>
<td>Touring musician</td>
<td>Jazz</td>
</tr>
<tr>
<td>P2</td>
<td>Hispanic</td>
<td>33</td>
<td>Self-employed</td>
<td>Extreme metal</td>
</tr>
<tr>
<td>P3</td>
<td>Hispanic</td>
<td>38</td>
<td>Musician</td>
<td>Hard rock</td>
</tr>
<tr>
<td>P4</td>
<td>Caucasian</td>
<td>36</td>
<td>Music teacher</td>
<td>Heavy metal</td>
</tr>
<tr>
<td>P5</td>
<td>Israeli</td>
<td>35</td>
<td>Touring musician</td>
<td>Punk rock</td>
</tr>
<tr>
<td>P6</td>
<td>Caucasian</td>
<td>40</td>
<td>Musician</td>
<td>Hard rock</td>
</tr>
<tr>
<td>P7</td>
<td>Hispanic</td>
<td>30</td>
<td>Artist</td>
<td>Punk rock</td>
</tr>
<tr>
<td>P8</td>
<td>Hispanic</td>
<td>40</td>
<td>Management</td>
<td>Punk rock</td>
</tr>
<tr>
<td>P9</td>
<td>Israeli</td>
<td>38</td>
<td>Musician</td>
<td>Jazz</td>
</tr>
<tr>
<td>P10</td>
<td>African American</td>
<td>34</td>
<td>Musician</td>
<td>Jazz</td>
</tr>
</tbody>
</table>

Note. \( n = 10. \)

Psychological Meaning of Drumming

Drumming had various psychological meanings for participants. At its essence, drumming was associated with providing a foundation for music and life. The musical activity was viewed as the universal pillar of rhythm and groove for a band and/or ensemble, as well as for human beings and everyday life. Such point of view is described by participant 8, “it’s [drumming] kind of this primitive instinct of rhythm and you hear it in everyday life… it [drumming] kind of transcends cultures and countries and borders and it's something that people can relate to… that feeling of rhythm and movement.”

Based on the ideas of providing human foundation, participants also correlate drumming with aspirational purpose and career drive which is harnessed by its motivational potential. “That's [drumming] my life. That's why I get out of bed. I've severely inconvenienced my life in every way to make sure I can play the drums,” narrates
participant 6 and participant 7, “I was lucky enough to be somewhat good at it and play in bands and do things that I never thought I'd be able to do.”

However, the majority of participants viewed drumming as a creative means for self-expression which provided them with a sense of individuality, as well as mental soundness. Participant 5 further explains this meaning:

It's the one thing [drumming] that keeps me sane. It's the one thing that I do that… can turn heads and I know when I play, it's like a showstopper type of act that I do and it's something that differentiates me from other people.

Through this medium, drummers are able to explore and communicate their feelings in a non-verbal, universal, and creative manner. This exploration further allows them to communicate and build connections with other individuals, in particular the audience, through their musical performances, as explained by participant 4, “It's a chance to have a voice in a way that people can connect with and just sort of create community through music and exchange meaning.” Many of the connections between drumming and participants are a result of emotional and sentimental attachment, such as memories, family, and other wordily entities. “I still play drums because that's the connection that I had with my cousin, so I don't want to give up something that I have that connection with him,” describes participant 2 and participant 4, “…it [drumming] is I guess, a chance to connect to a sort of more kind of spiritual sublime expression of myself to tap into a creativity and sort of a childlike wonder.”
**Psychological Importance of Drumming Apparel**

Mixed feelings were expressed by participants regarding the importance of specifically designed drumming apparel, despite the fact that they were highly aware of the strenuous and prolonged amounts of high-intensity physical activity required by drumming. Such beliefs were primarily influenced by the fact that there is a lack of importance given to drummers and their well-being, as explained by participant 7:

…the reason is because I feel like when it comes to drummers, they kind of get forgotten about to a certain point, because we're in the back. Even though I just finished saying we're the heart and soul of the band… they [drummers] just get thrown in the backburner and I feel like it's time that drummers get recognized in that sense and get catered to a little bit more because it is it's not easy. It's a tough instrument to play.

Hence, the concept of specifically designed drumming apparel appears difficult to comprehend and adopt by this musician group since they have continuously sacrificed and adapted to the thought that comfort may never be achieved. However, drummers are fully aware that such apparel product can be beneficial for their performance. Additionally, participants believe that apparel, in general, can potentially assist them perform better since it can provide them with some form of thermal comfort. According to participants, providing this comfort can alleviate stress, distraction, and anxiety associated with any physiological effects while performing; thus, assisting them to focus and perform at optimal levels, as described by participant 9, “…if I don't need to think
about or be distracted even for a millisecond, it just keeps you more engaged and more in
the moment, so the less things you need to think about while you're playing the better.”

**Drumming Apparel Behavior**

Drumming is practiced year-round regardless of environmental conditions; however, lack of space, convenience, and physiological factors can limit participants’ rehearsal frequency. Premised by the notion of drumming as a seasonless activity, participants’ drumming apparel reflects a minimalistic yet basic style which often includes a) t-shirts, b) jeans, and c) shorts. Minimal differences are exhibited by participants in dressing methods for rehearsals and musical performances. Worn-out casual, every day, wear is commonly preferred for rehearsing as the environment is more relaxed with fewer individuals around. However, event formality, concert type and size, as well as the band and/or ensemble aesthetic, can influence and determine participants’ drumming apparel, as explained by participant 1:

I'm kind of beholden to whatever the artist wants me to wear. I kind of have to match the style of whatever the artist is, you know, so I don't really have a lot to say necessarily, a lot of times they'll tell me what I need to wear on stage.

A change of clothes, including the top, bottom, and undergarments, is commonly performed by participants before and after drumming and conducting any other type of activity; more importantly, before and after performing at a concert event. Such behavior is highly dependent on the amount of heat and perspiration produced and venue factors,
such as the environmental conditions at the location, if separate cooling systems are
provided for musicians, and amount of heat generated on stage by the type of venue
lighting. A change of clothes is often packed and brought to musical performances, as
explained by participant 2, “If I'm drumming, usually I have two sets of clothes. So, I’ll
usually show up with my normal streetwear and always bring my socks in there
[backpack] with my shorts and my shirt and like a rag.” Although changing all clothes
after performing is preferred, convenience and privacy issues at venues, primarily lack of
dressing rooms, limits participants’ ability to do so. Hence, only the top is changed on
most occasions due to ease.

Various aspects of the drumming apparel worn are dissatisfactory for participants
which cause discomfort while practicing and/or performing. Discomfort was frequently
experienced by participants due to the garments’ lack of breathability, mobility, and
proper fit, resulting in restricting wet garments which adhere to their body. However, the
alteration and customization of these garments, such as cutting off sleeves and enlarging
armholes, by participants, allows for certain discomfort issues to be alleviated and
increase comfortability while drumming. Limited aspects of the drumming apparel worn
are satisfactory. Mainly, the smooth and soft hand feel of the garment’s material and any
material functionality, such as moisture-wicking and quick drying functions, were liked
by participants. Overall, participants have accepted and adapted to perform with such
issues because of the market unavailability of specifically designed drumming apparel.
Drumming Apparel Market Availability

Based on the minimalistic and basic style of the common drumming apparel worn, t-shirts, jeans, and shorts, the market availability is satisfactory and easily accessible, as described by participant 5, “It’s honestly, fairly easy [accessibility], just running shorts, and just a t-shirt.” However, participants are not searching and/or purchasing apparel specifically for drumming but rather search for garments which can transition into drumming apparel once their lifecycle comes to an end, as explained by participant 7:

Honesty, I've never actually went to the store and bought a t-shirt and was like, I'm gonna buy this specifically for drumming. It's like, I’ve bought it [t-shirt], I wore it and I saw that it was already starting to get runned down and then I cut off the sleeves and I’ll just use it to play tonight.

Sacrifices are continuously made by drummers as these types of commercially available garments do not possess the functionality needed for the high physical demands required by drumming. Additionality, availability challenges are faced by drummers of different body types, such as tall-thin and plus-size, as limited apparel options are available. Such issues are described by participant 4, “This [availability] is all affected by the fact that I'm six foot eight, so the market availability of clothes that fit me is lower than average in general,” and by participant 7, “For me, because I'm bigger, I feel like I jump through more hoops of trying to find clothes that are comfortable enough to play in and still can wear on a regular basis.”
The majority of participants did not search for a specific apparel brand for their drumming apparel. This behavior is affected by the fact that participants do not actively search and/or purchase apparel specifically for drumming; however, several basics and activewear brands were mentioned, including a) Under Armor, b) Nike, c) New Balance, d) American Apparel, e) Gildan, f) Hanes, g) Fruit of the Loom h) Rukka, and i) Brixton. Participants have used these brands for drumming as they have provided certain utilitarian benefits in the past, such as moisture management and cooling effects. Price is also an important factor which influences the selection and purchase decision of basic versus activewear apparel. Due to the lack of versatility in activewear apparel and its high price point, the majority of participants would rather purchase basic garments at lower price points which can be worn for multiple purposes and eventually transition into drumming apparel. Versality and multi-purpose features are more sought than specific brand names, as explained by participant 3:

…the athletic shirts, a lot of them, don't look nice enough to wear at a nicer gig where I do have to wear a button-up shirt and it's like you can't go up there with an athletic short sleeve shirt on that's gonna absorb sweat, because they're [band] gonna say no. I've just accepted the fact that… every year my stage shirts, black t-shirts, get recycled into practice shirts after a while and then, I buy new ones and then the practice shirts disintegrate, and they get thrown away and the whole process just starts over.
**Physiological Effects Experienced**

Participants experience similar physiological effects as drummers observed during the live performances. Increased muscular movement is mainly experienced at the upper body. Participants noticed such increased demands specifically at the shoulders, arms, torso, wrists, and hands. In addition, the legs and hips were also identified as highly involved. According to participants, several factors can affect the intensity of their muscular movement, including a) drumming technique, b) warm up and stretching techniques, and c) drumming style. Such effects were further explained by participant 8, “I definitely have to get everything moving and loosen up… because if I don't, when I play, my forearms will like cramp up and stuff… so it helps to stretch all that [upper and bottom limbs] out…” , and by participant 4, “…there can be fatigue or cramping, that's something that I work really hard to try to address with practice techniques so that it doesn't happen.”

Additionally, participants commonly experience excessive heat production. While the majority of participants described feeling excessive heat all over the body evenly, the face, chest, and back at the upper body were motioned to be more predominant, as well as the gluteal at the lower body while performing. However, performing at concert events, compared to rehearsals, requires additional activities to be completed prior to beginning the performance, as well as after completing the performance, which can contribute to the increased levels of heat experienced while drumming. These include but are not limited to a) loading and unloading the drum kit, b) transporting the drum kit to and from the performance stage, and c) setting up and disarming the drum kit and microphones. Participant 5 further explains this process:
…so, musicians, basically are a moving company, we get to the venue, we open the door, we grab our gear, and we load it in and load it out. There’s a lot of handwork before we even touch the stage. We are just carrying stuff around.

Consequently, excessive perspiration is also commonly experienced evenly throughout the body by participants. Specific body areas at the upper body are difficult to distinguish since the drumming apparel worn is typically drench in moisture during and after performing. However, excessive perspiration at the face, chest, back, and underarm areas, as well as the gluteal, were noticed by participants to begin perspiring early in the musical activity, as described by participant 2, “it gets really hot on stage… so I'm already kind of sweaty just setting up the stuff and by the time I start playing, after the first song, it's [perspiration] already started. Second, third, fourth, I'm like drenched already.” Participants sense these excessive levels of perspiration through tactile cues, including the accumulation of perspiration droplets on the body and trickling down of droplets from the head to the gluteal, as described by participant 7, “…all this sweat just like gravitates towards the bottom… then the bottom it just continues to stay wet because everything's just falling down.”

Furthermore, participants also experience various side effects from drumming. Posture and musculoskeletal injuries and disorders have been faced by drummers which has affected their performance and led to musical breaks in their careers, as participant 9 narrates:
About a year ago, I experienced some issues with my neck… I noticed that I keep my head like this [facing down] when I play sometimes and then I kind of realized that that must have been a factor that kind of contributed to the injury… But in general, if you don't sit right and if you spend time playing shows with bad posture, you're going to experience some injuries or something adjacent to that.

Similarly, loss of hearing and traumatic and over-use injuries due to continuous exposure to loud sound and excessive impact and force on muscle tissues causes inflammation and pain which leads to challenges for participants, as explained by participant 8, “…my hearing is terrible… and I've been going to punk shows for 30, 33 years or 34 years now and it's like that and then playing drums for so long… I think it takes its toll on me.” However, drumming has also provided positive side effects including the release of endorphins and adrenaline for participants.

**Physical Appearance**

Appearance while performing on stage is perceived as a symbol of effort, care, and professionalism by participants. The majority view appearance as an important factor that encompasses their overall self-image in terms of gestures, movements, and visual aesthetic. Due to the high levels of physical demand required by drumming, the way body parts and limbs are flailed, as well as uncontrollable face and body expressions, are caused by the feeling of strain and stress from exertive performances; hence, affecting participants’ appearance. Participant 1 describes these effects:
I'm very concerned about the way that I look while I am drumming, mostly my face like that cliche drummer face. I'm concerned that I'm making a stupid face. So, I've actually… spent a lot of time working on the way that I look when I'm playing. The expression that my face is making or the way that I'm moving my head or flailing my arms.

Visual aesthetic was mostly associated with the ability of apparel to convey participants’ self and band image. While performing, drummers’ identity is communicated to the audience and surrounding world through the apparel worn as it reflects their affiliation to a certain group and/or classification, as explained by participant 6, “…it’s [appearance] important no matter how big or small the gig is… people look at me and say, that dude looks like he's in a band… I'm a drummer and that's what I do.” Similarly, drummers portray band image through the specific selection and use of drumming apparel to express a sense of belonging, as described by participant 3:

I want to make sure that what I'm wearing on stage is appropriate for the band that I am playing with, and it matches their image of what they want to present… I feel like I'm almost acting a certain role for certain bands… if I'm playing with a metal band, I have to dress a certain way.

A majority of the time participants take high consideration and must adhere to the special visual aesthetic requirements set forth by the band and/or ensemble when selecting and/or purchasing drumming apparel.
However, conveying such images involves choosing visual aesthetic over comfort. Although fit is considered by participants, overall visual appearance is considered more important than any other factor associated with comfortability. Such decisions are explained by participant 1:

…a lot of it's by choice, I just played this show the last week where I wore a turtleneck and a leather jacket and I was so hot, but I did it to myself, it was my fault because I wanted to look good and it was part of like the aesthetic of the band… the issue is that you either look like a dweeb and you're comfortable or you look good and you're uncomfortable.

However, appearance is not viewed as an important factor for certain music genres, such as punk and hard rock, due to their specific beliefs, content, and aesthetic characteristics, and while rehearsing, as there is a lack of audience that will criticize such appearance. These differences are important as the limited participants who viewed appearance as not critical, preferred being comfortable over visual aesthetic.

**Drumming Apparel Needs**

Based on the physiological effects of drumming, participants’ current drumming apparel causes various restrictions and limitations, Figure 13; a discussion regarding those limitations and issues follows. Firstly, apparel limits and restrict mobility and/or muscular movement while drumming, specifically at participants’ arms and legs. Hence, apparel should allow freedom of movement to avoid hindering and limiting drummers’
capabilities. Furthermore, apparel, such as long-sleeved t-shirts or button-down dress shirts, which provides excessive coverage at predominately used body areas causes restriction for participants due to the garment’s lack of flexibility and stretchability, as expressed by participant 4, “…if they're [apparel] too tight or if they're not stretchy… that does definitely create restriction and that can affect playing at peak performance.” Yet when minimum coverage is present on these body areas, commonly through the use of sleeveless t-shirts and shorts, participants experience lower levels of restriction, as expressed by participant 5, “…it [restriction] depends on the type of shirt of course… but when it’s sleeveless and it's just shorts, no limitations.” Thus, drumming apparel should provide minimum coverage and flexibility to aid with increased body movement.

Apparel also restricts and interferes with the transfer of heat to the external environment while drumming. In particular, participants’ chest, back, and legs remain excessively hot while and after drumming due to this heat restriction. Hence, heat transfer should be facilitated through the garment’s material to potentially prevent additional increases in heat production. However, additional factors, such as supplementary activities completed before and after musical performances and heat generated on stage by certain types of venue lighting, can further affect heat production. As a result, drumming apparel should also reflect radiant energy from the surrounding environment to deflect the heat from the body and maintain thermal balance. Participant 2 explains this restriction, “…if I'm of on stage, it's kind of inevitable, the heat just gets trapped where I'm at, because the lights really don't help that situation and sometimes you have a fan on stage and sometimes you don’t.”
Another main limitation caused by apparel for participants is the restriction and evaporation of moisture from the skin’s surface while drumming. Based on the high-intensity physical demands, perspiration is produced evenly throughout the body of drummers at excessive levels. The main areas that remain excessively moist are the back, chest, and face, as well as the legs and gluteal. However, the use of apparel during drumming represents a barrier to evaporation and absorption of moisture, resulting in wet garments. Participants are commonly forced to wear excessively drenched and wet garments while and after performing, which leads to discomfort due to the added weight and adherence to the body. Participant 9 describes such discomfort, “I sweat when I play, just my entire body… during the show, I feel like I'm sitting on wet pants and my shirt is stuck to my back. I have sweat running down my face, it’s gross and uncomfortable.” Hence, air flow should be facilitated by drumming apparel to aid with the evaporation of perspiration and wicking of moisture from the skin’s surface to prevent wet garments and limit the use of additional items, such as rags and towels, to remove excessive perspiration.
However, the majority of participants do not take into consideration these apparel and body needs when selecting and/or purchasing drumming apparel. This is mainly because comfortability is perceived as an afterthought and participants are not actively searching and/or purchasing apparel specifically designed for drumming. Commonly, they would rather repurpose and transition old and worn garments into drumming apparel since they will become unwearable with such high wear and tear. Additionally, visual aesthetic is highly preferred over comfort especially since participants recognize that musical performances and set durations do not surpass more than a couple of hours and uncomfortable garments can be changed immediately after a performance. Hence, sacrifices are continuously made since drummers are unaware of how to alleviate,
improve, and meet their own body needs. A limited number of participants, however, do take into consideration and attempt to address such issues and body needs. These participants were older in age and had more years of drumming experience and commonly experienced and/or suffered from excessive physiological effects while drumming.

**Drumming Apparel Preferences**

Preferences for drumming apparel were identified through a series of questions regarding the design and functional features of a top, shown in Figure 14. A round collar was preferred by all participants (100%) and the preferred type of collar was a crew neck (50%) as it provides easy donning and doffing during and after performing, as well as versatility. Additionally, a top opening (90%) for donning and doffing was preferred. Oversized armholes (70%) were preferred by the majority as larger openings aid with ventilation. A combination of sleeveless and short (50%) sleeve length options were preferred by half of the participants since both lengths aid with mobility and range of motion. A fitted (40%) and loose (40%) fit at the torso and arms were equally preferred mainly due to aesthetic, breathability, and ventilation attributes. An overall full length slightly below the high hip (80%) was preferred by the majority of participants since it provides coverage and prevents a garment from riding up while sitting and playing the drums. Participants had no preference (40%) in terms of the type of hemming and finishing that should be used for raw edges in a garment.
Figure 14

Drumming Apparel Needs and Preferences

- **Donning/Doffing**: top opening
  - universal and ease of use

- **Collar**: round crewneck
  - easy donning/doffing

- **Armhole**: oversized
  - aids with ventilation

- **Sleeve length**: short or sleeveless
  - aids with mobility and range of motion

- **Fabric**: breathable, absorbent, and soft
  - aids with perspiration, heat production, and movement

- **Torso/Arm Fit**: loose or fitted
  - visual aesthetic and aids with breathability and ventilation

- **Overall length**: slightly below high hip
  - avoids riding up when sitting/playing

- **Color/Pattern**: dark and solid material
  - provides versatility and ease of care

*Note*: Preferences of drummers between the ages of 30 to 40 years old.

Participants preferred fabric materials that were breathable, absorbent, and soft with quick drying and odor management capabilities to aid with the common physiological effects experienced. Additionally, dark (80%), solid-colored (80%) materials are preferred due to their versatility for performances of all music types and multiuse as soil stains will be less visible when laundering is limited due to touring and traveling. Materials with high stretchability (90%) are preferred by the majority as it aids with flexibility and mobility. Similarly, smart material technology is highly preferred by the majority of participants, including moisture (100%) and heat (90%) removal, with the exception of UV (10%) protection; however, such smart materials should not be reflective and/or shiny as it can affect aesthetic and be perceived as activewear. The use of perforated materials (70%), such as athletic mesh, were also preferred, as well as the
use of vents (60%) at the underarms (66.7%) and back (33.3%), to aid with ventilation and air circulation; however, such approaches should be concealed and not be highly visible since it can similarly affect aesthetic and resemble activewear. Additional functional features including pockets (10%) and adjustable and/or removeable sleeve (10%) were not preferred as they were seen as over design.

Creative Exploration

A series of activities were explored and conducted to determine the important design factors and criteria to virtually develop viable drumming tops that met drummers’ identified needs and preferences. Identification and selection processes were used to systematically guide the development of ideas and drumming apparel designs and an evaluation of the designs was conducted to ensure the development satisfied all criteria and user needs.

Design Factor Identification

The key design factors in drumming were determined for drummers based on their identified user needs and preferences. These included: 1) mobility, 2) fit comfort, 3) thermal balance, 4) aesthetic, 5) versatility, and 6) ease of care. The key physiological effects of drumming determined in the assessment allowed for the identification of important design factors which should be considered when designing user-centered drumming apparel, as shown in Figure 15. Mobility is highly important as it allows drummers to have a full range of motion in the upper body and its related muscles. Fit
comfort affects mobility since ill-fitted garments can cause restrictions and limit range of motion for drummers, as well as contribute to body temperature and perspiration due to potential thermal insulation. Consequently, thermal balance is a significant factor as drummers produce high levels of metabolic heat which must be regulated to perform at optimal levels. Aesthetic is also a significant factor as it further allows drummers to convey their self and band image in an appealing manner through apparel. Drummers often must transition between different bands and/or ensembles, as well as perform at different types of concert events; thus, versatility is crucial as it allows apparel to be worn for various activities, functions, and events. Ease of care is a significant factor due to touring and traveling since laundering is limited in such situations for drummers, yet soil stains and odor must be prevented.
Design Criteria Selection

The key user needs identified from the user research and key design factors and physiological effects experienced were translated and complied into design criteria for a drumming top. The design criteria were as follows: 1) provide heat and moisture management, 2) increase air flow, 3) minimal coverage at arms, 4) use knit and stretchable materials, 5) use stretchable and soft seams, 6) use dark neutral colors and patterns, 7) comfortable fit at torso and arms, 8) easy donning and doffing, 9) be aesthetically appealing, and 10) be easy to care and launder. To analyze the selected design criteria, an interaction matrix was used to identify any potential conflicts (Watkins, 1995), as shown in Table 3. The interaction matrix did not contain any.
unresolvable conflicts and good inter-rater reliability was found for the design criteria based on a percentage-agreement score of 80% between raters (Stembler, 2004).

Accommodations were needed for the minor conflicts identified. Providing heat and moisture management (1) was constrained by the need to be aesthetically appealing (9) and easy to care and launder (10). Smart materials with moisture-wicking and heat transfer technology are typically reflective and shiny which are perceived as not visually and aesthetically appealing by drummers. This issue can be resolved by using smart materials with a delustering finish to prevent such reflection and shine while performing on stage. Furthermore, laundering and caring for these types of materials may be an issue since they tend to be more delicate; however, adding different material finishes to the garment, such as antimicrobial and stain repellency, can limit the amount of odor and stains on the garments which would require minimal laundering. Hence, ensuring the wearer can easily care for the garment.

Increasing air flow (2) was conflicted by the need to be aesthetically pleasing. Ventilation methods in apparel primary consist of using perforated material panels and auxiliary systems which can resemble activewear. This resemblance is perceived as not aesthetically appealing to drummers since it portrays a different identity to the audience which does not reflect their affiliation to musicians and drummers. However, this conflict can be resolved by strategically placing ventilation systems at unnoticeable and inconspicuous locations on the garment. Similarly, having minimal coverage at the arms (3) was also constrained by the need to be aesthetically appealing. The lack of sleeves on garments can be viewed as informal at certain types of concert events since there is more
skin being exposed; thus, affecting aesthetic appeal. Providing a garment option which provides more coverage but does not affect mobility can resolve this conflict.

Table 3

*Interaction Design Matrix for a Drumming Top*

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<tr>
<th>Design criteria</th>
<th>1</th>
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<th>3</th>
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<th>10</th>
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<tbody>
<tr>
<td>1. Provide heat and moisture management</td>
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<td>2. Increase air flow</td>
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<td>3. Minimal coverage at arms</td>
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<td>4. Use knit and stretchable materials</td>
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<td>5. Use stretchable and soft seams</td>
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<td>6. Use dark neutral colors and patterns</td>
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<td>7. Comfortable fit at torso and arms</td>
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<td>8. Easy donning and doffing</td>
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<td>9. Be aesthetically appealing</td>
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<td>10. Be easy to care and launder</td>
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*Note.* 0 = conflict, 1 = accommodation, 2 = no conflict.

**Preliminary Design Ideas**

Based on the user research, as well as the investigation of prior arts, it is foreseeable that drummers may benefit from the development of effective and functional drumming apparel that can achieve thermal balance and comfort while performing. Preliminary design and functional features for such development were the use of smart material technology and ventilation methods, contrasting sleeve lengths and seam types, minimalistic styles with proper garment fit, and materials of dark neutral colors with distinct fiber contents and properties.
**Smart material technology and ventilation methods**

Thermal comfort can be achieved through the removal of heat and moisture from the body and air circulation. Moisture-wicking technology is designed to transfer moisture from the skin’s surface to the outer surface of the garment to facilitate evaporation and maintain the body dry and cool. Several studies have demonstrated its ability to decrease body temperature and high evaporative capabilities (De Sousa et al., 2014; Hooper et al., 2015; Miao et al., 2018). Phase-change materials (PCMs) technology has the ability to regulate body temperature automatically as temperature fluctuations are detected. PCMs activate and begin to absorb or release heat as they change from a solid to liquid state when the material senses an increase or decrease in temperature beyond their melting or solidification point to maintain the body cool (Mondal, 2008). Its success in achieving thermal comfort for users of spacesuits (NASA, 2012), firefighter suits (Shaid et al., 2015), and military uniforms (Lee et al., 2015) has been satisfactory.

Materials with perforations are used to increase ventilation for the wearer and aid the body dissipate heat and transfer moisture more efficiently (Ho et al., 2016). Increased ventilation is achieved as air enters the microclimate, the space between the body and garment, to create air circulation (Gavin, 2003). Ventilation panels, which can be developed through design, such as cutouts or slashes, or perforated materials, such as mesh, is another common approach used in activewear which has led to positive heat and moisture effects during physical activity (Ho et al., 2008; Ho et al., 2016; Sun et al., 2015). Auxiliary ventilation systems, such as fans and vents, allow air to circulate and flow easily into the garment to maintain the body dry and cool (Hilty, 2015; Otani et al., 2021). Studies have demonstrated that the incorporation of such systems in apparel can
decrease body temperature and aid with moisture evaporation (Barwood, 2009; Zhao et al., 2013).

**Contrasting sleeve lengths and seam types**

Mobility and flexibility can be achieved through the use of different sleeve lengths and seam types. No sleeves, commonly known as sleeveless, provide the minimum coverage needed to allow mobility and range of motion while also acting as openings to permit air flow into the body and improve ventilation. Studies have shown how apparel coverage, such as long sleeves on coveralls and flight attendant uniforms, can restrict mobility; hence, minimum coverage is preferred for activities requiring increased movement (Adomaitis & Johnson, 2005; Wang et al., 2019). Short sleeves provide higher coverage but do not fully restrict range of motion. Such coverage can potentially alleviate modesty and formality issues that may arise with sleeveless garments. Furthermore, the use of different versions of a short sleeve, such as a set-in sleeve and raglan sleeve, can affect the wearer’s mobility and range of motion (Son, 2019).

Seam performance, the strength, elongation, and elasticity of a seam, can influence the flexibility of a garment (Gurarda, 2019). The use of convectional and alternative sewing methods for the assembly of a garment can impact the bulk, strength, and abrasion of the seam (Jana, 2011). Superimposed (SSa) seaming with overedge or overlock, Class 500, and lap (LS) and flat (FS) seaming with coverstitch and flatlock, Class 600, are commonly used in activewear to enhance the strength and elasticity of a garment, as well as avoid thread breakage and seam slippage amid vigorous physical
body movement (Beaudette & Park, 2016; Lee & Steen, 2014). Welded seaming, joining and sealing of seams through thermal bonding, and bonded seaming, joining and sealing through glue bonding, are alternative assembly methods which are increasingly being used for activewear due to the reduced bulk, softness, and overall clean visual and aesthetic appearance compared to conventional threaded seams (Jana, 2011).

**Minimalistic style with proper garment fit**

Visual aesthetic and fit comfort can be achieved by designing apparel with minimalistic elements and features and proper fit at the torso and arms. For certain user groups, functionality is essential as it can meet their physiological needs and utilitarian expectations. However, excess features and functional elements can reduce the visual appeal of a product due to over design and lack of simplicity (Flood Heaton & McDonagh, 2017). Minimalist design enhances the expected utilitarian capabilities of a product without the use of increased functional elements and features (Hagen et al., 2021). Moreover, minimalist design can achieve a level of timeliness in a product which can influence its longevity and lifecycle, as well as lead to a visually easier comprehension of the product’s functions and capabilities (Flood Heaton & McDonagh, 2017). Hence, increasing overall visual appeal and aesthetic.

Fit comfort is associated with the garment’s ease of movement on the skin, amount of pressure applied on the body, weight of the garment, and air circulation (Das & Alagirusamy, 2010). Tightness and looseness on the body are the most commonly faced fit issues caused by garment size; however, style can also affect perceived comfort due to aesthetic aspects (Liu et al., 2022). Furthermore, in activewear, the use of fitted
and loose garments can vary based on the specific activity being performed as it influences air gap thickness, contact area, and overall comfort (Chen et al., 2014; Ho et al., 2016; Lee et al., 2007; Lee et al., 2020). To maximize comfort at the upper body, the torso and arms are the main area of focus. Range of motion and mobility must be accommodated by the garment’s sleeves and armholes which further affects the shape of the torso and overall visual appearance (Liu & Kennon, 2005).

**Materials of dark neutral colors with distinct fiber contents and properties**

Versatility and ease of care can be achieved through the use of materials in dark neutral colors with different fiber contents and properties. A neutral color refers to a color which lacks hues and color, such as black, white, and gray (Munsell, 1929). Dark neutral colors are commonly reflected in a classic style which is unchanging and endures visual appeal due to its versatility, simplicity, and practicality (Kwon, 2017). Color is also a selection and purchase variable among users which can be further affected by laundering. Compared to white color materials, dark colored materials reflect more light after the laundering process which in return is perceived by the human eye as experiencing less color change and deterioration, such as visible stains (Miśkiewicz, 2018). Furthermore, dark colored materials are highly preferred as they conceal and make perspiration stains less visible (Shayesteh et al., 2019).

Fiber content influences a material’s properties, dimension stability, and type and care required. In activewear, a wide range of knitted materials are available with enhanced fiber and surface properties to meet user’s needs in relation to moisture management, breathability, and heat transfer and comfort (Souza et al., 2016). The use of
synthetic fibers, such as polyester, and blended fibers is highly preferred over natural fibers, such as cotton, due to their ease of care, including wrinkle, microbial, and soil resistance. Furthermore, material finishes and smart material technology have further enhanced the properties of garments and enabled effort free garment care which can potentially reduce laundering and improve garment longevity and visual appeal.

Design Development

Three drumming tops were designed virtually using Adobe Illustrator™ to communicate all design elements, features, and specifications. This process was guided by the key design factors and criteria determined, as well as the preliminary ideas developed. A description of each drumming top (DT) follows: a) DT1 is a crewneck sleeveless top with a back button-up vent, b) DT2 is a crewneck short sleeve top with a back pull-up vent and underarm ventilation panels, and c) DT3 is a collared raglan short sleeve top with underarm zipable vents. All designs were evaluated to ensure the development met users’ needs and satisfied the key design factors and criteria.

Technical Drawings and Design Specifications

DT1. The top, shown in Figure 16, has no sleeves and oversized armholes to facilitate mobility and ventilation. Its regular fit provides a comfortable and proportional fit at the torso which does not limit flexibility during upper body movement. The top has a high-low hem line, with side slits, Figure 17, to provide proper coverage at the front and back torso while sitting down and performing. A button-up vent with an underlying mesh panel at mid-back facilitates ventilation. The vent can be buttoned up, shown in
Figure 17, when air flow is needed and buttoned down when not performing. The top is made from dual materials; a smart polyester/cotton jersey PCMs material at the upper portion to absorb the heat produced during the early stages of drumming and limit perspiration and a moisture-wicking material at the bottom portion to absorb excessive perspiration found in the lower torso and aid with drying time. The underlying polyester athletic mesh material at the back vent facilitates air circulation due to the perforations on the material when exposed. All major inside seams use bonded seaming to reduce bulkiness and abrasion to the skin and ensure comfort. Edge-finishing hemming with a 2-needle coverstitch, EFa Inv. 406, at the high-low bottom hem and coverseaming, SSh 406, at the collar ensure high seam flexibility and stretchability during donning and doffing. A dark solid color with a delustering, antimicrobial, and stain repellant finish is recommended to provide versatility and ease of care, as well as avoid any type of shine and reflection while on stage due to venue lighting.
Figure 16

*Front and Back View of DT1*

(a) front  
(b) back

*Note. 1:8 scale.*

Figure 17

*Details View of DT1*

(a) back button-up vent  
(b) high-low hemline with side slit

*Note. 1:8 scale.*
DT2. The top, shown in Figure 18, has short sleeves to alleviate modesty issues and oversized armholes to increase mobility and ventilation. Its regular fit provides a comfortable and proportional fit at the torso and arms which does not limit mobility and flexibility during upper body movement. The top has a high-low hem line, with side slits, as DT1. A back pull-up vent with an underlying mesh panel increases air flow and the underarm mesh panels facilitate ventilation to aid with perspiration evaporation, shown in Figure 19. The top is made from dual materials as DT1. The underlying athletic mesh material at the back vent and underarm panels facilitate air circulation due to the perforations on the material. All major inside seams use bonded seaming as DT1. Edge-finishing hemming with a 2-needle cover stitch, EFa Inv. 406, at the high-low bottom and sleeve hems and coverseaming, SSh 406, at the collar ensure high seam flexibility and stretchability during donning and doffing. The underarm mesh panels use flatseaming, FSa 607, to ensure high seam stretchability during body movement. A dark solid color and the same material finishes as DT1 are recommended.
Figure 18

*Front and Back View of DT2*

(a) front  
(b) back

*Note.* 1:8 scale.

Figure 19

*Details View of DT2*

(a) back pull-up vent  
(b) underarm mesh panel

*Note.* 1:8 scale.
**DT3.** The top, shown in Figure 20, has a foldable collar to alleviate formality issues and raglan short sleeves with oversized armholes to facilitate mobility. Its regular fit provides a comfortable and proportional fit at the torso and arms which does not limit flexibility during upper body movement. The top has a high-low hem line, with side slits, as DT1 and DT2. Underarm zipable vents with underlying mesh panels facilitate ventilation. The vents can be zipped opened, shown in Figure 21, when air flow is needed to aid with perspiration evaporation and zipped closed when not performing. The top is made from a smart polyester/cotton jersey PCMs material to absorb the heat produced during the early the stages of drumming and limit perspiration. The underlying athletic mesh material at the underarm vents facilitate air circulation and aid with perspiration evaporation due to the perforations on the material, as well as alleviates full skin exposure when performing. All major inside seams use bonded seaming as DT1 and DT2. Flatseaming, FSa 607, at the raglan shoulder, edge-finishing hemming with a 2-needle cover stitch, EFa Inv. 406, at the high-low bottom and sleeve hems, and coverseaming, SSh 406, at the collar ensure high seam flexibility and stretchability during donning and doffing. Zippers at the underarm vents are welded to the top to ensure comfort and reduce bulk and abrasion at the underarms. A dark solid color and same material finishes at DT1 and DT2 are recommended.
Figure 20

Front and Back View of DT3

(a) front             (b) back

Note. 1:8 scale.

Figure 21

Details View of DT3

(a) closed underarm zipable vent              (b) opened underarm zipable vent

Note. 1:8 scale.
Evaluation of the Design Development

To ensure the development of the tops satisfied drummers’ needs and the key design factors and criteria determined, an evaluation of the design elements and features follows. Mobility is addressed by using sleeveless and short sleeve options with oversized armholes and a combination of different seam types. The use of single knit jersey materials in DT1, DT2, and DT3 provide flexibility and stretchability during increased body movement. No coverage at the arms in DT1 ensures full freedom of movement and range of motion. The use of a set-in short sleeve in DT2 and a raglan short sleeve in DT3 does not limit mobility caused by the added coverage at the arms as the oversized armholes provide lift and ease of movement. The placket in DT3 at the foldable collar provides ease of neck movement when unbuttoned. A combination of general, flat, hem, and bonded seaming ensures all seams in DT1, DT2, and DT3 provide elasticity, stretchability, and flexibility amid vigorous physical body movement.

Fit comfort is addressed by using a regular fit at the torso and arms and alternative assembly methods, bonded and welded sewing. The regular fit in DT1, DT2, and DT3 provides an overall comfortable and proportional fit at the torso and arms due to the lack of tightness and/or looseness on the body and ensures air gap thickness is minimal to reduce mobility, thermal insulation, and comfort issues. The use of single knit jersey materials and bonded and welded seaming in all major inside seams ensures bulkiness caused by material layering and abrasion to the skin caused by body movement is decreased; hence satisfying overall comfort. Furthermore, the high-low hemline in DT1, DT2, and DT3 ensure length and coverage requirements at the front and back torso are satisfied based on body movement.
Thermal balance is addressed by using several heat and moisture management and ventilation methods. The use of dual smart materials, PCMs and moisture-wicking technology, in DT1 and DT2 ensure body temperature is regulated through heat transfer and the body is maintained dry through perspiration absorption at the specific body areas highly impacted in drumming. DT3 uses of a single smart material, PCMs technology, and ventilation method, underarm zipable vents; however, thermal comfort is not hindered as thermoregulation is provided during the early the stages of drumming which limits the amount of perspiration produced. The oversized armholes and functional vents then facilitate air flow to aid with the evaporation of any perspiration. The use of lightweight single knit jersey materials in DT1, DT2, and DT3 further ensure breathability. Similarly, the use of back vents with perforated materials in DT1 and DT2 and underarm ventilation panels and oversized armholes in DT2 and DT3 increase air flow which further facilitates thermal comfort.

Aesthetic is addressed by strategically incorporating design and functional features at inconspicuous locations and maintaining such features to a minimal. The use of vents at the back torso in DT1 and DT2 do not affect visual appeal as they are not visible while performing. The functionality of the vents provide camouflaging capabilities as the user can expose and conceal the perforated material as needed before and/or after a performance which minimizes any resemble to activewear. The use of vents and ventilation panels at the underarms in DT2 and DT3, similarly, do not affect visual appeal as they are small in size, not visible when not performing, and camouflage during performances when arms are lifted due to the small diameter of the perforations in the
mesh material. Furthermore, the use of bonded seaming allows for minimal visible stitches and prevents thread breakage and seam slippage which can affect aesthetic.

Versatility is addressed by providing simple and practical garment styles and recommending the use of dark neutral colors. DT1 and DT2 are a classic t-shirt with a universal crewneck collar that can be worn for various activities and functions. The lack of sleeves in DT1 make it appropriate for informal events and other types of physical activities aside from drumming. The use of short sleeves in DT2 provide more formality which makes it suitable for outerwear and underwear usage and any type of function, activity, and event. DT3 is a classic collared short sleeve shirt which can be worn for activities and events that require formality. The use of raglan sleeves and a foldable collar provide a more casual alternative to DT1 and DT2 which makes it versatile for informal and formal events and activities, including different concert types. Furthermore, the use dark neutral colors allow DT1, DT2, and DT3 to effectively complement other garment styles and transition between dress codes.

Ease of care is addressed by using blended fiber materials and recommending the use of dark colors and material finishes. The polyester/cotton blend material used in DT1, DT2, and DT3 ensures colorfastness and minimizes shrinkages and wrinkles. Additionally, polyester/cotton materials provide superior quick drying properties due to their synthetic and natural fiber nature which reduces drying care and are a middle ground for odor and microbial control compared to 100% polyester or cotton materials; hence, preventing odor and reducing laundering efforts (Rathinamoorthy et al., 2014; Xu et al., 2013). Using dark colors for DT1, DT2, and DT3 requires minimal care efforts when laundering is limited as soil stains are less visible on and off stage. The use of an
antimicrobial and stain repellent material finish prevents and controls bacteria growth which decreases odor, protects against stains, and reduces laundering needs due to the materials’ functionalities, as well as improves the durability and longevity of DT1, DT2, and DT3.

**Virtual Implementation**

The three drumming tops were prototyped virtually using 3D software Browzwear VStitcher™ to provide a detailed visual representation of the designs on a male virtual avatar and assess the garment fit of the drumming tops. A series of virtual activities were performed to properly simulate the drumming tops and ensure a proper fit was achieved.

**3D Simulation of Prototypes**

To properly create and simulate the prototypes of the three designs, a size 40” chest male avatar was selected as it represents the industry average male chest size standard in the United States, avatar body measurements are shown in Table 4 (Brown & Rice, 2014). 2D garment patterns for each design were developed in the 3D software based on the avatar’s body measurements and followed the 2D technical flat drawings. A 60% polyester and 40% cotton single knit jersey, 145 g/m², and a 100% polyester athletic mesh, 100 g/m², were selected and used for all prototypes since these materials’ properties ensure stretchability and breathability. Upon the completion of the 2D garment patterns, pattern pieces were arranged and positioned according to their common placement on the body on the avatar to prepare for sewing. To sew the garment pieces
together, all corresponding seams were virtually stitched together, as shown in Figure 22, and the drape was then simulated for each garment. Once the simulation was complete, material color was selected and trims and stitching details were added to the prototypes to provide a realistic representation of the garment. Dark solid navy, gray, and black colors were chosen as suggestions since these colors meet drummers’ needs and preferences. Final prototypes are shown in Figure 23 and measurement specifications in Table 5.

Table 4

Male Avatar Body Measurements

<table>
<thead>
<tr>
<th>Body Location</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>40</td>
</tr>
<tr>
<td>Waist</td>
<td>34(\frac{13}{16})</td>
</tr>
<tr>
<td>Hip</td>
<td>40(\frac{3}{16})</td>
</tr>
<tr>
<td>Neck</td>
<td>15(\frac{15}{16})</td>
</tr>
<tr>
<td>Shoulders</td>
<td>16(\frac{7}{8})</td>
</tr>
<tr>
<td>Bicep</td>
<td>12(\frac{3}{8})</td>
</tr>
</tbody>
</table>

*Note. Size 40 male avatar; all measurements in inches.*

Figure 22

Simulation Process of Prototypes

*Note. Placement of garment pattern pieces on avatar and virtual sewing of a) DT1, b) DT2, and c) DT3.*
Figure 23

*Final Drumming Top Prototypes*

Note. Front, side, and back view of a) DT1, b) DT2, and c) DT3.
Table 5

Measurement Specifications of Prototypes

<table>
<thead>
<tr>
<th>Point of Measure</th>
<th>DT1</th>
<th>DT2</th>
<th>DT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Across shoulder</td>
<td>14½</td>
<td>14½</td>
<td>-</td>
</tr>
<tr>
<td>Across front (5” fm HPS)</td>
<td>13⅜</td>
<td>13⅜</td>
<td>12⅛</td>
</tr>
<tr>
<td>Across back (5” fm HPS)</td>
<td>13⅜</td>
<td>13⅜</td>
<td>9⅜</td>
</tr>
<tr>
<td>Armhole</td>
<td>10⅜₁₆</td>
<td>10⅜₁₆</td>
<td>12⅜₈</td>
</tr>
<tr>
<td>Chest (1” blw AH)</td>
<td>20⅜₄</td>
<td>20⅜₄</td>
<td>20⅜₄</td>
</tr>
<tr>
<td>Waist (16” fm HPS)</td>
<td>20⅜₄</td>
<td>20⅜₄</td>
<td>20⅜₄</td>
</tr>
<tr>
<td>Front length (fin HPS)</td>
<td>27₁₁₁₆</td>
<td>27₁₁₁₆</td>
<td>28</td>
</tr>
<tr>
<td>Back length (fm HPS)</td>
<td>28⅘₂</td>
<td>28⅘₂</td>
<td>29</td>
</tr>
<tr>
<td>Bottom opening</td>
<td>20⅘₄</td>
<td>20⅘₄</td>
<td>20⅘₄</td>
</tr>
<tr>
<td>Neck width</td>
<td>7</td>
<td>7</td>
<td>7⅜₈</td>
</tr>
<tr>
<td>Front neck drop</td>
<td>3⅛₈</td>
<td>3⅛₈</td>
<td>3½</td>
</tr>
<tr>
<td>Back neck drop</td>
<td>1½₈</td>
<td>1½₈</td>
<td>1½₈</td>
</tr>
<tr>
<td>Sleeve length</td>
<td>-</td>
<td>8⅜₈</td>
<td>14⅘₄</td>
</tr>
<tr>
<td>Sleeve opening</td>
<td>-</td>
<td>15</td>
<td>15½₄</td>
</tr>
</tbody>
</table>

*Note.* Measurements based on 2D garment patterns; all measurements in inches; HPS = high point shoulder, AH = armhole.

3D Fit Evaluation

A fit evaluation of each prototype was conducted through the 3D software’s pressure and tension map tool. This tool showed a visual indication of material pressure and tension exerted on the body which differs based on the type of garment being assessed. A 360° assessment of all areas of the prototypes, neck, shoulders, arms, and torso was conducted to identify any high pressure and tension areas in the following body
poses: 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting. For a drumming top, colors ranging between a white and green are considered acceptable as drummers indicate a regular fit is preferred and needed.

**DT1**

The overall fit of DT1 was acceptable. No high pressure and tension areas, denoted by an orange and/or red color, were found within the prototype in any of the body poses analyzed, as shown in Figure 24 and 25. At the neck area, a light blue and green color was found which indicated minimal pressure and tension. A white and light blue color, minimal pressure and tension, was predominantly found at the upper portion of the torso. However, when the arms were spread, slightly higher pressure and tension was found at the chest compared to other poses, but it was still minimal. The prototype had no or minimal contact with the body at the lower portion of the torso as there was no color, transparency, observed. At the shoulders, similarly, minimal pressure and tension was observed as a white and light blue color were found, yet slightly higher pressure and tension was found when the arms were forward and spread. The overall pressure and tension observed in DT1 was acceptable and caused no issues.
Figure 24

Pressure Map of DT1

Note. Front and back view of avatar in the 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting pose; 6) color scale = red/high pressure; white/no pressure.

Figure 25

Tension Map of DT1

Note. Front and back view of avatar in the 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting pose; 6) color scale = red/high tension; white/no tension.
The overall fit of DT2 was acceptable. No high pressure and tension areas were found within the prototype in any of the body poses analyzed, as shown in Figure 26 and 27. At the neck area, a light blue and green color was found which indicated minimal pressure and tension. A white, light blue, and green color was predominantly found at the upper portion of the torso which also indicated minimal pressure and tension. However, when the arms were lifted, slightly higher pressure was found at the chest compared to other poses, but it was still minimal. The prototype had no or minimal contact with the body at the lower portion of the torso, except when lifting the arms, the contact was higher but caused no pressure or tension, white color. At the shoulders, minimal pressure and tension was observed as a white and light blue color were found except when the arms were forward and lifted which resulted in slightly higher pressure and tension, green color, but it was still minimal. Similarly, at the arms, minimal pressure and tension, light blue and green color, was observed at the sleeves yet when the arms were forward and lifted slightly higher pressure and tension were observed, light blue and green color. The overall pressure and tension observed in DT2 was acceptable and caused no issues.
Figure 26

*Pressure Map of DT2*

Note. Front and back view of avatar in the 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting pose; 6) color scale = red/high pressure; white/no pressure.

Figure 27

*Tension Map of DT2*

Note. Front and back view of avatar in the 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting pose; 6) color scale = red/high tension; white/no tension.
The overall fit of DT3 was acceptable. No high pressure and tension areas were found within the prototype in any of the body poses analyzed, as shown in Figure 28 and 29. At the neck area, a white, light blue, green color was found which indicated minimal pressure and tension. Similarly, a white, light blue, and green color was predominantly found at the upper portion of the torso indicating minimal pressure and tension. Slightly higher pressure and tension was found at the upper back when the arms were forward; however, it was still minimal. The prototype had no or minimal contact with the body at the lower portion of the torso as there was no color, transparent, observed, except when spreading and lifting the arms, the contact was higher but caused no pressure or tension, white color. At the shoulders, minimal pressure and tension was observed, blue and green color, except when lifting the arms. Similarly, at the arms, minimal pressure and tension was observed, light blue and green color, but pressure and tension were slightly higher when the arms were forward and spread. The overall pressure and tension observed in DT3 was acceptable and caused no issues.
Figure 28

Pressure Map of DT3

Note. Front and back view of avatar in the 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting pose; 6) color scale = red/high pressure; white/no pressure.

Figure 29

Tension Map of DT3

Note. Front and back view of avatar in the 1) arms down, 2) arms forward, 3) arms spread, 4) arms up, and 5) sitting pose; 6) color scale = red/high tension; white/no tension.
Working Problem Evaluation

To ensure the proposed virtual prototypes addressed the identified working problem and satisfied drummers’ needs, an evaluation of the garment fit and design elements and features of the prototypes follows. Body movement restriction was addressed through the use of sleeveless and short sleeve options, stretchable materials and seams, and proper fit at the neck, shoulders, arms, and torso (Adomaitis & Johnson, 2005; Beaudette & Park, 2016; Osiani et al., 2020; Son, 2019; Wang et al., 2019). No high pressure and tension areas were found within the prototypes at the upper body which could restrict body movement; thus, drummers can potentially perform all associated muscle and body movements without restriction. Increased heat insulation was addressed through the use of ventilation panels and vents, smart thermoregulatory materials, and proper contact area between the prototypes and the torso (Chen et al., 2014; Ho et al., 2016; Lee et al., 2007; Lee et al., 2020; Mert et al., 2017). Contact area was limited to the upper portion of the torso in most prototypes which reduces air gap thickness. Thus, drummers can potentially experience decreases in body temperatures while drumming due to the facilitation of heat transfer.

Decreased moisture transfer was addressed through the use of smart moisture-wicking materials and ventilation panels and vents at high prone perspiration areas which increase air flow to evaporate perspiration (De Sousa et al., 2014; Ho et al., 2008; Ho et al., 2016; Hooper et al., 2015; Miao et al., 2018; Sun et al., 2015). Minimal and/or no contact was found in all prototypes at the lower portion of the torso as increased air flow is needed to evaporate any accumulation of perspiration found at this particular area caused by sitting while drumming. Hence, drummers can potentially maintain the body
dry while drumming due to the facilitation of moisture transfer and increased evaporation. Overall, the proposed prototypes provide a potential apparel solution for drummers to properly regulate their body temperature and reduce perspiration without hindering mobility. Based on the evaluation it can be concluded that the working problem was addressed by all proposed designs.
Although drumming is considered a high-intensity physical activity, there is currently no apparel commercially available specifically designed for drummers to alleviate the extreme body temperatures experienced and no studies focusing on assessing their user needs despite the overall increased levels of physical demand. Thus, the purpose of this study was to assess the user needs of drummers to determine design factors and criteria for developing effective functional drumming apparel. A three-stage design process by LaBat and Sokolowski (1999) was utilized and adopted as the theoretical framework to systemize the user research and design process. User needs were assessed through a series of research and drumming apparel was developed through a series of virtual design activities.

An investigation of prior arts regarding musicians’ performance apparel revealed that musician performance apparel commercially available was limited and possessed three problem areas for drummers, these included body movement restriction, increased heat insulation, and decreased moisture transfer. Observations of drummers during live performances revealed the key physiological effects that occur at strenuous levels specifically at drummers’ upper body while drumming which could potentially affect the development of drumming apparel. These included increased muscular movement, heat production, and perspiration. Additionally, it was found that a variety of garments were worn by drummers at the upper body consisting of a range of different styles of multiple colors, patterns, and artwork; thus, interview data was needed to define their needs and
preferences toward drumming apparel. Yet, the majority of observed drummers wore a regular fit t-shirt with short sleeves in a black solid color material.

In-depth interviews with professional drummers further defined and revealed drummers’ apparel behavior and needs. The common drumming apparel worn reflects a minimalistic and basic style which often includes a t-shirt, jeans, and shorts. Discomfort is frequently experienced by drummers due to these garments’ lack of breathability, mobility, and proper fit, resulting in restricting wet garments which adhere to their body. Despite such discomfort, drummers have accepted and adapted to perform with such issues because of the unavailability of drumming apparel and importance of visual appearance. Appearance while performing on stage is perceived as a symbol of effort, care, and professionalism by drummers. Furthermore, apparel aids to convey drummers’ personal and band image which involves choosing visual aesthetic over comfort.

Drumming apparel preferences were also identified during the interviews. In a drumming top, these include a top opening and round collar, oversized armholes, short sleeves or sleeveless options, a fitted or loose fit at the torso and arms to provide breathability and aid with ventilation, and an overall length slightly below the high hip for coverage while sitting and playing the drums. Breathable, absorbent, and soft materials in dark solid colors are preferred due to their versatility for performances of all music types and multiuse as soil stains will be less visible when laundering is limited due to touring and traveling. The key design factors of drumming were determined based on the physiological effects of drumming and user needs of drummers. These included mobility, fit comfort, thermal balance, aesthetic, versatility, and ease of care.
Design criteria for functional drumming apparel were determined based on the key design factors of drumming, these included to provide heat and moisture management, increase air flow, minimal coverage at arms, use knit and stretchable materials, use stretchable and soft seams, use dark neutral colors and patterns, comfortable fit at torso and arms, easy donning and doffing, be aesthetically appealing, and be easy to care and launder. Three drumming tops, which satisfied drummers’ needs and design criteria, were virtually designed. A crewneck sleeveless top with a back button-up vent, crewneck short sleeve top with a back pull-up vent and underarm ventilation panels, and collared raglan short sleeve top with underarm zipable vents were virtually prototyped and evaluated for garment fit. The proposed drumming tops had acceptable fit with no observed areas of high pressure and tension which addressed the problem areas of commercially available apparel for drummers. Subsequently, the discussed results and proposed design solutions have practical implications for academia and industry.

**Implications**

For drummers primarily, this study provides them guidance to better understand their functional apparel needs and preferences in relation to drumming and the physiological effects experienced. Thus, potentially leading them to search and adopt drumming apparel that meets their specific needs and reduces the discomfort experienced while drumming. Additionally, it provides guidance to designers interested in the development of drumming apparel as the key design factors and criteria are outlined to
successfully fulfill drummers’ needs. In particular, drum brands and manufacturers can utilize the findings from this study to effectively develop and incorporate drumming apparel into their merchandise, as well as properly market drumming apparel to their consumers due to their immediate accessibility to the drummer population.

This study also extends LaBat and Sokolowski’s (1999) framework into a virtual implementation context through the use of 3D virtual prototyping. Hence, it aids designers and researchers reduce development time involved during the refinement of a design. Due to the lack of studies and commercially available apparel for certain user groups, the adapted framework in this study provides an efficient design approach heavily guided thorough user data to develop functional apparel solutions for understudied and vulnerable groups facing apparel problems. Furthermore, the findings from this study contribute to the limited knowledge of musicians’ performance apparel in the apparel discipline and extends LaBat and Sokolowski’s (1999) framework into the apparel assessment of musicians’ needs.

The virtual implementation used in study can further be adopted into an academic setting as a way of integrating a virtual component into the product development process. Learning such skill set can ensure designers have been prepared to explore the user needs of different groups to develop effective functional apparel in industry and implement such process in practice. Furthermore, virtual technology, specifically virtual prototyping, has been found be an advantageous teaching tool to enhance designers’ skill sets (Baytar, 2017; Dunne, 2012; Hodges et al., 2020). Hence, this study provides future designers guidance to approach design problems through a virtual product development process to further assist their creative practices.
Limitations

This study had limitations which should be acknowledged. First, there were theoretical limitations. Due to the lack of research studies regarding drumming apparel and drummers’ needs, relevant literature to provide a theoretical foundation to understand the research problem and needs was limited. Hence, the use of LaBat and Sokolowski’s (1999) framework and a triangulation data collection approach were needed to establish the required user needs of drummers. Second, there were sample limitations. Participant recruitment was limited to male drummers between the ages of 30 to 40 years in the Southern California area; hence, the results should not be generalized as physiological differences can exist between drummers of different gender due to muscle and body mass differences, age range based on aging, and region and/or location due the difference in environmental conditions.

There were also scope limitations. A virtual design and development approach was used for the implementation stage of the study; hence, no physical prototypes of the design solutions were produced and user tests were not conducted to ensure wearer acceptability. Lastly, there were technological limitations. The virtual avatar and poses used for the fit evaluations differ from human drummers and the actual drumming movements used as a virtual environment does not possess the identical physical characteristics of a human body. Based on the software’s capabilities, the virtual drape simulation of the prototypes’ materials is also limited even though parameters can be manipulated to closely imitate a physical material. Hence, the design solutions presented should only be considered recommendations and suggestions for drumming apparel until
further research and user testing is conducted to confirm the potential effects of the designs, as well as drummers’ acceptability.

**Future Research**

Based on the limitations of this study and current literature gap regarding drumming apparel, future research is needed. As a continuation of this study, a mixed method survey consisting of close and opened-ended questions regarding drummers’ attitudes and perceptions towards the proposed design can be conducted to further obtain feedback on potential areas of improvement prior to the physical development of the designs. Future studies can also focus on physically developing the proposed designs and comparing the virtual and physical prototypes for any fit discrepancies. Furthermore, user tests can be conducted to evaluate comfort and wearer acceptability during drum performances and the thermoregulatory effects of the proposed designs to analyze the level of thermal comfort provided compared to apparel commercially available to drummers. Findings can provide further insight into drummers’ needs, as well as additional areas at the upper body which should assessed in a drumming top and potential areas of improvement for the proposed designs.

This study focused specifically on the needs of male drummers at the upper body. Future studies can assess drummers’ lower body needs as the majority of participants in this study stated they experienced increased physiological effects at the lower body as well, in particular the gluteal. Hence, it would be beneficial to also develop drumming bottoms to provide drummers overall thermal comfort in both the upper and lower
portion of the body. Furthermore, although the majority of the drummer population is male, the user needs of female drummers should also be assessed as differences in physiology can exist compared to males as females commonly tend to have lower muscle mass and higher body fat than males which could affect the physiological effects of drumming (Blair, 2007). Findings can discover valuable differences between genders and provide female drummers viable drumming apparel.

Drummers also usually range based on the type of drums and/or drums used (von Hornbostel & Sachs, 1961). These include but are not limited to marching or drumline drums, drum sets, hand drums, and electronic drums. Future studies can investigate the needs of different types of drummers based on the specific apparel requirements for that particular drumming style. Findings can provide insight into the different type of drummer needs and the differences among drumming apparel used and needed for the drummer population. Furthermore, drum experience levels range among drummers which can affect the perceptions and attitudes towards the adoption of drumming apparel. Hence, futures studies can focus on analyzing drummers’ acceptance and adoption of drumming apparel and the differences among drummers with different professional and experience levels to provide insight into drummers’ apparel psychological attitudes.
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APPENDIX A. Academic and Patent Search


   This study developed and tested a thoracic and posture correctional device for brass musicians in attempts to alleviate the symptoms experienced by pharyngoceles. The design was inspired by a training device used by singers with adjustable nylon straps which focuses on the lower rib cage and back muscles without restricting the abdomen while taking breaths.


   Garments with audio wearable technologies were designed in this study for performing musicians. Small speakers, microphones, and sensors were attached to different garments, collars, bras, trousers, etc., to transmit sensory information to the audience through performances and increase involvement, aesthetics, and metaphysics.


   The study developed and tested a suit jacket for musical conductors to improve arm mobility. The jacket used a combination of different design elements, race suit-
floating sleeve, partial lining, and body zoning, performance materials, twills made of wool/spandex and nylon/spandex, and seams, overlock and superimposed, to enhance mobility.


This invention was designed to prevent wear, discoloration and burn-off on the shoulder of musicians and clothing worn. The long sleeve dress shirt has openings at the front chest and lower side back where the instrument strap can be inserted, as well as a strap holder at the lower back where the instrument strap can be stored when not in use.
APPENDIX B. Market Search

1. **Coregami.** Retrieved March 18, 2022, from https://coregami.com/

   The company has developed technical musician performance garments for formal stage events. The products claim to maintain musicians dry and cool while providing enhanced mobility and ease of care.

2. **Southeastern Performance Apparel.** Retrieved March 18, 2022, from https://sepapparel.com/

   The company offers basic and performance garments to be used for orchestra stage events. The performance products claim to have dry wicking properties to maintain the musician and/or artist cool.


   The company has developed black colored musician performance garments for formal stage events. The products claim to provide enhanced mobility for musicians, while using fabrics that are breathable and easy to care.
APPENDIX C. Musicians’ Performance Apparel Currently on the Market


   The garment claims to provide enhanced mobility based on the fit of the back torso, arms, and underarms. The long sleeve dress shirt has a pocket at the left chest, long tails to avoid lifting issues, a soft collar to prevent digging at the neck, and placket coverings at the center front and cuffs to avoid button rattling and glare during musical performances. The shirt is made from a patented fabric, Rubato™, that is 96% two-fold cotton and 4% elastane poplin which claims to be light and breathable to maintain musician cool.


   The garment is a performance t-shirt that has dry wicking properties to maintain the musician cool and offers a tearaway label feature. The t-shirt is made from an interlock knit fabric, no content is disclosed, and is meant to be worn as an undershirt for musicians.


   The garment claims to provide enhanced mobility based on the fabric’ stretchability, a four-way stretch, and maintain musicians cool and dry due to the added moisture wicking and ultra-fast quick drying properties. The short sleeve dress shirt has an open-shoulder design, similar to a raglan sleeve, to reduce friction and
increase range of motion, a solid fabric panel at the front of the shirt with no pleats, and flat seams to reduce chaffing. The shirt is made from a patented fabric, Fortissimo©, which is a lightweight, machine washable, odor resistant knit fabric with a perforated athletic look, no fiber content is disclosed.
APPENDIX D. Recruitment Email

Hello!

You are invited to participate in a research study, *Assessing the Apparel Needs of Drummers*, by completing a 60-minute interview. The study assesses the apparel needs of drummers in attempts to design functional garments based on the identified specific needs of drumming. You can participate in this study if you are a male, engage in drumming and have 17 years or more of experience, and are currently part of a band and/or ensemble where you are the drummer.

If you agree to participate, you will be asked to complete a one-on-one interview where you will be asked questions regarding your apparel needs while drumming, as well as some background information. A $15 gift card will be given as compensation for your time. There are no foreseeable risks from participating in this study. Your participation is voluntary, and you may choose to withdraw at any time. Your survey responses will be confidential and will NOT be linked to your name and email in any way.

A consent form has been attached to this email outlining information about the study, risks and benefits, and confidentially, and agreement to participate in the study.

If you have any questions or need further information about the study, please feel free to contact Irma Villanueva at idvillanueva@cpp.edu or Seoha Min at smin@cpp.edu

Your efforts in participating in this study are truly appreciated!

Sincerely,

Irma Villanueva
Department of Apparel Merchandising & Management
California State Polytechnic University, Pomona
APPENDIX E. Informed Consent Form

You are being invited to participate in a research study, which the Cal Poly Pomona Institutional Review Board (IRB) has reviewed and approved for conduct by the investigators named here. This form is designed to provide you - as a human subject/participant - with information about this study. The investigator or his/her representative will describe this study to you and answer any of your questions. You are entitled to an Experimental Research Subject’s Bill of Rights and a copy of this form. If you have any questions about your rights as a subject or participant, complaints about the informed consent process of this research study or experience an adverse event (something goes wrong), please contact the Research Compliance Office within Cal Poly Pomona’s Office of Research at 909.869.4215. More information is available at the IRB website, http://www.cpp.edu/~research/irb/index.shtml

Assessing the Apparel Needs of Drummers
Primary Investigator: Irma Villanueva Faculty Advisor: Seoha Min
IRB protocol # IRB-21-172

Voluntary Status: You have met the requirements for enrollment as a volunteer in a research study conducted by the researchers listed above. You are now being invited to participate in this study. Before you can make your decision, you will need to know what the study is about, the possible risks and benefits of being in this study, and what you will have to do in this study. The research team will discuss with you the details, and they will provide you this consent form to read. You may also decide to discuss it with your family and/or friends. Some of the language may be difficult to understand and if this is the case, please ask the researcher and/or the research team for an explanation. If you decide to participate, you will be asked to sign this form. Your participation is voluntary. You may withdraw any time without penalty and there will be no loss of any benefits to which you are entitled.

Purpose: The Primary Investigator states: “In my graduate program at Cal Poly Pomona, I am developing a project on the apparel needs of drummers. This study aims to assess the user needs of drummers to determine effective functional apparel designs for drumming.”

Procedures: You will be asked a few questions regarding your apparel needs while drumming, as well as some background information. A one-on-one interview will be conducted at a time and location that is convenient for you. With your consent, the interview will be audio recorded and transcribed to properly capture and maintain an accurate record of the discussion. After the raw data have been collected, all names will be removed. Your name will be assigned a code number. Only the code number will be left as identifiers.

Commitment and Compensation: Your total participation in the study will take one session, which will last approximately 60 minutes. You will receive a $15 gift card as compensation for your participation in the study.

Possible Risks and Benefits: It is expected that participation in this study will provide you with no more than minimal risk or discomfort, which means that you should not experience any more difficulty than what would occur in your normal daily life. However, there is always the chance of an unexpected risk. The foreseeable risks in this study include an accidental disclosure of your private information, or discomfort by answering questions that are embarrassing. If you feel
uncomfortable or distressed, please tell the researcher and she will ask you whether you wish to continue. You can withdraw from the study at any time without penalty.

You may receive additional benefits, aside from the $15 compensation, from participating in this study. These include learning and better understanding your apparel preferences and needs for drumming. Your participation is intended to add to the knowledge about drumming, in terms of functional apparel, and may lead to the availability of better functional apparel specifically designed for drummers. It may also benefit other people with similar concerns.

**Confidentiality and Consent:** The investigator and staff involved with the study will not reveal the personal information which they collect about you. Any information that is obtained in connection with this study -- and that can be identified with you -- will remain private and will be disclosed only with your permission or as required by law. Your identity will be kept strictly confidential by removing your name and all identifiers. Once the project is completed, all interview materials will be destroyed. Do be aware, that the results, in either a confidential or a summarized format, will likely be used to present at conferences and/or to write manuscripts for publication consideration to peer-reviewed journals.

**New Information:** During the course of this study, the investigators may discover information that could be important to you. They will notify you as soon as possible when such information becomes available.

**Consent:** I attest that I am at least 18 yeas of age and consent to participate in the study. I understand that my participation in this study is entirely voluntary and that I may refuse to participate or withdraw from the study at any time without penalty. I have received a copy of this consent form for my records.

Printed name of participant   Signature   Date

Printed name of participant   Signature   Date

*Signing here means that you agree to be audio recorded.*

Signature of primary investigator   Date
APPENDIX F. IRB Approval

Memorandum
California State Polytechnic University, Pomona
Institutional Review Board -- Office of Research Compliance
Federal Assurance 00001759 -- IRB principles: respect for persons, beneficence, and justice

Date: November 23, 2021
Pi Name: Irma Villanueva, Department/College: Apparel Merchandising & Mgmt, Extended University
Co-PI(s): Soho Min
IRB Protocol Number: IRB-21-172
Protocol Title: Assessing the Apparel Needs of Drummers
Protocol Submission Type: Initial, Review Board Type: CPP IRB members
Review Type: Expedited
Decision: Approved

Dear Investigator(s),

The protocol as described above has been reviewed by the Cal Poly Pomona Institutional Review Board (IRB) by the expedited review method. It was found to be in compliance with applicable federal and state regulations and Cal Poly Pomona policies regarding the protection of human subjects used in research. Thus, the Cal Poly Pomona IRB grants you approval to conduct the research. On its behalf, I thank you for your adherence to established policies meant to assure the safety and privacy of your study participants. You may wish to keep a copy of this memo with you while conducting your research project.

You may initiate the project as of November 23, 2021, and it must be completed by . Federal regulations limit the IRB approval of studies for up to one year. If you find the need to renew your protocol, please remember to submit a request to the IRB at least six (6) weeks before this end date to ensure continuous human subjects’ protection and IRB approval. The Cayuse system will remind you, however the responsibility lies with the study investigators.

It would be appreciated that you advise the IRB upon the completion of your project involving the interaction with human subjects. Please use the “Closure or termination of the protocol” form in the Cayuse system. Approval is conditional upon your willingness to carry out your responsibilities as the principal investigator under University policy. Your research project must be conducted according to the methods described in the final approved protocol. Should there be any changes to your research plan as described, please advise the IRB, because you may be required to submit an amendment (with recertification). Additionally, should you as the investigator or any of your subjects experience any “problems which involve an undescribed element of risk” (adverse events in regulatory terms), please immediately inform the IRB of the circumstances. There are forms for both in the Cayuse system.

These are additional notes, if any, from the Board:

The committee wishes you success in your future research endeavors. If you need further assistance, you are encouraged to contact the IRB.

Sincerely,

Kristen Schiele, Ph.D., MBA
Chair, Institutional Review Board
Associate Marketing Professor
College of Business Administration

This message has been automatically generated by the Cayuse system installed at Cal Poly Pomona. Please contact the IRB office (irb@cpp.edu or 909.866.4215 or .3713) if you have questions or you believe you have received this message in error. Thanks for your compliance with the regulations while conducting human subjects research. [2/13]
APPENDIX G. Interview Questions

Interview Date: ____________

Background Information
Participant #: _______________________________________
Age: ______________________________________________
Ethnicity:  __________________________________________
Occupation: _________________________________________
Drumming Style: _____________________________________
Years Drumming: ____________________________________

Questions
1. Do you play the drums year-round?
   a. If no, what conditions keep you from drumming year-round?
2. Describe what you would typically wear while drumming on an average day and while
   performing at a concert type event.
   a. Are there any specific aspects or areas about the attire that you feel dissatisfied
      with or dislike?
   b. Are there any specific aspects or areas about the attire that you feel satisfied with
      or like?
3. Do you change your clothes between drumming and performing any other activity?
   a. If yes, do you change all your clothes or only certain ones?
4. How would you characterize the market availability of clothes you would feel
   comfortable drumming in?
   a. Is there a specific brand that you look for?
5. Do you experience excessive body heat production while drumming?
   a. If yes, in what specific body areas?
6. Do you experience excessive sweat production while drumming?
   a. If yes, in what specific body areas?
7. Do you experience increased muscle movement while drumming?
   a. If yes, in what specific body areas?
8. Are there any other body responses or mechanisms that you experience while drumming?
9. Does clothing restrict or interfere with your body releasing the heat produced while
   drumming?
   a. If yes, what specific body areas does it restrict or remain hot while drumming
      due to clothing?
10. Does clothing restrict or interfere with your body evaporating the sweat produced while
    drumming?
    a. If yes, what specific body areas does it restrict or remain moist while drumming
       due to clothing?
11. Does clothing restrict or interfere with your mobility or muscle movement while
    drumming?
    a. If yes, what specific body areas are restricted from movement due to clothing?
12. Do you take into consideration the previously mentioned body needs when choosing or
    purchasing your drumming attire?
    a. Are there any other body needs you take into consideration?
13. Do you think about your appearance while drumming?
   a. If yes, what aspect do you think about or worry the most in terms of appearance?
   b. Does clothing play a role in your visual appearance while drumming?
   c. Do you take into consideration appearance when choosing or purchasing your drumming attire?
14. What would be your preference on the following features for a drumming top and why?
   a. What would be the proper overall length?
   b. What kind of collar would be appropriate?
   c. What would be the best sleeve length?
   d. What would be the proper armhole size?
   e. What kind of fit would you best on the torso and arms?
   f. What kind of hemming or finishing should be used for raw edges?
   g. What would be the proper type of fabric or material?
   h. Would pattern or solid fabric be best and what colors?
   i. Are there any other specific features that you would like in a drumming top?
15. What would be your preference on the following functional features for a drumming top and why?
   a. Would you prefer fabric materials with smart technology to remove moisture?
   b. Would you prefer mesh fabric to aid with ventilation?
   c. Would you prefer fabric materials with smart technology to remove heat?
   d. Would you prefer fabric materials with smart technology for UV protection?
   e. Would you prefer fabric materials that are highly stretchable?
   f. Would it be proper to have multiple pockets?
      i. If yes, what would be the ideal location?
         1. What type of closures would be appropriate?
   g. Would you prefer removable or adjustable sleeves?
      i. What type of closure would be appropriate?
   h. Would it be proper to have vents?
      i. If yes, what would be the ideal location?
      ii. Would functional vents be appropriate?
         1. If yes, what type of closures would be appropriate?
   i. What type of opening would be best for donning/doffing?
   j. Are there any other functional features that you would like in a drumming top?
16. What does drumming mean to you?
17. Do you believe there should be apparel specifically designed for drumming?
   a. If yes, why?
18. If you could have a clothing item made specifically for you to drum in, what would it be and what would it look like?
19. Is there any way apparel can assist you perform better while drumming?
20. Is there anything else you would like to add or have any additional comments?
<table>
<thead>
<tr>
<th>Drummer</th>
<th>Date</th>
<th>Event Location</th>
<th>Set Duration</th>
<th>Drumming Style</th>
<th>Apparel Used</th>
<th>Key Body Movements</th>
<th>Key Body Mechanisms/Responses Experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12/9/21</td>
<td>Indoor</td>
<td>38.00</td>
<td>Rock</td>
<td>black fitted sleeveless t-shirt with stripe motifs; black fitted pants</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; black towel used to wipe sweat from face</td>
</tr>
<tr>
<td>2</td>
<td>12/9/21</td>
<td>Indoor</td>
<td>29.00</td>
<td>Rock</td>
<td>no shirt with black leather vest; black regular fit varsity shorts</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweating at chest; black towel used to wipe sweat from face</td>
</tr>
<tr>
<td>3</td>
<td>12/11/21</td>
<td>Outdoor</td>
<td>27.00</td>
<td>Jazz</td>
<td>black regular fit polo shirt with stripe motifs on collar; black regular fitted pants</td>
<td>swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; sleeve used to wipe sweat from face</td>
</tr>
<tr>
<td>4</td>
<td>12/11/21</td>
<td>Outdoor</td>
<td>49.00</td>
<td>Jazz</td>
<td>black regular fitted graphic t-shirt; black regular fitted pants</td>
<td>swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; sleeve used to wipe sweat from face</td>
</tr>
<tr>
<td>5</td>
<td>12/11/21</td>
<td>Outdoor</td>
<td>58.00</td>
<td>Rock</td>
<td>white fitted t-shirt; khaki regular fit dress shorts</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat visible at underarms; black towel and sleeve used to wipe sweat from face; flushing</td>
</tr>
<tr>
<td>6</td>
<td>12/18/21</td>
<td>Outdoor</td>
<td>58.00</td>
<td>Jazz</td>
<td>white short sleeve dressshirt regular fit; black regular fitted pants</td>
<td>swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat visible at underarms; black towel used to wipe sweat from face</td>
</tr>
<tr>
<td>7</td>
<td>12/18/21</td>
<td>Outdoor</td>
<td>46.00</td>
<td>Jazz</td>
<td>brown regular fitted graphic longsleeve sweater; black regular fitted t-shirt; black regular fitted pants</td>
<td>swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to change in top to a black short sleeve t-shirt 10 mins into performance</td>
</tr>
<tr>
<td>8</td>
<td>12/19/21</td>
<td>Indoor</td>
<td>32.00</td>
<td>Rock</td>
<td>black fitted graphic longsleeve t-shirt; black fitted pants</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; sleeve used to wipe sweat from face</td>
</tr>
<tr>
<td>9</td>
<td>12/19/21</td>
<td>Indoor</td>
<td>44.00</td>
<td>Rock</td>
<td>black fitted t-shirt with cutoff sleeves and neck; black fitted pants</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; black towel used to wipe sweat from face; flushing</td>
</tr>
<tr>
<td>10</td>
<td>12/19/21</td>
<td>Indoor</td>
<td>38.00</td>
<td>Rock</td>
<td>black regular fitted graphic t-shirt; black regular fitted pants</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; black towel used to wipe sweat from face and neck</td>
</tr>
<tr>
<td>11</td>
<td>1/6/22</td>
<td>Outdoor</td>
<td>55.00</td>
<td>Jazz</td>
<td>tan longsleeve dressshirt regular fit with embroidered motifs; gray regular fitted pants</td>
<td>swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat visible at underarms; black towel used to wipe sweat from face</td>
</tr>
<tr>
<td>12</td>
<td>1/6/22</td>
<td>Outdoor</td>
<td>35.00</td>
<td>Jazz</td>
<td>black regular fitted graphic t-shirt; fitted blue jeans</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; sleeve used to wipe sweat from face; flushing</td>
</tr>
<tr>
<td>13</td>
<td>1/15/22</td>
<td>Indoor</td>
<td>47.00</td>
<td>Rock</td>
<td>grey fitted t-shirt with cutoff sleeves and neck; black fitted pants</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat visible at chest; white towel used to wipe sweat from face and neck</td>
</tr>
<tr>
<td>14</td>
<td>1/15/22</td>
<td>Indoor</td>
<td>34.00</td>
<td>Rock</td>
<td>black fitted graphic t-shirt; black regular fitted pants</td>
<td>lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations</td>
<td>sweat not visible on apparel due to dark color; black towel used to wipe sweat from face; flushing</td>
</tr>
<tr>
<td>Event</td>
<td>Date</td>
<td>Venue</td>
<td>Duration</td>
<td>Style</td>
<td>Description</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>15</td>
<td>1/15/22</td>
<td>Indoor</td>
<td>30.00</td>
<td>Rock</td>
<td>Lifting arms; swinging arms; sweat not visible on apparel due to bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1/20/22</td>
<td>Indoor</td>
<td>48.00</td>
<td>Rock</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1/20/22</td>
<td>Indoor</td>
<td>33.00</td>
<td>Rock</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1/20/22</td>
<td>Outdoor</td>
<td>36.00</td>
<td>Rock</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1/29/22</td>
<td>Outdoor</td>
<td>50.00</td>
<td>Jazz</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1/29/22</td>
<td>Outdoor</td>
<td>42.00</td>
<td>Jazz</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>1/29/22</td>
<td>Outdoor</td>
<td>56.00</td>
<td>Rock</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>2/3/22</td>
<td>Indoor</td>
<td>30.00</td>
<td>Jazz</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>2/3/22</td>
<td>Indoor</td>
<td>54.00</td>
<td>Jazz</td>
<td>Lifting arms; swinging arms; bending arms; crossing arms; torso twist; bending torso; wrist rotations; hand grips; neck rotations.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>