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AN EVALUATION OF THE PERFORMANCE OF LEGGINGS BASED ON A CONSUMER SURVEY

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AN EVALUATION OF THE PERFORMANCE OF LEGGINGS BASED ON A CONSUMER SURVEY

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in
Retailing and Tourism Management
in the College of Agriculture, Food and Environment
at the University of Kentucky

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ABSTRACT OF THESIS

AN EVALUATION OF THE PERFORMANCE OF LEGGINGS BASED ON A CONSUMER SURVEY

The purpose of this research was to identify the legging features that athleisure consumers desire and the performance problems they frequently encounter. A non-probability sample (n=133) of college students who identified as female and wore leggings for non-athletic purposes were surveyed. The questionnaire was designed based upon examination of online product reviews and current complaints with legging products. The results of the survey were used to design and complete a laboratory evaluation. Laboratory samples and methods were then chosen to assess the performance qualities desired when purchasing leggings and the problems encountered when wearing leggings by the surveyed consumers. Three brands were identified by the survey as regularly consumed legging brands and included: Lululemon, Nike, and 90 Degree. All laboratory samples were a nylon, spandex blend fabric. Garments were laundered and evaluated after one, five, ten, and twenty washes. All evaluations were completed in a Textile Testing Laboratory according to AATCC and ASTM standard test methods.

KEYWORDS: Leggings, Athleisure, Performance Evaluation, Consumer Survey

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Chapter One

The zeitgeist of the US is reflected in the way consumers dress in the workplace and their everyday activities, which tend towards casual lifestyles that demand versatility and comfort from fashion (Weinswig, 2018). As the millennial generation has increased their interest in living a healthy lifestyle, athletic clothing has become more acceptable for everyday wear including in the workplace (Trefis Team, 2016). Athleisure is the title given to clothing items which fall into the category of athleticwear worn for everyday wear (Green, 2017). Athleisure has changed the fashion industry and has become a vital segment. The former head of J. Crew menswear Todd Snyder stated that athleisure is an "evolution" in the fashion industry, not just a fad, suggesting that athleisure is here to stay (Green, 2017). Snyder's stance is supported by Euromonitor, which projects sportswear and athleisure sales will increase by 12% by 2020 (Weinswig, 2018).

This research will focus on perhaps one of the most prevalent garments in the athleisure category, leggings. Leggings provide a staple athleisure piece for athletic and non-athletic brands to enter the athleisure market due to their popularity. An abundant number of retailers have included leggings under their private label brands to join the athleisure market; discount retailers like Wal-Mart and Target have joined as well as high-end brands (Trefis Team, 2016). For the first time in US history, the US Census Bureau reports that imports of women's elastic knit pants surpassed jean imports, which reflects the widespread acceptance and growth of leggings (Hanbury, 2018). While consumers face multiple choices in brands and styles, little research exists on consumers' performance desires for leggings.

Problem Statement

With many brands entering the athleisure market by offering leggings, consumers face numerous options while shopping**.** Technology surrounds consumers every day and presents them with constant updates and improvements; therefore, they understandably wish to purchase leggings with superior performing features (Green, 2017). Brands are now designing athleisure for both functional and fashionable uses, which can cause consumers to have a difficult time judging performance quality. Lauren Blanda, City Sport's category manager of apparel, claims that there is a quality difference in the high end $100 workout pants and lower end workout leggings due to factors such as the

fabric's durability and ability to stretch (Ducharme, 2013). However, in both lab testing and a wear study, Champion leggings were considered the top-rated legging for a price of only $35 (The Good Housekeeping Institute, 2016). It is simple to see why consumers can grow confused and frustrated by the legging market with countless options available and the desire for higher performance with purchases.

Purpose

The purpose of this research was to identify desired legging features and encountered problems for consumers and to create a consumer profile related to legging preferences through a survey. This study also compared the performance qualities of three consumer identified brands of leggings.

Consumers' desires for any apparel item, such as leggings, according to Lamb & Kallal's (1992) FEA Model, include three categories of consideration: functional features, expressive features, and aesthetic features. Functional features describe a garment's utility, such as protection and comfort, while expressive features describe the message a consumer communicates or a garment's symbolism, such as reflecting an active lifestyle through the wearing of leggings (Swan and Combs, 1976; Chen-Yu, Williams & Kincade, 1999; Lamb & Kallal, 1992). Aesthetic features relate to observable traits, such as color and appearance (Eckman, Damhorst, & Kadolph, 1990). The laboratory evaluation for this thesis included both functional and aesthetic performance analysis of leggings. Functional performance evaluations included examining fabric specifications and testing opacity and bursting strength. Aesthetic performance evaluations included color change, stretch recovery, pilling/fuzzing, and dimensional stability.

Research Objectives

1. Identify and evaluate the desired characteristics for women's leggings for athleisure consumers.
2. Identify and analyze the encountered problems for women's leggings.
3. Measure and compare the performance of three brands of leggings identified through a survey as frequently purchased.

Research Questions

1. What are the features desired by athleisure consumers for women's leggings?
2. What are the problems encountered by athleisure consumers while wearing women’s leggings?
3. Is there a significant difference in the performance of three frequently purchased brands of leggings?

Assumptions

The difference between athleisurewear and performance wear is dictated by how the consumer chooses to use an athletic garment (Weinswig, 2018). The line between these categories is imprecise because of their interrelatedness. The consumer may use a garment with performance qualities for casual purposes as well as for athletic purposes. For this research, it was assumed that any garment that falls into the performance wear or athleticwear category also falls into the athleisurewear category; therefore, terms such as activewear and athleticwear are used interchangeably. This study also assumes that the sample of surveyed consumers answered each question to reflect their own opinion and not the opinions of others.

Justification

With numerous choices available to consumers, it is crucial to examine the characteristics and performance features consumers desire for the leggings they wish to purchase. Traditional retailers have introduced activewear collections to join the $33 billion-dollar market; even celebrities such as Beyonce and Carrie Underwood have found a way to join the athleisure movement by partnering and offering their own athletic lines with retailers ("Winning in the U.S. activewear market," 2014; Kell, 2016). The number of options available creates an extremely competitive market (Kell, 2016).

Lululemon and Under Armour sales initially benefited from the growth of athleisure; however, the companies’ more recent sales declined in 2017 because the athleisure market became saturated and volatile (Gottfried, 2017). Nike is less at risk to the unpredictable market because of the company’s reliance on research and effective marketing, which enables them to remain competitive in the athleticwear category (Gottfried, 2017). The success from which Nike benefits reveals the importance of research and development in the extremely competitive athleisure industry.

Under Armour's president Ben Pruess believes that athleisure is not a trend but will continue to evolve; he believes that brands can be sustained and broadened through appeal and incorporating innovative designs (Kell, 2016). Companies cannot improve without first hearing from their consumers; it is vital for brands that wish to remain relevant in the athleisure market to place value on consumer desires before developing a superior product.

Limitations

The limitations of this research include the methods of sample selection. A nonprobability convenience sample was used to survey consumers of leggings while a convenience sample was also used to select the leggings which underwent laboratory evaluation. The data collection was restricted due to limited time and resources available. The study replicated consumer behavior by laundering the garments and testing after various intervals; however, deterioration which may occur from wearing was not accounted for in the study.

Chapter Two

Literature Review

The purpose of this research was to identify what features consumers desire and the problems they encounter with their leggings. The study also compared the performance qualities of three frequently purchased brands of leggings. A review of relevant literature provides information on the historical background and current market for leggings, as well as a discussion on the composition, performance features, and care of leggings.

History of Leggings

Pinpointing the origins of the athletic legging worn throughout the late 20th and early 21st century is complicated due to the range of definitions surrounding leg coverings. The Oxford Dictionary defines leggings as "tight-fitting stretch trousers, typically worn by women or girls" ("Leggings," 2018). According to this definition, the past of leggings is contextualized in the history of trousers. Some have claimed that trousers or the first version of leggings originated from barbarian tribes that resided in Northern Europe; during the Imperial Period of Rome, Roman soldiers adopted the trouser from these tribes for protection from their armor and the weather (Tortora & Eubank, 2010)**.** By the time the Roman Empire declined, the trouser leg covering had begun to permeate Western culture (Tortora & Eubank, 2010). In contrast, Beck (2014) uses the recent excavation of approximately 3,000-year-old trousers in China to indicate that the purpose of trousers worn in Eastern culture, at a much earlier date than the Roman soldiers, was for horseback riding. Beck (2014) argues that the origin of trousers, and therefore leggings, is deeply ingrained in the athletic movement and motion of horseback riding. Regardless of the date of the first worn trouser, it should be noted that women did not begin wearing bifurcated garments until a much later date.

The impracticality of women's long skirts for exercise, along with the beginning of the feminist movement in the 1840s, gradually led to significant changes to leg covering garments for women. Although all women did not accept it, the Bloomer costume of the feminist movement, which included Turkish trousers, gained widespread attention throughout the world (Tortora and Eubank, 2010). The pantaloons worn in the Bloomer costume made the changes that followed in women's clothing possible (Cole,

1986). Women wore variations of bloomers and knickers for gymnasium clothing until World War I; the war created a need for the rationing of materials and brought women into the workforce, completely changing women's fashion (Cole, 1986).

Following World War I and into the 1920s and 1940s, women's sportswear was transformed as hemlines and silhouettes varied throughout these decades and manufactured washable fabrics were invented (Cole, 1986). When the first fully synthetic fiber, nylon, was created in 1938, it introduced manufactured materials (Brunn & Langkjaer, 2016). Goods used in military efforts incorporated the strength and durability of nylon, which later led to its use in women's stockings (Totora & Eubank, 2010). The invention of other synthetic fibers such as polyester and spandex are used today in sportswear and women's leggings (Brunn and Langkjaer, 2016). During the decade after World War II, there was an increased responsibility for women to oversee their fitness and health (Mckenzie, 2013). Perhaps in response to this push for health, casual sportswear garments became a significant part of women's wardrobes and included pants that fit so close to the leg that shoes had to be removed to pull them up (Tortora & Eubank, 2010). In 1970 the Oxford dictionary defined leggings as tight trousers made of stretch fabric (Waxman & Chan, 2016).

The popularity of the legging as a sportswear garment increased with the health and wellness craze of the 1980s. Many women wore Lycra leggings to participate in aerobic exercise (Waxman & Chan, 2016). Influential actress of the fitness craze Jane Fonda wore leggings paired with a leotard, and Madonna adopted leggings in her music videos and concert wear, often donning them under long shirts or skirts (Payer, 2018). The trend of wearing leggings to the gym calmed in the 90s before escalating once again in the 21st century, two decades later (Payer, 2018). There are noticeable differences between the legging fashions of the 1980s and those of the 21st century; women now often wear them as an acceptable standalone leg covering (Payer, 2018). Also, leggings are no longer only associated with the gym. A survey conducted by Cotton Incorporated reported that 9 out of 10 consumers wear athletic clothing (i.e., leggings) for activities that are not exercise related (Winning in the U.S. activewear market, 2014). For consumers, non-exercise related activities include work apparel.

Time is extremely valuable in modern culture; therefore, many consumers prefer versatile garments which are acceptable in multiple locations and settings including work and leisure (Weinswig, 2018). Casual dress codes allow workplaces to appear more relaxed and informal, appealing to the current workforce of Millennials (Elmer, 2017). Clothing which is now considered appropriate in the workplace can include sports type fabrics such as spandex and polyester which permit versatility and comfort (Green, 2017). There are many opinions when it comes to athleisure garments being worn in the workplace; some believe the fashion shift is not appropriate and could cause less productivity because of encouraging laziness, while others believe the ease casual garments provide encourages engagement and higher productivity (Elmer. 2017; Gay, 2017). Those who encourage athleisure in the workplace may believe feeling comfortable inspires happier more productive employees; additionally, it allows employees to express their individuality which can promote a positive culture in the workplace (Gay, 2017). Therefore, it is not uncommon to see athleisure incorporated into a casual, more relaxed work environment. Leggings are a large part of the athleisure trend in the office and can be subtly paired with the right piece, such as a blazer, and then might qualify as a suitable, comfortable business outfit (Holmes, 2015). It is evident that athleisure has become extremely relevant and permeated the culture and fashion industry of the U.S.

The Legging Market

It is impossible to examine the present market in the U.S. without recognizing the importance of leggings in the athleisure movement. Wall Street Journal reporter Holmes (2015) credits Lululemon with popularizing the concept of wearing yoga pants to places outside of the yoga studio. Leggings, as well as other athletic pieces, have successfully been integrated into consumers' leisurewear and workwear, building the athleisure market. This segment of the apparel industry became so successful that in 2016 athleisure first appeared in Merriam Webster Dictionary defined as "casual clothing designed to be worn both for exercising and for general use" (Athleisure, n.d.).

As stated previously, the difference between the athleticwear and athleisurewear categories depends how consumers choose to wear their clothing items; it is essential to look at the sportswear market to assess the sales of athleisure (Weinswig, 2018). According to Hanbury (2018), from 2011-2016, athletic clothing became responsible for

30% of the total apparel and shoe industry sales in the US. There is a need to realize the prevalence of leggings in these statistics. Leggings are now such a key part of the apparel and sportswear industry that they have replaced denim as the staple wardrobe piece of many women in the US (Weinswig, 2018). The US Census Bureau reported that in 2017, elastic stretchy knit pants surpassed jean imports (as cited in Hanbury, 2018). There is no doubt that the legging trend has dramatically escalated in the fashion industry, but many people question what will happen in the future for this trend.

How long leggings endure is unclear, as with most fashion trends. Some researchers claim that athleisure has reached its peak (Hanbury, 2018). However, many brands believe that athleisure is not a trend at all but instead is a way of life for consumers (Holmes, 2015). Wellness is a status symbol, and athleisure plays a part by allowing consumers to showcase their dedication to a healthy lifestyle (Weinswig, 2018). Expressive considerations, as stated by Lamb and Kallal (1992), are the desired communication or symbolism a consumer wants to express through a garment. For many, athleisure provides the ability to communicate a commitment to living a fit and active lifestyle (Lamb & Kallal, 1992).

In addition to wearing prestigious athleisure brands, consumers can add to their healthy and elite image through wearable technology such as the Apple Watch or Fitbit, which partner well with athleisure; many brands and manufacturers hope that the athleisure category is sustained through further technological developments (Holmes, 2015). Wearable X released leggings with electronic sensors sewn into the fabric. Using a partnering iPhone app and Bluetooth connection, the vibrating sensors embedded in the wearer’s leggings corrects their yoga formations. (Feitelberg, 2017). Companies such as Wearable X are at the forefront of the technological developments in leggings and athleisure.

In addition to incorporating technology, brands also can enhance the performance and fabric quality of leggings and other performance garments. The healthy living culture surrounding athleisure has helped leggings to find a prominent position in the apparel market. Athleisure is not a typical trend because of the lifestyle it represents, and according to Global Industry Analysts, Inc., it is projected to grow 27% from 2015 to 2020 (as cited in "Athleisure category remains strong," 2017).

Fabric

When examining the structure of leggings, fabric construction that allows for ease of movement is essential. Fabric is "a pliable, planelike structure made into two- or three-dimensional products that require some shaping and flexibility" (Kadoplph, 2010, p. 256). Fabric is not just a conglomerate of yarns and fiber but instead should be thought of as a structure which can impact the intended performance of the garment (Shishoo, 2015). Sportswear uses the major construction types of knitted, woven, and non-woven fabrics with knitted being the most used in skin-layer and middle-layer sportswear due to its ability to stretch more than woven fabrics (Troynikov & Watson, 2015; Uttam, 2013).

Knitted fabrics. Leggings commonly use knitted material, which is characterized by interlocked loops of yarns with vertical stitches called wales and horizontal rows of stitches termed courses (Kadolph, 2010). A machine that interloops continuous yarns generally creates knitted textile apparel items (Keiser, Vandermar, & Garner, 2017). Knits can differ depending on the direction of the formed loops, but there are two primary categories in which nearly all knitted fabrics are classified: weft knits and warp knits (Kaufmann, 2015).

Weft knits. Weft knits are formed when “one yarn or yarn set is carried back and forth and under needles to form a fabric. Yarns move horizontally” (Kadolph, 2010, p. 313). Even though weft knits can unravel more easily than warp knits, weft knitting is generally used in fashion and apparel items (Kaufmann, 2015). Jersey knits, rib knits, and purl knits are among the most common types of weft knit types (Elsasser, 2010). Weft-knitting machines comprise approximately 90-95% of all machines used for apparel creation, which is likely due to the increased demand and production for athleisure (Kaufmann, 2015). Weft knitted fabrics have been used frequently in seamless sportswear and have widespread structural abilities (Troynikov & Watson, 2015).

In an experiment conducted by Chen, Miao, Mao, and Jiang (2016), participants rated cotton weft knitted fabrics as the smoothest when feeling cotton and polyester fabrics woven or knitted using warp and weft construction, suggesting that cotton weft knit fabrics are a smooth knit option for apparel. Additionally, all weft knitted fabrics tested were rated as having the highest comfort when dry, regardless of whether they

contained polyester or cotton, suggesting that dry weft knitted fabrics are more comfortable than dry warp knitted fabrics.

Warp knits. Usually a machine creates warp knits, and unlike weft knits, they are not likely to unravel due to their construction (Kaufmann, 2015). “Warp knitting is a process in which a warp beam is set into a machine, and yarn sets are interlooped to form a fabric. Yarns move vertically” (Kadolph, 2010, p. 313). This type of construction is used mainly for industrial and technical fabrics but also some apparel (Kaufmann, 2015). Tricot and raschel knits are the two main types of warp knits, but the term tricot is sometimes used to encompass all warp knits (Elsasser, 2010) Adidas specifies that some of their seamless leggings are made with a warp knit, indicating that customers should expect smoothness and comfort while wearing them (Adidas, 2017).

When Chen, Miao, Mao, and Jiang (2016) had participants rate wet and dry warp knitted, weft-knitted and woven fabrics for comfort, warp knits generally scored lower for comfort when compared to weft knits; however, dry warp knits were still considered more comfortable than woven fabrics. The comfort of the warp knits was similar to weft knits when both fabrics were wet. In another study conducted on warp and weft knitted fabrics by Tiwari, Fei, and McLaren (2013), the best knitting pattern for moisture management in sports apparel was warp knit.

Fiber Content

The fiber content of leggings differs depending on brands, retailers, and styles. Fibers are raw materials which are spun into yarns and make up textiles (Keiser, Vandermar, & Garner, 2017). The fibers used in athletic apparel have different attributes on which current researchers wish to improve; for example, a fiber’s natural features may be enhanced by blending multiple fibers or applying finishes. Nylon, polyester, and spandex are among the most frequently used synthetic fibers in the athletic apparel industry (McCann, 2015). These fibers are human-made and developed to be durable, making them ideal for performance apparel. Sportswear may also incorporate natural fibers such as cotton, wool, and silk. (Shishoo, 2015). These fibers have natural performance abilities, which can significantly enhance athletic apparel.

Nylon. Nylon, introduced into the market in 1938, was the first fully synthetic fiber (Brunn & Langkjaer, 2016). According to Kadolph (2010), nylons are polyamides that differ in chemical arrangements; nylon's molecular chains are long and straight without crosswise linkages. According to Kadolph's book, the fiber was introduced in women's hosiery and continues to be the best fiber for pantyhose due to its high elongation and elastic recovery. Because it is durable and has low absorbency, nylon is also widely used in outer shell garments such as jackets which are wind and water resistant (Shishoo, 2015; Kadolph, 2010). Also, nylon is abrasion resistant, having high dimensional stability, and is resistant to many molds and chemicals (Kadolph, 2010). However, nylon does have drawbacks. Due to its chemical makeup, the fiber is not always 100% recycled, and the textile industry continues to explore ways to refurbish and promote the sales of recycled nylon fibers (McCann, 2015).

Polyester. Polyester is a synthetic smooth rodlike fiber which has various performance abilities; these include excellent durability, abrasion resistance, elongation, dimensional stability, and elastic recovery (Kadolph, 2010). It is considered the most common material used in sportswear (McCann, 2015). Polyester has few bonding sites for water molecules, meaning it is hydrophobic and has excellent moisture transportation and release, typically not getting wet (Su, Fang, & Cheni, 2007). Inherently polyester is challenging to clean; however, a treatment developed by Milliken Mills makes polyester hydrophilic and improves both washing and wicking abilities (McCann, 2015). Many athletic garments are designed to have this wicking ability due to controlling moisture such as sweat.

Cotton. Cotton is a natural fiber with many inherent performance abilities as well as enhanced capabilities through textile development. It has good strength, which is improved 10 to 20 percent when wet (Elsasser, 2010). An additional benefit of cotton is its breathability, which is especially desirable for performance wear due to not retaining bad odors; cotton fabrics also shed accumulated pilling when washed, minimizing visible pilling (The benefits of cotton, n.d.)**.** Cotton is hydrophilic, which means it is absorbent but has poor moisture transportation and is susceptible to mildew and molds (Su, Fang, & Cheni, 2007; Elsasser, 2010). When they are wet, cotton fabrics can be difficult to dry and will cling to the body (Chen, Miao, Mao, Ma, & Jiang, 2016)**.**

Cotton Incorporated worked on innovating cotton's natural performance abilities through technological developments ("Performance Technology," n.d.). These developments include improvement in moisture management (TransDRY® and WICKING WINDOWS™), water repellency (STORM COTTON™), and durability (TOUGH COTTON™).

Spandex blends. Sports apparel frequently uses spandex blended with nylon and polyester. It is a manufactured fiber, also referred to as elastane or Lycra. There are many uses for the fiber in the textile industry, but the properties of elastane make it especially relevant in athletic apparel. Comprised of a long synthetic elastomer, spandex is highly elastic (Tezel & Kavusturan, 2008). There are two methods for processing elastane: wrapping the fiber in non-elastic thread or knitting or weaving elastane threads into fabrics made from other fibers (McCann, 2015).

Sports apparel, which contains spandex, can fit close to the wearer like a second skin and will follow the movements of the body (Tezel & Kavusturan, 2008; Marmarali, 2003). When relaxed, spandex recovers its original shape without deformation during the lifetime of the fabric (Marmarali, 2003). Elastane stretches four to seven times its length and can return to its original shape (McCann, 2015). In addition to elasticity and shape retention, spandex is also easy to care for, has low absorption, is resistant to sunlight exposure and is resilient to many common chemicals (Marmarali, 2003; Tezel & Kavusturan, 2008).

Spandex is often blended with other fiber types in garment materials; the percentage used depends on the manufacturer’s intent for the fabric. Fabrics used in sportswear usually contain 15-40% elastane content (McCann, 2015). The sportswear industry worked on developing new forms of spandex such as a hygroscopic spandex for improved moisture management and a soft spandex for more stretch (Hu & Lu, 2015).

Design

Due to the growth of the athleisure market, consumers have more options when shopping for legging and sports apparel; therefore, the construction and design features are of great importance when selecting a garment for purchase. The construction and design of the garment impact the wearer’s comfort (Troynikov & Watson, 2015). Designers should consider both appearance and visual appeal when designing

athleticwear (Uttam, 2013). While some consumers wish to purchase activewear for exercise-related activities, many desire to own sports apparel for fashion-related reasons and do not need enhanced technical features (Bringard, Perrey, & Belluye, 2006).

Sportswear categories. Gupta (2011) states that athletic clothing is characterized by two categories: sports-functional or everyday athletic apparel. She reports that while everyday sportswear can have functional features such as stretch and moisture management, these apparel items are different from garments in the functional sportswear category. The design of functional sportswear includes the intent of enabling and enhancing athletic performance with performance engineering (Gupta, 2011). Brands are exploiting the trend of athleisure by mixing both functional and everyday sportswear into their product mixes which can confuse consumers (Beaudette & Park, 2017).

Everyday athleticwear. Designing for sports is kept in mind when creating garments for the athleisure market since many consumers are not purchasing sportswear with the intent of participating in sports but are instead wearing athletic garments for leisure and fashion purposes (McCann, 2015). Desirable properties for sportswear include temperature regulation, air permeability, quick drying, dimensional stability, odor control, stretch, durability, lightweight feel, and moisture management (Gupta, 2011; Uttam, 2013**).** Functional athleticwear designed and worn by athletes influences apparel items offered in the everyday sportswear category (Liu & Little, 2009).

Functional athleticwear. Functional athletic garments are created to improve an athlete's performance (Gupta, 2011). Properties considered when designing functional sportswear include protection, comfort, performance improvement, and aesthetic appeal (Uttam, 2013). Functional sportswear designed to promote muscle blood flow uses compression engineering; also, wind and air drag can be reduced to increase athletic performance (Gupta, 2011).

The functional sportswear category greatly influences everyday athleticwear; technical garments designed for the Olympic Games trickle down into the performance features and fashion of athleticwear worn by non-Olympians (Liu & Little, 2009). It is certain that functional sportswear even influences fashion apparel not used for athletic purposes (Liu & Little, 2009). The design of sports garments includes having

performance features that show off the wearer's body and expresses their personality, combining fashion and sports (Liu & Little, 2009).

Seam construction. Stitches and seams can enhance or hinder a performance garment; they must be carefully selected based on their durability and extensibility to join together stretchy materials (Beaudette & Park, 2017). Including durability and elasticity, designers must also consider the aesthetic appeal, security, comfort, and ease of assembly (Shishoo, 2015). A problem faced in sportswear is the wearer's skin rubbing against tight fabrics and seams which can be extremely uncomfortable; smooth seaming and stitching are desired to prevent this friction (Beaudette & Park, 2017). The threads often used for stitches in athleticwear are textured polyester or textured nylon because of the softness and elasticity they can provide (McLoughlin & Hayes, 2015). It is vital to use the correct stitch density and balance in athletic wear to avoid weakness and seam grin; stretchy fabrics should include a higher count of stitches than non-stretchy fabrics (McLoughlin & Hayes, 2015). Athleticwear often uses the overlock stitch and flatlock stitch because of the stiches' durability and ability to stretch (Beaudette & Park, 2017).

Stitched seams. When discussing construction, product developers often use ASTM International D6193-16 Standard Practice for Stitches and Seams to clarify which seams and stitch types they wish to use in a garment (Keiser et al., 2017). The ASTM 514 class overlock mock safety stitch, which uses two needles and two looper threads, is often used in athletic wear (Beaudette & Park, 2017; Keiser et al., 2017). The 514 overlock stitch offers elasticity; testing on stretchy knitwear revealed that this stitch has higher tensile strength than lockstitches or chain stitches (McLoughlin & Hayes, 2015). When using an overlock stitch, the fabrics joined together are pressed to one side instead of being ironed open (Beaudette & Park, 2017).

The most common stitches used in leggings are cover stitches 607 and 605 (McLoughlin & Hayes, 2015). ASTM 607 is created with four needle threads while ASTM 605 is created with three needle threads; both stitches are comprised of a top cover thread and a bottom looper thread (Keiser et al., 2017). Both stitches have an elastic quality that allows for seam flexibility (McLoughlin & Hayes, 2015). ASTM 607 is used with flat seaming in athleticwear because of the absence of bulk which minimizes potential abrasion in garments (Beaudette & Park, 2017). Two plies of overlapped fabrics

are joined together with seam allowance creating a relatively smooth feel in close-fitting athleticwear; at least two rows of stitching are used (McLoughlin & Hayes, 2015; Beaudette & Park, 2017).

Seamless. While cut and sew is the most common method used in producing athletic wear, seamless garments are an expanding segment of the sportswear apparel category (McLoughlin & Hayes, 2015). Seamless technology allows for minimized bulk and comfort for the wearer (Beaudette & Park, 2017). Many flexible athleticwear items, including leggings, are constructed using seamless technology (McLoughlin & Hayes, 2015). According to Troynikov and Watson (2015), there are two classes of seamless weft-knitting machines that include body-width machines and flat V-bed machines. The authors report that seamless knitting machines create tubular preforms at specific circumferences and widths depending on the sizing of the garment. When constructing the garment, the preforms need to be manipulated, and some seaming and cutting may be used to shape and insert gussets depending on the style of the apparel item (Troynikov & Watson, 2015). Because seamless technology allows for the opportunity to easily incorporate new technologies such as measuring wearers movements, the future of seamless garments should continue to expand (Troynikov & Watson, 2015).

Panels. A recent development in the sports apparel industry is body mapping which uses garment panels and zones with the body's movements and responses to exercise in mind (Troynikov & Watson, 2015). An example of this is utilizing mesh panels in specific locations of a garment to promote moisture management and regulate the temperature of the wearer (Liu & Little, 2009). Bike shorts sometimes use panels to promote the wearer's performance by contouring for a better fit while riding a bicycle (Liu & Little, 2009). It is important to remember that functional sportswear greatly influences the designs used in the everyday athleticwear and the athleisure market; therefore, panels may be used for fashion and visual appeal in leggings to flatter the body or express the personality of the wearer (Liu and Little, 2009).

Performance

Consumers have expectations regarding the performance of a garment they purchase. With the widespread use of technology in everyday life, consumers have begun to desire and demand technically advanced performance in their clothing (Green, 2017).

Dissatisfaction occurs when a product does not perform as desired or does not meet the expectations of the consumer (Chen-Yu, Williams & Kincade, 1999). When studying consumer satisfaction and dissatisfaction, Swan and Comb's (1976) foundational research suggests that consumer satisfaction can be divided into two categories of psychic and physical utility. Chen-Yu, Williams, and Kincade (1999) elaborate upon this idea by stating that psychic utility can also be defined as the aesthetic characteristics of a garment and that physical utility relates to functional characteristics.

Functional performance. Functional performance features describe a garment's usefulness (Lamb & Kallal, 1992). Consumers will likely not be able to evaluate functionality without first trying on the garment or wearing it.

Comfort. Comfort is described as "possessing those qualities that promote a feeling of well-being, ease, and freedom from pain" (Fairchild's Dictionary of , 2014). Garment comfort is a subjective performance feature and is divided into two categories of satisfaction; thermophysiological and sensorial (Barker, 2002). While thermophysiological comfort is dependent upon a garment's ability to handle heat and moisture, sensorial comfort depends upon the wearer's tactile response to fabric against the skin (Barker, 2002). Sensorial comfort refers to fabric hand, or how a fabric feels to touch. Fabric comfort may be adjusted through mechanical or chemical methods (Realff & Casico, 2005). Chemical methods include treating the fabric surface with "softeners," which can improve pilling and durability or changing the makeup of fibers through a process such as mercerization (Realff & Casico, 2005).

Thickness. The yarn's stitches per unit and construction of a fabric are the main determinants of its weight and thickness (Troynikov & Watson, 2015). Fabric weight is the physical density of fabric and can be subjectively evaluated based on what consumers deem is suitable for an apparel item; for instance, competitive cyclists wish to have the lightest fabric weight possible for improved performance (Keiser et al., 2017). Lightweight fabrics allow for a closer fit and better movement in garments. Because spandex is a lightweight fiber, fabrics made up of spandex are often used in athletic wear to allow for ease of movement (Hu & Lu, 2015). Fabric thickness is often discussed when concerning the thermal impact it has on a garment. Research of single jersey knits has

found that increased fabric thickness better enables that body to resist heat flow which is referred to as thermal resistance (Oğlakcioğlu & Marmalali 2007).

Compression. Pressure applied to soft tissues has been used for medical reasons for many years and has carried over to the athletic wear industry (Wannop, Worobets, Madden, & Stefanyshyn, 2016). Sports garments use compression to improve the speed of recovery after muscle use (Liu & Little, 2009). Berk and Kahveci (2018) identify four ways in which compression may improve performance: accelerating circulation, stabilizing muscles, creating muscle perception, and minimizing muscle micro-vibrations.

Moisture management. Moisture management is a fabric's ability to carry liquid humidity away from the skin to the surface of a garment, then releasing it into the air (Senthilkumar, Sampath, & Ramachandran, 2012). Moisture management performance is dependent upon a garment's absorbance capacity, absorbance rate and evaporation (Pavlidou & Paul, 2015) Because sweating is the human body's natural cooling method, it is essential that athletic fabrics attempt to manage moisture since damp fabrics can create discomfort to the wearer (Daanen, 2015). There are several chemical applications which can be applied to fabric in an attempt to adjust moisture management properties without impacting comfort (Pavlidou & Paul, 2015).

Odor control. "Most body odors are caused by bacteria on skin and clothing consuming the nutrients provided by sweat and producing compounds that evaporate and are detected as odor by someone nearby" (Trogolo, 2011 p. 158). Reader's Digest lists potential health problems that can arise from microorganism growth on leggings such as ringworm and bacterial vaginosis (Schmid, 2018). The growth of microorganisms can also damage a fabric (Nayak & Padhye, 2015). Antimicrobial technology in garments attempts to reduce the number of bacteria which form on the fabric; for athletic apparel, antimicrobial finishes are often incorporated to control odor (Trogolo, 2011). The most widespread element to fight microorganisms in textiles is silver since it is not carcinogenic nor toxic (Rai, Yadav & Gade, 2009). Although metallic compounds can be incorporated into natural or synthetic fibers, natural fibers such as cotton are usually more susceptible to bacteria forming than synthetic fibers; commercially available silver treatments such as Silpure® and AlphaSan® have been made specifically for polyester or nylon (Nayak & Padhye, 2015).

Aesthetic performance. Aesthetic performance relates to the "human desire for beauty" (Lamb & Kallal, 1992, p. 43). Consumers can examine aesthetic performance through their senses (Chen-Yu et al., 1999).

Colorfastness. Colorfastness is "resistance to fading; i.e., the property of a dye to retain its color when the dyed (or printed) textile material is exposed to conditions or agents such as light, perspiration, atmospheric gases, or washing that can remove or destroy the color" (Encyclopedic Dictionary of Textiles, 2007, p. 208). Colorfastness performance is typically determined by the interaction between a dye and the fibers used to make a garment (Millington, 2018). Colorfastness is a performance feature which allows a garment to fulfill its purpose; many garments are disposed of before completely wearing out due to undesirable color fading (Millington, 2018).

Stretch recovery. The skin expands 10-50% when a body moves, therefore athletic garments must be flexible (Senthilkumar & Anbumani, 2010). Knit fabrics are often classified by their ability to stretch; two-way stretchy knits can be used for skintight appearance, and super stretchy knits are used in sportswear for performance enhancement, having the ability to stretch 100% or even greater in the lengthwise and crosswise directions (Tondl, 2006). Elastic fibers are also often used in athletic apparel to allow for flexibility and shape retention (Hu & Lu, 2015). The "yield point" in elastic fabrics is the point at which fabric has reached its extension limit but will recover (Gorjanc & Bukosek, 2008). Fibers such as spandex can add up to 30% elasticity and can be repeatedly stretched to twice their length and usually recover after stretching (Tondl, 2006; Hu & Lu, 2015; Haji, 2013).

If a garment is stretched beyond its yield point or extension limit, it will not behave elastically and will take longer to recover (Gorjanc & Bukosek, 2008). Dynamic elastic recovery is used to assess a garment's response to movement; higher dynamic elastic recovery equates to a higher response to movement which is desirable for athletic apparel (Senthilkumar & Anbumani, 2010). If a garment has a low dynamic elastic recovery, the resistance to movement can cause energy loss for the wearer (Senthilkumar & Anbumani, 2010). However, it is not desirable for a garment to be stretched beyond its yield point frequently and become too loose or "stretched out."

Abrasion resistance. Abrasion occurs when fabric rubs against itself or an external surface such as another fabric (Barakzehi, Asadi, & Aghaji, 2016). When abrasion occurs, fibers may transfer to the surface of a fabric resulting in fuzzing or pilling (Annis, Bresee, & Cooper, 1992). Pilling and fuzzing are not desirable since they can impact the appearance of a garment and degrade its serviceability to its wearer.

Fuzzing. When examining a fabric's reaction to continual abrasion, fuzzing is the step that occurs before a fabric begins to show pilling (Annis, Bresee, & Cooper, 1992). Fuzzing is the result of broken microfibers beginning to protrude from the fabric's surface; with continual abrasion, the fibers begin to split or fray into smaller fibers giving the fabric a fuzzy appearance (Annis et al., 1992). Fuzzing may also be referred to as linting. Lint has different meanings, but for this research, the definition most similar to fuzzing will be used: "loose, short, fine ravelings or fluff from yarn or fabric" (Fairchild's Dictionary of Textiles, 2014). Lint accumulation on a garment may come from the garment itself or abrasion with another textile. Both linting and fuzzing cling to the surface of a fabric and negatively impact the appearance of a garment.

Pilling. Pilling is caused by the short fibers and fiber ends protruding from a garment entangling and forming pills which are balled up or knotted fibers (Barakzehi, Asadi, & Aghaji, 2016; Jensen & Carstensen, 2002). In addition to impacting the appearance of the fabric, pilling can create a texture change and cause degradation in the comfort and serviceability of a garment (Guan, Li, Wang, & Lei, 2018). The degree of pilling depends on factors such as fiber durability, yarn fineness, the number of short fibers present, and fiber cross-section shape (Barakzehi et al., 2016). The ability of a fabric to resist pilling is a performance factor used to evaluate its quality (Guan et al., 2018).

Haji's (2013) testing of single jersey knit cotton/spandex fabrics found that pilling decreases as the amount of spandex in a garment increases. These results are due to the ability of spandex to create tight fabrics with small loops which reduce pilling (Haji, 2013). In contrast, polyester fibers typically have low pilling resistance due to their high molecular weight; however various compounds can be incorporated to modify polyester to increase its pilling resistance (Sharova et al., 2002). Because pilling can be caused by wearing or washing, it can be difficult for consumers of athletic apparel to avoid.

Dimensional stability. Dimensional stability is the "ability of a fabric to retain its shape and size after being worn, washed, and/or dry-cleaned. Stability is governed by fiber content and by chemical and mechanical treatments" (Fairchild's Dictionary of Textiles, 2014). A reduction in the length and width of a fabric is known as shrinkage (Neckarand & Das, 2007). Garments may have relaxation shrinkage or progressive shrinkage. While relaxation shrinkage is due to manufacturing processes which lead to fiber contraction during the first few washes, progressive shrinkage occurs each time a fabric is laundered (Elsasser, 2010). Yarn count and yarn twist are recognized as impacting fabric shrinkage (Neckarand & Das, 2007). Heat setting is considered the most successful way to ensure that knit synthetic fibers, such as nylon and polyester, do not reduce in dimension, resulting in little to no shrinkage (Elsasser, 2010). In contrast, cotton has a moderate relaxation shrinkage potential but can be treated to reduce shrinkage likeliness (Elsasser, 2010).

Care and Maintenance

While care labels vary for different garments, there are general instructions to consider when laundering and storing leggings. It is suggested that to avoid shrinkage, low heat settings, or air drying should be used for knitted garments, especially those which contain cotton and have not been appropriately preshrunk (Elsasser, 2010). Lululemon advises its customers to machine wash their products in cold water and tumble dry on low or let air dry to protect the life of the spandex (Lululemon Care Instructions, n.d.). Nylon is considered an easy-care fabric and is safe to machine wash and dry, but a high heat setting may cause wrinkling (Elsasser, 2010). While cotton fabrics may be susceptible to mildew and should be stored in a dry location, nylon and polyester do not; therefore, special storage is not required (Elsasser, 2010).

Summary

Uses for leggings have evolved throughout their history, yet they were often intended for exercise related activities because of the range of motion and movement they allow. However, the leggings of the athleisure movement transitioned outside of the gym for wear during non-exercise related activities when creating the athleisure industry (Winning in the U.S, activewear market, 2014). The relatively new athleisure market is extremely competitive because of the vast number of options consumers face, and many

believe that athleisure is here to stay because of its associations with an esteemed lifestyle of wellness (Weinswig, 2018). When a market is competitive, it is important to prioritize the opinions of those who will be purchasing the final product, meaning the consumer. Fabric, design, construction, performance features, and intent for wear vary; therefore, understanding the consumer's desires for performance will allow brands and manufacturers to select and create relevant products. This research will examine consumers' desires and evaluate the performance of leggings consumed by relevant brands in the athleisure market.

Chapter Three

Methodology

In this chapter, the research design, the selection process used to acquire the samples, and a summary of the statistical analysis are described in more detail. Today's consumer is often faced with a multitude of options while shopping for athleisure and can quickly grow confused or frustrated by the array of leggings available. The purpose of this research was to identify what features consumers desire in their leggings, as well as what issues they encounter.

This study compared the performance features of leggings frequently purchased by consumers that participated in the survey. The survey was constructed and presented to a sample group of consumers (n=133) to gain an understanding of the qualities they desire in their leggings and to determine what inadequate performance features they typically encounter. According to the FEA Model, consumers' desires for apparel items are separated into three categories: functional features, expressive features, and aesthetic features (Lamb & Kallal, 1992). Performance problems which frequently appear in the online reviews of products were organized and developed into a questionnaire based on the three categories identified in the FEA Model. The second phase of this project was a laboratory evaluation which examined the aesthetic and functional performance capabilities of the three brands of leggings.

Research Design

A quantitative research design was used to create a consumer profile related to legging preference and to evaluate the performance of three legging brands. Research Questions one and two were addressed by collecting descriptive survey data through a questionnaire (Appendix B). In the second phase, a quasi-experimental method was used to compare three brands of leggings identified from the results of the survey. The comparison evaluated the fabric specifications of the samples as well as the aesthetic and functional performance features.

Methodology: Survey

Qualtric's online survey software system was used to create an accessible internet questionnaire which was estimated to take each respondent 10 –15 minutes to complete. A pretest of the survey was distributed to ensure that the questionnaire was

understandable and that there was clarity in the questions. IRB approval was received through the University of Kentucky before distribution of the finalized questionnaire (Appendix C). The survey was made available for two weeks in April 2019.

Sample. The target population of the study was women who are college students and wear leggings for non-athletic purposes. A non-probability sampling method was used to gather a voluntary sample. The survey was made available through an online link; participants were able to select the link which took them to the survey in the Qualtrics online survey software system. The link was shared on two private Facebook group pages. These social media groups consisted of college-aged women who were members of sororities at the University of Kentucky. A social media representative from each sorority's social media page shared the survey.

Survey instrument. To create the survey, online reviews of various legging styles from different brands were examined. Problems frequently identified in the reviews as well as consumer written literature such as blogs and social media posts were noted and grouped into categories based on similarities. These categories of problems were grouped according to Lamb & Kallal's FEA model (1992), which states that consumers' desires for a clothing product include functional, expressive, and aesthetic qualities.

The first category analyzed via the questionnaire was that of function which describes a garment's utility such as protection and comfort. Two survey questions directed consumers to select the functional and durability issues they had encountered while wearing leggings. Garment functionality includes seven dimensions: uncomfortable material, see-through fabric, restrictive or thick fabric, lingering body odors, loss of compression, loss of wicking abilities, and loss of water resistance. Garment functional durability included fabric ripping, ripping at seams, holes, and worn-down fabric. Consumers were also asked to rate their level of frustration with these encountered problems using a five-point scale. Two additional survey questions prompted the consumers to select the functional features they found to be most desirable when considering purchasing leggings and to rate the appeal of these desires using a five-point scale. Six questions were dedicated to the functional category.

The second category of the FEA model is that of expressive features which relate to the messages a consumer communicates or the symbolism they express through their

clothing (Swan and Combs, 1976; Chen-Yu, Williams & Kincade, 1999; Lamb & Kallal, 1992). Brands were the primary expressive feature this study chose to examine. Consumers were asked what brands they routinely purchase for leggings and why. They were also asked to identify the brand they would ideally purchase and why. Next, consumers were directed to make a selection from a list of locations in which they would wear leggings, including places such as shopping, work, parties, and travel. Finally, consumers were asked to identify how they typically wear their leggings as attire; choices included options such as wearing leggings as a stand-alone pant or preferring to wear them with a longer shirt. Six questions in total were dedicated to understanding the expressive desires of leggings.

Aesthetic features relate to observable features such as color and appearance (Eckman et al., 1990). The survey asked consumers what style features and lengths were preferable for leggings. Similar to the questions dedicated to the functional desires and complaints consumers have in leggings, the survey asked about aesthetic performance by requesting a selection of aesthetic performance problems encountered and a rating of their level of frustration with the issues stated. It was also asked what aesthetic desires they have for their leggings and the level of importance of each desire. The aesthetic dimensions were fivefold and included pilling, lint accumulation, shrinkage, color fading, and stretched out fabric.

Additional questions constructed to understand consumer preferences included optional text box responses, which requested consumers to identify any problems not addressed, and, if known, the style and fabric of leggings they frequently purchase. The final question of the survey asked consumers to select five desirable features for their leggings from a list of both functional and aesthetic qualities.

Pretest. A pretest was developed and distributed to a small sample (n=25) to ensure that the questionnaire was suitable for future, larger data collection. A convenience sample of college-age women was selected by the researcher. Participants were sent the survey in an email and asked to participate in the pretrial study**.** Open-ended questions asked participants to provide any additional performance problems and desires that were not mentioned in the questionnaire**.** This was to ensure that a comprehensive list of leggings performance problems and desires was being addressed.

Participants were also asked to identify any questions or terms that were unclear or contained errors. Results were used to refine and clarify the finalized survey for this research.

Methodology: Laboratory Evaluation

The laboratory evaluation of three brands of leggings was conducted in the University of Kentucky's Textile Testing Laboratory. Standard test methods from the American Society for Testing Material (ASTM) and the American Association of Textile Chemist and Colorists (AATCC) defined evaluation and measurement procedures for each test.

The evaluation included examining the leggings' aesthetic and functional performance features as well as fabric specifications. Fabric specifications included fabric weight, fabric count, and thickness. Functional evaluations included bursting strength and opacity. Aesthetic performance evaluations included color change, stretch recovery, pilling/fuzzing, and dimensional stability.

Sample. Leggings were selected based on survey data. Consumers were asked "What brand(s) of leggings do you regularly purchase?" The question allowed respondents to select all brands that applied to their purchasing habits. Lululemon and Nike were the most frequently purchased brands. Old Navy, Victoria's Secret, and 90 Degree were the next most commonly mentioned brands. Consumers were also asked to indicate the style name or fiber content of the leggings they typically purchase if known. Approximately 62% of the Lululemon consumers (24% of survey respondents) indicated that they wore Lululemon "Align" leggings which have a nylon/spandex blend. Only two Nike respondents indicated a fiber content or style. The Lululemon "Align" legging was selected as Sample 1 as a result of the survey. Online research was conducted to find a Nike legging that was similar in fabric content to the Lululemon "Align" legging since the Nike survey respondents could not specify the fiber content of their preferred legging. The Nike "Epic Lux," which is also made of nylon/spandex, was selected for Sample 2. Significant in-store and online research for Old Navy, Victoria's Secret, and 90 Degree leggings was conducted. Because Samples one and two are considered higher-end brands and since Old Navy and Victoria's Secret leggings were found to have a limited number

of available nylon/spandex leggings offered, a highly consumed nylon/spandex legging sold by 90 Degree was selected as Sample 3.

Four samples were purchased for Lululemon and 90 Degree. Five samples were evaluated from Nike because of a polyester design feature which was excluded from the evaluation. The 13 samples were purchased in black and ankle length since these are standard options and commonly selected among consumers. The three styles selected shared a similar fiber content blend of nylon and spandex. Table 3.1 provides a summary description of the three sample types chosen for evaluation.

Table 3.1

Description of Samples

Brand	Style Name	Fiber Content	Color	Purchase Price
Lululemon	Align	81% Nylon/ 19% Spandex	Black	$98.00
Nike	Epic Lux	78% Nylon/ 22% Spandex	Black	$66.00
90 Degree by Reflex	Power Flex	87% Nylon/ 13% Spandex	Black	$29.99

Procedures. To ensure consistency between samples, the leggings were conditioned according to ASTM D1776 – 16 *Standard Practice for Conditioning and Testing Textiles* (ASTM, 2019). The samples were placed in an atmospheric chamber registering at 70° ± 2° Fahrenheit and relative humidity of 65% ± 5% for a minimum of four hours before each test. The tests conducted for fabric specifications included fabric weight, fabric count, and fabric thickness. Functional qualities included opacity, and bursting strength. Aesthetic performance evaluation included color change, stretch recovery, pilling/fuzzing, and dimensional change.

Laundering. The legging samples were laundered together in a consumer front-load washer and dried in a tumble dryer. The care labels of each brand were evaluated to determine the wash parameters. Care label information can be found in table 3.2. The samples were laundered on the ‘colors/normal’ cycle with ‘cold’ water (30 °C/ 86 °F). Each cycle duration was approximately 60 minutes. For each laundry cycle, 30 grams of a national brand of liquid detergent was used. Water hardness from a municipal source averaged 12 grains per gallon. Samples were tumble dried on the ‘color/normal’ cycle.

Leggings were washed for 20 wash/dry cycles and evaluated initially before washing and after wash one, five, ten, and twenty (see Table 3.3 and Table 3.4). Sample 1 from each brand was used as an unwashed control.

Table 3.2

Care Instructions

Care Label Information			
Criteria	Lululemon	Nike	90 Degree
Wash	Machine Wash	Machine Wash	Machine Wash
Wash Cycle	Normal	Normal	Permanent Press
Wash Temperature	Cold	Cold	Cold
Dry	Tumble Dry	Tumble Dry	Tumble Dry
Dry Cycle	Delicates	Normal	Permanent Press
Dry Heat	Low	Low	Low

Table 3.3

Design of Evaluation for Lululemon and 90 Degree

Performance		Sample Number			
		Sample 1	Sample 2	Sample 3	Sample 4
Fabric Specifications	Fabric Weight	-	-	Wash 1 & 5	Wash 10 & 20
	Fabric Count	-	-	Wash 1 & 5	Wash 10 & 20
	Fabric Thickness	-	Wash 1, 5, 10, & 20	-	Wash 1, 5, 10, & 20
Function	Bursting Strength	-	-	Wash 1 & 5	Wash 10 & 20
	Opacity	-	Wash 1	-	Wash 20
Aesthetic	Color Change	Wash 1, 5, 10, & 20	Wash 1, 5, 10, & 20	-	Wash 1, 5, 10, & 20
	Stretch Recovery	-	-	Wash 5	Wash 20
	Pilling.& fuzzing	-	-	Wash 1 & 5	Wash 10 & 20
	Dimensional Stability	-	Wash 1, 5, 10, & 20	-	Wash 1, 5, 10, & 20

Table 3.4

Design of Evaluation for Nike

Performance		Sample Number				
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Fabric Characteristics	Fabric Weight	-	-	Wash 1 & 5	Wash 10	Wash 20
	Fabric Count	-	-	Wash 1 & 5	Wash 10	Wash 20
	Fabric Thickness	-	Wash 1, 5, 10, & 20	-	-	Wash 1, 5, 10, & 20
Function	Bursting Strength	-	-	Wash 1	Wash 5 & 10	Wash 20
	Opacity	-	Wash 1	-	-	Wash 20
Aesthetic	Color Change	Wash 1, 5, 10, & 20	Wash 1, 5, 10, & 20	-	-	Wash 1, 5, 10, & 20
	Stretch Recovery	-	-	Wash 5	Wash 5 &20	Wash 20
	Pilling & fuzzing	-	-	Wash 1 & 5	Wash 10	Wash 20
	Dimensional Stability	-	Wash 1, 5, 10, & 20	-	-	Wash 1, 5, 10, & 20

Fabric weight. Mass per unit weight was measured using ASTM D3776/D3776M – 09a (2017): *Standard Test Methods for Mass per Unit Area (Weight) of Fabric (ASTM, 2019).* An A J.A. King® Universal Sample Cutter was used to cut two 5.94 in^2 circular specimens from each legging brand. The specimens were weighed on an analytical balance. Specimens were cut and weighed on the balance before laundering and after one, five, ten, and twenty wash/dry cycles. The weight was recorded in grams and converted to ounces per square yard using the following formula:

$$Ounces/Yards^2 = 45.72 \times \text{weight in grams} / 5.94$$

Fabric count. Yarn count was conducted according to ASTM D8007 –15: *Standard Test Method for Wale and Course Count of Weft Knitted Fabrics (ASTM, 2019).* Two 1 x 1-inch specimens were cut from each brand of leggings. The fabric count

was reported as ‘wale x course,' and the total count was the addition of the two values. Counting was performed after one and twenty laundering cycles.

Thickness. The thickness of the legging samples was measured according to ASTM D1777-96 (2015): *Standard Test Method for Thickness of Textile Materials (ASTM, 2019)*. After conditioning in an environmental chamber, samples were placed face up on a thickness gauge. The gauge’s presser foot was released until in contact with the fabric and left for 5 to 6 seconds before recording the measurement. Ten measurements were taken from two samples of each brand; the results were reported as the average of the samples. Evaluations were conducted on two samples from each brand before laundering and after one, five, ten, and twenty wash/dry cycles.

Bursting strength. Evaluation for bursting strength followed ASTM D3786/D3786M – 18: *Bursting Strength of Textile Fabrics: Diaphragm Bursting Strength Tester Method (ASTM, 2019)*. Two 5x5 inch squares were cut from the samples for each testing interval. A circle with a one-inch diameter was drawn in the center of each specimen. The specimens were placed in a sewing hoop and stretched until the circle had a diameter of two inches. After conditioning in an atmospheric chamber, face up on a James Heal TruBurst Bursting Tester. Pneumatic pressure was applied to an expandable diaphragm until the point of rupture. The TruBurst Tester was set to achieve fabric rupture at 20 ± 5 seconds. Three samples from each brand were evaluated after one, five, ten, and twenty laundering cycles.

Opacity. Transparency was measured to assess how see-through the legging fabrics were after one and twenty laundering cycles. Opacity was assessed by using a HunterLab LabScan Spectrophotometer with a 2-inch port with a 45° viewing angle. A standard 5-inch circle was drawn on the back side of the fabric samples. The fabric was put in a sewing hoop and stretched to a specific 5.5-inch circumference. The stretched fabric in the sewing hoop was placed over the HunterLab LabScan port and measured with a white standard and black standard behind the fabric. Opacity was calculated as follows:

$$\%\text{Opacity} = [Y_{\text{black}}/Y_{\text{white}}] \times 100.$$

Color change. The color change of the leggings was evaluated according to AATCC Evaluation Procedure 1-2012: *Gray Scale for Color Change (*AATCC, 2019*).* An unwashed control sample for each brand was placed next to its corresponding washed sample and visually evaluated. Samples were positioned at a 45° ± 5° angle in a Spectra Light QC light booth using a D65 illuminant. The AATCC Gray Scale for Color Change (ISO International Standard 105/A02) was placed over the samples and used to evaluate color differences. The Gray Scale uses mounted gray reference chips to visually demonstrate the five-grade scale with half step increments. A color change rating of 5 indicates *none*, 4: *slight*, 3: *moderate*, 2: *severe*, 1: *very severe.* The researcher selected a color change grade using the Gray Scale Color Change while examining the washed and unwashed samples side by side. Evaluations were made after one, five, ten, and twenty wash/dry cycles.

Stretch recovery. A modified version of ASTM D2594: *Standard Test Method for Stretch Properties of Knitted Fabrics (*ASTM, 2019*)* was used to guide evaluating the legging samples stretch growth. After wash five and twenty, two lengthwise and widthwise 4 x 12-inch specimens were cut from each brand. The specimens were then folded in half and sewn into a loop. Benchmarks spanning 4 inches were marked on each sample. Rigid tubes were placed into the end of each specimen end, one to allow the specimen to be suspended and the other to allow the attachment of a five-pound weight to uniformly elongate the fabric and to provide tension. After two hours, the benchmarks were measured while the fabric was stretched to determine stretch ability. The specimen was then removed and allowed to recover for both one minute and one hour. The following equations were used to calculate the percent of fabric growth:

$$\text{Fabric Growth (Total Stretch) \%} = 100 \times [(B - A)/ A]$$

$$\text{Fabric Growth \%} = 100 \times [(C - A)/ A]$$

$$\text{Fabric Growth \%} = 100 \times [(D - A)/ A]$$

A = initial distance between benchmark measurements before tension applied

B = distance between benchmark measurements after two hours of tension applied

C = distance between benchmark measurements after one minute of recovery

D = distance between benchmark measurements after one hour of recovery

Pilling and fuzzing. Pilling was evaluated according to ASTM D4970/D4970M – 10: *Pilling Resistance and Other Related Surface Changes of Textile Fabrics: Martindale Tester* (ASTM, 2019*)*. Four circular specimens with diameters of 1.5 inches and four specimens with diameters of 5.5 inches were cut from each brand of leggings. The specimens were placed on a James Heal Nu-Martindale Abrasion and Pilling Tester. The smaller specimen was placed over the larger specimen using a 9 kPa pressure spindle. The specimen pairs underwent 1200 rubbing cycles before removing and evaluating. A subjective evaluation was conducted under a SpectraLight QC light booth at a 45° ± 5° angle using a D65 illuminant. The 1.5-inch specimens were compared to the ASTM photographic standard for Random Tumble Pilling Tester. Pilling severity was given a 1 through 5 rating with incremental half steps. A rating of 1 indicated *very severe pilling*; 2: *severe pilling*; 3: *moderate pilling;* 4 *slight pilling*; and 5: *no pilling*. Evaluations were conducted after one, five, ten, and twenty laundering cycles.

Dimensional stability. Dimensional change after home laundering was evaluated according to AATCC Test Method 150-2018: *Dimensional Changes of Garments after Home Laundering* (AATCC, 2019*)*. Three lengthwise and widthwise benchmarks were marked on two samples from each brand and measured before laundering. The samples were laid flat without tension and measured after one, five, ten, and twenty wash/dry cycles. Samples were conditioned in an atmospheric chamber before recording measurements. Dimensional change was calculated using the following formula:

$$\% \text{ Dimensional Change} = [100\ (B - A)/A]$$

where:

A = Original measurement

B = Measurement after laundering

Data Analysis

For analysis of the survey data, descriptive summary statistics were used. Percentages and frequency of responses were reported. Product evaluation results were recorded in Microsoft Excel software. For analysis, the data was exported to Minitab statistical software where descriptive statistics and one-way ANOVA were utilized. Statistical significance was determined by using a 95% confidence interval with a

significance level (α) of 0.05. Through one-way ANOVA, a pairwise comparison of the data was also used. A discussion of the varying performance of the leggings concludes the study.

Chapter Four

Results

The purpose of this research was to create a consumer profile of legging preferences by identifying consumers' desired legging features and encountered problems using a survey. The survey sample included 133 female, college-age students who wear leggings for non-athletic purposes. Additionally, this research evaluated the fabric characteristics along with both the aesthetic and functional performance qualities of three survey participant-identified frequently purchased brands of leggings. The evaluation sample included leggings from Lululemon, Nike, and 90 Degree.

Evaluation of the three legging brands included laboratory analysis of fabric weight, fabric count, fabric thickness, opacity, bursting strength, color change, stretch recovery, pilling/fuzzing, and dimensional change. Evaluations were performed on the legging samples after one, five, ten, and twenty laundering cycles. All leggings from the three brands were made of a similar nylon/spandex fabric blend; detailed data tables of each test and sample replication are presented in Appendix D.

The survey results were categorized and reported based on whether the question pertained to the functional, expressive, or aesthetic qualities of leggings according to the FEA Model (Lamb & Kallal, 1992). Summary statistics were used to describe the responses with percentages, averages, and frequency. Survey questions were categorized and reported based on whether the question related to the functional, expressive, or aesthetic qualities of leggings. Laboratory evaluations were categorized by brand and testing interval (i.e., Wash 1, Wash 5). Statistical significance of the data was determined by using a one-way ANOVA and a 95% confidence interval with an alpha level (α) of 0.05.

ASTM D4156-14 *Standard Performance Specification for Women's and Girls' Knitted Sportswear Fabrics* (ASTM, 2019) was used to evaluate the results of the laboratory studies when applicable. More detailed data tables for each evaluation after a laundering interval are presented in Appendix D.

For this research, the focus was made on comparing the sample analyses after washes five and twenty. The product evaluation conducted after five laundering cycles reflects a garment's performance after residual or temporary fabric finishes have been

removed. The product evaluation after twenty laundering cycles reflects a garment's serviceability over its lifetime.

Survey Results

A total of 134 participants completed the research questionnaire. Only one participant did not meet the predetermined study requirements; this response was excluded from the data summaries. Therefore, the final sample included 133 female participants who met the survey criterion of wearing leggings for non-athletic purposes. The age demographics of the sample are presented in Table 4.1.

Table 4.1

Summary of Sample Age

Age:	18-19	20-21	22-23	24-25	26 or older
Count:	40	68	17	6	2

Results of the survey responses are grouped according to questions related to function, expressive, and aesthetic qualities of leggings (FEA Model). Questions in the questionnaire which could not be categorized by the FEA model categories are included at the end of the survey results.

Function. Consumers were presented with a list of functional and durability problems with leggings in the first survey questions related to function. There were eleven options in total which included: (1) uncomfortable material, (2) see-through fabric, (3) thick/restrictive fabric, (4) lingering body odor, (5) loss of compression abilities, (6) loss of wicking abilities, (7) loss of water resistance ability, (8) ripping fabric, (9) ripping seams, (10) holes, and (11) worn down fabric. The consumers were asked to select all the functional issues they had encountered after wearing leggings; the percentages are reported in Figure 4.1.

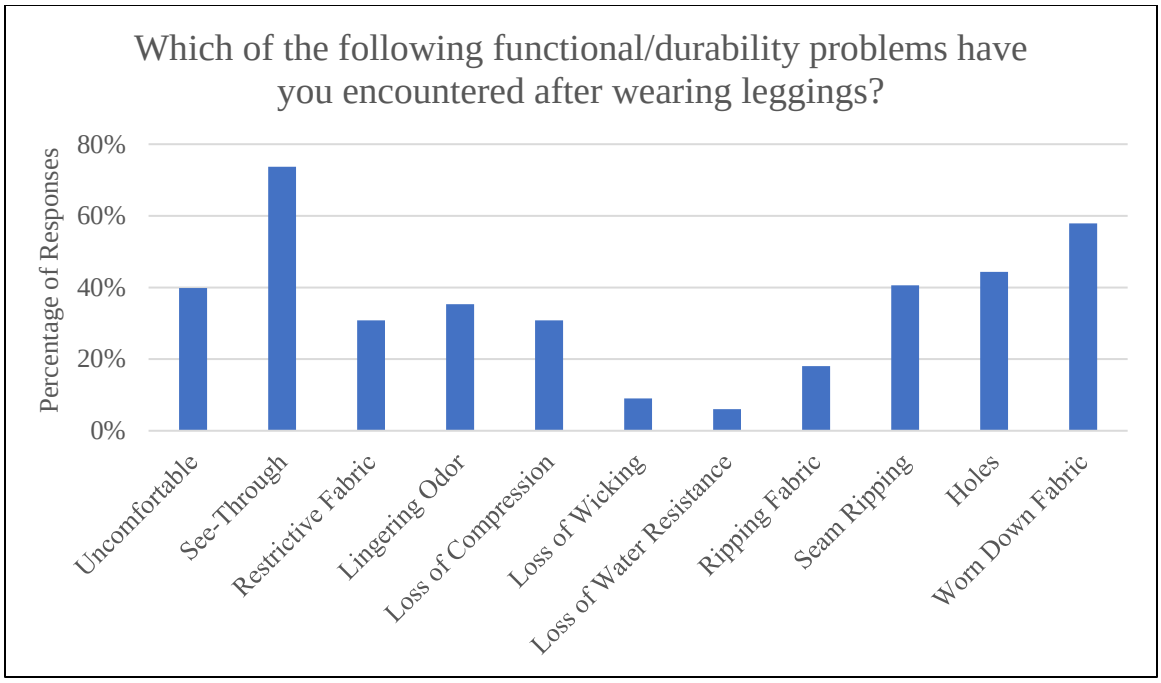

Figure 4.1 Frequency of Encountered Functional Problems.

When considering functional or durability problems encountered, “see-through fabric” was the most frequently selected response, with approximately 74% of responses indicated that they had encountered “see-through fabric” after wearing leggings. Another frequently encountered problem was that of “fabric becoming worn down;” approximately 58% of the respondents had experienced this problem.

The questionnaire presented the eleven functional and functional durability performance problems previously discussed. Survey respondents were also asked to rank their level of frustration with the functional performance problems encountered. The level of frustration was rated using a five-option scale which included *not frustrating, slightly frustrating, moderately frustrating, very frustrating,* and *extremely frustrating*. The response percentages are presented in Table 4.2. Responses which indicated that the problem was not encountered are excluded from the table.

Table 4.2

Level of Functional Frustration

Level of Functional Frustration					
Performance Frustration	Not Frustrating	Slightly Frustrating	Moderately Frustrating	Very Frustrating	Extremely Frustrating
Uncomfortable Material	4.5%	22.0%	19.7%	13.6%	9.8%
See-Through Fabric	1.5%	11.4%	17.4%	34.8%	22.0%
Thick/Restrictive Fabric	9.1%	18.2%	28.8%	9.8%	4.5%
Lingering Body Odor	2.3%	13.6%	15.9%	18.9%	15.9%
Loss of Compression	6.8%	10.6%	16.7%	22.7%	6.1%
Loss of Wicking Ability	6.1%	13.6%	16.7%	10.6%	2.3%
Loss of Water Resistance	9.1%	15.2%	10.6%	10.6%	1.5%
Ripping Fabric	0.8%	8.4%	12.2%	17.6%	18.3%
Ripping Seams	1.5%	8.4%	16.8%	19.1%	22.9%
Holes	0.0%	8.3%	14.4%	25.8%	22.7%
Worn Down Fabric	2.3%	19.4%	19.4%	19.4%	17.1%

The top two levels of importance (*very frustrating* and *extremely frustrating*) were combined for each category to achieve a substantive rating level. “See-through fabric” had the highest combined percentage of responses with 57%. The second highest was that of “holes” which when combined had 49% of responses, closely followed by 42% who indicated noteworthy frustration with “ripping seams.” The following combined categories ranked as follows: 37% for “worn down fabric,” 36% for “ripping fabric,” 35% for “lingering body odor,” 29% for “loss of compression,” and 23% for “uncomfortable material,” 14% for “thick or restrictive fabric,” 13% for “loss of wicking abilities,” and 12% for “loss of water resistance.”

The survey next asked consumers which functional features they found to be most desirable when selecting a new pair of leggings. Respondents were given seven functional performance features: (1) comfortable material, (2) material is not see-through, (3) odor control, (4) compression ability, (5) wicking ability, (6) material is not too thick,

and (7) water resistance. Consumers were required to select one feature that they found to be the most important. The survey question and response percentages are presented in Figure 4.2.

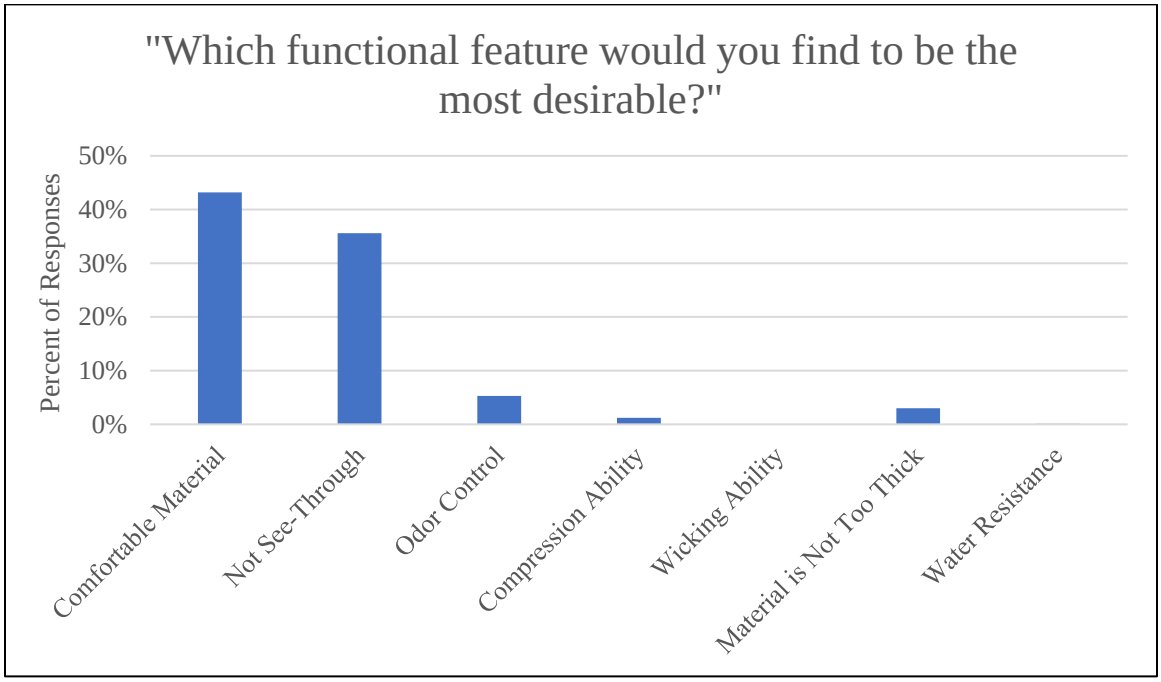

Figure 4.2 Frequency of Desired Functional Features.

Consumers indicated that the most desirable functional feature was firstly "comfortable material" with approximately 43% of respondents selecting this option. The second most frequently selected option was "material is not see-through" which was selected by 36% of respondents. "Compression ability" was selected by 12%, while "odor control" was selected by 5%. "Material is not too thick" was found to be the most desirable functional feature by 3% of respondents. No consumers selected "wicking abilities" or "water resistance" as a top desirable functional feature for their leggings.

The survey sample was also asked to rate the level of importance for functional performance categories when shopping for a new pair of leggings. Consumers were presented with the seven functional performance features discussed in the question above and were asked to rate the level of importance. There were five rating options, which ranged from *not important* to *extremely important.* The percentages of responses for each rating category are presented in Table 4.3.

Table 4.3

Level of Functional Importance

Level of Functional Importance					
Performance Features	Not Important	Slightly Important	Moderately Important	Very Important	Extremely Important
Comfortable Material	0.0%	2.3%	6.1%	39.4%	52.3%
Not See-Through	0.0%	2.3%	6.8%	35.6%	55.3%
Fabric Not Thick/Restrictive	6.1%	15.9%	36.4%	31.1%	10.6%
Compression Ability	9.9%	16.0%	33.6%	29.0%	11.5%
Wicking Ability	21.2%	19.7%	37.9%	16.7%	4.6%
Water Resistance	27.3%	26.5%	33.3%	9.9%	3.0%
Odor Control Ability	6.8%	23.5%	26.5%	30.3%	12.9%

For “comfortable material” and “material not see-through,” most respondents selected *extremely important*. When *extremely important* and *very important* were combined, over 90% of respondents showed substantive importance with “comfortable material” and “material not see-through.” Those selecting “odor control ability,” “fabric which is not thick or restrictive,” and “compression ability” combined responses were as follows: 43%, 42%, and 41%. “Wicking ability” had a much lower combined importance rate of 21%. The lowest combined importance value was that of “water resistance” which only had 13% of consumers describe it as either *very important* or *extremely important*.

Expressive. When examining the expressive qualities of leggings, consumers were asked about their brand preferences. They were presented with ten brands and asked from which brands they regularly purchase their leggings. In a separate question, consumers were asked from which of the brands they would ideally wish to purchase their leggings. Figure 4.3 shows the results of both questions by comparing the brands from which consumers regularly purchase their leggings next to the brands from which they would ideally purchase leggings. Consumers were also given an "Other" option which allowed them to write their own response.

Figure 4.3 Brand Preference Comparison.

Lululemon was considered to be the most regularly purchased and most ideally purchased brand for leggings. Nike, Fabletics, and Athleta were also frequently selected as ideal brands to purchase. However, consumers indicated that Lululemon, Nike, and Old Navy are the leggings brands which they choose to purchase regularly. When describing other brands that are frequently purchased, ten consumers mentioned Aerie, and five indicated that they purchase Target's private label brand, JoyLab.

After selecting the brands, survey respondents were asked to give a reason for why they purchased from the "regularly purchased brands." They were also asked to identify the reason they considered a legging brand to be ideal to purchase; a comparison of the percentages of responses is presented in Table 4.4. The options given were: (1) I like the designs and colors they use, (2) the price is best for me, (3) they offer quality products, (4) I want to be associated with the brand, (5) many of my friends wear their products, or (6) my favorite celebrity or social influencer wear the brand's products.

Table 4.4

Brand Selection Reasoning

Reasons	Ideally Purchased Brand	Regularly Purchased Brand
Colors/Designs	12.2%	6.8%
Price	12.2%	23.3%
Quality	67.9%	60.2%
Brand Association	5.3%	4.5%
Friend Influence	0.8%	0.8%
Celebrity Influence	0.0%	0.0%
Other	1.5%	4.5%

Approximately 60% of the respondents indicated that they regularly purchased from the brand they selected because they believe that the brand offers “quality” products. Additionally, 68% of consumers indicated that they selected an ideal brand to purchase leggings from because they believed those brands offer “quality products.” "The price is best for me" was also recurrently selected as a reason for regularly purchasing from a brand. Celebrities and social influencers appeared not to influence consumers’ reasons for regularly purchasing leggings from a brand, nor did celebrities appear to influence consumers when deciding what legging brand they found to be ideal.

Survey respondents were also asked, “In which of the following situations would you wear leggings?” They were given eight social or situational locations which included: (1) attending class, (2) running errands, (3) business casual work environment, (4) professional business work environment, (5) to a bar or restaurant, (6) to a party, (7) to travel, or (8) other. Response frequencies are presented in Figure 4.4.

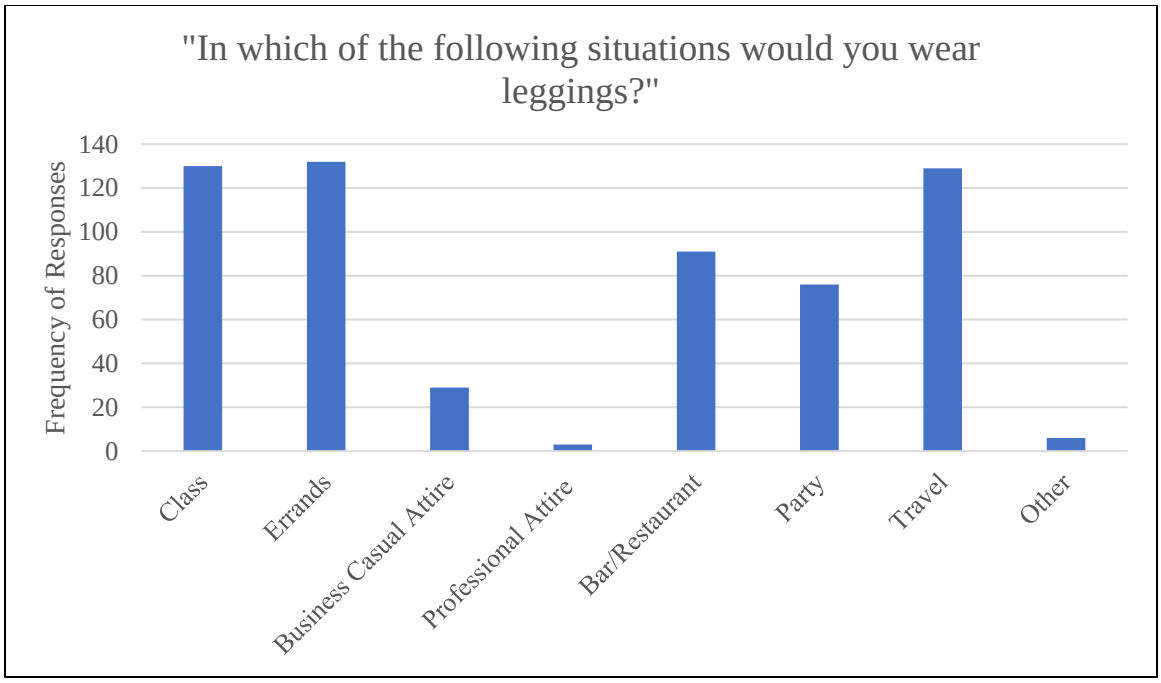

Figure 4.4 Situational Participation in Wearing of Leggings.

"Running errands" was the most commonly selected situation for wearing leggings, with almost all survey respondents (132 of 133) indicating they wore leggings for this activity. Wearing leggings for "travel" and "class" was picked almost as frequently as "running errands." Several consumers indicated that they would wear leggings out to a "bar/restaurant" or a "party." However, very few consumers indicated that they would wear leggings for "professional business attire."

The final question for the expressive category was, "How do you typically wear your leggings?" Consumers were asked how they typically wear their leggings when paired with other apparel items. Three options were given which included: (1) as pants regardless of top length, (2) as pants but only with longer style tops, (3) as a base layer beneath a skirt or dress, and (4) other. The percentages of responses are presented in Table 4.5.

Table 4.5

Legging Outfit Pairing

Legging Pairing	Percent
As pants regardless of top length	86.5%
As pants but only with longer style tops	12.8%
As a base layer beneath a skirt or dress	0.8%
Other	0.8%

Approximately 86.5% of the survey participants indicated that they wear their leggings "as pants regardless of top length." Approximately 13% of the participants selected that they wear leggings as pants but require a "longer style top" to be worn with the leggings. Very few consumers wear leggings with other outfit pairings such "as a base layer beneath a skirt or dress."

Aesthetic When evaluating consumers' aesthetic desires for their leggings, survey respondents were asked two questions regarding preferences for features. They were first asked, "What style features do you prefer for your leggings?" Consumers were presented with a list of six features and asked to select all that apply. Options included: (1) mesh panels, (2) seamless, (3) high waistband, (4) normal waistband, (5) slashes or cut-outs in fabric to expose skin, (6) pockets, and (7) other. The percentages of responses were determined for each style feature option. The style features and response percentages are presented in Table 4.6.

Table 4.6

Style Feature Preference

Style Feature	Percent of Responses
Mesh Panels	13.1%
Seamless	13.4%
High Waistband	41.0%
Normal Waistband	3.6%
Slashes/Cuts in Fabric	3.2%
Pockets	21.6%

A “high waistband” accumulated 41% of the responses. “Pockets” were the second most frequently mentioned style feature with 22% of responses. Nearly the same percentage of respondents preferred “mesh panels” as those who favor a “seamless” option (i.e. ~ 13%). Almost four percent of responses were for a “normal waistband,” and three percent were for slashes or cuts in the fabric that are created as a style feature to expose segments of skin.

The second question regarding feature preferences was, "What length do you prefer for your leggings?” The questionnaire gave participants three options for length preference which included: (1) ankle length, (2) mid-calf length, (3) just below the knee, stirrup, (footed), and (4) other. The frequency of responses for each category is presented in Figure 4.5.

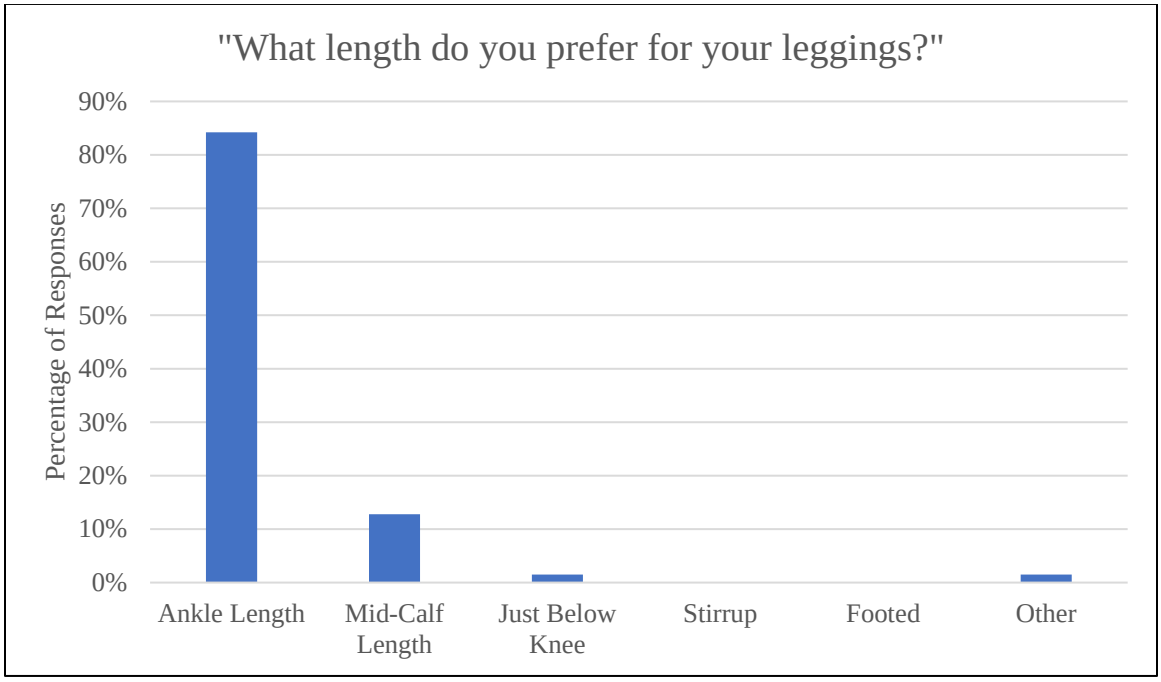

Figure 4.5 Legging Length Preference.

A large majority of the survey participants (approximately 84%) selected “ankle length” as their preferred legging length. “Mid-calf length” was the next most frequently selected option, with only 13% of respondents preferring this length.

The questionnaire next asked participants to select the aesthetic performance problems they had encountered after wearing leggings. They were presented with five

aesthetic performance problems, which included: (1) excessive lint accumulation, (2) color fading or change, (3) pilling, (4) shrinking, and (5) stretched out fabric. The question required that they select all issues that had been encountered. Percentages of responses are shown in Figure 4.6.

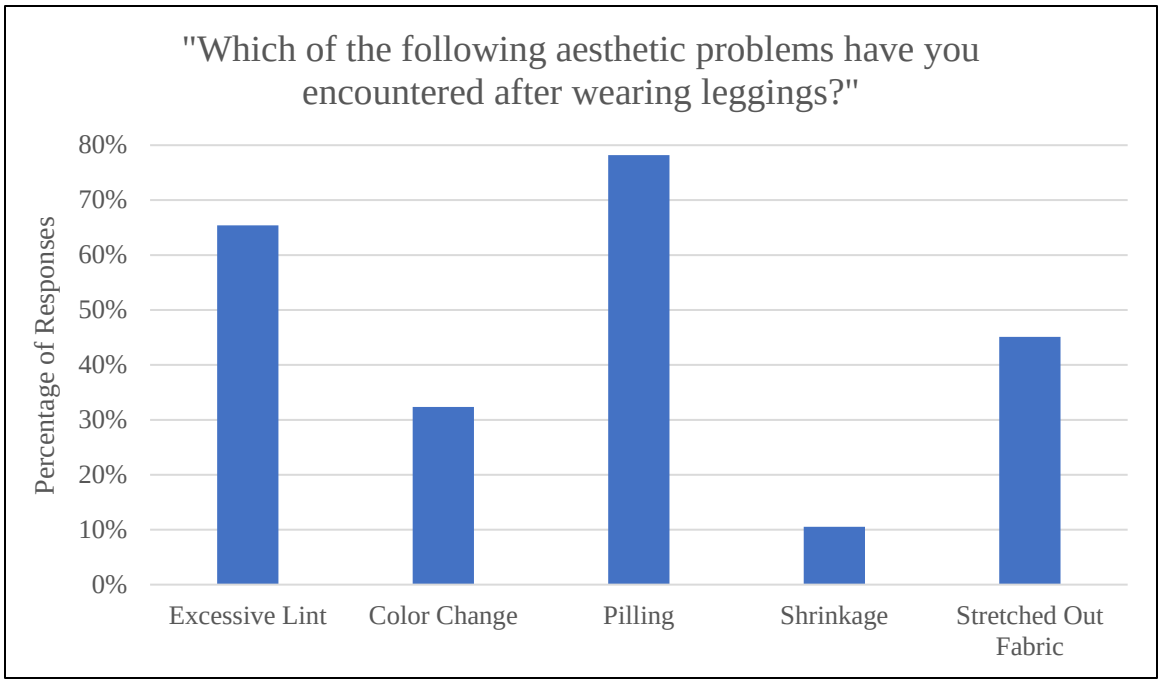

Figure 4.6 Frequency of Encountered Aesthetic Problems.

When the sample was asked about aesthetic problems, “pilling” was the most often reported issue, being selected by 78% of the respondents. “Excessive lint” was reported by 65% of respondents, while “stretched out fabric” was experienced by 45%. “Color change” was encountered by 32% of the respondents, and, finally, “shrinkage” was the least experienced aesthetic problem with 11% of responses.

Survey respondents were requested to rate their frustration level with the aesthetic problems. They were offered the five aesthetic problems presented in Figure 4.6 and then asked to express their level of frustration with each option. To rank the levels of frustration, the sample was given a five-option rating scale, ranging from *not frustrating* to *extremely frustrating.* The percentages reported for each aesthetic frustration level are presented in Table 4.7.

Table 4.7

Level of Aesthetic Frustration

Average Level of Aesthetic Frustration					
Performance Frustration	Not Frustrating	Slightly Frustrating	Moderately Frustrating	Very Frustrating	Extremely Frustrating
Lint Accumulation	4.9%	22.0%	30.1%	26.0%	17.1%
Color Fading or Change	6.7%	24.4%	42.2%	14.4%	12.2%
Pilling	3.4%	16.2%	20.5%	27.4%	32.5%
Shrinkage	5.7%	17.1%	28.6%	31.4%	17.1%
Stretched Out Fabric	5.8%	19.2%	23.1%	30.8%	21.2%

"Pilling" had the highest percentage (33%) of responses for *extremely frustrating.* When *very frustrating* and *extremely frustrating* were combined, 60% of consumers found "pilling" to be frustrating. The next highest combined percentage was that of "stretched out fabric," which had 52% of responses. "Shrinkage" had 49%, "lint accumulation" 43%, and "color change" 27% when *very frustrating* and *extremely frustrating* were combined.

Consumers were asked what aesthetic features they desired when shopping or purchasing a new pair of leggings. The questionnaire presented six aesthetic performance feature options which included: (1) no pilling, (2) no lint accumulation, (3) no color change/fading, (4) no shrinkage, or (5) fabric does not become stretched out. The respondents were required to select the one feature they found to be most desirable. Frequency of responses is presented in Figure 4.7.

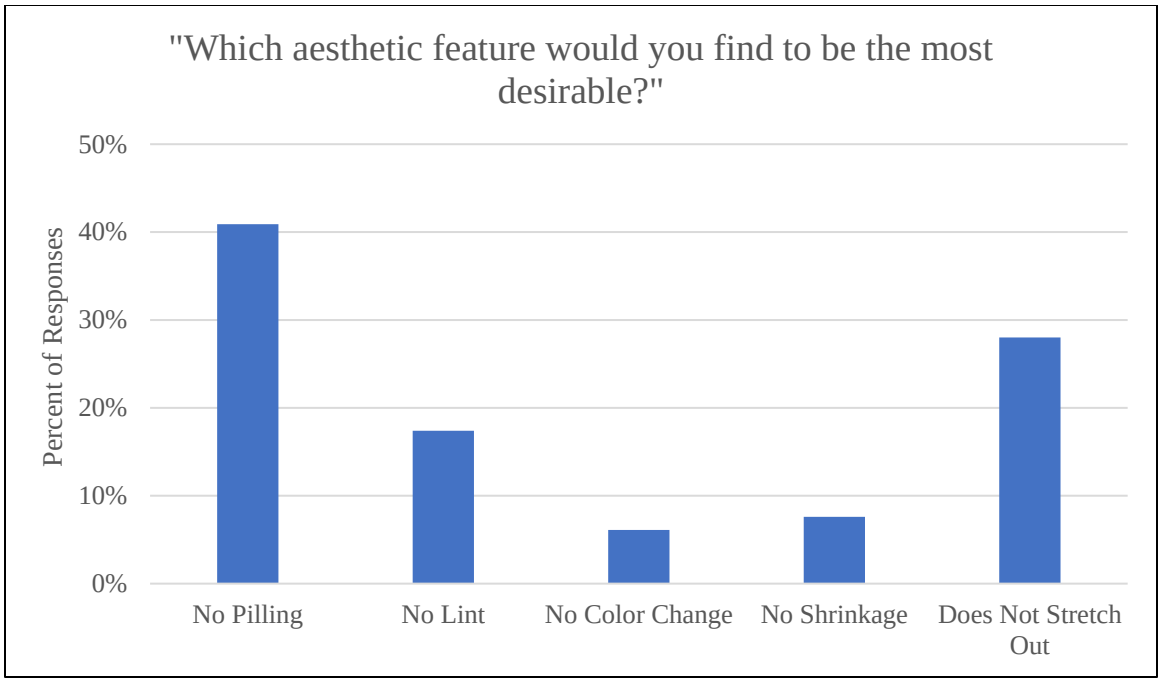

Figure 4.7 Frequency of Desired Aesthetic Features.

"No pilling" was the most selected aesthetic performance feature, with approximately 40% of the surveyed sample. "Fabric does not stretch out" was the second highest category, selected by 28% of consumers. "No lint accumulation" was considered desirable by 17%, while the feature of "no shrinkage" was desirable to 8%. Finally, "no color change" was selected as a desirable aesthetic feature by 6% of the surveyed sample.

The consumers were asked to rate the level of importance for aesthetic performance categories when shopping for a new pair of leggings. They were presented with the five aesthetic performance categories shown above (Figure 4.7) and were asked to rate the level of importance for each group. There were five rating options, which ranged from *not important* to *extremely important.* The percentages for each aesthetic performance category are presented in Table 4.8.

Table 4.8

Level of Aesthetic Importance

Level of Aesthetic Importance					
Performance Features	Not Important	Slightly Important	Moderately Important	Very Important	Extremely Important
Low Pilling	5.4%	6.9%	32.3%	28.5%	26.9%
Low Lint	1.5%	13.9%	33.9%	33.1%	17.7%
Minimal Color Change	5.4%	9.2%	41.5%	31.5%	12.3%
Minimal Shrinkage	6.2%	13.2%	35.7%	29.5%	15.5%
Does Not Stretch Out Easily	3.1%	5.5%	30.5%	39.1%	21.9%

When valuing the importance of the aesthetic performance qualities, the highest percentage of responses were for *moderately important*. The exception to this was "fabric which does not become stretched out easily," which 39% of consumers said was *very important.* When combining the *very important* and *extremely important* responses, 61% of consumers valued "fabric does not stretch out easily" as important. "Low pilling" and "low lint" accumulation were described by 55% and 51% of survey respondents when the two levels of importance were combined. "Color change" and "minimal shrinkage" were the only two categories which had less than 50% of the respondents describe the categories as *very important* or *extremely important*. Approximately 45% chose "shrinkage" while 44% selected "minimal color change" at these levels of importance.

Performance quality. Consumers were finally asked, "If you were to design your own leggings, which of the following would be most appealing?" They were presented with a total of eleven aesthetic and functional performance features for leggings and asked to select up to five of the features. Frequency of responses is presented in Figure 4.8.

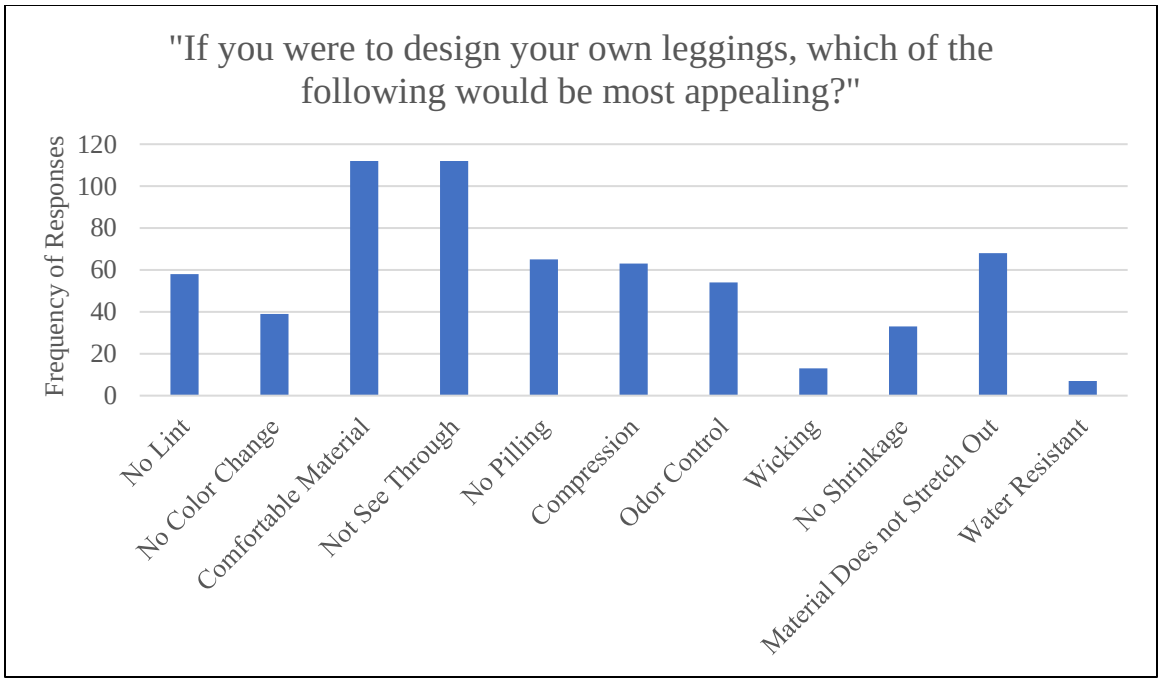

Figure 4.8 Preferred Performance Qualities.

The top five responses were “comfortable material,” “material which is not see-through,” (both selected with the highest frequency), “material that does not stretch out,” “no pilling,” and “compression ability.” The remaining options were, ranked in decreasing order of frequency: “no lint,” “odor control,” “no color change,” “no shrinkage,” “wicking abilities,” and “water resistance.”

Laboratory evaluation results

The laboratory evaluation examined three brands of leggings. Four legging samples were tested from Lululemon and 90 Degree, and five Nike pairs were purchased for testing. A nylon/spandex blend style from the three brands was chosen according to its similarity in fabric composition. The Nike style selected had a polyester panel design that was excluded from the evaluation with only the nylon/spandex fabric portion of the Nike leggings being tested. Details for each type of legging are presented in Table 4.9.

Table 4.9

Laboratory Evaluation Sample Details

Brands	Lululemon	Nike	90 Degree by Reflex
Fiber Content	81% Nylon/19% Spandex	78% Nylon/22% Spandex	87% Nylon/13% Spandex
Fabric	Warp Knit	Warp Knit	Warp Knit
Color	Black	Black	Black
Size Range	0-14	XS-XL	XS-XL
Samples Size	6, 12, 14	S, L, XL	S, L
Style Name	Align Pant	Epic Lux	Power Flex
Country of Origin	Vietnam	Cambodia	Vietnam
Registration Number (RN)	106259	56323	144527
Suggested Retail Price	$98.00	$95.00	$88.00
Purchase Price	$98.00	$66.00	$29.00

Fabric specifications. A fabric specification evaluation was conducted for each brand of leggings. Fabric weight, fabric count, and fabric thickness were each measured. Fabric weight and thickness were measured after one, five, ten, and twenty laundering cycles while fabric count was determined after one and twenty washes. The results for the fabric specifications are presented below.

Fabric weight. The weight of the leggings was measured according to ASTM D3776/D3776M – 09a (2017): *Standard Test Methods for Mass per Unit Area (Weight) of Fabric*. Two 5.94 in^2 circular specimens were cut from each brand of leggings using an A J.A. King® Universal Sample Cutter. Their weights were measured after one, five, ten, and twenty laundering cycles. The fabric weights of the three specimens were averaged after each testing interval. The resulting data is presented in Figure 4.9 and Table 4.10.

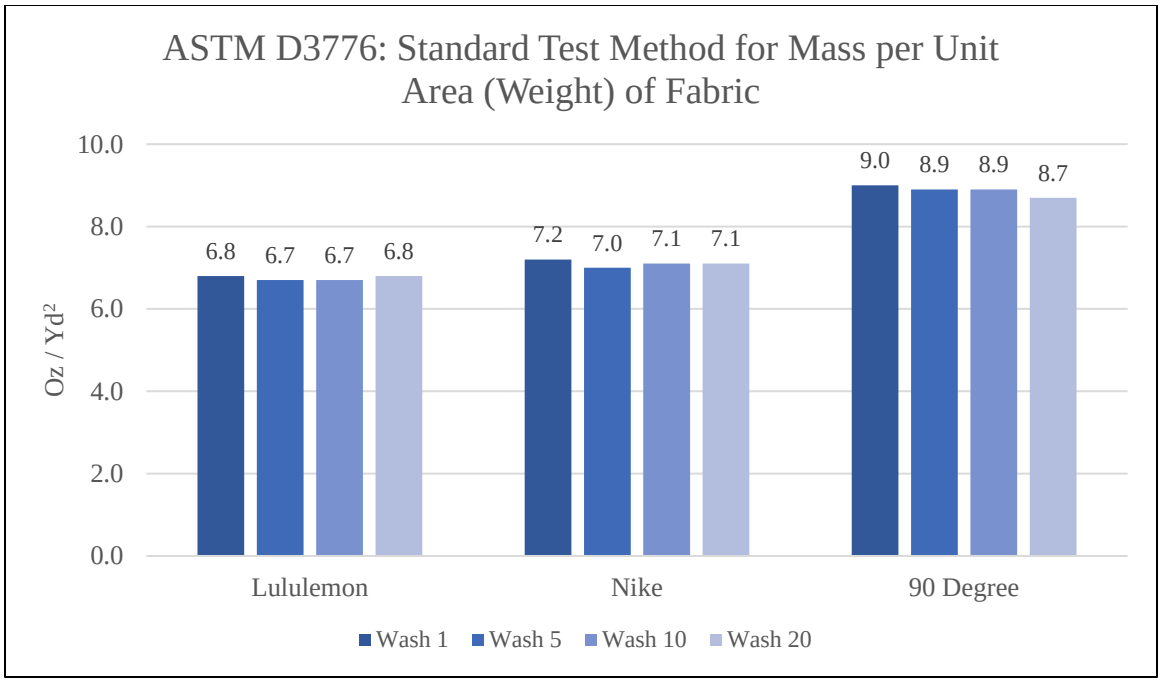

Figure 4.9 Mass per Unit Area of Fabric.

Table 4.10

Mass per Unit Area of Fabric

Test Interval	Brand	Mean Weight (oz/yd^2)	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	6.7	0.0	0.000	B	1:2	0.064
	Nike	7.0	0.0		B	2:3	0.000
	90 Degree	8.9	0.2		A	3:1	0.000
Wash 20	Lululemon	6.8	0.1	0.000	B	1:2	0.053
	Nike	7.1	0.0		B	2:3	0.000
	90 Degree	8.7	0.1		A	3:1	0.000

*Lululemon: 1; Nike: 2; and 90 Degree: 3

According to Bubonia (2014), fabrics between 6 and 8 ounces per square yard are categorized as a medium weight while medium heavy fabrics fall between 8 and 10 ounces per square yard. Based on this criteria, the Lululemon and Nike leggings had a medium fabric weight while the 90 Degree leggings had a medium heavy weight. One-way ANOVA confirmed that there was a difference in the mean weights of the fabrics after both five (p-value=0.000) and twenty (p-value=0.000) laundering cycles.

A pairwise comparison determined that the mean weight of the 90 Degree leggings was significantly heavier than that of the Lululemon leggings after both Wash 5 and Wash 20 (p-value=0.000). The 90 Degree leggings' weights were also found to be statistically significant when compared to the Nike leggings (p-value=0.000); however, Lululemon and Nike's fabric weight demonstrated no significant difference (p-value=0.053). Overall, the 90 Degree fabric weight was significantly heavier than the Lululemon or Nike fabric weights.

Fabric count. Count of the legging fabrics followed ASTM D8007 –15: *Standard Test Method for Wale and Course Count of Weft Knitted Fabrics*. Two 1 x 1-inch specimens were cut from each brand of leggings and evaluated after one and twenty laundering cycles. The average fabric count of the two specimens from each brand is reported in Figure 4.10 and Table 4.11.

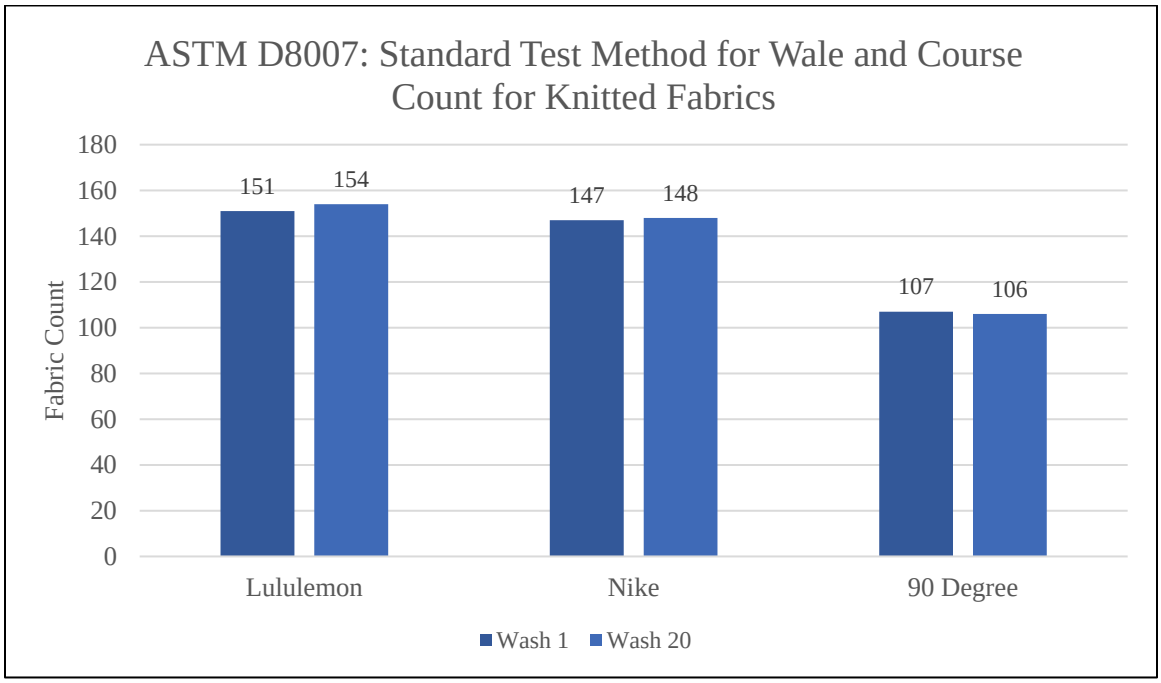

Figure 4.10 Comparison of Fabric Count after Wash 1 and Wash 20.

Table 4.11

Comparison of Fabric Count after Wash 1 and Wash 20

Test Interval	Brand	Mean Count	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 1	Lululemon	151	6.0	0.004	A	1:2	0.399
	Nike	147	4.2		A	2:3	0.003
	90 Degree	107	2.5		B	3:1	0.002
Wash 20	Lululemon	154	1.1	0.000	A	1:2	0.002
	Nike	148	0.0		B	2:3	0.000
	90 Degree	106	0.4		C	3:1	0.000

*Lululemon: 1; Nike: 2; and 90 Degree: 3

After twenty washes, the Lululemon leggings had the highest fabric count of the three brands, which was determined to be 154. Nike was counted as 148 while the 90 Degree leggings appeared to have a significantly lower count of 106. One-way ANOVA determined that the difference in the mean fabric count of the leggings was statistically significant. There was significance after one laundering cycle (p-value=0.004) because the 90 Degree leggings had a lower mean fabric count when compared to both Nike (p-value=0.000) and Lululemon (p-value=0.000). However, the fabric counts of Lululemon and Nike leggings were not significantly different from each other (p-value=0.399).

Statistical significance was determined after twenty laundering cycles (p-value=0.000). A pairwise comparison determined that all mean fabric counts of the leggings differed. Overall, the fabric count of the 90 Degree leggings was significantly lower than that of the Lululemon and Nike leggings after Wash 1; however, after Wash 20, Lululemon, Nike, and 90 Degree had significantly different fabric counts from one another.

Fabric thickness. Thickness was measured according to ASTM D1777-96 (2015): *Standard Test Method for Thickness of Textile Materials.* Two leggings samples from each brand were measured for thickness in ten locations after one, five, ten, and twenty laundering cycles. Results for thickness are presented in Figure 4.11 and Table 4.12.

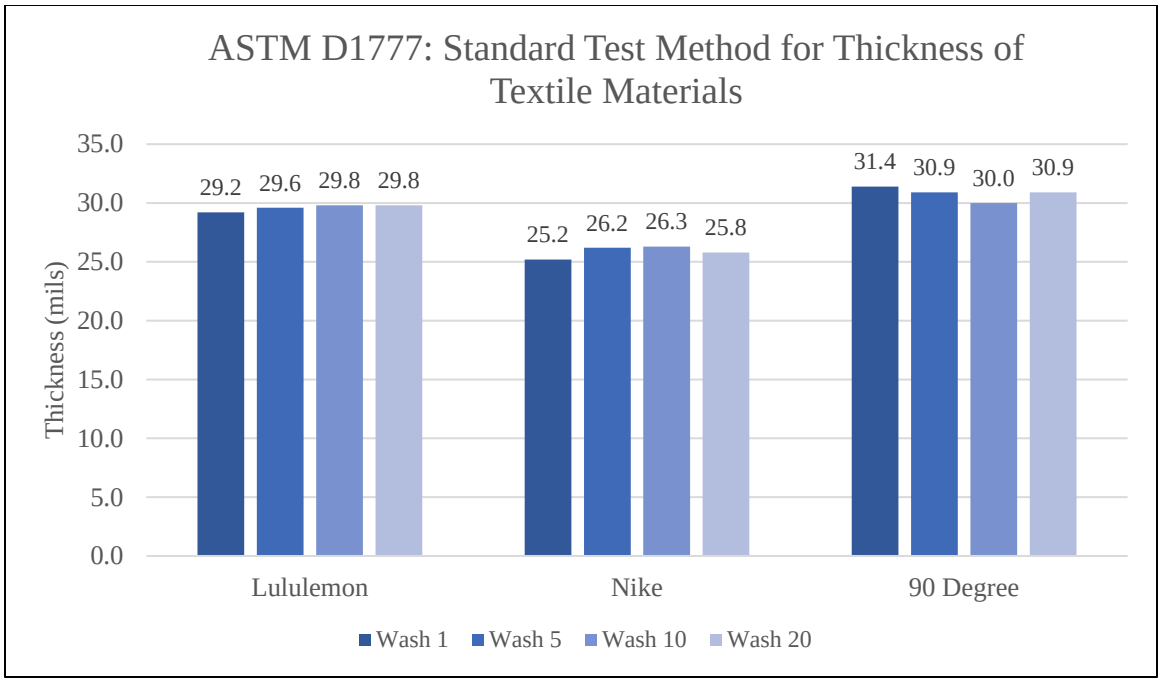

Figure 4.11 Comparison of Fabric Thickness after Test Intervals.

Table 4.12

Comparison of Fabric Thickness

Test Interval	Brand (mils)	Mean Thickness	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	29.6	0.2	0.015	A	1:2	0.018
	Nike	26.2	1.2		B	2:3	0.007
	90 Degree	30.9	0.3		A	3:1	0.159
Wash 20	Lululemon	29.8	0.7	0.003	A	1:2	0.003
	Nike	25.8	1.0		B	2:3	0.002
	90 Degree	30.9	0.4		A	3:1	0.113

*Lululemon: 1, Nike: 2, and 90 Degree: 3

The evaluation of thickness indicated that the 90 Degree leggings had the thickest material of the three brands: 30.9 mils. However, after twenty washes, the Lululemon leggings had a thickness reading of 29.8 mils, which is similar to that of the 90 Degree leggings. The Nike leggings were found to have a thinner mean thickness than the other brands (25.8 mils). One-way ANOVA confirmed that these differences were statistically significant after both five ($p=0.015$) and twenty ($p=0.003$) laundering cycles.

A pairwise comparison determined a difference in the Lululemon leggings' thickness compared to that of Nike after five and twenty laundering cycles (p-

value=0.018 for Wash 5 and p-value=0.003 for Wash 20). When the Nike leggings were compared to 90 Degree leggings, there was a statistically significant difference after Wash 5 (p-value=0.007) and Wash 20 (p-value=0.002). The difference between Lululemon and 90 Degree was not statistically significant for Wash 5 (p-value=0.159) nor Wash 20 (p-value=0.113). Overall, the Nike leggings had significantly less thickness than that of the Lululemon or 90 Degree leggings after both five and twenty laundering cycles.

Functional performance. For functional evaluations, the Lululemon, Nike, and 90 Degree leggings were tested for bursting strength. Testing was conducted after one, five, ten, and twenty laundering cycles, Results for the functional performance evaluations are presented below.

Bursting strength. Strength of the leggings was tested using ASTM D3786/D3786M – 18: *Bursting Strength of Textile*. Three specimens were cut from each brand after one, five, ten, and twenty laundering cycles. The specimens were tested on a James Heal TruBurst Bursting Tester. Pneumatic pressure was applied until the point of rupture. Averages for each testing interval are presented in Figure 4.12 and Table 4.13.

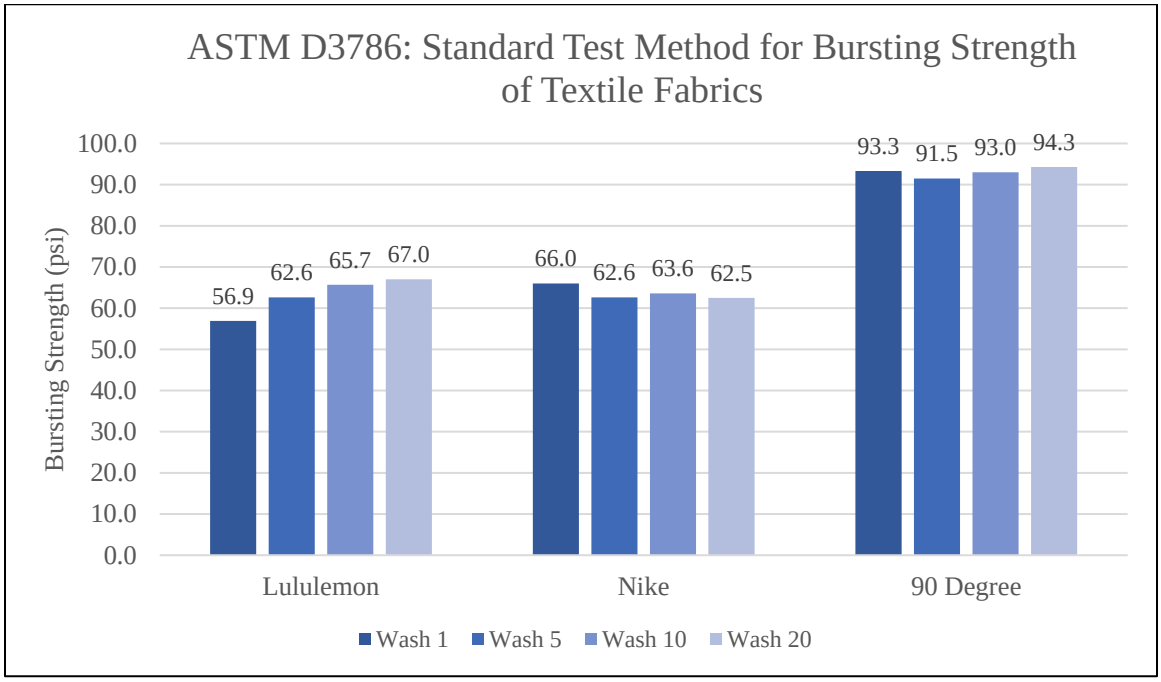

Figure 4.12 Comparison of Bursting Strength after Test Intervals.

Table 4.13

Comparison of Bursting Strength

Test Interval	Brand	Mean psi	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	62.6	2.8	0.000	B	1:2	1.000
	Nike	62.6	2.3		B	2:3	0.000
	90 Degree	91.5	3.0		A	3:1	0.000
Wash 20	Lululemon	67.0	3.7	0.001	B	1:2	0.345
	Nike	62.5	6.6		B	2:3	0.000
	90 Degree	94.3	5.4		A	3:1	0.001

*Lululemon: 1; Nike: 2; and 90 Degree: 3

While the Lululemon leggings' bursting strength gradually increased throughout testing, the Nike and 90 Degree results fluctuated very little in comparison. The bursting strength of the 90 Degree leggings was found to be higher than that of either the Lululemon or Nike leggings. One-way ANOVA determined that there was a statistically significant difference in the bursting strength of the brands after both five (p=0.000) and twenty (p=0.001) laundering cycles.

A pairwise comparison found that there was no difference between the Lululemon and Nike leggings' bursting strengths after both Wash 5 (p-value=1.000) and Wash 20 (p-value=0.345). However, there was statistical significance when comparing Nike to Lululemon after five (p-value=0.000) and twenty (p-value=0.000) laundering cycles. Furthermore, the difference between the 90 Degree and Lululemon leggings was also found to be statistically significant after both Wash 5 (p-value=0.000) and Wash 20 (p-value=0.001). Overall, the 90 Degree leggings' bursting strength was significantly higher than that of the Lululemon or the Nike Leggings, but Nike and Lululemon were not significantly different from each other.

Opacity. Sheerness of the fabric was tested using a HunterLab LabScan. A standard 5-inch circle was drawn on the fabric samples and stretched in a sewing hoop to a predetermined 5.5-inch circumference. The stretched fabric was first measured with a white standard behind it and then with a black standard behind it. Opacity percentages after one and twenty laundering cycles are presented in Figure 4.13 and Table 4.14.

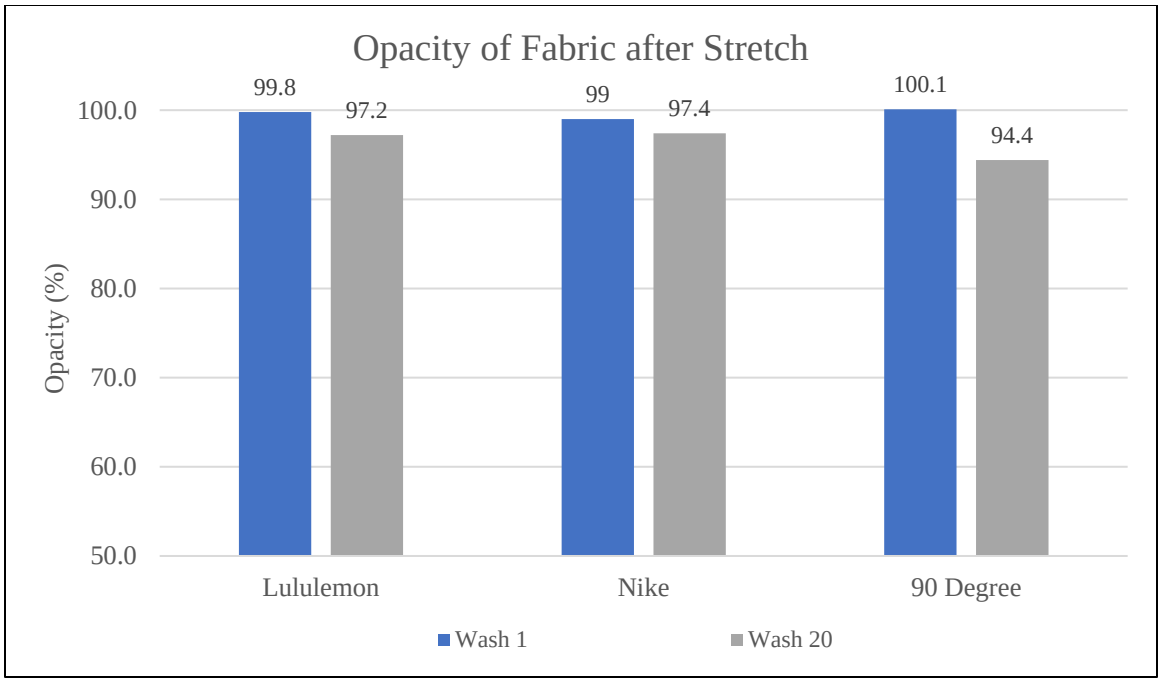

Figure 4.13 Percent of Opacity of Stretched Leggings

Table 4.14

Percent of Opacity of Stretched Leggings

Test Interval	Brand	Percent Opaque	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 1	Lululemon	99.8%	1.6	0.591	A	1:2	0.493
	Nike	99.0%	0.1		A	2:3	0.356
	90 Degree	100.1%	0.4		A	3:1	0.776
Wash 20	Lululemon	97.2%	1.8	0.185	A	1:2	0.952
	Nike	97.4%	1.4		A	2:3	0.116
	90 Degree	94.4%	2.2		A	3:1	0.123

*Lululemon: 1, Nike: 2, and 90 Degree: 3

After one laundering cycle, all leggings maintained approximately 100% opacity; no brand of leggings was statistically different from the other brands of leggings (p-value=0.591). The percentage of opacity decreased for all leggings after twenty laundering cycles. The 90 Degree leggings had the lowest result which was 94.4% opaqueness; however, the difference in the brands was not statistically significant (p-value=0.185). Overall, the leggings did not demonstrate a large decrease in opacity, meaning that no sample became extremely see-through after laundering for twenty cycles.

Aesthetic performance. The aesthetic performance of the Lululemon, Nike and 90 Degree leggings were tested after one, five, ten, and twenty washes. Aesthetic testing included: color change, stretch recovery, pilling and fuzzing, and dimensional stability. Results of the evaluation are presented below.

Color change. The color change was evaluated according to AATCC Evaluation Procedure 1-2012: *Gray Scale for Color Change*. Two legging samples from each brand were compared to an unwashed standard. The color difference between the washed sample and standard were evaluated using the AATCC Gray Scale for Color Change after one, five, ten, and twenty laundering cycles. The scale for color change was as follows: (1) very severe, (2) severe (3) moderate, (4) slight, (5) none. Results are presented in Figure 4.14 and Table 4.15.

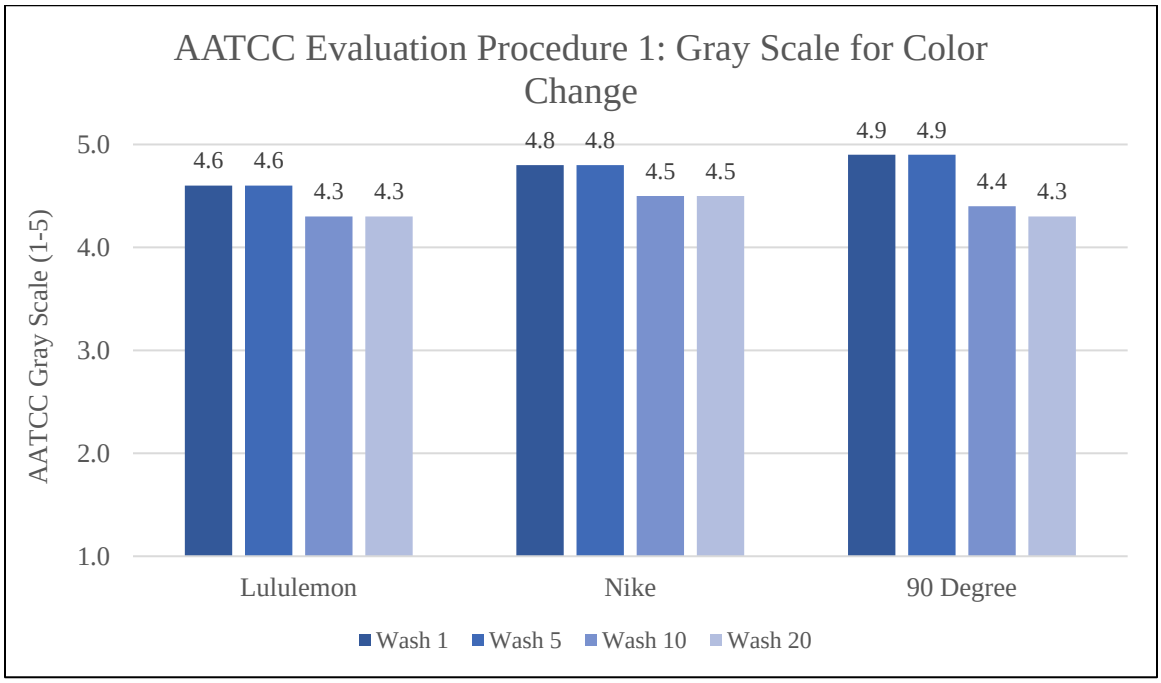

Figure 4.14 Comparison of Gray Scale for Color Change after Test Intervals.

Table 4.15

Gray Scale for Color Change after Test Intervals

Test Interval	Brand	Mean Rating	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	4.6	0.2	0.354	A	1:2	0.450
	Nike	4.8	0.0		A	2:3	0.450
	90 Degree	4.9	0.2		A	3:1	0.125
Wash 20	Lululemon	4.3	0.0	0.465	A	1:2	0.308
	Nike	4.5	0.0		A	2:3	0.308
	90 Degree	4.3	0.0		A	3:1	1.000

*Lululemon: 1, Nike: 2, and 90 Degree: 3

The color appearance of all evaluated brands of leggings showed a gradual decline after laundering. According to ASTM D4156-14 *Standard Performance Specification for Women's and Girls' Knitted Sportswear Fabrics*, a minimum grade of a 4 is required for a garment to present suitable color change results. All leggings maintained the requirement by surpassing this minimum rating. One-way ANOVA found that there was not a statistically significant difference in the mean ratings of the leggings. This was true after both five (p=0.354) and twenty (p=0.465) laundering cycles. Overall, all legging samples surpassed the specification of a minimum grade of 4 (ASTM D4156-14), and the mean color change was not significantly different between each of the samples.

Stretch recovery. A modified version of ASTM D2594: *Standard Test Method for Stretch Properties of Knitted Fabrics* was used to guide evaluating the legging samples' recovery and growth after stretching. From each brand, two lengthwise and widthwise specimens (4-inch x 12-inch) were stitched into a loop and marked with a benchmark distance of four inches before testing. Specimens were elongated uniformly with a five-pound weight for two hours, after which the maximum amount of stretch was measured. The distance between benchmarks was measured after one minute and one hour of recovery. Data results are presented in Tables 4.16 through 4.18 and presented graphically in Figures 4.16 through Figure 4.21.

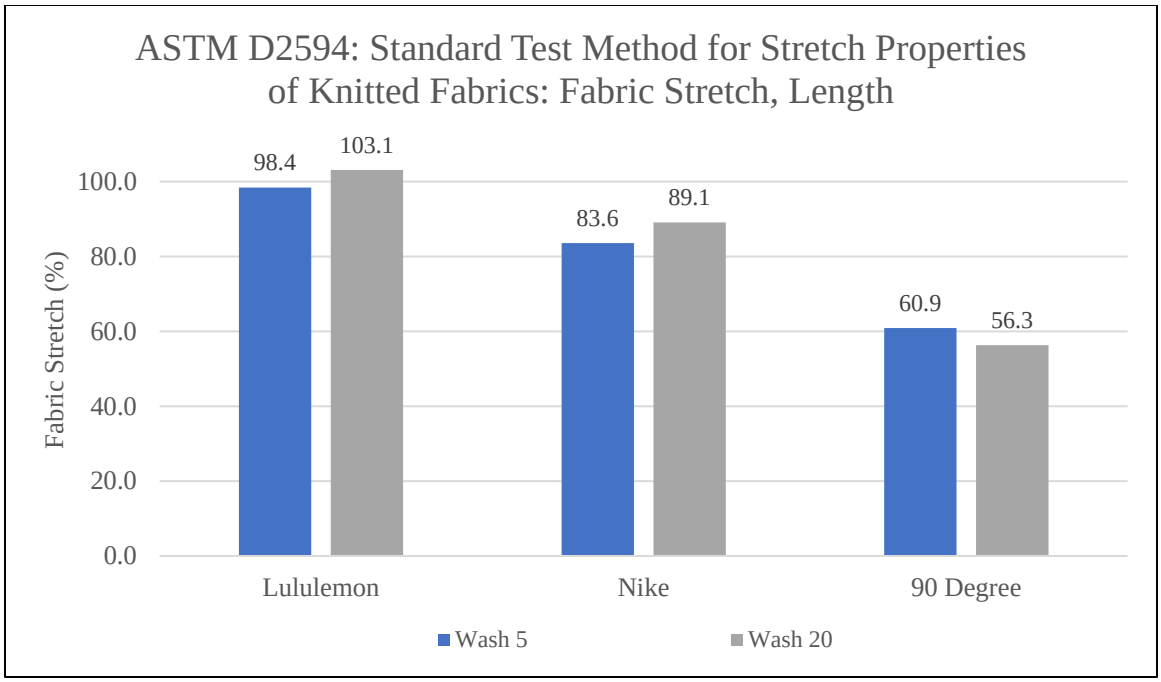

Figure 4.15 Stretch Properties with Respect to Length.

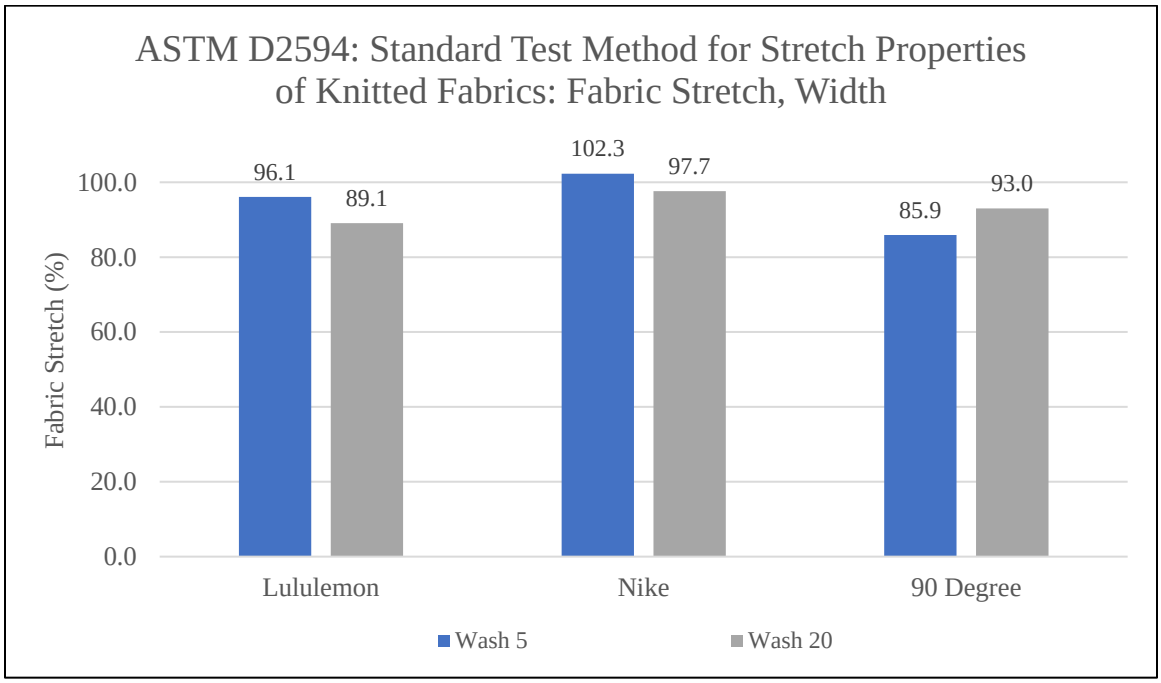

Figure 4.16 Stretch Properties with Respect to Width.

Table 4.16

Comparison of Stretch Properties

Fabric Stretch, Length							
Test Interval	Brand	Mean Growth	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	98.4%	0.0	0.006	A	1:2	0.036
	Nike	83.6%	0.1		B	2:3	0.012
	90 Degree	60.9%	0.4		C	3:1	0.003
Wash 20	Lululemon	103.1%	0.4	0.001	A	1:2	0.012
	Nike	89.1%	0.0		B	2:3	0.001
	90 Degree	56.3%	0.0		C	3:1	0.000
Fabric Stretch Width							
Test Interval	Brand	Mean Growth	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	96.1%	0.0	0.008	A	1:2	0.051
	Nike	102.3%	0.0		A	2:3	0.004
	90 Degree	85.9%	0.0		B	3:1	0.014
Wash 20	Lululemon	89.1%	0.0	0.441	A	1:2	0.237
	Nike	97.7%	0.1		A	2:3	0.479
	90 Degree	93.0%	0.1		A	3:1	0.552

*Lululemon: 1, Nike: 2, and 90 Degree: 3

In the length direction, the Lululemon leggings demonstrated the highest amount of stretch with 98.4% growth after Wash 5 and 103.1% after Wash 20, and the 90 Degree leggings had the lowest amount of stretch after both washes (60.9% growth after Wash 5 and 56.3% after Wash 20). One-way ANOVA determined that the difference in the mean growth of the leggings was statistically significant after both five (p-value=0.006) and twenty (p-value=0.001) laundering cycles. A pairwise comparison determined that all brands of legging demonstrated significantly different stretch properties from one another in the length direction.

In the width direction, the Nike leggings demonstrated the most amount of stretch after both Wash 5 (102.3%) and Wash 20 (97.7%). However, the ability of the Nike leggings to stretch in the width direction was not statistically significant after either wash. The 90 Degree leggings were the only leggings which were statistically different in the width direction, and this was because the 90 Degree leggings stretch was significantly lower than the other brands after Wash 5 (p-value=0.008). After Wash 20, no brand's mean growth was statistically significant (p-value=0.441)

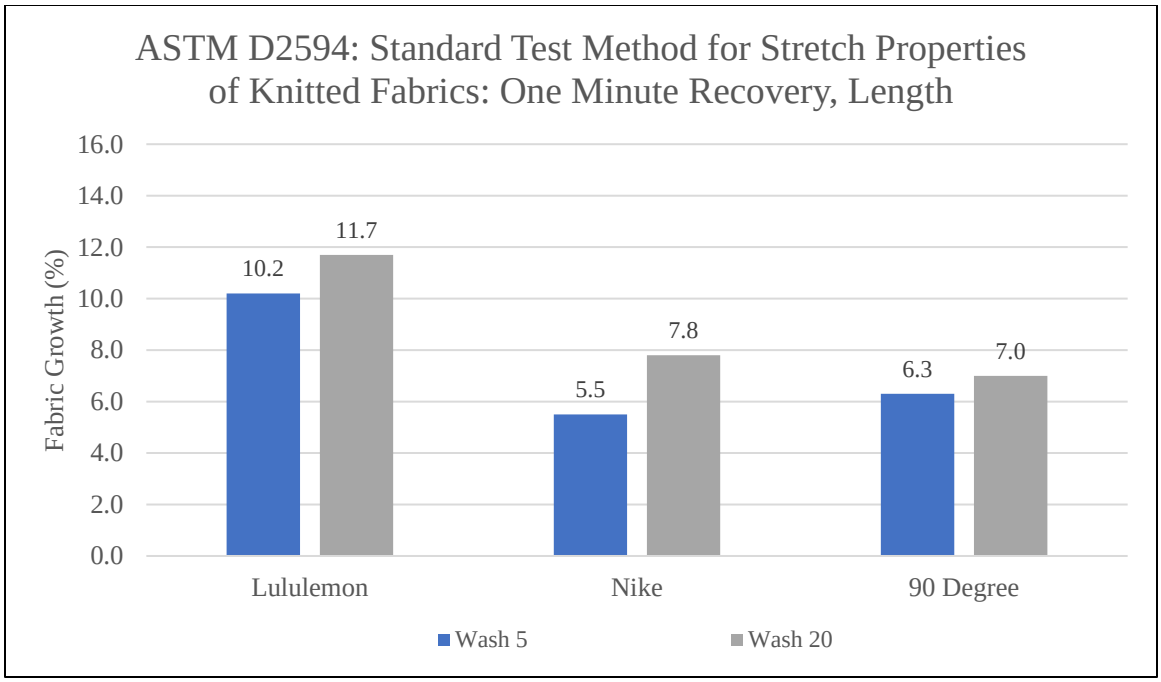

Figure 4.17 Fabric Growth after One Minute of Recovery with Respect to Length.

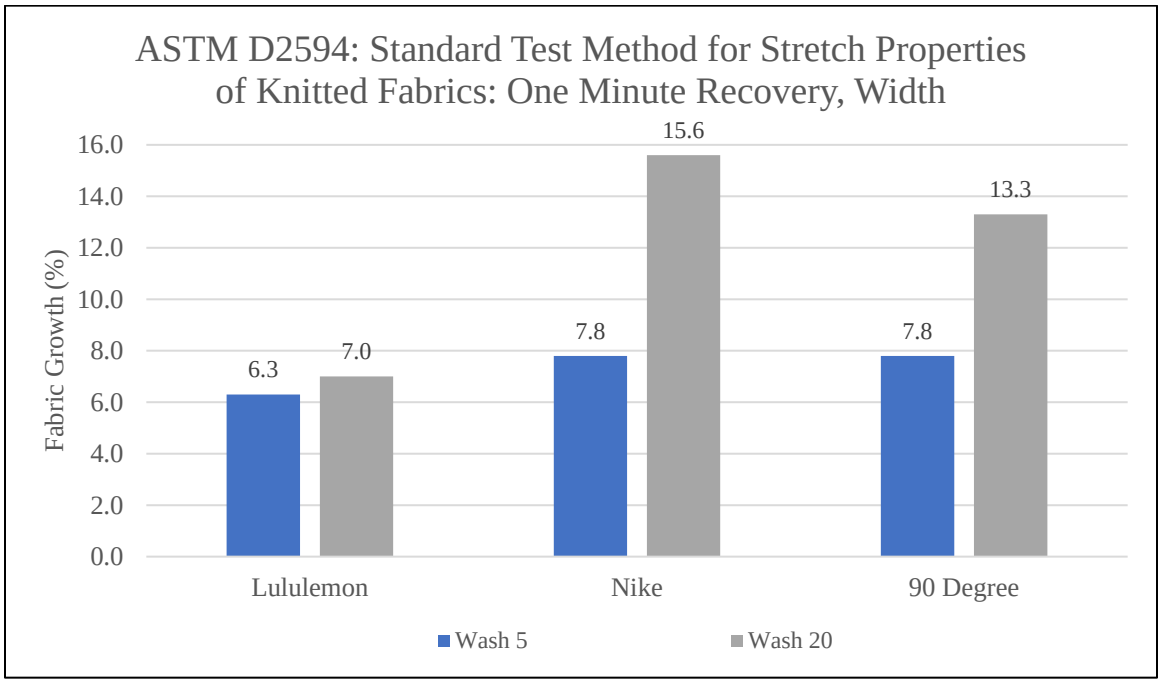

Figure 4.18 Fabric Growth after One Minute of Recovery with Respect to Width.

Table 4.17

Comparison of Fabric Growth after One Minute of Recovery

One Minute of Recovery, Length							
Test Interval	Brand	Mean Growth	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	10.2%	0.0	0.192	A	1:2	0.106
	Nike	5.5%	0.0		A	2:3	0.719
	90 Degree	6.3%	0.0		A	3:1	0.154
Wash 20	Lululemon	11.7%	0.0	0.026	A	1:2	0.022
	Nike	7.8%	0.0		B	2:3	0.464
	90 Degree	7.0%	0.0		B	3:1	0.014
One Minute of Recovery, Width							
Test Interval	Brand	Mean Growth	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	6.3%	0.0	0.002	B	1:2	0.001
	Nike	7.8%	0.0		A	2:3	1.000
	90 Degree	7.8%	0.0		A	3:1	0.001
Wash 20	Lululemon	7.0%	0.0	0.177	A	1:2	0.090
	Nike	15.6%	0.0		A	2:3	0.548
	90 Degree	13.3%	0.1		A	3:1	0.170

*Lululemon: 1, Nike: 2, and 90 Degree: 3

The length measurements after one minute of recovery increased for all brands when comparing Wash 5 and Wash 20. Lululemon had the greatest amount of growth in the length direction after both washes while Nike had the least after Wash 5, and 90 Degree demonstrated the least after Wash 20. One-way ANOVA determined that there was no significant difference in the mean growth of the brands after Wash 5 (p-value=0.192); however, after Wash 20, there was a significant difference (p-value=0.026). A pairwise comparison determined that the Lululemon leggings had significantly more growth than Nike (p-value=0.022) and 90 Degree (p-value=0.014).

The percent of growth increased for all brands when comparing the width measurements after Wash 5 and Wash 20. The width growth of the Lululemon leggings from 6.3% to 7.0% was minimal when compared to Nike, which ranged from 7.8% to 15.6% and 90 Degree, which increased from 7.8% to 13.3%. The mean growth of the leggings after Wash 5 was significantly different (p-value=0.002). This difference can be explained by the growth of the Lululemon leggings which was lower than that of the Nike leggings (p-value=0.001) and the 90 Degree leggings (p-value=0.001). After Wash

20, the difference in the mean width growth of the brands was not significant (p-value=0.177).

Overall, after one minute of recovery, the growth of all leggings in the length direction was not different after Wash 5, but after Wash 20, the Lululemon leggings showed significantly more growth. However, in the width direction after Wash 5, the Lululemon leggings showed significantly less growth when compared to both Nike and 90 Degree. After Wash 20 the mean growth in the width direction was not significantly different.

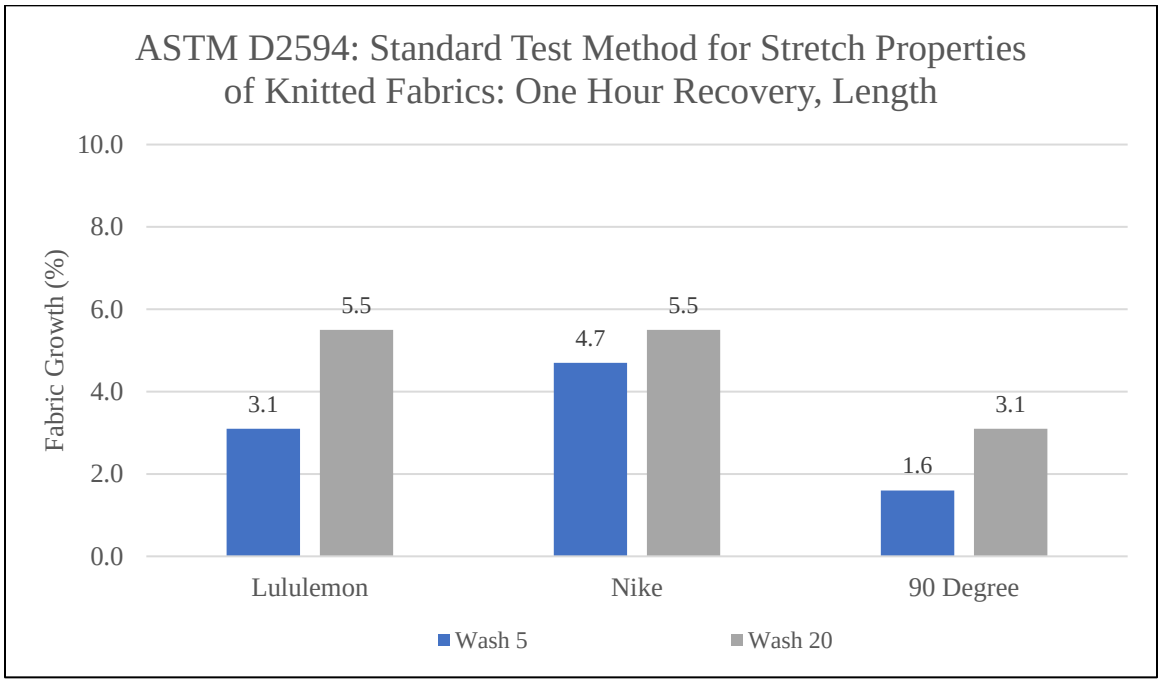

Figure 4.19 Fabric Growth after One Hour of Recovery with Respect to Length.

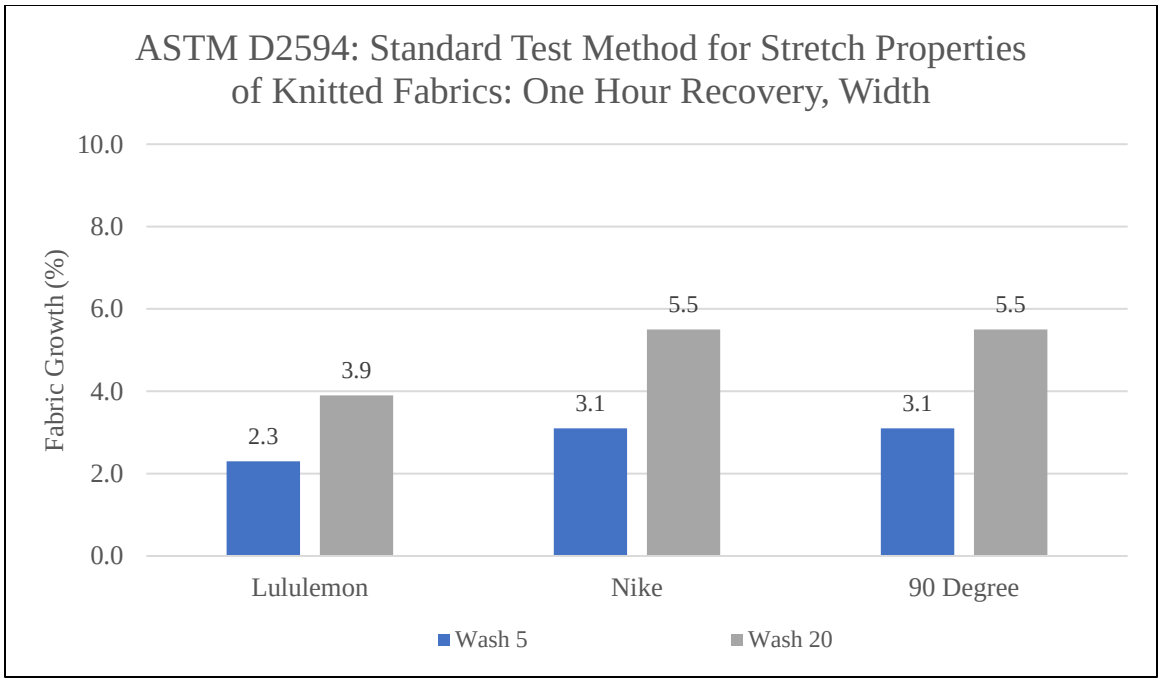

Figure 4.20 Fabric Growth after One Hour of Recovery with Respect to Width.

Table 4.18

Comparison of Fabric Growth after One Hour of Recovery

One Hour of Recovery, Length							
Test Interval	Brand	Mean Growth	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	3.1%	0.0	0.000	A	1:2	0.001
	Nike	4.7%	0.0		B	2:3	0.000
	90 Degree	1.6%	0.0		C	3:1	0.002
Wash 20	Lululemon	5.5%	0.0	0.125	A	1:2	1.000
	Nike	5.5%	0.0		A	2:3	0.081
	90 Degree	3.1%	0.0		A	3:1	0.081
One Hour of Recovery, Width							
Test Interval	Brand	Mean Growth	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	2.3%	1.1	0.465	A	1:2	0.308
	Nike	3.1%	0.0		A	2:3	1.000
	90 Degree	3.1%	0.0		A	3:1	0.308
Wash 20	Lululemon	3.9%	0.1	0.385	A	1:2	0.252
	Nike	5.5%	0.1		A	2:3	1.000
	90 Degree	5.5%	0.0		A	3:1	0.252

*Lululemon: 1, Nike: 2, and 90 Degree: 3

The growth in the length direction increased from Wash 5 to Wash 20 when the specimens relaxed for one hour. One-way ANOVA determined that each brand's mean growth was significantly different after five laundering cycles (p-value=0.000); however, after twenty laundering cycles, there was no difference in the growth of each brand of leggings (p-value=0.125).

Dissimilar to results of the length direction evaluations, the width growths of Wash 5 and Wash 20 did not demonstrate a significant difference. One-way ANOVA determined no difference in the growth of the width measurements after Wash 5 (p-value=0.465) and Wash 20 (p-value=0.385). In conclusion, the length growth of the legging specimens was significantly different after five laundering cycles with Nike having the highest growth, Lululemon had the second highest and 90 Degree had the least. After twenty laundering cycles, there was no significant difference between the brands' growth in the length direction. There was no statistical significance in the width growth after Wash 5 or Wash 20.

Pilling and fuzzing. Pilling was evaluated according to ASTM D4970/D4970M – 10: *Pilling Resistance and Other Related Surface Changes of Textile Fabrics: Martindale Tester*. Four specimens were cut and tested from each brand of leggings after one, five, ten, and twenty laundering cycles. The appearance after abrasion was evaluated compared to an ASTM photographic standard. Ratings one through five were as follows: (1) very severe pilling, (2) severe pilling, (3) moderate pilling, (4) slight pilling, and (5) no pilling. Average pilling results of the evaluation are presented in Figure 4.22 and Table 4.19.

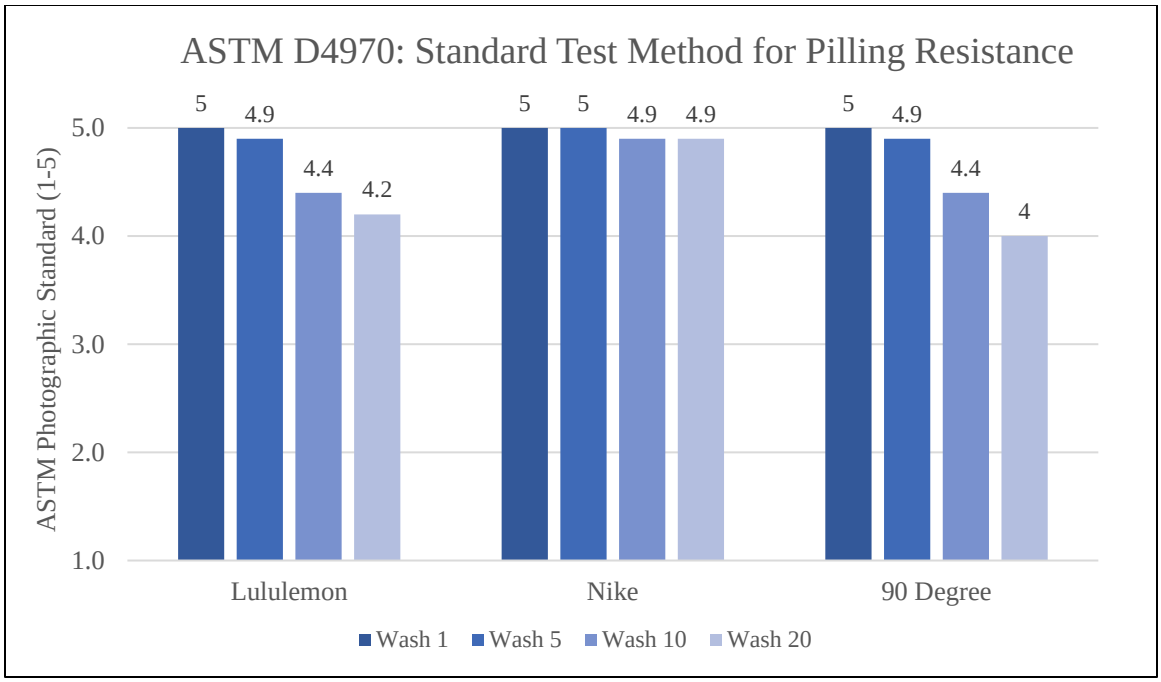

Figure 4.21 Comparison of Pilling Resistance after Test Intervals.

Table 4.19

Comparison of Pilling Resistance

Test Interval	Brand	Mean Rating	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	4.9	0.1	0.274	A	1:2	0.168
	Nike	5.0	0.0		A	2:3	0.168
	90 Degree	4.9	0.1		A	3:1	1.00
Wash 20	Lululemon	4.2	0.1	0.000	A	1:2	0.000
	Nike	4.9	0.1		B	2:3	0.029
	90 Degree	4.0	0.0		C	3:1	0.000

*Lululemon: 1, Nike: 2, and 90 Degree: 3

When comparing Wash 5 and Wash 20, the average pilling resistance of each brand decreased. The rating of the Nike leggings degraded the least; however, when comparing the ratings for each brand, the difference in the mean rating was not statistically significant (p-value=0.274) after Wash 5. However, after twenty laundering cycles, the difference was found to be statistically significant (p-value=0.000). A pairwise comparison determined that all brands were found to be significantly different from one another after twenty laundering cycles. The Nike leggings had the least amount of pilling with an average rating of 4.9. The Lululemon leggings had a lower average rating of 4.2,

and 90 Degree had the lowest pilling rating of 4.0 after twenty laundering cycles. In the visual evaluation of the pilling specimens, it was noted that very slight fuzzing began to form on the Lululemon and Nike specimens after five laundering cycles. Fuzzing also appeared on the 90 Degree leggings after Wash 5 but was more prevalent than the other two brands. As discussed previously, fuzzing is the step that occurs before a fabric begins to show pilling (Annis, Bresee, & Cooper, 1992).

Overall, after five laundering cycles, the brands of leggings demonstrated no difference in pilling; however, after Wash 20 there was a significant difference in the brands' pilling ratings with Nike having the best rating, Lululemon having the second highest rating and 90 Degree having the lowest.

Dimensional stability. Dimensional change was tested according to AATCC Test Method 150: Dimensional Changes of Garments after Home Laundering. Two garments were marked and measured before laundering and then measured after one, five, ten, and twenty laundering cycles in the length and width directions. Results are presented in Figures 4.23 and 4.24, as well as Tables 4.20 and 4.21

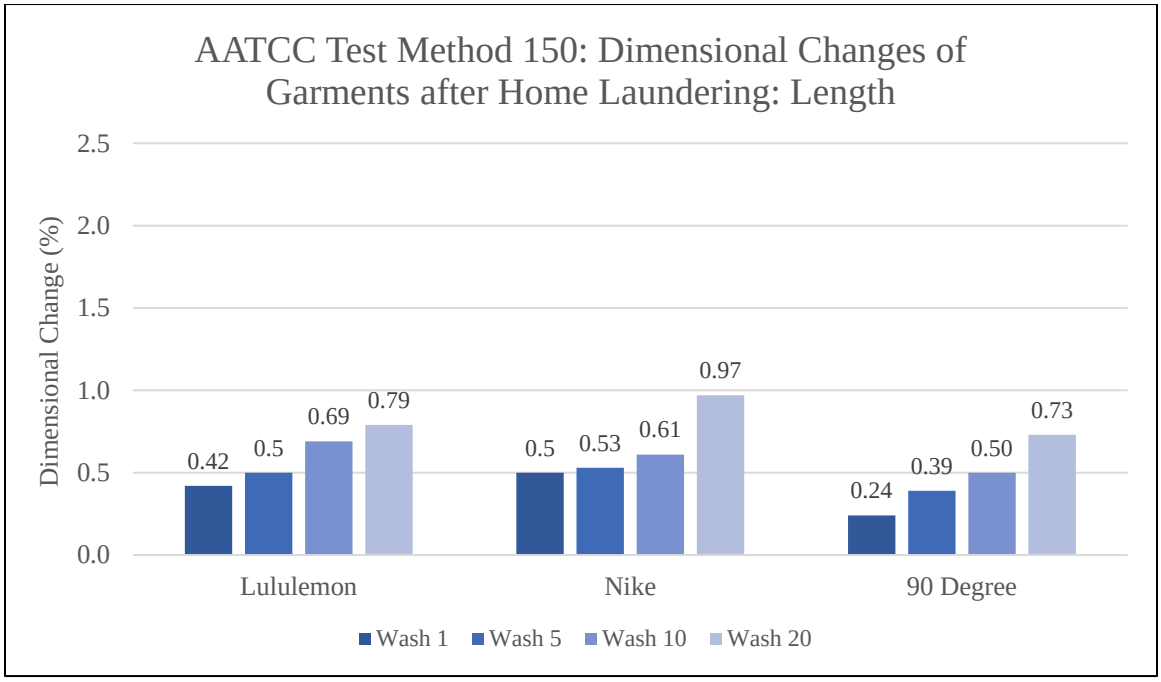

Figure 4.22 Dimensional Change after Home Laundering with Respect to Length.

Table 4.20

Dimensional Change after Home Laundering with Respect to Length

Test Interval	Brand	Mean Change	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	0.50%	0.2	0.849	A	1:2	0.938
	Nike	0.53%	0.1		A	2:3	0.676
	90 Degree	0.39%	0.3		A	3:1	0.623
Wash 20	Lululemon	0.79%	0.1	0.753	A	1:2	0.614
	Nike	0.97%	0.3		A	2:3	0.853
	90 Degree	0.73%	0.5		A	3:1	0.501

*Lululemon: 1, Nike: 2, and 90 Degree: 3

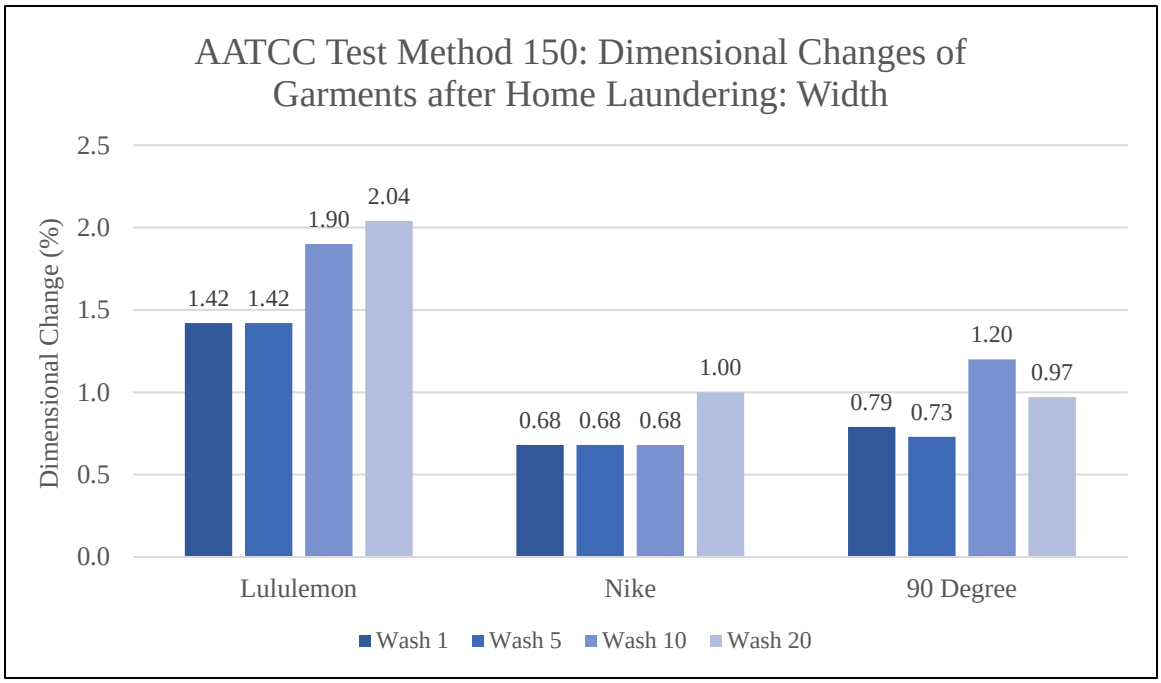

Figure 4.23 Dimensional Change after Home Laundering with Respect to Width.

Table 4.21

Dimensional Change after Home Laundering with Respect to Width

Test Interval	Brand	Mean Change	*SD*	p-value	Group	Pairwise Comparison*	Adjusted p-value
Wash 5	Lululemon	1.42%	0.4	0.411	A	1:2	0.258
	Nike	0.68%	0.1		A	2:3	0.930
	90 Degree	0.73%	0.8		A	3:1	0.285
Wash 20	Lululemon	2.04%	0.4	0.263	A	1:2	0.176
	Nike	1.00%	0.1		A	2:3	0.166
	90 Degree	0.97%	1.0		A	3:1	0.957

*Lululemon: 1, Nike: 2, and 90 Degree: 3

According to ASTM D4156-14, the dimensions of leggings should change no more than 3% after home laundering. All legging samples met this specification in both the length and width directions. Almost all changes were below 2%, excluding Lululemon's average width change after Wash 20.

One-way ANOVA determined that there was no difference in the garment's length measurements after Wash 5 (p-value=0.849) and after Wash 20 (p-value=0.753). The width measurement changes also revealed no significant difference after five (p-value=0.411) and twenty (p-value=0.263) wash cycles. Overall, all samples met the ASTM D4156-14 specification of 3% maximum shrinkage, and no brand of leggings demonstrated significantly more or less shrinkage when compared to the other brands' mean dimensional change.

Research Questions

Results from the survey were used to answer research questions one and two. A questionnaire was distributed to college-age, female consumers. Survey questions asked consumers about the desired characteristics for leggings and the problems they encounter. Discussion regarding each research question is presented below.

Research question one. *What are the desired characteristics for women's leggings for athleisure consumers?*

Functional preference. Based on the survey, customers valued comfortable material and fabric which is not see-through more than any other functional feature. Comfortable material was found to be more frequently preferred than non-see-through material with 43% of respondents preferring comfortable material compared to 36% preferring fabric which is not see-through. All other functional performance features were selected by less than nine percent of the surveyed sample, indicating they were not as desirable.

The frequency of preference for functional features aligned with the responses consumers gave when asked about the level of importance they rated these functional features. Comfortable material and fabric which is not see-through were described as *extremely important* by more than 50% of the respondents for both categories. Approximately 52% valued comfortable material as *extremely important*, and see-through material was considered *extremely important* by 55% of the consumers. The other

functional features presented in the survey were most regularly described as *moderately important*. Fabric which is not thick or restrictive was considered *moderately important* by 36% of respondents, compression ability by 34%, wicking ability by 38%, and water resistance by 33%; these were the highest percentages for each category. Odor control ability was the only category with the highest percentage of participants who valued it at a different level of importance. Approximately 30% of consumers described odor control as *very important*.

The top two levels of importance (*very important* and *extremely important*) were combined for each feature category to achieve a substantive rating level. Results from the survey show that comfortable material and fabric which is not see-through were the two categories considered the most substantive by the surveyed consumers. Approximately 91% of respondents indicated that they valued comfortable material and fabric which is not see-through as *very important,* or *extremely important*. In comparison, odor control ability, fabric which is not thick or restrictive, and compression ability had 43%, 42%, and 41% of respondents describe their importance as either *very important* or *extremely important,* respectively. Wicking ability had a much lower combined importance rating of 21%. The lowest combined importance value was that of water resistance which only had 13% of consumers describe it as either *very important* or *extremely important*.

Expressive preferences. When questioning consumers about the brands they often purchase and the brands they would ideally purchase, Lululemon was the most commonly selected response for both categories. Nike was the second most selected brand, again for both categories. Other brands chosen for regular purchase included Old Navy, 90 Degree, Victoria's Secret, and Athleta. Brands which are considered ideal for purchase included Athleta and Fabletics. The survey revealed that believing a brand offers quality products most directs a consumer's choice of a regularly purchased brand, as well as what brand they considered ideal.

Consumers were also asked to identify to which places they wear leggings. Nearly all consumers chose to wear leggings to attend class, to run errands, and to travel. To a bar or restaurant and to a party were also selected by several consumers with 68% and 57% of responses, respectively. The survey revealed that approximately 22% of

consumers do wear leggings for business casual attire, and even a small percentage (2%) wear leggings for professional business attire.

When asked what article of clothing they prefer to wear their leggings with, the survey showed that a large percentage of the sample (87%) choose to wear leggings as pants regardless of the type of top they are wearing. A smaller percentage 13% only wear leggings as pants when they have a longer style top. Almost no consumers reported wearing leggings as a base layer beneath a skirt or dress.

Aesthetic preference. Survey participants were asked their preference for aesthetic qualities; approximately 41% desired a fabric which does not pill, and 28% considered fabric which does not stretch out to be the second most desirable feature. The remaining aesthetic preference categories were selected by participants in the following descending order: no lint (17%), no shrinkage (8%), and no color change (6%).

When describing the importance of aesthetic features, the highest percentage of consumers described them as *moderately important.* The only exception was "material which does not become stretched out" which was described as *very important* by 39% of the survey. When combining the *very important* and *extremely important* responses, 61% of consumers valued fabric which does not become stretched out as important. When these two levels of importance were combined for the other categories, low pilling and low lint accumulation were described by 55% and 51% of survey respondents. Color change and minimal shrinkage were the only two categories which had fewer than half of the respondents describe the categories as *very important* or *extremely important*. Approximately 45% described shrinkage, and 44% had minimal color change above *very important*.

When consumers were required to select the five most appealing functional and aesthetic performance features, the top responses were: comfortable material, fabric which is not see-through, material that does not stretch out, no pilling, and compression.

Style preferences. Regarding style features preferred by consumers, a high waistband was selected more than any other feature with 41% of responses. Pockets, which were the second most selected feature were chosen nearly half as often (22%) as a high waistband. Mesh panels and seamless leggings were both preferred by approximately 13%. When asked about the feature of length, a vast majority (84%) of the

survey participants selected ankle length. In comparison, just below the calf was the second most picked category, but only received 13% of responses.

Research question two. What problems do athleisure consumers encounter when wearing women's leggings?

Functional performance. Consumers were asked to identify the functional and durability problems they had encountered; the see-through fabric was the most frequently identified problem, being encountered by 74% of consumers. The second most experienced problem was that of worn down fabric by 58% of the survey respondents. Holes were experienced by 44% and ripping seams by 41% of respondents. Uncomfortable material was identified by 40% and lingering body odor by 35%. All other functional or durability problems were encountered by less than 31% of the surveyed consumers.

When presented with the above functional performance problems and asked to evaluate their level of frustration with these problems, see-through fabric accumulated 35% of responses for *very frustrating*. When the upper two levels of responses for see-through were combined, 57% of consumers said it was either *very frustrating* or *extremely frustrating*. The second highest rating was 49% of the sample which found holes in leggings either *very frustrating* or *extremely frustrating*, followed by ripping seams with a rating of 42%. Combined responses for nearly half of the categories ranged between 20% and 40%. The following combined categories ranked as follows: 37% for worn down fabric, 36% for ripping fabric, 35% for lingering body odor, 29% for loss of compression, and 23% for uncomfortable material. The remaining functional categories were below 15% when combining *very frustrating* and *extremely frustrating* and were ranked as follows: thick or restrictive fabric (14%), loss of wicking abilities (13%), and loss of water resistance (12%).

Aesthetic performance. Consumers were asked about the aesthetic problems they had encountered. Approximately 78% of respondents experienced pilling, which was the most frequently encountered. Excessive lint accumulation was experienced by 65%, stretched out fabric by 45%, color change by 32%, and shrinkage by 11%. When the survey asked respondents to value their level of frustration with the aesthetic problems, pilling had the highest percentage of responses at *extremely frustrating* with 33%. When *very frustrating* and *extremely frustrating* were combined, 60% of consumers found pilling to be frustrating. The next highest combined percentage was that of stretched out fabric which received 52% of responses. Shrinkage had 49%, lint accumulation 43%, and color change 27% when *very frustrating* and *extremely frustrating* were combined.

Research question three. *Is there a significant difference in the aesthetic and functional performance of Lululemon, Nike, and 90 Degree leggings?*

Three brands of leggings were selected based on the brand preferences consumers identified in the survey. Performance testing was then conducted based on the performance problems and desires voiced in online consumer reviews and the survey questionnaire.

Fabric weight. It was determined that the Lululemon and Nike leggings were comprised of medium weight fabric. After twenty laundering cycles, the Lululemon leggings weighed 6.8 oz/yd^{2,} and the Nike leggings weighed 7.1 oz/yd^2. In contrast, the 90 Degree leggings had the heaviest weight (8.7 oz/yd^2), which is classified as a medium heavy fabric. The difference in the legging weight was further confirmed by statistical analysis. The weight of the 90 Degree leggings was significantly higher when compared to the Lululemon and Nike leggings after both five ($p=0.000$) and twenty ($p=0.000$) laundering cycles.

Fabric count. When comparing the brands after one wash, the mean fabric count of the 90 Degree leggings was significantly lower than that of both the Lululemon and Nike Leggings (p-value=0.004). The Nike and Lululemon leggings were not found to be significantly different from each other. However, after twenty laundering cycles, all brands' fabric counts were found to be significantly different from one another (p-value=0.000). Lululemon had the highest count of 154, Nike had the second highest of 148, and 90 Degree had the lowest count of 106.

The fabric counts from each brand did not substantially increase or decrease when comparing fabric count after one and twenty laundering cycles. Increase in fabric count could suggest shrinkage. The Lululemon leggings had the most considerable difference in fabric count, meaning the count of the fabric increased after twenty washes. This difference could suggest slight shrinkage.

Fabric thickness. The mean thickness of each brand of leggings after five washes (p-value=0.015) and twenty washes (p-value=0.003) was significantly different. The 90 Degree fabric was the thickest of the three while Nike was the least thick. The Lululemon and 90 Degree leggings were not significantly different from each other; however, the mean thickness of the Nike leggings was significantly lower than the other two brands of leggings after both Wash 5 and Wash 20.

When comparing the performance as the leggings were washed, there was a negligible difference between the Lululemon fabric thickness after Wash 5 (29.6 mils) and Wash 20 (29.8 mils). The Nike leggings also resulted in a minimal thickness change from 26.2 mils to 25.8 mils after twenty washes. The 90 Degree leggings showed no difference in thickness between wash cycles with readings of 30.9 mils after both washes.

Bursting strength. There was a significant difference between the bursting strengths of the brands after both five (p-value=0.000) and twenty (p-value=0.001) laundering cycles. The 90 Degree leggings had the highest bursting strength (94.3 psi) after Wash 20. The final bursting strength of the Lululemon leggings was 67.0 psi while Nike had the lowest strength of 62.5 psi. The 90 Degree leggings' performance was significantly higher than the other brands, while the Lululemon and Nike leggings' performance were not significantly different from each other.

The performance of the brands after washing twenty times did not drastically change. The Lululemon and 90 Degree leggings had an increased bursting strength while the Nike leggings revealed almost no change in strength between Wash 5 and Wash 20. The increased strength of the Lululemon legging correlates to the increased fabric count, which suggests shrinkage.

Opacity. Stretched samples were measured for opacity after one and twenty laundering cycles. All brands of leggings demonstrated a decline, indicating that the fabrics became more see-through after laundering; however, the change was minimal.

Nike and Lululemon had readings of 97% opaqueness after Wash 20. The 90 Degree leggings were the least opaque of the three brands after twenty washes (94%); however, there was no statistically significant difference between the three brands after Wash 1 (p-value=0.085) and Wash 20 (p-value=0.185).

Stretch recovery. Fabric specimens were elongated for two hours with five pounds of tension applied. After two hours, the Lululemon leggings demonstrated the highest amount of stretch in the length direction after Wash 5 (98.4%) and Wash 20 (103.1%). The amount of stretch was significantly higher than the other brands after both five (p-value=0.006) and twenty (p-value=0.001) laundering cycles. The stretch in the width direction was less than that of Nike but was not significantly less. Instead, the 90 Degree leggings had significantly less stretch growth in the width direction after Wash 5. No leggings were significantly different in width stretch after Wash 20.

When the Lululemon leggings recovered for one minute, their growth in the length direction was not significantly different after Wash 5 but was significantly higher than the other brands after Wash 20 (p-value=0.026).

Pilling and fuzzing. The ASTM photographic standard for pilling was used to assign a rating value to the leggings. Ratings one through five were as follows: (1) very severe pilling, (2) severe pilling, (3) moderate pilling, (4) slight pilling, and (5) no pilling. The performance of the leggings gradually declined for all brands. Nike declined the least amount with a final rating of 4.9 after twenty washes while Lululemon was assigned a rating of 4.2. The 90 Degree leggings declined the most with a final rating of 4.0 which indicates slight pilling. After Wash 5 the ratings were not significantly different from one another (p-value=0.274), but after twenty washes, all leggings were significantly different from one another (p-value=0.000).

Dimensional stability. In the length direction, the Nike leggings had the greatest amount of dimensional change and diminished 0.97%, Lululemon had the second most change with 0.79% change, and 90 Degree had 0.73% shrinkage, which was the least of the three brands. However, the differences were not statistically significant (p-value=0.753).

In the width direction, the final dimensional changes were also not statistically different (p-value=0.263). Lululemon had the greatest amount of width shrinkage with

2.04% while Nike had 1.00% change, and 90 Degree leggings decreased 0.97%. According to ASTM D4156-14 *Standard Performance Specification for Women's and Girls' Knitted Sportswear Fabrics* dimensional change should be no more than 3%. All legging samples met this specification in both the length and width directions. Almost all changes were below 2% excluding Lululemon's average width change after Wash 20 which was just slightly above 2% shrinkage. Lululemon's slight shrinkage correlates with its increase in fabric count and strength when evaluated for bursting strength.

Discussion

According to survey results, nearly all functional performance problems with leggings had been encountered by consumers and were also valued as frustrating by the consumers. When describing desires for a new pair of leggings, nearly all functional performance features were considered desirable, and all were rated at various levels of importance. Functional laboratory evaluations of the three brands of leggings revealed that the 90 Degree leggings had significantly higher bursting strength, indicating that its fabric is quite durable and may not rip or form holes as easily as the other brands. However, fabric specifications indicated that the 90 Degree leggings had the highest fabric weight but lowest fabric count, which indicates the yarn size of the fabric is larger than that of the other brands. The fabric of the 90 Degree leggings was the thickest of the three but not significantly higher than the Lululemon legging's thickness; however, consumers who indicated that they desired leggings which are not too thick or restrictive may prefer the Nike leggings which had significantly lower thickness than the other three brands. The Lululemon leggings had thickness close to that of the 90 Degree leggings and weight and count similar to that of Nike.

In the survey, consumers expressed that fabric which is see-though is the most commonly encountered functional problem and valued as the most frustrating functional problem. Fabric which is not see-through is highly desired and important to consumers. Results for opacity demonstrated that all legging samples evaluated did not decline greatly after washing for twenty cycles. The opaqueness of the 90 Degree leggings declined the most to 94% while both the Lululemon and Nike leggings decline to 97% opacity when stretched.

According to the survey, all aesthetic problems were encountered by consumers and all performance features were desired by consumers. Pilling and lint were frequently identified as frustrating, and a problem consumers' often encounter. Likewise, leggings which have low pilling and low lint were seen as desirable. The leggings' performance revealed that after washing, all samples had the appearance of fuzz, which occurs before a fabric begins to pill. Ratings of pilling were significantly different for each brand. Nike showed the least pilling, Lululemon demonstrated the second best, and 90 Degree had the most pilling, which was rated as a 4.0 or demonstrating "slight pilling."

All brands demonstrated excellent resistance to color change and dimensional change. ASTM D4156-14 specifies color change cannot surpass a grade of 4, which all leggings met. Additionally, dimensional change cannot exceed a maximum of 3%. All leggings were below this maximum, and in fact, nearly all changes were below 2%. The stretch properties of the garments revealed that Lululemon was significantly more-stretchy than the other brands in the length direction. After one minute of recovery, the length direction of the Lululemon leggings showed significantly less recovery than the other brands; however, after one hour of recovery, the leggings were not significantly different. All leggings maintained less than 6% growth in the length direction. In the width direction after Wash 20, there was no significant difference in the stretch properties or recovery after one minute or one hour.

Overall, the performance of the nylon/spandex blended fabrics revealed little degradation in performance after laundering twenty cycles. Color change and dimensional change met ASTM D4156-14 specifications. No garment demonstrated significantly diminished performance after laundering.

Chapter Five

Conclusion

The intent of this research was to better understand consumer opinion by creating a customer profile of legging preferences and complaints through a survey and to compare the performance of three frequently purchased legging brands through laboratory evaluations. Online consumer reviews and blogs identified frequently discussed performance problems that were used to construct survey questions. The FEA model described in this paper aided in the organization of the questionnaire, which asked consumers about the legging features they desire and the problems they encounter. The survey was administered on private social media pages to a population of sorority students. The final sample was 133 female students of college-age.

The questionnaire identified three frequently consumed brands: Lululemon, Nike, and 90 Degree; these brands were selected for laboratory evaluations using the American Association of Textile Chemists and Colorists (AATCC) and American Society for Testing and Materials (ASTM) standard test methods. The laboratory sample was comprised of four Lululemon leggings, five Nike leggings, and four 90 Degree leggings. All styles of legging samples had a similar fabric content of spandex and nylon**.** Each legging was evaluated for fabric specification, functional performance, and aesthetic performance. Fabric specification evaluations included fabric weight, fabric count, and fabric thickness. Functional performance evaluations included bursting strength and opacity, and aesthetic evaluation included color change, stretch recovery, pilling/fuzzing, and dimensional change. All evaluations were performed under controlled laboratory settings in an atmospheric chamber registering at 70° ± 2°F and relative humidity of 65% ± 5% for a minimum of four hours according to ASTM D1776. The research objectives of this study were to:

1. *Identify and evaluate the desired characteristics for women's leggings for athleisure consumers*

Leggings are a significant part of the expansive athleisure category due to their popularity. They also provide a staple piece for athletic and non-athletic brands to produce and offer to enter the large athleisure market. The significant number of athleisure options available for consumers to assess and select while shopping makes it

an extremely competitive market (Kell, 2016). Therefore, it is vital for companies who sell athleisure to place value on consumer desires.

The consumer survey asked participants to reveal their desires for leggings by selecting wanted features and performance options. The survey results showed that when considering the functional performance of leggings, the main two desires were comfort and not see-through fabric, with the fabric comfort being valued slightly more than not being see-through. Likewise, these functional categories were valued highly when consumers stated their importance in consideration when purchasing new leggings.

Although comfort and see-through were selected by consumers as the primary two functional performance features, there were no main features chosen consistently by consumers for aesthetic performance problems. No specific aesthetic category totaled more than 50% of the consumers' selections; however, more than one third of consumers desired leggings which do not pill, and more than one fourth desired a fabric which does not stretch out easily. Similarly, the survey questions that address rating the consumers' desires for these features found that the desire of no pilling was rated highest, and the desire of fabric which does not become stretched out received the next highest rating. When both functional and aesthetic performance features were considered in the survey, consumers indicated that their top five desired performance features are: (1) comfortable material, (2) material which is not see-through, (3) material which does not stretch out, (4) no pilling, and (5) compression ability. Other desirable legging features included having a high waist band, and although selected half as frequently, pockets. *Ankle length* was clearly the most preferred length for leggings.

Believing a brand produces quality products guides consumers' decisions about what legging brands they choose to purchase. Lululemon was the most commonly consumed brand by the survey respondents. Nike, Old Navy, Victoria's Secret, 90 Degree, and Athleta were the other regularly purchased brands identified from the survey. Lululemon is often considered an ideal brand from which to purchase leggings by many consumers. Other ideal brands include Nike, Athleta, and Fabletics. Situational locations where consumers choose to wear leggings were numerous. Nearly all consumers reported that they wear leggings to attend class, run errands, and to travel. Leggings are also worn for business casual attire, although not commonly, and even much less frequently for

professional business attire. Also, most consumers choose to wear leggings as pants regardless of the type of top they are wearing.

2. *Identify and analyze the encountered problems for women's leggings*

The survey revealed that see-through fabric is frequently encountered by legging consumers. Worn down fabric, holes, and ripping seams were other functional problems which respondents often encounter. All other functional problems identified in this survey each had at least eight respondents indicate that they had experienced the malfunction with leggings. When regarding frustration with functional performance, consumers were most irritated by see-through fabric. Other functional performance features which provoked higher levels of frustration from the survey sample included holes, ripping seams, worn down fabric, ripping fabric, and lingering body odor.

The most frequently encountered aesthetic problem was pilling. Excessive lint and stretched out fabric were also identified as often encountered problems. The remaining aesthetic problems of color change and shrinkage were each identified by at least 14 respondents. Likewise, pilling provoked the highest level of frustration in consumers, followed by stretched out fabric, shrinkage, and then lint accumulation. Color change incited the least amount of frustration but was described at high levels of frustration by more than one fourth of the consumers.

3. *Measure and compare the aesthetic and functional performance characteristics for three consumer identified brands of women's leggings*

The leggings selected for the laboratory evaluations were knit, black in color, and made from a nylon/spandex blended fabric. The evaluations conducted on the Lululemon, Nike, and 90 Degree leggings determined that there are some differences in the performance characteristics.

The fabric specification evaluation revealed that the 90 Degree leggings had a significantly higher fabric weight than either the Lululemon or Nike leggings. While the 90 Degree leggings were classified as medium heavy weight, the Lululemon and Nike leggings were a medium fabric weight. Additionally, the fabric count of the 90 Degree leggings was significantly lower than that of the Nike or Lululemon leggings. Because the weight of the 90 Degree leggings was significantly higher, but the fabric count was lower, the size of the yarns could be larger in this garment.

The Nike leggings were significantly less thick than the other two brands of leggings. However, Lululemon and 90 Degree were similar in thickness despite their significantly different results for fabric weight and count. Nike and Lululemon performed similarly when evaluated for fabric weight and count. All brands showed little variation between wash evaluations when examining the fabric specifications. This suggests little change or variation to the fabric construction of these garments when they undergo home laundering. Lululemon showed the greatest difference in fabric count, which correlated with its increased strength and shrinkage after washing.

The 90 Degree leggings had the highest bursting strength which was significantly higher than that of the other brands. Meanwhile, Nike and Lululemon demonstrated similar bursting strengths. As mentioned above, the Lululemon leggings were more resistant to bursting after washing whereas the Nike leggings' strength decreased, and the 90 Degree leggings showed neither increased nor decreased strength. The opacity of the leggings gradually declined for all brands of leggings after twenty laundering cycles; however, decline was minimal. All leggings maintained a high percentage of opaqueness.

Evaluations of aesthetic performance revealed that the brands showed little difference when comparing color change and dimensional change. Change of color gradually increased for all brands but not significantly. Additionally, shrinkage occurred in all brands but not significantly. The Lululemon leggings shrank the most in the length direction, which correlates with their increased fabric count and resistance to bursting after laundering. However, all brands surpassed the specification required by ASTM D4156-14.

When comparing the brands' stretch recovery, it was determined that there was no difference in the width direction performance for all brands. However, the 90 Degree leggings had the lowest stretch ability while the Lululemon leggings had the greatest stretch ability in the length direction. This may account for why the Lululemon leggings also demonstrated the largest growth in the length direction after one minute of recovery. However, after one hour of recovery, there was again, no significant difference in the growth of each brand of leggings.

Pilling ratings for all brands gradually declined after washing; however, all leggings demonstrated different levels of pilling. The Nike leggings had the highest

pilling and fuzzing ratings of the brands while Lululemon had the second highest. The 90 Degree leggings had the lowest rating for pilling in the visual evaluation. In conclusion, the specific styles of leggings selected for evaluation from the desired brands performed well. The leggings did not decline considerably after twenty laundering cycles.

Conclusion

Leggings which are not see-through and that provide comfort were highly valued by consumers as desirable functional features for leggings to possess. See-through fabric was the most frequently encountered functional problem by the sample and considered highly frustrating. Opacity evaluations showed that all leggings demonstrated high percentages of opacity when stretched after laundering, but 90 Degree demonstrated the most degradation in opacity readings after laundering. The 90 Degree leggings also had the highest fabric weight, lowest fabric count, and highest bursting strength. In the survey, consumers expressed high levels of frustration with holes in their leggings and worn down fabric. It was concluded that the 90 Degree leggings have durable fabric that may not rip or form holes and may satisfy many consumers. However, consumers expressed frustration in the survey with thick/restrictive fabric; therefore, the 90 Degree leggings may be considered too heavy by some. Nike had the least thick fabric of the three brands and may be more desirable to consumers who want a less thick fabric.

Pilling and lint were frequently encountered and highly frustrating aesthetic problems for survey consumers. Conversely, fabric which does not pill or show lint was highly desired and valued as important to consumers when shopping for leggings. Laboratory evaluation showed that all samples had the appearance of fuzzing after five washes. The 90 Degree legging had the most pilling but was only rated as having “slight pilling.” Lululemon pilled the second most while Nike had the least amount of pilling of the three brands.

All brands demonstrated excellent resistance to color change and dimensional change. The stretch properties of the garments revealed that Lululemon was significantly more-stretchy than the other brands in the length direction. After one minute of recovery, the length direction of the Lululemon leggings showed significantly less recovery than the other brands; however, after one hour of recovery, the leggings were not significantly

different. In conclusion, the performance of the three brands of nylon/spandex blended leggings demonstrated little degradation in performance after laundering twenty cycles.

Limitations

The survey portion of this research was limited to a non-randomized sample of participants. Students who completed the questionnaire were predominantly from two sororities at the University of Kentucky. This research chose to focus on women who are in college; therefore, opinions of other age ranges may not be reflected in the results. The samples selected for laboratory evaluation were also limited by resource availability. Each laboratory evaluation was conducted on two to three legging samples, therefore conclusions were based on relatively small sample sizes. Finally, the study did not account for a garment's behavior after wear. Soiling and wear from every day activities may impact the leggings' performance and cause them to perform differently during evaluation.

Recommendations for Future Research

Descriptive survey data was collected through a questionnaire. Future studies should consider other methods of collecting consumers' opinions regarding leggings. Qualitative approaches such as focus groups, oral interviews, or observing decision processes of consenting legging shoppers would perhaps give additional insights into consumers' purchase decisions. Future studies should also select other legging brands for laboratory evaluation. Many leggings are made up of various combinations of polyester, spandex, cotton, and nylon. Future studies should select other fabric types as well as brands to examine. Additionally, a wear study would allow for assessment of the impact of when a consumer wears and washes their leggings.

Appendix A

Definition of Terms

Aesthetic Features: observable traits of a garment, such as color and appearance (Eckman, Damhorst, & Kadolph, 1990).

Athleisure: casual clothing designed to be worn both for exercising and for general use (Merriam Webster Dictionary, 2018).

Abrasion: the wearing away of any part of a material by rubbing against another surface (ASTM, 2019; Fairchild's Dictionary of Textiles, 2014).

Colorfastness: resistance to fading; i.e., the property of a dye to retain its color when the dyed (or printed) textile material is exposed to conditions or agents such as light, perspiration, atmospheric gases, or washing that can remove or destroy the color (Encyclopedic Dictionary of Textiles, 2007).

Bursting Strength: the force or pressure required to rupture a textile by distending it with a force, applied at right angles to the plane of the fabric, under specified conditions (ASTM, 2019).

Comfort: possessing those qualities that promote a feeling of well-being, ease, and freedom from pain (Fairchild's Dictionary of Textiles, 2014).

Dimensional Stability: ability of a fabric to retain its shape and size after being worn, washed, and/or drycleaned. Stability is governed by fiber content and by chemical and mechanical treatments (Fairchild's Dictionary of Textiles, 2014).

Expressive features: the messages a consumer communicates through the wear of a garment or a garment's symbolism (Swan and Combs, 1976; Chen-Yu, Williams & Kincade, 1999; Lamb & Kallal, 1992).

Fabric Count: the number (counted units) of wale and courses per 1 inch (ASTM, 2019).

Fabric Growth: the increase in the original dimension of a specimen after the application of a specified force for a prescribed time and subsequent removal of the force (ASTM, 2019).

Fabric Stretch: the increase in the dimension of a specimen of fabric resulting from a force applied under specified conditions (ASTM, 2019).

Fabric Weight: mass per unit area (ASTM, 2019).

Functional Features: a garment's utility such as protection and comfort (Swan and Combs, 1976; Chen-Yu, Williams & Kincade, 1999; Lamb & Kallal, 1992).

Fuzzing: broken microfibers protruding from a fabric's surface which begin to split or fray (Annis, Bresee, & Cooper, 1992).

Leggings: tight-fitting stretch trousers, typically worn by women or girls (Oxford Living Dictionary, n.d.).

Lint: loose, short, fine ravelings or fluff from yarn or fabric (Fairchild's Dictionary of Textiles, 2014).

Moisture management: a fabrics ability to carry liquid humidity away from the skin and to the surface of a garment (Senthilkumar, Sampath, & Ramachandran, 2012).

Stretch recovery: ability of a stretch fabric or yarn to recover to its original configuration after it has been stretched (Fairchild's Dictionary of Textiles, 2014).

Thickness: the distance between one surface and its opposite (ASTM, 2019).

Appendix B

Survey

Consent to Participate in a Research Study

EVALUATION OF ATHLEISURE LEGGINGS

Dear Interviewee,

You are invited to participate in a web-based survey. This page is to give you key information to help you decide whether to participate.

PURPOSE

We are interested in understanding more about consumers' desires for **"athleisure leggings"** which are athletic leggings worn in non-athletic settings (at home, to class, etc.). Your participation in this research will last **about fifteen minutes.**

QUALIFICATIONS

You should participate in this study if you wear leggings for non-athletic purposes. Please do not participate in this study if the only activities for which you wear leggings are workout or exercise related. Or if you are under the age of 18.

INSTRUCTIONS

You will be presented with information related to athleisure leggings and asked to answer some questions about them.

BENEFITS

You will receive no direct benefits from participating in this research study. However, your responses will help us learn more about consumers' desires for athleisure leggings.

RISKS

There are no foreseeable risks involved in participating in this study. Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. As a student, if you decide not to take part in this study, your choice will have no effect on your academic status or class grade(s).

PRIVACY

Please be assured that **your answers will be kept strictly confidential** and never associated with your name. When results from this study are reported, your response will be combined with others. Internet Protocol (IP) addresses will not be collected.

CONTACT

The person in charge of this study is Virginia Groppo who is a master's student of Dr. Elizabeth Easter in Department of Retailing and Tourism Management at the University of Kentucky**. If you have questions**, **suggestions, or concerns** regarding this study, their contact information is virginia.groppo@uky.edu and elizabeth.easter@uky.edu

If you have any questions, suggestions or concerns about your rights as a volunteer in this research, contact staff in the University of Kentucky (UK) Office of Research Integrity (ORI) between the business hours of 8am and 5pm EST, Monday-Friday at 859-257-9428 or toll free at 1-866-400-9428

ELECTRONIC CONSENT

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

Please note that this survey will be best displayed on a laptop or desktop computer. Some features may be less compatible for use on a mobile device.

O I consent, begin the study

O I do not consent, I do not wish to participate

What is your age?

O 18-19

O 20-21

O 22-23

O 24-25

O 26 or older

What is your gender?

O Male

O Female

O Non-binary

O Prefer to self-describe _____

O Prefer not to say

Do you wear leggings for non-athletic purposes (eg. loungewear, going to class, etc.)? If no, please discontinue survey.

O Yes

O No

In which of the following situations would you wear leggings? Select all that apply.

- [ ] Attending class
- [ ] Running errands
- [ ] Business casual work environment
- [ ] Professional business environment
- [ ] To a bar or restaurant
- [ ] To a party
- [ ] To travel
- [ ] Other _____

How do you typically wear your leggings?

- O As pants regardless of top length
- O As pants but only with longer style tops
- O As a base layer beneath a skirt or dress
- O Other _____

What brand(s) of leggings do you regularly purchase? Select all that apply.

- [ ] Nike
- [ ] Lululemon
- [ ] Fabletics
- [ ] Under Armour
- [ ] 90 Degree
- [ ] Adidas
- [ ] Outdoor Voices
- [ ] Athleta
- [ ] Old Navy
- [ ] Victoria's Secret
- [ ] Other(s) _____
- [ ] No preference

Which of the following best describes why you regularly purchase leggings from the brand(s) selected above?

- O I like the designs and colors they use
- O The price is best for me
- O They offer quality products
- O I want to be associated with the brand
- O Many of my friends wear their products
- O My favorite celebrity or social influencer wears their products
- O Other _____

If known, please indicate the style name of the leggings you usually purchase (e.g. Lululemon "Align", 90 Degree "Comfytek").

_____

If known, please indicate what fabric your leggings usually are (e.g. 50% Cotton/50% Polyester)

_____

What brand(s) of leggings would you consider ideal for purchasing? Select all that apply.

- [ ] Nike
- [ ] Lululemon
- [ ] Fabletics
- [ ] Under Armour
- [ ] 90 Degree
- [ ] Adidas
- [ ] Outdoor Voices
- [ ] Athleta
- [ ] Old Navy
- [ ] Victoria's Secret
- [ ] Other(s) _____
- [ ] No preference

Which of the following best describes why you would prefer to purchase leggings from the brand(s) you selected above?

- O I like the designs and colors they use
- O The price is best for me
- O They offer quality products
- O I want to be associated with the brand
- O Many of my friends wear their products
- O My favorite celebrity or social influencer wears their products
- O Other _____

What length do you prefer for your leggings?

- O Ankle length
- O Mid-calf length
- O Just below the knee
- O Stirrup
- O Footed
- O Other _____

What style features do you prefer for your leggings?

- [ ] Mesh panels
- [ ] Seamless
- [ ] High waistband
- [ ] Normal waistband
- [ ] Slashes or cut outs in fabric to expose skin
- [ ] Pockets
- [ ] Other _____

Which of the following functional problems have you encountered after wearing leggings. Select all that apply.

- [ ] Uncomfortable material
- [ ] See-through fabric
- [ ] Restrictive/thick fabric
- [ ] Lingering body odors
- [ ] Loss of compression abilities
- [ ] Loss of wicking abilities
- [ ] Loss of water resistance ability

Which of the following aesthetic problems have you encountered after wearing leggings. Select all that apply.

- [ ] Excessive lint (loose fibers, yarns, debris, etc.)
- [ ] Color fading or change
- [ ] Pilling (balls of fibers from the legging fabric)
- [ ] Shrinkage
- [ ] Stretched out fabric

Which of the following durability problems have you encountered after wearing leggings. Select all that apply.

- [ ] Fabric ripping
- [ ] Ripping at seams
- [ ] Holes
- [ ] Worn down fabric
- [ ] NA

Please indicate your level of frustration with the following functional problems.

	Problem not encountered	Not frustrating	Slightly frustrating	Moderately frustrating	Very frustrating	Extremely frustrating
Uncomfortable material	O	O	O	O	O	O
See-through fabric	O	O	O	O	O	O
Thick/restrictive fabric	O	O	O	O	O	O
Lingering body odors	O	O	O	O	O	O
Loss of compression ability	O	O	O	O	O	O
Loss of wicking ability	O	O	O	O	O	O
Loss of water resistance	O	O	O	O	O	O

Please indicate your level of frustration with the following aesthetic problems.

	Problem not encountered	Not frustrating	Slightly frustrating	Moderately frustrating	Very frustrating	Extremely frustrating
Lint accumulation	O	O	O	O	O	O
Color fading or change	O	O	O	O	O	O
Pilling	O	O	O	O	O	O
Shrinkage	O	O	O	O	O	O
Stretched out fabric	O	O	O	O	O	O

Please indicate your level of frustration with the following durability problems.

	Problem not encountered	Not frustrating	Slightly frustrating	Moderately frustrating	Very frustrating	Extremely frustrating
Fabric ripping	O	O	O	O	O	O
Ripping at seams	O	O	O	O	O	O
Holes	O	O	O	O	O	O
Worn down fabric	O	O	O	O	O	O

Please describe any additional problems you have encountered with your leggings.

_____

If you were to select a new pair of athleisure leggings to purchase, which functional feature would you find to be the most desirable.

- O Not see-through
- O Material is not too thick
- O Compression ability
- O Comfortable material
- O Wicking ability
- O Water resistance
- O Odor control

Please indicate how important the following functional characteristics are to you when purchasing leggings.

	Not important	Slightly important	Moderately important	Very important	Extremely important
Comfortable material	O	O	O	O	O
Not see-through	O	O	O	O	O
Material is not too thick	O	O	O	O	O
Compression ability	O	O	O	O	O
Wicking ability	O	O	O	O	O
Water resistance	O	O	O	O	O
Odor control ability	O	O	O	O	O

If you were to select a new pair of athleisure leggings to purchase, which aesthetic characteristic would you find most desirable.

- O No pilling
- O No lint accumulation
- O No color change/fading
- O No shrinkage
- O Material does not become stretched out

Please indicate how important the following aesthetic characteristics are to you when purchasing athleisure leggings.

	Not important	Slightly important	Moderately important	Very important	Extremely important
Low pilling	O	O	O	O	O
Low lint accumulation	O	O	O	O	O
Minimal color change/fading	O	O	O	O	O
Minimal shrinkage	O	O	O	O	O
Material does not stretch out easily	O	O	O	O	O

Please describe any additional characteristics that would be desirable for your leggings to have.

_____

If you were to design your own leggings, which of the following would be most appealing? Select up to 5.

- [ ] No lint accumulation
- [ ] No color change/fading
- [ ] Comfortable material
- [ ] Not see-through
- [ ] No pilling
- [ ] Compression
- [ ] Odor control
- [ ] Wicking
- [ ] No shrinking
- [ ] Material does not become stretched out
- [ ] Water resistant

Appendix C

IRB Approval

University of Kentucky | Office of Research Integrity
IRB, RDRC

XP Initial Review

Approval Ends:
4/8/2020

IRB Number:
49753

TO: Virginia Groppo
Retailing & Tourism Management
PI phone #: 8592271964

PI email: vegr222@g.uky.edu

FROM: Chairperson/Vice Chairperson
Non Medical Institutional Review Board (IRB)
SUBJECT: Approval of Protocol
DATE: 4/9/2019

On 4/9/2019, the Non Medical Institutional Review Board approved your protocol entitled:

Graduate Thesis: An Evaluation of Legging Performance in Relation to Consumer Desires and Complaints

Approval is effective from 4/9/2019 until 4/8/2020 and extends to any consent/assent form, cover letter, and/or phone script. If applicable, the IRB approved consent/assent document(s) to be used when enrolling subjects can be found in the "All Attachments" menu item of your E-IRB application. [Note, subjects can only be enrolled using consent/assent forms which have a valid "IRB Approval" stamp unless special waiver has been obtained from the IRB.] Prior to the end of this period, you will be sent a Continuation Review (CR)/Administrative Annual Review (AAR) request which must be completed and submitted to the Office of Research Integrity so that the protocol can be reviewed and approved for the next period.

In implementing the research activities, you are responsible for complying with IRB decisions, conditions and requirements. The research procedures should be implemented as approved in the IRB protocol. It is the principal investigator's responsibility to ensure any changes planned for the research are submitted for review and approval by the IRB prior to implementation. Protocol changes made without prior IRB approval to eliminate apparent hazards to the subject(s) should be reported in writing immediately to the IRB. Furthermore, discontinuing a study or completion of a study is considered a change in the protocol's status and therefore the IRB should be promptly notified in writing.

For information describing investigator responsibilities after obtaining IRB approval, download and read the document "PI Guidance to Responsibilities, Qualifications, Records and Documentation of Human Subjects Research" available in the online Office of Research Integrity's IRB Survival Handbook. Additional information regarding IRB review, federal regulations, and institutional policies may be found through ORI's web site. If you have questions, need additional information, or would like a paper copy of the above mentioned document, contact the Office of Research Integrity at 859-257-9428.

Appendix D

Table D1

ASTM D3776/D3776M – 09a (2017): *Standard Test Methods for Mass per Unit Area (Weight) of Fabric*

Brand	Test Interval	Sample	Specimen	Fabric Weight (g)	Fabric Weight (oz/yd^2)	*SD*	Average Fabric Weight (oz/yd^2)
Lululemon	Wash 1	3	1	0.879	6.77	0.022	6.78
			2	0.883	6.80		
	Wash 5	3	1	0.875	6.73	0.000	6.73
			2	0.875	6.73		
	Wash 10	4	1	0.874	6.73	0.033	6.70
			2	0.868	6.68		
	Wash 20	4	1	0.876	6.74	0.060	6.78
			2	0.887	6.83		
Nike	Wash 1	3	1	0.926	7.13	0.027	7.15
			2	0.931	7.17		
	Wash 5	3	1	0.909	7.00	0.000	7.00
			2	0.909	7.00		
	Wash 10	4	1	0.926	7.13	0.033	7.10
			2	0.920	7.08		
	Wash 20	5	1	0.918	7.07	0.022	7.05
			2	0.914	7.04		
90 Degree	Wash 1	3	1	1.168	8.99	0.038	9.02
			2	1.175	9.04		
	Wash 5	4	1	1.144	8.81	0.169	8.92
			2	1.175	9.04		
	Wash 10	3	1	1.170	9.01	0.163	8.89
			2	1.140	8.77		
	Wash 20	4	1	1.146	8.82	0.136	8.72
			2	1.121	8.63		

Table D2

ASTM D8007 – 15: *Standard Test Method for Wale and Course Count of Weft Knitted Fabrics*

Brand	Test Interval	Sample	Rating	Specimen	Wales	Courses	Knit Count	Average Knit Count	*SD*	Overall Average Count	Overall *SD*
Lululemon	Wash 1	3	1	1	83	63	146	147	1	151	6.010
				2	86	62	148				
			2	1	88	68	156	156	1		
				2	90	65	155				
	Wash 20	4	1	1	88	64	152	154	2	154	1.061
				2	91	64	155				
			2	1	87	66	153	155	3		
				2	93	64	157				
Nike	Wash 1	4	1	1	92	51	143	144	1	147	4.243
				2	93	51	144				
			2	1	100	52	152	150	4		
				2	95	52	147				
	Wash 20	5	1	1	97	51	148	148	0	148	0.000
				2	97	51	148				
			2	1	96	51	148	148	1		
				2	98	51	148				
90 Degree	Wash 1	3	1	1	65	44	109	109	0	107	2.475
				2	64	45	109				
			2	1	62	40	102	106	5		
				2	65	44	109				
	Wash 20	4	1	1	64	42	106	107	1	106	0.354
				2	64	43	107				
			2	1	64	43	107	106	1		
				2	63	42	105				

Table D3

ASTM D1777-96 (2015): *Standard Test Method for Thickness of Textile Materials*

Brand	Test Interval	Sample	Replication Location										Average	Overall Average	*SD*
			1	2	3	4	5	6	7	8	9	10			
Lululemon	Wash 1	2	30	28	29	28	26	31	27	30	30	29	28.80	29.15	0.495
		4	30	29	31	30	30	31	26	30	31	27	29.50		
	Wash 5	2	31	30	31	27	30	29	29	30	32	25	29.40	29.55	0.212
		4	32	30	32	29	32	27	29	29	31	26	29.70		
	Wash 10	2	31	31	30	27	25	31	31	31	30	21	29.80	30.00	0.283
		4	32	31	32	31	29	31	32	29	27	28	30.20		
	Wash 20	2	26	31	31	31	30	28	30	26	29	31	29.30	29.80	0.707
		4	27	32	30	29	32	32	31	31	31	28	30.30		
Nike	Wash 1	2	25	26	24	23	22	25	23	23	25	25	24.10	25.15	1.485
		5	27	27	27	27	23	26	24	27	26	28	26.20		
	Wash 5	2	26	27	25	27	23	26	26	26	23	24	25.30	26.15	1.202
		5	28	28	27	27	25	26	23	26	27	23	27.00		
	Wash 10	2	25	27	27	26	24	27	23	25	27	25	25.60	26.25	0.919
		5	27	29	27	25	24	28	27	27	28	27	26.90		
	Wash 20	2	27	25	27	25	23	26	26	26	27	24	25.60	25.75	0.212
		5	26	26	27	26	26	25	25	26	26	26	25.90		
90 Degree	Wash 1	2	32	29	30	32	32	32	31	32	32	31	31.30	31.35	0.071
		4	29	32	33	31	33	31	32	32	32	29	31.40		
	Wash 5	2	32	28	32	31	28	321	32	32	32	32	31.10	30.90	0.283
		4	32	32	27	31	29	32	32	32	31	29	30.70		
	Wash 10	2	31	31	30	27	25	31	31	31	30	31	29.80	30.00	0.283
		4	32	31	32	31	29	31	32	29	27	28	30.20		
	Wash 20	2	32	28	32	31	28	32	32	32	32	32	31.10	30.85	0.354
		4	32	32	27	31	29	31	33	32	31	29	30.60		

Table D4

ASTM D3786/D3786M – 18: *Bursting Strength of Textile Fabrics: Diaphragm Bursting*

Brand	Test Interval	Sample	Specimen	Psi	Interval Psi Average	*SD*	Sec to Burst
Lululemon	Wash 1	3	1	54.8	56.9	4.440	21
			2	53.9			21
			3	62.0			23
	Wash 5	3	1	65.8	62.6	2.771	23
			2	61.0			21
			3	61.0			21
	Wash 10	4	1	65.1	65.7	1.721	22
			2	67.6			22
			3	64.3			21
	Wash 20	4	1	70.5	67.0	3.722	21
			2	67.5			21
			3	63.1			20
Nike	Wash 1	3	1	65.5	66.0	2.542	20
			2	68.8			22
			3	63.8			22
	Wash 5	4	1	60.0	62.6	2.261	21
			2	63.7			22
			3	64.1			21
	Wash 10	4	1	62.6*	63.6	2.307	21
			2	66.2*			22
			3	61.9			21
	Wash 20	5	1	66.5	62.5	6.612	22
			2	66.2			22
			3	54.9*			19
90 Degree	Wash 1	3	1	92.7	93.3	2.804	29
			2	90.9			24
			3	96.4			23
	Wash 5	3	1	92.9	91.5	3.017	21
			2	93.5			21
			3	88.0			20
	Wash 10	4	1	90.9	93.0	2.893	21
			2	96.3			22
			3	91.8			21
	Wash 20	4	1	99.6	94.3	5.403	22
			2	94.5			21
			3	88.8			20

*Did not burst: specimen stopped inflating due to a pressure drop

Table D5

Opacity of Leggings when Stretched

Brand	Test Interval	Sample	Location	Opacity	Average Opacity	*SD*
Lululemon	Wash 1	2	1	100.9	99.8	1.62
			2	98.6		
	Wash 20	4	1	95.9	97.15	1.76
			2	98.4		
Nike	Wash 1	2	1	99.1	99.0	0.14
			2	98.9		
	Wash 20	5	1	96.4	97.4	1.41
			2	98.4		
90 Degree	Wash 1	2	1	99.8	100.1	0.35
			2	100.3		
	Wash 20	4	1	95.9	94.4	2.19
			2	92.8		

Table D6

AATCC Evaluation Procedure 1-2012: *Gray Scale for Color Change*

Brand	Wash Interval	Wash 1		Wash 5		Wash 10		Wash 20	
Lululemon	Sample ID	2	4	2	4	2	4	2	4
	Rating 1	4.5	4.5	4.5	4.5	4.0	4.0	4.5	4.5
	Rating 2	4.5	5.0	4.5	5.0	4.5	4.5	4.0	4.0
	Average	4.50	4.75	4.50	4.75	4.25	4.25	4.25	4.25
	Overall Average	4.63		4.63		4.25		4.25	
	SD	0.177		0.177		0.000		0.000	
Nike	Wash Interval	Wash 1		Wash 5		Wash 10		Wash 20	
	Sample ID	2	5	2	5	2	5	2	5
	Rating 1	4.5	5.0	4.5	5.0	4.5	4.5	4.5	4.5
	Rating 2	5.0	4.5	5.0	4.5	4.5	4.5	4.5	4.5
	Average	4.75	4.75	4.75	4.75	4.50	4.50	4.50	4.50
	Overall Average	4.75		4.75		4.5		4.50	
	SD	0.000		0.000		0.000		0.000	
90 Degree	Wash Interval	Wash 1		Wash 5		Wash 10		Wash 20	
	Sample ID	2	4	2	4	2	4	2	5
	Rating 1	4.5	5.0	5.0	5.0	4.5	4.5	4.5	4.5
	Rating 2	5.0	5.0	4.5	5.0	4.5	4.0	4.0	4.0
	Average	4.75	5.00	4.75	5.00	4.50	4.25	4.25	4.25
	Overall Average	4.88		4.88		4.38		4.25	
	SD	0.177		0.177		0.177		0.000	

Table D7

ASTM D2594: *Standard Test Method for Stretch Properties of Knitted Fabrics*

Brand	Interval	Direction	Distance Before (in)	1 Minute (in)	Fabric Growth (1 Min)	Average (1 Min)	1 Hour (in)	Fabric Growth (1 Hour)	Average (1 Hour)	Stretch (in)	Fabric Stretch	Average Stretch
Lululemon	Wash 5	Width	4.0	4.25	6.3%	6.3%	4.06	1.6%	2.3%	7.94	98.4%	96.1%
			4.0	4.25	6.3%	*SD* 0.00	4.13	3.1%	*SD* 0.01	7.75	93.8%	*SD* 0.03
		Length	4.0	4.50	12.5%	10.2%	4.13	3.1%	3.1%	7.94	98.4%	98.4%
			4.0	4.31	7.8%	*SD* 0.03	4.13	3.1%	*SD* 0.00	7.94	98.4%	*SD* 0.00
	Wash 20	Width	4.0	4.25	6.3%	7.0%	4.19	4.7%	3.9%	7.56	89.1%	89.1%
			4.0	4.31	7.8%	*SD* 0.01	4.13	3.1%	*SD* 0.01	7.56	89.1%	*SD* 0.00
		Length	4.0	4.50	12.5%	11.7%	4.19	4.7%	5.5%	8.25	106.3%	103.1%
			4.0	4.44	10.9%	*SD* 0.01	4.25	6.3%	*SD* 0.01	8.00	100.0%	*SD* 0.04
Nike	Wash 5	Width	4.0	4.31	7.8%	7.8%	4.13	3.1%	3.1%	8.13	103.1%	102.3%
			4.0	4.31	7.8%	*SD* 0.00	4.13	3.1%	*SD* 0.00	8.06	101.6%	*SD* 0.01
		Length	4.0	4.25	6.3	5.5%	4.19	4.7%	4.7%	7.50	87.5%	83.6%
			4.0	4.29	4.7	*SD*0.01	4.19	4.7%	*SD* 0.00	7.19	79.7%	*SD* 0.06
	Wash 20	Width	4.0	4.56	14.1%	15.6%	4.19	4.7%	5.5%	7.63	90.6%	97.7%
			4.0	4.69	17.2%	*SD* 0.02	4.25	6.3%	*SD* 0.01	8.19	104.7%	SD 0.10
		Length	4.0	4.31	7.8%	7.8%	4.25	6.3%	5.5%	7.56	89.1%	89.1%
			4.0	4.31	7.8%	*SD* 0.00	4.19	4.7%	*SD* 0.01	7.56	89.1%	*SD* 0.00
90 Degree	Wash 5	Width	4.0	4.31	7.8%	7.8%	4.13	3.1%	3.1%	7.44	85.9%	85.9%
			4.0	4.31	7.8%	*SD* 0.00	4.13	3.1%	*SD* 0.00	7.44	85.9%	*SD* 0.00
		Length	4.0	4.25	6.3%	6.3%	4.06	1.6%	1.6%	6.31	57.8%	60.9%
			4.0	4.25	6.3%	*SD* 0.00	4.06	1.6%	*SD* 0.00	6.56	64.1%	*SD* 0.04
	Wash 20	Width	4.0	4.38	9.4%	13.3%	4.19	4.7%	5.5%	7.75	93.8%	93.0%
			4.0	4.69	17.2%	*SD* 0.06	4.25	6.3%	*SD* 0.01	7.69	92.2%	*SD* 0.01
		Length	4.0	4.25	6.3%	7.0%	4.13	3.1%	3.1%	6.25	56.3%	56.3%
			4.0	4.31	7.8%	*SD* 0.01	4.13	3.1%	*SD* 0.00	6.25	56.3%	*SD* 0.00

Table D8

ASTM D4970/D4970M–10: *Pilling Resistance and Other Related Surface Changes of Textile Fabrics: Martindale Tester*

Brand	Wash Interval	Wash 1		Wash 5		Wash 10		Wash 20	
Lululemon	Sample ID	3		3		4		4	
	Rating	Rating 1	Rating 2	Rating 1	Rating 2	Rating 1	Rating 2	Rating 1	Rating 2
	Specimen 1	5	5	5	5	4	4.25	4.5	4
	Specimen 2	5	5	4.5	5	4	4.25	4.5	4
	Specimen 3	5	5	5	5	4.5	4.5	4.5	4
	Specimen 4	5	5	4.5	5	4.5	4.5	4	4
	Average	5.00		4.88		4.38		4.19	
	SD	0.000		0.144		0.144		0.125	
Nike	Sample ID	3		3		4		5	
	Rating	Rating 1	Rating 2	Rating 1	Rating 2	Rating 1	Rating 2	Rating 1	Rating 2
	Specimen 1	5	5	5	5	5	5	5	5
	Specimen 2	5	5	5	5	5	4.5	5	5
	Specimen 3	5	5	5	5	5	5	5	5
	Specimen 4	5	5	5	5	5	5	5	4.5
	Average	5.00		5.00		4.94		4.94	
	SD	0.000		0.000		0.125		0.125	
90 Degree	Sample ID	3		3		4		4	
	Rating	Rating 1	Rating 2	Rating 1	Rating 2	Rating 1	Rating 2	Rating 1	Rating 2
	Specimen 1	5	5	5	5	4.5	4.5	4	4
	Specimen 2	5	5	5	5	4	4.25	4	4
	Specimen 3	5	5	5	4.5	4.5	4.5	4	4
	Specimen 4	5	5	4.5	5	4	4.25	4	4
	Average	5.00		4.89		4.38		4.00	
	SD	0.000		0.144		0.144		0.000	

Table D9

AATCC Test Method 150-2018: *Dimensional Changes of Garments after Home Laundering, Lululemon*

	Sample	Initial	Wash 1			Wash 5			Wash 10			Wash 20		
			(in)	Change	Overall Change	(in)	Change (%)	Overall Change	(in)	Change (%)	Overall Change	(in)	Change (%)	Overall Change
Length	2	24.63	24.44	0.76%	0.42%	24.38	1.02%	0.50% SD	24.38	1.02%	0.69%	24.38	1.02%	0.79%
		4.69	4.69	0.00%		4.69	0.00%		4.63	1.33%		4.63	1.33%	
		32.31	32.31	0.00%		32.31	0.00%		32.38	-0.19%		32.38	-0.19%	
	4	27.50	27.25	0.91%		27.19	1.14%		27.19	1.94%		27.13	1.36%	
		5.56	5.56	0.00%		5.56	0.00%		5.56	0.00%		5.56	0.00%	
		35.75	35.44	0.87%		35.44	0.87%		35.44	2.94%		35.31	1.22%	
Width	2	12.88	12.63	1.94%	1.42%	12.63	1.94%	1.42%	12.63	1.94%	1.90%	12.56	2.43%	2.04%
		5.06	5.06	0.00%		5.06	0.00%		5.06	0.00%		5.06	0.00%	
		4.25	4.19	1.47%		4.19	1.47%		4.13	2.94%		4.13	2.94%	
	4	15.94	15.88	0.36%		15.88	0.39%		15.81	0.78%		15.75	1.18%	
		6.06	6.06	0.04%		6.06	0.00%		6.00	1.03%		6.00	1.03%	
		4.00	3.81	4.69%		3.81	4.69%		3.81	4.69%		3.81	4.69%	

Table D10

AATCC Test Method 150-2018: *Dimensional Changes of Garments after Home Laundering, Nike*

	Sample	Initial	Wash 1			Wash 5			Wash 10			Wash 20		
			(in)	Change	Overall Change	(in)	Change (%)	Overall Change	(in)	Change (%)	Overall Change	(in)	Change (%)	Overall Change
Length	2	24.25	24.06	0.77%	0.50%	24.06	0.77%	0.53%	24.00	1.03%	0.61%	23.94	1.29%	0.97%
		5.50	5.50	0.00%		5.50	0.00%		5.50	0.00%		5.44	1.14%	
		33.69	33.56	0.37%		33.50	0.56%		33.50	0.56%		33.31	1.11%	
	5	24.25	23.94	1.29%		23.94	1.29%		23.88	1.55%		23.88	1.55%	
		5.69	5.69	0.00%		5.69	0.00%		5.69	0.00%		5.69	0.00%	
		33.81	33.63	0.55%		33.63	0.55%		33.63	0.55%		33.56	0.74%	
Width	2	15.38	15.25	0.81%	0.68%	15.25	0.81%	0.68%	15.25	0.81%	0.68%	15.25	0.81%	1.00%
		6.38	6.38	0.00%		6.38	0.00%		6.38	0.00%		6.31	0.98%	
		4.38	4.31	1.43%		4.31	1.43%		4.31	1.43%		4.31	1.43%	
	5	15.50	15.44	0.40%		15.44	0.39%		15.44	0.40%		15.44	0.40%	
		6.31	6.31	0.00%		6.31	0.04%		6.31	0.00%		6.25	0.99%	
		4.44	4.38	1.41%		4.38	1.41%		4.38	1.41%		4.38	1.41%	

Table D11

AATCC Test Method 150-2018: *Dimensional Changes of Garments after Home Laundering, 90 Degree*

	Sample	Initial	Wash 1			Wash 5			Wash 10			Wash 20		
			(in)	Change	Overall Change	(in)	Change (%)	Overall Change	(in)	Change (%)	Overall Change	(in)	Change (%)	Overall Change
Length	2	26.88	26.63	0.93%	0.24%	26.56	1.16%	0.39%	26.63	0.87%	0.50%	26.63	0.93%	0.73%
		4.56	4.56	0.00%		4.56	0.00%		4.50	0.00%		4.50	1.37%	
		36.25	36.06	0.52%		36.00	0.69%		36.00	0.00%		35.94	0.86%	
	4	26.25	26.25	0.00%		26.25	0.00%		26.38	-0.48%		26.38	-0.48%	
		5.31	5.31	0.00%		5.31	0.00%		5.31	0.00%		5.25	1.18%	
		37.19	37.19	0.00%		37.00	0.50%		37.00	0.50%		37.00	0.50%	
Width	2	14.31	14.25	0.44%	0.79%	14.25	0.44%	0.73%	14.19	1.57%	1.20%	14.19	0.87%	0.97%
		5.56	5.56	0.00%		5.56	0.00%		5.56	1.96%		5.56	0.00%	
		3.81	3.81	0.00%		3.81	0.00%		3.81	2.78%		3.81	0.00%	
	4	15.94	15.63	1.96%		15.69	1.57%		15.69	1.57%		15.69	1.57%	
		6.38	6.31	0.98%		6.31	0.98%		6.25	0.00%		6.25	1.96%	
		4.50	4.44	1.39%		4.44	1.39%		4.38	0.50%		4.44	1.39%	

References

AATCC. (2019). AATCC technical manual (Vol. 94). Research Triangle Park, NC: American Association of Textile Chemists and Colorists

Adidas. (2017). Warp knit tights: seamless tights primed for comfort. Retrieved from https://www.adidas.com/us/warp-knit-tights/BK4492.html

Annis, P. A., Bresee, R. R., & Cooper, T. R. (1992). Influence of textile structure on single fiber transfer from woven fabrics. *Textile Research Journal, 62*(5), 293-301.

ASTM. (2019). Annual book of ASTM standard (Vols. 70.01-7.02). West Conshohocken, PA: American Society for Testing and Materials

Athleisure. (n.d.). In Merriam Webster Dictionary. Retrieved from https://www.merriam-webster.com/dictionary/athleisure

Athleisure category remains strong. (2017). Retrieved from https://lifestylemonitor.cottoninc.com/athleisure-category-remains-strong/

Barakzehi, M., Asadi , F., & Aghaji, A. G. (2016). Effect of the fabric color on the visual perception of pilling. *International Journal of Clothing Science and Technology, 28*(5), 612-623.

Barker, R. L. (2002). From fabric hand to thermal comfort: the evolving role of objective measurements in explaining human comfort response to textiles. *International Journal of Clothing Science and Technology, 14*(3/4), 181-200.

Beaudette, E., & Park, H. (2017). Impact of seam types on thermal properties of athletic bodywear. *Textile Research Journal, 87*(9), 1052-1059.

Beck, U., Wagner, M., Li, X., Durkin-Meisterernst, D., & Tarasov, P. E. (2014). The invention of trousers and its likely affiliation with horseback riding and mobility: a case study of late 2nd millennium BC finds from Turfan in eastern Central Asia. *Quaternary International, 348*, 224-235.

Berk, G. G., & Kahveci, S. (2018). Design of novel running leggings with thermoplastic polyurethane membrane comrpession zone. *Textile Research Journal, 0*(00), 1-13.

Bringard, A., Perrey, S., & Belluye, N. (2006). Aerobic energy cost and sensation responses during submaximal running exercise-positive effects of wearing compression tights. *International Journal of Sports Medicine, 27*(5), 373-378.

Brunn, M. B., & Langkjaer, M. A. (2016). Sportswear: between fashion, innovation and sustainability. *The Journal of Design, Creative Process & The Fashion Industry, 8*(2), 181-188.

Bubonia, J. (2014). Apparel quality: a guide to evaluating sewn products. New York, NY: Bloomsbury Inc.

Chen, Q., Miao, X., Mao, H., Ma, P., & Jiang, G. (2016). The comfort properties of two differential-shrinkage polyester warp knitted fabrics. *Autex Research Journal, 16*(2), 90-99.

Chen-Yu, J. H., Williams, G., & Kincade, D. H. (1999). Determinants of consumer satisfaction/dissatisfaction with the performance of apparel products. *Family and Consumer Science Research Journal, 28*(2), 167-192.

Cole, A. M. (1986). Pantaloons, bloomers, and shorts. *Journal of Physical Education, Recreation, & Dance, 57*(7), 66-75.

Daanen, H. (2015). Physiological strain and comfort in sports clothing. In R. Shishoo (Ed.), *Textiles in Sportswear* (pp. 153-168). Cambridge, UK: Woodhead Publishing.

Ducharme, J. (2013, April 25). Ask the expert: are expensive workout pants worth it? *Boston Magazine*. Retrieved from https://www.bostonmagazine.com/health/2013/04/25/ask-the-expert-workout-pants/

Eckman, M., Damhorst, M., & Kadolph, S. J. (1990). Toward a model of the in-store purchase decision process: consumer use of criteria for evaluating women's apparel. *Clothing and Textile Research Journal, 8*(2), 13-22.

Elmer, V. (2017, January 16). For many workers casual is cool. *SAGE Business Research.* Retrieved from http://businessresearcher.sagepub.com.ezproxy.uky.edu/. doi: 10.1177/237455680302.n5

Elsasser, V. H. (2010). *Textiles: Concepts and principles* (3rd ed.). New York, NY: Fairchild Books.

Encyclopedic Dictionary of Textiles. (2007). New York, NY: Springer.

Fairchild's Dictionary of Textiles (2014). (8th ed.). New York, NY: Fairchild Publications

Feitelberg, R. (2017, January 1). Wearable X introduces yoga pants embedded with sensors. *Los Angeles Times*. Retrieved from http://www.latimes.com/fashion/la-ig-wwd-chloe-grace-moretz-appaled-ads-20170601-story.html

Gay, W. (2017, July 26). Millennials dress casually at work, and it's helping the athleisure industry explode. Forbes. Retreived from https://www.forbes.com/sites/wesgay/2017/07/26/millennials-casual-dress/#278626ed3544

Gooch, J.W. (2007). The Encyclopedic Dictionary of Textiles. New York, NY: Springer.

Gorjanc, D. Š., & Bukosek, V. (2008). The behaviour of fabric with elastane yarn during stretching. *Fibres and Textiles in Eastern Europe, 16*(3), 63-68.

Gottfried, M. (2017, March 30). Lululemon shows athleisure market is out of breath. *The Wall Street Journal*. Retrieved from https://www.wsj.com/articles/lululemon-shows-athleisure-market-is-out-of-breath-1490904874

Green, D. (2017, February 4). Athleisure is not just a trend - it's a fundamental shift in how Americans dress. *Business Insider* . Retrieved from https://www.businessinsider.com/athleisure-is-more-than-a-trend-2017-2

Guan, S., Li, W., Wang, J., & Lei, M. (2018). Objective evaluation of fabric pilling based on data-driven visual attention model. *International Journal of Clothing Science and Technology, 30*(2), 210-221.

Gupta, D. (2011). Functional clothing - definition and classification. *Indian Journal of Fibre & Textile Research, 36*(4), 321-326.

Haji, M. M. (2013). Physical and mechanical properties of cotton/spandex fabrics. *Pakistan Textile Journal, 62*(1), 52-55.

Hanbury, M. (2018, March 26). There's a monumental shift in American fashion - and it's killing denim for good. *Business Insider*. Retrieved from https://www.businessinsider.com/yoga-pants-are-more-popular-than-denim-2018-3

Holmes, E. (2015, May 25). Are you going to the gym, or do you just dress that way? *Wall Street Journal*. Retrieved from https://www.wsj.com/articles/are-you-going-to-the-gym-or-do-you-just-dress-that-way-1430847310

Hu, J., & Lu, J. (2015). Recent developments in elastic fibers and yarns in sportswear. In R. Shishoo (Ed.), *Textiles in Sportswear* (pp. 53-76). Cambridge, UK: Woodhead Publishing.

Jensen, K. L., & Carstensen, J. M. (2002). Fuzz and pills evaluated on knitted textiles by image analysis. *Textile Research Journal, 72*(1), 34-38.

Kadolph, S. J. (2010). *Textiles* (11th ed.). Upper Saddle River, NJ: Pearson Education Inc.

Kaufmann, J. (2015). The wide world of knits. *Textile World*. Retrieved from https://www.textileworld.com/textile-world/knitting-apparel/2015/03/the-wide-world-of-knits/

Keiser, S. A., Vandermar, D., & Garner, M. B. (2017). *Beyond Design: The Synergy of Apparel Product Development* (4th ed.). New York, NY: Bloomsbury Publishing.

Kell, J. (2016, October 22). A bunch of new brands are joining the athleisure wear craze. *Fortune*. Retrieved from http://fortune.com/2016/10/22/fashion-brands-athleisure-trend/

Lamb, J. M., & Kallal, J. M. (1992). A conceptual framework for apparel design. *Clothing and Textiles Research Journal, 10*(2), 42-47.

Leggings. (n.d.). In Oxford Living Dictionary Online. Retrieved from https://en.oxforddictionaries.com/definition/leggings

Liu, R., & Little, T. (2009). The 5Ps model to optimize compression athletic wear. *Journal of Fiber Bioengineering and Informatics, 2*(1), 41-52.

Lululemon. (n.d.). *Lululemon Care Instructions*. Retrieved from https://info.lululemon.com/design/product-care/product-care-instructions

Marmarali, B. A. (2003). Dimensional and physical properties of cotton/spandex single jersey fabrics. *Textile Research Journal, 73*(1), 11-14.

McCann, J. (2015). Environmentally conscious fabric. In R. Shishoo (Ed.), *Textiles for Sportswear* (pp. 17-52). Cambridge, UK: Woodhead Publishing.

McKenzie, S. (2013). *Getting physical: the rise of fitness culture in America.* Lawrence, KS: University Press of Kansas.

McLoughlin, J., & Hayes, S. (2015). Joining techniques for sportswear. In R. Shishoo (Ed.), *Textiles for Sportswear* (pp. 119-149). Cambridge, UK: Woodhead Publishing.

Millington, K. R. (2018). Colorfastness. In M. Miao, & J. H. Xin (Eds.), *Engineering of High-Performance Textiles* (pp. 155-185). Duxford, UK: Woodhead Publishing

Nayak, R. & Padhye, R. (2015). Antimicrobial finishes for textiles. In R. Paul (Ed.), *Functional Finishes For Textiles: Improving comfort, performance and protection* (pp. 361-385). Cambridge, UK: Woodhead Publishing.

Neckarand, B., & Das, D. (2007). Modelling of yarn shrinkage due to washing. *Journal of Textile Institute, 98*(6), 479-482.

Oğlakcioğlu, N & Marmarali, A. (2007). Thermal comfort properties of some knitted structures. *Fibres and Textiles in Eastern Europe. 15*(5&6), 64-65.

Pavlidou, S., & Paul, R. (2015). Moisture management and soil release finishes for textiles. In R. Paul (Ed.), *Functional Finishes For Textiles: Improving comfort, performance and protection* (pp. 99-121). Cambridge, UK: Woodhead Publishing.

Payer, A. (2018, September 25). The little-known history of leggings. *Who What Wear*. Retrieved from https://www.whowhatwear.com/history-of-leggings-trend

Performance Technology. (n.d.). *Cotton Incorporated*. Retrieved from https://www.cottoninc.com/quality-products/performance-technologies/

Rai, M., Yadav, A., & Gade, A. (2009). Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances, 27*(1), 76-83.

Realff, M.L. & Cascio, A. (2005). Effects of fiber factors on fabric hand. In H.M. Behery (Ed.), Effects of Merchanical and physical properties on fabric hand. (pp. 197-218). Cambridge, UK: Woodhead Publishing

Schmid, J. (2018, April 22). How leggings can make these 7 health problems worse. *Reader's Digest*. Retrieved from https://www.rd.com/health/wellness/leggings-health/

Senthilkumar, M., & Anbumani, N. (2010). Dynamics of elastic knitted fabrics for sports wear. *Journal of Industrial Textile (JIT),* 38(1), 13-24.

Senthilkumar, M., Sampath, M. B., & Ramachandran, T. (2012). Moisture management in an active sportswear: technique and evaluation. *Journal of The Institution of Engineers, 93*(2), 61-68.

Sharova, L. P., Zhukov, V. V., Gal'chun, V. V., Verfenich , E. M., Markhotenko, M. N., Skovysh, S. P., Kulish, L.P., Sedakov, V. I., & Baranovskii, V. G. (2002). Pilling-resistant polyester fibre. *Fibre Chemistry, 34*(4), 260-262.

Shishoo, R. (2015). Introduction to textiles in sport. In *Textiles for Sportswear.* Cambridge, UK: Woodhead Publishing.

Su, C. L., Fang, J. X., & Cheni, H. C. (2007). Moisture absorption and release of profiled polyester and cotton composite knitted fabrics. *Textile Research Journal, 77*(10), 764-769.

Swan, J. E., & Combs, L. J. (1976). Product performance and consumer satisfaction: a new concept. *Journal of Marketing, 40*(2), 25-33.

Tezel, S., & Kavusturan, Y. (2008). Experimental investigation of effects of spandex brand and tightness factor on dimensional and physical properties of cotton/spandex single jersey fabrics. *Textile Research Journal, 78*(11), 966-976.

The benefits of cotton. (n.d.). *Cotton Incorporated*. Retrieved from https://thefabricofourlives.com/learn-about-cotton/the-benefits-of-cotton

The Good Housekeeping Institute. (2016, December 6). 38 best workout leggings for the gym - and life. *Good Housekeeping*. Retrieved from https://www.goodhousekeeping.com/health-products/g4042/best-workout-leggings/?slide=1

Tiwari, S. K., Fei, P. T., & McLaren, J. D. (2013). A pilot study: Evaluating the influence of knitting patterns. *Procedia Engineering, 60*, 373-377.

Tondl, R. (2006). Sewing with knit fabric [PDF File]. *College of Agriculture Cooperative Extension Service*. Retreived from https://digitalcommons.unl.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2381&context=extensionhist .

Tortora, P. G., & Eubank, K. (2010). *Survey of historic costume* (5th ed.). New York, NY: Fairchild Publications.

Tortora, P. G., & Merkel, R. S. (2014). *Fairchild's Dictionairy of Textiles* (8th ed.). New York, NY: Fairchild Publications.

Trefis Team. (2016, October 6). The Athleisure trend is here to stay. *Forbes*. Retrieved from https://www.forbes.com/sites/greatspeculations/2016/10/06/the-athleisure-trend-is-here-to-stay/#2aec85d528bd

Trogolo, J. A. (2011). Odor Control Textiles: Is "Antimicrobial" Enough? *Annual International Conference & Exhibition of AATCC* (pp. 158-164). Charleston, SC: American Association for Textile Chemsits and Colorist.

Troynikov, O., & Watson, C. (2015). Knitting technology for seamless sportswear. In R. Shishoo (Ed.), *Textile for Sportswear* (pp. 95-117). Cambridge, UK: Woodhead Publishing.

Uttam, D. (2013). Active sportswear fabric. *International Journal of IT, Engineering and Applied Science Research, 2*(1), 34-40.

Wannop, J. W., Worobets, J. T., Madden, R., & Stefanyshyn, D. J. (2016). Influence of compression and stiffness apparel on vertical jump performance. *Journal of Strength and Conditioning Research, 30*(4), 1093-1101.

Waxman, O. B., & Chan, M. (2017, March 27). How leggings became the most important controversial pants. *Time*. Retrieved from http://time.com/4713921/leggings-history-origins/

Weinswig, D. (2018). *Athleisure Update and Market in Transition.* Coresight Research. Retrieved from https://www.fungglobalretailtech.com/wp-content/uploads/2018/08/Athleisure-Update-Market-in-Transition-Aug-13-2018.pdf

Winning in the U.S. activewear market. (2014). *Cotton Incorporated*. Retrieved from https://lifestylemonitor.cottoninc.com/winning-in-the-u-s-activewear-market/

VITA

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