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Thermal Comfort and Performance Evaluation of High-End Versus Popular Dupe Athleticwear Leggings

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Abstract

Activewear clothing consumption has significantly taken hold of the apparel industry, shifting the way consumers dress day to day. During the COVID-19 pandemic, work at home orders and pivoting business agendas prompted consumers to purchase comfortable garments that make them feel active and on-the-move. More time at home has resulted in consumers' researching and comparing products to find the best overall value of their purchases. This research evaluated the material and comfort performance of higher price versus lower price point leggings (knits). Based on consumer research, four pairs of leggings were selected by first determining the higher price point leggings and their consumer preferred dupes. The laboratory evaluations for each pair of leggings included fabric weight, thickness, pilling resistance, opacity, vertical wicking, and air permeability. A dynamic sweating thermal manikin was utilized to assess the physiological responses (primarily skin temperature and comfort sensation) of each pair of leggings, tested on a 35 zone ANDI thermal manikin in a controlled environmental chamber. Although the Brand A leggings were the most expensive, they could be considered the most valuable as they significantly outperformed all leggings in this study. Brand D dupe leggings may be considered a better value than brand C as they were half the price and had a similar material performance.

Keywords: Athleticwear; Comfort; Performance; Price; Thermal Manikin

Introduction

Athleisure and activewear have taken the lead in the textile and apparel industry, influencing the way consumers dress and feel about their clothing. Comfort and versatility play a huge role in the development of athleisure garments. Athleisure is defined as the fusion of performance clothing and leisurewear [1]. Companies are competing for the attention of consumers globally and the coronavirus pandemic has heightened this sector of the apparel industry. More people are working from their homes, exercising frequently, and shopping for comfortable clothing. According to research data, the global activewear market was estimated to reach $353.5 billion in 2020 and is projected to grow an additional 3.7% by 2026 [2].

Social media platforms such as Instagram and YouTube have impacted the buying behaviors of consumers who purchase athleisure or activewear. Due to the COVID-19 pandemic, consumers are discovering at-home-workouts on social media which in turn, influences people to purchase the activewear that is being promoted. Not only are influencers making at-home-workout videos, but they are reviewing and wearing various activewear brands. Part of this influence now involves the trend of duping which has become popular on YouTube and involves a customer comparing a higher-end garment to a budget garment. The term "duping" means to replicate or copy a higher priced product and sell for less. This has allowed influencers to give thoughtful opinions on different activewear brands and their products' value. Social media platforms have become a hub for customer reviews which allow consumers to thoroughly research athleticwear before making a purchasing decision.

Big players like Lululemon and Athleta are now being compared to smaller brands sold on Amazon. These smaller brands are competing by essentially "duping" the big players' designs. Social media platforms have given customers a voice to assess the

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aesthetics, durability, and comfort of these garments and provide potential customers with feedback in real-time. As more specialty stores, high-end designer brands, and fast fashion companies join the activewear industry, there is a need to continuously improve garment aesthetics to remain competitive [3]. In addition to aesthetics, economic value is important to consumers as they will invest in higher price tags if they receive quality products [3]. The activewear market's exponential growth provides resources and data which are readily available for companies to produce high-performing activewear at budget, moderate, and high-end price points.

Beyond aesthetics, however, it is important for companies to test the functional and technical performance of their fabrics [4]. Consumers want the fusion of fashion and function which includes comfort, breathability, wicking, and opacity. Thermoregulation and moisture management are essential to the comfortability of activewear. Functional sportswear brands tend to focus on quick moisture absorption and transport capacity, good air and water permeability, low water absorption, and rapid dry times [5]. Consumers also pay attention to the fit and stretch of a garment, especially in the activewear or athleisure sector of the apparel industry [6]. Stretch and fit can be a determinant of pressure comfort which is dependent on fabric elastic characteristics and elastic recovery properties [6]. The ability to stretch while remaining opaque is also extremely important to consumers and their subjective opinions about the value of their activewear is contingent on both material and athletic performance.

The pandemic has made athleisure/activewear a top apparel category for consumer purchasing. J.P. Morgan conducted a stimulus spending survey and found 24% of those surveyed chose active/athleisurewear as their top product to spend their stimulus checks on [7]. As more consumers are venturing into the activewear sector of the apparel industry, brands need to understand their consumers' needs and wants.

Review of Literature

Previous research has explored the performance of leggings based on consumer surveys and identified features that athletic consumers desire most. The surveys were used to design a laboratory evaluation of performance qualities and problems encountered when wearing activewear [8]. Groppo's research concluded that consumers cared most about the opacity (see-through) of their activewear while also wanting lighter and thinner fabrics [8]. Hahnel KM [1] explored performance claims in athleisure such as aesthetic properties and functional claims. A nonprobability sample of activewear was used to determine popular garments [1]. The garments selected were from different apparel categories such as t-shirts, leggings, and sweatpants therefore, the fiber contents were also different. The garments chosen were based on performance properties related to moisture management and hang-tag claims such as wicking, quick-dry, stay cool, and breathable [1].

Although previous research has explored athleisure garments' material and performance characteristics, these studies have not compared higher-end products to their lower-priced dupe counterparts, nor have previous studies attempted to quantify thermal comfort. Thermal comfort is important to most consumers of activewear and follows right behind fit as one of the biggest consumer desires. With the utilization of a sweating thermal manikin, thermal comfort can be used to evaluate human thermal sensations in various environments [9]. This type of data can determine how consumers feel and at what state they are comfortable in their activewear.

Therefore, based on limited previous research, the purpose of this study was to compare the performance of popular budget priced leggings to high-end activewear leggings to determine if dupes really are worth the consumer hype. A purposeful selection of four different activewear legging brands, two pairs of high-end versus low-end dupes, were chosen to compare budget versus high-end athleisure garments. The material and garment level evaluations were compared across the four pairs of leggings and analyzed for significant differences. This research will enable product developers, designers, and manufacturers to better understand both the consumer opinion and technical side of activewear legging performance.

Methodology

Sample

Four pairs of leggings were chosen by first determining two higher-end legging brand products and their respective corresponding dupes. Based on consumer research, the leggings with popular demand on social media platforms and high numbered reviews were categorized. YouTube and Amazon reviews were the main source of information. The objective was to discover top consumer preferences and complaints based on the leggings chosen and evaluate each high-end versus dupe comparison. Table 1 summarizes 56 consumer phrases taken from consumer reviews that were correlated to one or more performance properties (thickness, stretch recovery, opacity, hand, air permeability, etc.) for each pair of leggings. Consumers of the leggings used specific phrases or terms to describe their comparisons of the dupes. Negative consumer phrases included: "pilling on inseams", "seams unraveling", "waist rolls down", "looser than expected", and "thin material". Positive consumer phrases included: "very soft", "squat-proof", "stretchy", "very thick", "retained shape", "tummy control", "breathable", and "sweat wicking".

The leggings selected for laboratory evaluations in this study were fabricated from knit materials with various blends of nylon, polyester, elastane, and spandex. The first pair of leggings chosen, Brand A, are the highest end pair of leggings included in the study from one of the most popular women's athleisure brands in the world. A common dupe for Brand A is Brand B, a popular legging found on Amazon and shared by social media influencers. The

second set of comparable leggings are Brands C and D with Brand C being a popular moderately priced brand, also found on Amazon, and Brand D being a well-known dupe at an even lower price. The fiber content and price point of each pair of leggings is provided in Table 2 below.

Table 1: Summary of consumer legging review properties.

	Thickness	Stretch Recovery	Opacity	Wicking	Hand	Air Permeability	Pilling	Seam Appearance
Brand A	3	3	3	0	4	0	2	1
Brand B	4	1	1	1	2	0	2	1
Brand C	5	3	3	2	2	1	1	0
Brand D	3	3	0	0	3	2	0	0
TOTAL	15	10	7	3	11	3	5	2

Table 2: Fiber content and price information for each pair of leggings according to brand.

Legging	Fiber Content	Retail Price
Brand A	80% Nylon/20% Spandex	$98.00
Brand B	80% Nylon/20% Spandex	$22.99
Brand C	58% Nylon/32% Polyester/10% Elastane	$50.00
Brand D	54% Nylon/34%Polyester/12% Elastane	$23.99

All leggings included in this study were black and purchased in a size XL to allow for as much material sampling as possible. The fiber content of Brands A and B were the exact same. The fiber content of Brands C and D varied only slightly in their percentage by weight. Although the four pairs of leggings were grouped into two pairs (higher end versus dupe), they were equally evaluated and compared for all material testing.

Procedures

Laboratory evaluations of four brands of leggings were conducted in a textile testing laboratory using standard test methods from the American Society for Testing and Materials (ASTM) and the American Association of Textile Chemists and Colorists (AATCC). Based on positive and negative consumer review phrases, summarized in Table 1, and lab capabilities, the following evaluations were conducted: fabric weight, thickness, pilling resistance, opacity, vertical wicking, and air permeability. The standard test methods for these evaluations are provided in Table 3.

Table 3: Test methods used for laboratory evaluations.

Evaluation	Test Method
Fabric Weight	ASTM D3776/D3776M – 20: Standard Test Methods for Mass Per Unit Area (Weight) of Fabric
Fabric Thickness	ASTM D1777 – 96(2019): Standard Test Method for Thickness of Textile Materials
Air Permeability	ASTM D737 – 18: Standard Test Method for Air Permeability of Textile Fabrics
Pilling Resistance	ASTM D4970/D4970M – 16e3: Pilling Resistance and Other Related Surface Changes of Textile Fabrics: Martindale Tester
Vertical Wicking	AATCC Test Method 197-2018: Vertical Wicking of Textiles

In addition to material performance, a dynamic sweating thermal manikin was utilized to evaluate consumer comfort (average temperature sensation, average surface temperature, and average comfort) when exercising in each legging. Prior to testing, the leggings were conditioned according to ASTM D1776-16 (ASTM D1776-16 Standard Practice for Conditioning and Testing Textiles, 2020) [10]. The samples were placed in a controlled room at 21ºC ± 1ºC and relative humidity of 65% ± 2% for a minimum of four hours before each test.

Opacity test: In addition to the standard test methods listed in Table 3, a HunterLab LabScan XE Spectrophotometer with a 2" port and a 45-degree viewing angle was used to determine the opacity of each legging after stretch [8]. A single 5.5" circle was cut from each pair of leggings and a 5" circle was drawn on the back side. Each 5.5" circle was placed in a 5" embroidery hoop without any stretching and read as a standard sample on the spectrophotometer using EasyMatchQC software. From there, each circle was stretched so that the drawn 5" circle fit in the 5" embroidery hoop. The embroidery hoop was then placed over the HunterLab LabScan port and three readings were taken from different locations on each circle for each legging. Opacity was measured by considering the ΔE value of overall color change calculated from the L*a*b* values between the stretched and unstretched fabric samples of each legging. The ΔE value provides the overall change in whiteness and darkness for each sample.

Thermal manikin testing: An advanced dynamic sweating thermal manikin with a Manikin PC (physiological comfort) plugin was utilized to assess the physiological responses of each pair of

leggings. Samples were tested on a 35 zone ANDI thermal manikin in a controlled environmental chamber. The purpose of this test was to determine the physiological response (primarily skin temperature and comfort sensation) between the four leggings. Test protocols were determined that used physiological model control of the manikin in which the manikin responds to the test environment based on a human thermoregulation model. Two separate exercise protocols were created for each pair of high-end versus dupe leggings. For the Brand A and B leggings, Yoga Hatha exercise was replicated in a 22 ºC and 35% relative humidity environment at a MET rate of 2.5 for one hour. For the Brand C and D leggings, a resistance (weight) training exercise was replicated in a 20 °C and 50% relative humidity environment at a MET rate of 5.0 for one hour. These exercise protocols were determined based on the typical consumer end use of each product and the compendium of physical activities ("Compendium of Physical Activities") [11]. Each legging was tested once in a single condition. The test protocol is detailed in Table 4.

Table 4: Thermal Manikin testing protocol.

Steps	Test Protocol
1.	Dress manikin in sweating skin to evenly distribute sweat over the manikin surface.
2.	Run "Model Initialization" to set manikin to steady state conditions including thermal neutral temperature set point for all 35 zones.
3.	Dress manikin in leggings.
4.	Begin physiological model control at the metabolic work rate dependent on legging brand being tested (yoga versus weightlifting activity).
5.	Record physiological response of the manikin for a total test duration of 60 minutes.
6.	Manually end test.

Data analysis: The basic statistical software toolpak in Microsoft Excel was used to conduct the statistical analysis for this study. One-way, single factor ANOVAs were performed between all four leggings for fabric weight, thickness, air permeability, vertical wicking, and opacity. There were little to no differences between leggings for pilling resistance and repeated measures were not available based on the nature of the sweating thermal manikin testing conducted, therefore, no statistical analysis was conducted on those two performance characteristics. A p-value of 0.05 was chosen to indicate statistical significance. If significant differences were found between the four pairs of leggings based on the results of the one-way ANOVAs, then individual two-sample T-tests, assuming equal variance, were conducted between all pairs of leggings, with special attention paid to comparisons between the Brand A and B leggings and the Brand C and D leggings.

Results

Laboratory evaluations examined four brands of athletic leggings with two groups of similar or exact fiber blends. This research was conducted to assess comparisons of high end versus lower-priced dupe leggings to establish which pair had greater performance. Table 5 provides the average results for the laboratory evaluation of performance characteristics for each legging.

Physical textile testing

The first physical properties collected were fabric weight and thickness. Fabrics between 200 and 275 gsm are categorized as being medium weight while medium to heavy fabrics fall between 275 and 350 gsm [12]. The Brand A and B leggings in this study would be considered medium weight and the Brand C and D legging material were classified as heavyweight according to Bubonia's definition. Brand A had the lowest fabric weight of the four leggings (256 gsm), however, Brand B, the dupe for Brand A, weighed only 39 gsm more. Brand C was also lighter than its respective dupe, Brand D, but only by 35 gsm. Both higher priced leggings were lighter than their dupe comparisons. The same trend was true for fabric thickness as both higher-end legging brands (A and C) were thicker than their lower-priced dupe comparisons (B and D, respectively).

Table 5: Summary of laboratory evaluation results.

Textile Evaluations	Legging Brand	Average Results
Fabric Weight (gsm)	A	255
	B	296
	C	403
	D	412
Fabric Thickness (mm)	A	0.75
	B	0.67
	C	0.97
	D	0.89

Air Permeability (cfm)	A	38.48	
	B	21.58	
	C	15.25	
	D	15.8	
Opacity (ΔE)	A	0.18	
	B	3.28	
	C	5.25	
	D	4.79	
Pilling Resistance (rating)	A	4.8	
	B	5	
	C	5	
	D	5	
Vertical Wicking: Short Period	A	Machine Direction	1.2
		Cross-Machine	1.17
	B	Machine Direction	0.32
		Cross-Machine	0.24
	C	Machine Direction	0.64
		Cross-Machine	0.69
	D	Machine Direction	1.02
		Cross-Machine	0.84
Vertical Wicking: Long Period	A	Machine Direction	1.07
		Cross-Machine	1.1
	B	Machine Direction	0.67
		Cross-Machine	Did not wick
	C	Machine Direction	0.98
		Cross-Machine	0.97
	D	Machine Direction	1.03
		Cross-Machine	1.06

Air permeability is a measure of breathability through fabric and therefore provides information regarding the potential comfort of the material when worn on the human body. The Brand A leggings had significantly greater ($p < 0.05$) air permeability (38.5 cfm) than the Brand B leggings (21.6 cfm) and all other leggings in the study. The Brand C and D leggings both had similar average air permeability (cfm) readings between 15.2 and 15.8 cfm. Differences in air permeability between the two sets of leggings (Brands A and B versus Brands C and D) are reflective of their fiber content and fabric construction as evidenced by the fabric weight and thickness results in Table 5.

Another measure of comfort from the moisture management perspective is how quick a fabric wicks or moves sweat away from the body. Three specimens were taken in the lengthwise (machine) direction and three specimens were taken in the widthwise (cross-machine) direction of each pair of leggings and tested for vertical wicking. A wicking rate was calculated for both the short and long period ranges according to AATCC TM 197-2011e2(2018)e in which the wicking distance (mm) is divided by the time (seconds) it takes to reach that distance for both the short period (20mm) and long period (150mm). The higher the wicking rate, the greater the materials' ability to wick. All legging fabrics in this study wicked

to the 20mm line within the 5-minute period (short range). In the vertical, machine-direction for the short range, Brand A leggings had a significantly higher wicking rate than the Brand B and C leggings. Brand C leggings also wicked significantly faster than their lower priced dupe leggings, Brand D, but only in the machine-direction. In the cross-machine (widthwise) direction of the leggings, there were no significant differences between the Brand C and D leggings. For the long period test, the Brand A, C, and D leggings all wicked to the 150 mm line in under 30 minutes. The Brand B leggings did not reach the 150 mm line within 30 minutes and the test was ended per the standard. There were no significant differences between the Brand A, C, and D leggings for the long period wicking tests. The only significant differences between leggings were for Brand B which had the lowest wicking rate of all four leggings in both garment directions for both time periods.

A primary desire of activewear consumers is that their leggings are opaque, especially when the fabric is stretched during exercise or other body movements. There is no standard test method for measuring the opacity of fabric, however, a non-standardized method was adapted from Groppo, 2019 [8]. The ΔE value reflects the change between the stretched sample of each legging and the standard value that was read for each legging when it was unstretched. All leggings in this study had significantly different ($p < 0.05$) ΔE values from one another when stretched in the 5" embroidery hoop. Brand A was by far the opaquest, meaning they were the least transparent, as they had the lowest average ΔE value (0.18). The most see-through leggings were Brand C with an average ΔE value of 5.25 when stretched. In this case, the lower-priced Brand D dupe leggings outperformed the moderately-priced Brand C leggings. In addition, the dupe leggings from Brand B, the lowest priced leggings of all four in the study, were significantly opaquer than Brands C and D despite being thinner and lighter weight.

Pilling is another commonly cited issue by consumers of activewear in online reviews, as shown in Table 1. Pilling resistance was visually rated on a scale from 1 to 5 with 1 meaning "severe pilling" and 5 meaning "no pilling." Pilling was assessed on four specimens from each pair of leggings. All leggings exhibited "no pilling" after 5,000 cycles except for Brand A which exhibited minimal detections of pills only (4.8/5).

Physiological manikin testing

The results in Table 6 below reflect the average sensation, surface temperature, and subjective comfort of each pair of leggings in 12 primary manikin zones (upper thighs, lower thighs, & calves). These zones were selected because they were directly covered by the leggings. The average comfort was based on a subjective perception scale of -4 (very uncomfortable) to 4 (very comfortable) with "0" representing a neutral state (MTNW Internal Technical Manual) [9]. After the hour-long protocol, Brand A and B leggings were found to be at a near neutral state, whereas Brand C and D leggings created a slightly uncomfortable state. It is important to note, Brands A and B were tested in a separate, less strenuous protocol than legging Brands C and D.

Table 6: Summary of physiological manikin testing results.

Legging Brand	Average Sensation	Average Surface Temperature (°C)	Average Comfort
A	-1.25	32.2 °C	0.2
B	-1.2	32.4 °C	0.2
C	-2.3	31.0 °C	-1.3
D	-2.3	31.0 °C	-1.3

The sensation measure reflects how warm or cold the environment around the manikin feels relative to skin temperature and is based on a scale of -4 to 4, where 0 means the manikin feels no sensation of warmth or cold [9] (MTNW Internal Technical Manual). The average sensation values were negative indicating the manikin felt cooler when wearing all four legging brands. There were no differences in the temperature sensation results between Brands A and B or between Brands C and D. The average surface temperature reflects the mean skin temperature (Tsk) for al 35 zones for the duration of the hour-long protocol [9] (MTNW Internal Technical Manual). There were negligible differences in average surface temperature between leggings tested under the same protocol.

Discussion

Physical textile testing evaluations revealed that Brand A leggings had significantly higher air permeability and quicker wicking capabilities than the Brand B dupe leggings. Both data points indicate the Brand A leggings may be more comfortable, especially when worn during exercise as they wick sweat away faster and are more breathable. Brand A leggings also had the lowest fabric weight and were the opaquest. Based on the results of this study, the higher-end, higher-priced Brand A leggings may be of more value to consumers than the lower-priced dupes in terms of material performance. However, when tested on the garment level in a simulated exercise scenario using a sweating thermal manikin, there were little to no differences in perceived comfort sensations or manikin surface temperature when wearing either the Brand A or Brand B leggings.

When comparing the Brand C and D leggings, differences between the higher-end Brand C and dupe Brand D were not as pronounced as they were between Brands A and B. Brand C leggings had a lower fabric weight and greater thickness than

Brand B leggings, similar to the relationship between Brands A and B, however, there was no difference in air permeability between the Brand C and D leggings. There were slight significant differences in wicking rate between the two pairs of leggings, however, Brand C only significantly outperformed Brand D in the vertical machine direction during the short period test only. There were also no differences in thermal comfort sensations or average surface temperature between the Brand C and D leggings, indicating Brand D performed as well as Brand C under the same exercise protocol. While Brand C leggings were opaquer than the Brand D leggings, both were found to be significantly more see-through than Brand A and even the lowest priced legging in the study, Brand B.

Conclusion

The objective of this research was to compare the material performance and thermal comfort of high-end activewear leggings versus their popular lower-priced dupe counterparts. A random selection of activewear based on consumer review research consisted of four different garments, including two sets of high-end versus low-end dupes, to compare budget versus moderate and high-end leggings. Results were analyzed and comparisons between leggings determined which garments would be deemed of greater value based on top consumer desires for activewear (comfort, opacity, breathability, lightweight, pilling resistant, etc.).

In line with consumer reviews, the highest priced Brand A legging outperformed all other leggings in this study on all performance characteristics except pilling resistance, as it was the only pair found to exhibit even the slightest pilling. However, these differences in pilling were negligible. Brand A leggings, purchased at a retail price of $98.00, were found to be more comfortable in terms of air permeability, vertical wicking, and fabric weight, as well as the opaquest. Interestingly, while not directly compared, the dupe Brand B leggings, purchased for only $22.99, outperformed the higher-end Brand C leggings in many areas including fabric weight, air permeability, and opacity. However, the Brand B leggings had the lowest wicking rate of all leggings in the study. The moderately priced ($50.00) Brand C leggings were not as superior to their Brand D dupe ($23.99) as the Brand A leggings were to their Brand B dupe. In addition, the Brand B dupe leggings outperformed the Brand C and D leggings in many cases.

In terms of overall consumer value, Brand A leggings could be considered the most valuable even with their high-end purchase price as they significantly outperformed all leggings included in this study. As Brand C leggings were double the price of Brand D leggings, they would not be considered a better value based on their retail price and performance in this study. Brand D leggings may be considered the better value because they are less expensive and have very similar material performance compared to legging Brand C.

Limitations of this research include the limited sample size of leggings which prevented additional repeat measures in some cases as well as the need to evaluate additional performance characteristics such as stretch recovery, fabric hand, and seam appearance. Information was also limited regarding the proprietary nature of each leggings' production including internal performance specifications. The sweating thermal manikin testing in this study could also be expanded. Future research should consider performing additional testing on the full systems ensemble level for multiple material and athleticwear garment types. The useful life of activewear leggings at various price points should also be considered by performing laundering durability and wear studies to better define their value over time.

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None.

Conflict of Interest

Author declares no conflict of interest.

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