AN ABSTRACT FOR THE THESIS OF

Deborah A. Christel for the degree of Master of Science in Design and Human Environment presented on April 29, 2010.

Title: Perceived Comfort of Three Styles of Men's Running Pants

Abstract approved:

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Kathy K. Mullet

Athletic workout clothing is designed to help the wearer stay comfortable, cool, and dry. There are several different styles of athletic apparel available at retailers and each individual has a preference as to what is comfortable for him or her. Comfort of clothing has traditionally been related to the fabric feel and thermal comfort of the individual. However, comfort can be defined with numerous other variables; such as fit, the environment, and the style of the garment. Therefore, the purpose of this study is to understand how runners perceive the fit, skin sensation and thermal comfort of three style treatments of running pants. In each treatment, the textile, environment, and fit of the pant was controlled. The three pant treatments were Style A: fitted pant with 0% design ease; Style B: loose fit with +5% design ease; and Style C: compression fit with -20% design ease. The subjects were asked to rate their perceived comfort while wearing each treatment.

The objectives of the study were to determine human subjects' perceived fit

comfort, perceived skin sensation, and perceived thermal comfort of three pants with varying levels of ease. Both qualitative and quantitative data were collected. Questionnaires were filled out once before running and once after to collect the subject's perceived comfort in each of the three variables. In the statistical program Stata, an ANOVA, a Repeated Measured ANOVA was used to calculate the differences between each style, subject and time. Within each repeated measured ANOVA, an ANOVA contrast will be conducted if there is a significant difference found. This was done to determine the specific differences between styles. Each mean score for fit, skin sensation and thermal perception was calculated.

The results of the study indicated that there was a significant difference of fit scores between Style A and Style B and between Style B and C. The hypothesis of a significant difference between perceived thermal comforts between all styles was rejected, although the overall model is approaching significant. The principal conclusion was that there is a preference in running pant style among subjects. Across all subjects, Style C was overall rated the highest for fit comfort. Style C was perceived to be the coolest after exercise.

This study will assist in understanding how garment style contributes to the perceived comfort. The importance of knowing how people perceive a garment has a large impact on its overall comfort and selling ability. Finding a correlation between pant style and perceived comfort will be a great benefit to apparel designers who wish to design more comfort pant styles and will help support functional clothing design.

Perceived Comfort of Three Styles of Men's Running Pants

by

Deborah A. Christel

A THESIS

Submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented April 29, 2010
Commencement June 2010

Master of Science thesis of Deborah A. Christel

presented on April 29, 2010

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Deborah A. Christel

ACKNOWLEDGEMENTS

There are several people who deserve recognition for their participation in my thesis. I am heartily thankful to my major professor, Dr. Kathy Mullet, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject. I would also like to express my appreciation to my other committee members, Dr. Hsiou-Lien Chen, Dr. Brigitte Cluver and Larry Roper, who assisted me in collecting data, gave wonderful feedback and offered their time and support.

A special thanks goes to Becky Hurd for her support. I would also like to recognize Erika Green for facilitating the location to conduct the research. Without her cooperation and assistance, I would not have been able to make this project happen. I want to thank Kendra Lewis for assistance in data analysis.

I would like to thank my family and friends for their never ending encouragement. Lastly, I offer my respect and blessings to all of those who supported me in any element during the completion of the project.

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Perceived Comfort of Three Styles of Men’s Running Pants

CHAPTER I

INTRODUCTION

Athletic workout clothing is designed to help the wearer stay comfortable, cool, and dry. There are several different styles of athletic apparel available at retailers and each individual has a preference as to what is comfortable for him or her. Fitness experts say that walking and running are the most popular form of exercise in the world. Over 70 million people participate in walking or running every day (Bernall, 2008). Running has zero cost and is great for heart and overall body health. It can be an individual or group sport. Running is involved in many sports; such as track, soccer, football, basketball along with many others. Running can be enjoyed at several levels of difficulty. These levels of running range from a leisurely jog, to training for a marathon or triathlon. At the highest level of competition, athletes put their bodies through extreme training and practice. Running can be an extreme test of a person's physical and mental limits and comes with the potential for serious injury. Therefore, it is critical to have proper equipment and attire while running. As a fitness trainer of four years, and finisher of 2 half- marathons, I personally relate and see the difficulty of training that the body endures. Wearing the improper clothing can spoil a run several ways. Wrong fiber type, incorrect fit, wearing items that ride up, articles fall down, chafing, rubbing, and blisters or just not feeling comfortable can all contribute to a poor performance.

Comfort of clothing has traditionally been related to the fabric feel and thermal comfort of the individual. However, comfort can be defined with numerous other variables; such as fit, the environment, and the style of the garment. Therefore, the purpose of this study is to understand how runners perceive the fit comfort, skin sensation comfort and thermal comfort of three styles of running pants. In each treatment, the textile, environment and fit of the pant were controlled. The subjects were asked to rate their perceived comfort while wearing each style.

The study will assist in understanding how garment style contributes to the overall perceived comfort. The importance of knowing how people perceive a garment has a large impact on its overall comfort and selling ability. Due to the popularity of compression garments in sports and the oversized fashion style of 2010, this study was conducted to determine if the consumer athlete perceives a difference in comfort for three different styles of pants. Finding a correlation between pant style and perceived comfort was a great benefit to apparel designers who wish to design more comfortable pant styles and will help promote functional clothing design.

Statement of Purpose

The majority of studies on clothing comfort have usually dealt with the fit of the garment or the influence of different textile properties. Few studies have evaluated the design ease and style of garments as it relates to comfort. The purpose of this study is to determine if the style or design ease of a man's running pant influences the subject's

perceived comfort of the garment. For each style treatment, the fabric, fitting ease, environment, and construction will remain the same, only the design ease was changed.

Objectives

The following research objectives were used to guide the study. For each objective, hypotheses have been written to test the differences between each pant style.

1. To determine human subjects' perceived fit comfort of three pants with varying levels of ease.

    H1: There was a difference between the perceived fit comfort of Pant Style A and Pant Style B.

    H2: There was a difference between the perceived fit comfort of Pant Style A and Pant Style C.

    H3: There was a difference between the perceived fit comfort of Pant Style B and Pant Style C.

2. To determine human subjects' perceived skin sensation of three pants with varying levels of ease.

    H4: There was a difference between perceived skin sensation of Pant Style A and Pant Style B.

    H5: There was a difference between the perceived skin sensation of Pant

Style A and Pant Style C.

H6: There was a difference between the perceived skin sensation of Pant Style B and Pant Style C.

3. To determine human subjects' perceived thermal comfort of three pants with varying levels of ease.

H7: There was a difference between perceived thermal comfort of Pant Style A and Pant Style B.

H8: There was a difference between the perceived thermal comfort of Pant Style A and Pant Style C.

H9: There was a difference between the perceived thermal comfort of Pant Style B and Pant Style C.

Assumptions of the Study

1. The subjective evaluation of perceived comfort is due to the pant's design ease, since the fabric, construction and environment of the pant treatments was controlled

2. Each human subject is fit and capable of following through the required exercise.

3. Fit of the garments was the same among all subjects and the thermal manikin.

4. All subjects are capable of describing comfort and fit of apparel.

Definition of Terms

Clo Value: One Clo represents the clothing necessary to allow a resting individual to be in a comfortable state when the ambient temperature is 21°C (70°F). Thermal manikin results are reported as the dry thermal resistance value. Clo value was determined from the thermal resistance value with the following formula:

Dry Thermal Resistance, Rct

Calculated in SI units for each zone by the formula:

$$Rct = \frac{(Tskin - Tamb)}{Q/A}$$

Rct = Thermal resistance (m2·°C)/W

T-skin = Zone average temperature (°C)

T-amb = Ambient temperature (°C)

Q/A = Area weighted Heat Flux (W/m2)

The conversion to Clo units is as follows:

$$R\text{-}Clo = (Rct \cdot 6.45)$$

Compression Garment: a knit garment that is reduced by 10%-20% of a regular size the person would wear and compresses the muscles on the body.

Design Ease: the fullness added to a garment to provide a desired look or shape to the garment (Mullet & Chen, 2005).

Fit: How well the garment conforms to the three-dimensional body. The five elements of fit include Grain, Set, Line, Balance and Ease (Brown, 2001).

Fitting Ease: “also called movement ease, comfort ease, or garment ease that is required for a livable fit” (Brown, 2001).

Garment Style: The garment shape based on the desired fit and design ease.

Moisture Wicking Material: a knit fabric that pulls sweat and moisture away from the skin and transfers it through to the surface, therefore keeping the wearer dry and cooler.

Perceived Comfort: an individual’s sense of the perceived fit, a combination of perceived thermal sensation and design ease.

Perceived fit: how an individual notices the overall appearance and ease of an apparel item.

Perceived thermal comfort: how an individual notices the hotness or coldness of an apparel item.

Perceived thermal sensation: how an individual describes body sensations of hot and coldness.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this study is to determine the perceived comfort of different styles of running pants. One style of pant was a compression garment, which studies have shown to enhance the performance of athletes. The other two styles are based on modern running pant styles. Therefore, the review of literature will concentrate on studies that have evaluated compression garments, the various definitions of comfort and other factors contributing to comfort during physical exercise such as injury prevention, environment and textile. Literature that relates to the correlation between a thermal manikin's results and human subjects will also be reviewed, since a thermal manikin was used to determine the Clo value of the pants.

Compression garments

Compression shorts have recently gained popularity in the athletic arena. These can be worn as undergarments or outer garments. They are tight, form-fitting and when worn cover the athlete's waist to the mid, lower thigh, calf or entire leg. These garments are usually made from a thick spandex-type material, similar to cycling shorts. The main benefits advertised of compression shorts are that they keep the muscles warm to prevent muscle strain, reduce chafing and rashes; assist in wicking sweat away from the body. In addition, there is some evidence that compression shorts may enhance athletic performance. They may also be used as a way to keep the male genitalia in place in the

same way briefs or a jock strap do. According to an article by Daniel Akst titled, “Where have all the jockstraps gone”, jockstraps have fallen out of favor with young athletes, and garments such as compression shorts have seen an increase in popularity, because of their comparable function and less embarrassing looks (Akst, 2005).

Support tights and other tight-fitting apparel have been available for decades, intended for those suffering circulatory conditions such as varicose veins, deep vein thrombosis or problems associated with diabetes. However, using those types of clothes for running is relatively new. Due to recent research on the benefits of compression apparel, wearing them for exercise has increased dramatically.

Originally compression garments were used to increase circulation among those with deep vein thrombosis or diabetes related issues. Deep vein thrombosis occurs when a blood clot develops in the deep veins of the leg extremities. This is treated with medication and compression stockings (Goldhaber, 2004). After medication or surgical treatment of the blood clot, the compression stockings are continually worn to prevent post-thrombotic syndrome. Post-thrombotic syndrome is the long-term effects that can occur after deep vein thrombosis. These long-term effects include pain, swelling, heaviness or development of ulcers. The American Heart Association has had a 90% success treatment rate by using the combination of medication and compression stockings in treatment of deep vein thrombosis (Goldhaber, 2004).

A study by Flam (1996) provides us with more evidence of increased circulation in the deep veins due to compression garments. They randomly assigned 26 young healthy adult subjects without any history of deep vein thrombosis, high blood

pressure/hypertension, diabetes, stroke or vascular pathologies, to either a compression above the knee high or below the knee high. Each treatment had different sequences of compression. The main objective was to observe a difference in the above knee or below knee compression levels of blood flow. The study concluded that they were both effective in increasing the levels of blood flow with the below the knee compression being more effective.

With the knowledge of compression garments increasing blood flow, it created curiosity among sport researchers to study the other effects of compression garments. They wanted to test if the increased blood flow might warm up the body quicker.

In a study by Smin, Don, Newton and Kwon (2001), they researched the effects of lower body compression pants on warm up time and jump performance. The purpose of this investigation was to determine how these custom-fit compression shorts affect athletic performance. They used a total of 20 subjects, which were college varsity track athletes. Each compressive garment was custom fitted based on the girth and inseam measurements of each participant's waist, hip, thigh and knee. The purpose of custom fitting the garment was to achieve the exact fitting ease on each subject. "The garment was a 15-20% smaller representation of the subjects lower body, while the material would expand to nearly 100% of the original measurements and compress the tissues underneath" (Smin, 2001). Testing used either the compression or the control shorts that were a loose fitting gym short. Each subject performed a warm up protocol prior to the testing session, once in the compression and once wearing the control garment. Subjects were asked to jump, squat and cycle on a bike for warm-up. The performance

test means were calculated and compared within subjects for both conditions. For the warm up, this study concludes that when wearing the compression shorts, your skin warms up quicker, therefore reducing warm up time and increasing muscle warmth that leads to reduction for potential injuries. Vertical jump height significantly increased with the use of the compression garment in this study. The elastic energy reserved from downward movement may have increased the force of jump that resulted in a higher jump. This study also found that subjects could significantly squat deeper in the compression shorts than the control shorts. Overall, this study demonstrates that compression shorts provide a quicker warm-up time, a higher vertical jump and the ability to squat deeper than average. To further support the increased jumping power, a studying using volleyball players was conducted. Volleyball is a sport that consistently requires jumping and squatting.

A study by Kreamer et al. (1998) tested the influence of compression garments on vertical performance in NCAA Division I volleyball players. They used 18 men and 18 women who were all familiar with the vertical jump tests and techniques. Each participant had three separate shorts, compression shorts of normal fit, undersized compression shorts, and loose fitting gym shorts as the control garment. They used a force plate that was connected to a computer that collected mean jump force and power production. Each participant performed 10 maximal countermovement jumps with hands held at waist level. This study revealed that the volleyball players were better able to maintain a consistent output during repeated jumping when wearing normally fitted compression shorts. The undersized compression shorts show a slight increase in

jumping power but not as much as the regular compression shorts. The undersized compression shorts were also reported to be uncomfortable and too tight.

Another benefit of compression garments is that of increased blood flow to deep tissue veins that leads to reduction in lactic acid build up. Lactic acid is the by-product of anaerobic glycolysis thought to cause localized muscle fatigue and soreness associated with very high intensity exercise (Bryant, 2007). A study by Berry M.J, McMurray R.G. (1987) conducted objective research to determine the effects of wearing graduated compression stockings on the exercise response. They used twelve highly fit males in a series of two experiments. The first experiment consisted of six subjects performing two tests of maximal oxygen consumption (VO2 max) on a treadmill once with and once without the graduated compression stocking. The second experiment consisted of six subjects performing three separate, three-minute tests on a bicycle ergo-meter at 110% of their VO2 max. The experimental conditions for the three tests were as follows: graduated compression stockings worn during the test and during recovery, graduated compression stockings worn only during the test and no stockings worn during either the test or recovery. Oxygen consumption (VO2) was measured at rest, throughout all tests and during recovery in both experiments. Blood samples were obtained at rest, at 5, 15, 30, 45 and 60 minutes post exercise in the first experiment, and at rest and at 5, 15 and 30 minutes post exercise in the second experiment, to determine the level of lactate. The use of graduated compression stockings, in the first experiment, resulted in lower lactate values throughout the duration of the recovery period with the 15-minute values being significantly different

with the use of graduated compression stockings. Significant differences in post exercise blood lactate values were found in the second experiment. The graduated compression stockings trial resulted in significantly less lactate when compared to the graduated compression stockings -O/O and the NO-graduated compression stockings trials. In conclusion of these studies, the graduated compression stocking reduced the levels of lactic acid found in the blood levels taken after the exercise. Further subjective studies on compression support this finding of reduced soreness.

Another article concerning compression garments focused on the subjective recovery from eccentric exercise when wearing compression garments. This article by Trenell, Rooney, Sue and Thompson (2006) focuses on post exercise soreness and how compression on the legs after the exercise affects that. Participants walked on a treadmill at a downward slope for 30 minutes. After the exercise the subjects put on the compression pants. The pants designed had one leg compressed and the other was not. Participants were asked to rate their level of soreness by comparing each leg. A scale was used to have participants report soreness on a scale of 1 (no pain at all) to 10 (very, very sore). The data collected from the study suggests that wearing compression garments during the recovery of eccentric exercise may alter the inflammatory response to damage and accelerate the repair process inside the muscle. Another benefit of compression apparel is that of quicker recovery from muscle soreness.

Compression tights are advertised as adding support to the musculature of the lower extremities. Postural steadiness is thought to be another benefit of the musculature support of the legs. Heise, Mack and Shinohara (2007) conducted a study

designed to examine the effects of compression pants on postural steadiness. They selected a group of 11, young, healthy women who visited the lab on three separate occasions. Each visit corresponded with one of three separate clothing treatments. These treatments included 1 pair of running shorts, brand 1 compression pants and brand 2 compression pants. Balance and postural steadiness were measured before and after tiring exercises. This study used vertical jumping, an anaerobic power test, knee extensor muscle testing, and a 30-minute treadmill run as the tiring exercises. Following each exercise and treatment, there was no difference in the level of balance or postural steadiness found when the subjects were wearing shorts or compression pants. Although there are multiple reported benefits of compression garments, in this study however they found that compression garments do not increase balance or postural steadiness.

Another study concerning everyday wear and use of compression stockings examines standing fatigue in women. Kramer et al. (2000) studied overall leg health in women who stand more than 8 hours a day and if a graduated compression stocking would assist in elevating pain and discomfort. Circumference of thighs, calves and ankles were taken prior to the study and after the study. Each subject participated four times, once in no stockings (as the control) and three more times in three separate commercially available compression stockings. The findings of this study indicate the commercially available stockings were all effective in reducing the swelling and pooling of blood in the ankles and legs of the young healthy women. Along with the objective measurements of the thigh, calf and ankle area, reported by all subjects was a reduction in lower leg discomfort. Subjects were asked to rate their perceived

discomfort on a Likert scale from 0(none)-120(very noticeable). Perceived discomfort was also measured after each day, at 7pm and 10pm. As well as measured the following morning at 7a.m. and 10a.m. Discomfort was reported lower with all three of the compression stockings compared to the control group.

With the abundant objective benefits of compression apparel, designers are left without the subjective knowledge of comfort for the wearer. It is valuable to any designer to completely understand the sport and the apparel that is worn and what is comfortable to the athlete. To better understand how people describe and interpret comfort, further readings on subjective comfort were reported.

Comfort

What is comfort? There are endless definitions of comfort. The individual ultimately decides perceived fit and comfort (Ashdown and Delong, 1995). There are several different views on how comfort can be defined. LaMotte (1977) stated that physical comfort might be greatly influenced by tactile and thermal sensations arising from contact between skin and the immediate environment. Slater (1986) defined comfort as “pleasant state of physiological and physical harmony between a human being and the environment”. Webster’s dictionary defines comfort as “a state of physical ease and freedom from pain or constraint” (Webster, 2009). Bartels (2005) explains the four main aspects in comfort of sportswear being thermo-physiological wear comfort, skin sensorial wear comfort, ergonomic wear comfort and psychological wear comfort. Comfort can be expressed as relation to clothing fit, the relationship of

the environment, the textile and personal preference. Slater (1986) states, the factors that contribute to comfort are physiological, physical and the environment. Fit is very important to athletes because improper equipment and apparel can lead to serious skin injuries. Research that demonstrates why comfort and proper fit is important among athletic apparel is reviewed. Along with, how comfort is related to clothing fit, environment and textile.

Tactile Comfort

Injury prevention in sports is largely related to the equipment used. Equipment can range from protective padding, shoes, clothing and helmets. There is substantial research on sports injuries and prevention. The most common injuries among athletes are relative to the skin. These injuries range from bruising, chafing, rashes, calluses, urticaria (hives), blisters, joggers nipple and nail dystrophies. Almost all athletes interact with textiles and the environment to some degree. Those who perform in the winter are susceptible to frost bite and those in the summer to heat exhaustion and sunburns.

Urticaria or hives is most common among runners (Adams, 2002 pp.315). This can occur in cold and hot environments and is developed by rubbing of the skin or repeated rubbing of ill-fitting apparel.

Calluses and blisters most commonly occur from long term repeated friction. Wearing synthetic socks and, well fitted athletic wear decreases friction and help to

prevent calluses. In the case of joggers nipples it is shown that wearing semi-synthetic or other soft fiber bras and shirts also help prevent jogger's nipple (Swedan, 2001).

Sunburns can occur from pro-longed sun exposure without proper protection. Pro-longed sun exposure can lead to melanoma or skin cancer. This article (Adams 2002) examines two ways to protect against the suns harmful rays. One option is to use a water-proof sunscreen. Another option is to wear apparel that has sun protective product in the fabric. There are clothing manufactured with UV rays repellent in them. This is a much better option for those who spend hours in the sun. Instead of re-applying sunscreen they can wear the UV protecting apparel. For those who enjoy winter sports also need protection from the UV rays as well the cold temperatures.

The major re-occurring theme among skin injuries in athletes is to resolve the issue by adjusting apparel. Recommendations from this article (Adams, 2002) are for athletes to be aware of the type of fibers and how they hold moisture, to know the symptoms of skin problems and to use well-fitted athletic wear to decrease friction.

Further research discovers that sports burns, abrasions, chafing and chin-strap acne can be reduced by wearing proper equipment and apparel as well. In an article by Rodney Blaset (2004), in "Sports Medicine Journal", states that by preventing sports injuries it can greatly enhance a participant's ability to compete successfully over a short and long period of time. The skin is the body's largest organ and also the one that experiences the most disruption due to repeated friction or pressure in sports. Blaset examines several sports related injuries, how to prevent and treat them. Abrasion to the skin occurs when the skin cells are abruptly removed from the skin surface. This can

exposes the layers of skin closer to the blood resulting in either bleeding or what is clinically referred to as a “raspberry”. This can occur, for example, when an athlete slides an exposed area of skin across artificial turf. “Because artificial turf has a lower coefficient of friction than natural grass, especially when wet, the athlete slides a greater distance, thus generating heat and producing and injury that is part abrasion and part burn” (Baslet, 2004). If the skin were not exposed, the article of clothing would have taken the brunt of the slide, therefore protecting the skin of the athlete and preventing them from experiencing pain or discomfort. Another sports injury that appears from more long-term friction is chafing. Mechanical rubbing of the skin by another body part or clothing causes this. The neck, under arms, chest and upper inner thigh are most frequently affected. The upper inner thigh is the most troublesome and occurs in tennis and cyclist because they develop disproportionately large thigh muscles. Baslet (2004) recommends athletes with larger thighs to wear apparel that “is made of elasticized fabric or made of low resistance polyester fabric”. In doing this, it will separate the skin and create a protective barrier with fabric, using a smoother polyester will create less friction between the upper thighs. One other form of skin injury very common in athletes is acne. Acne related to equipment and apparel is more prominent on the back. This is due to chronic friction and pressure. This is commonly found under protective padding or less bulky equipment. Other factors that contribute to the acne are weather and duration of exercise. Wearing absorbent cotton t-shirt under uniforms can greatly help reduce heat, friction and pressure. However, many athletes are unwilling to compromise style for proper protection.

Perceived Fit

Developing proper apparel for athletes that is comfortable and protective can be challenging. Reviewing how other researchers have examined fit and comfort is critical to developing a questionnaire for this study. The human brain is complex and each person has his or her own views of comfort.

It is obvious that humans are perceptive to fit and can distinguish when a specific area has been manipulated or something is not comfortable. Ashdown and Delong (1995) suggest that the fit of a garment is based on both visual and tactile information. Their study focused on perceptions of fit judged by the tactile reactions of the wearer. This study established the smallest difference in garment dimensions that can be consistently perceived and identified by humans. They used a set of 15 pants, which varied in size and was made for each individual by computer-generated patterns. There were four women who comprised the subject panel and they each recorded their responses to these pants compared to a control. The control pants were custom fit for each subject and the 15 test pants each varied from the control by 0.5cm to 1.5cm at a single location (waist, hips or crotch length). The results indicated that participants were able to perceive changes in waist size, crotch length and in the hips. The majority of participants were able to perceive increments of +1.0 cm and +0.5 cm at the hip and crotch. They were also asked questions about fit preferences. It varied greatly among each subject but the one common preference for fit was in the hip area. This study establishes that humans are capable of perceiving ease tolerances and fit in their apparel. It also reveals that each person has individual preferences for fit and comfort.

Another study by Hollies, Custer, Moring and Howard (1979) examined human perceptions analysis approach to clothing comfort. Their methods include asking participants to describe body sensations that occurred when mild or heavy sweating occurred, and during modest excursions of warming or chilling following the inception of sweating. The list of terms developed include: snug, loose, heavy, light weight, stiff, staticy, sticky, non-absorbent, cold, clammy, damp, clingy, picky, rough and scratchy. A scale rating these sensations ranged from 4-partially to 1-totally. There were 9 separate rating periods that varied across 0 minutes to 74 minutes in a controlled temperature chamber. Subjects were asked to exercise for 10 minutes in antechamber as the temperature increased from 30°C (86°F) to 33°C (92°F). Subjects evaluated their levels of comfort in three separate jean types. Two consisting of 100% cotton and one pair a blend of cotton and polyester (65/35). Subjects consisted of 53 men and 25 women, an average comfort rating made it possible to rank the garments for each comfort descriptor used. After 25 subjects had been used, there were distinguishable differences between the two garments. This study provides consistent information on the comfort perceptions of humans across 3 jeans. Over 90% of the subjects agreed with one another on the comfort level and comfort descriptors. The cotton jeans were both rated higher than the blend. All three pairs of jeans were clearly distinguishable between each subject and evaluated on comfort. Again, this article demonstrates that humans are capable of distinguishing fit and explaining what feels comfortable.

Wong (2003) states, “There has been no clear definition of comfort”. In order to help clearly understand what descriptive factors lead to comfort, the following study

was completed. They conducted a series of wear trials in which the following ten sensory perceptions (clammy, clingy, damp, sticky, heavy, prickly, scratchy, fit, breathable and thermal) and overall clothing comfort were evaluated by twenty-two professional athletes in a controlled laboratory. They were asked to wear four different garments in each trial and rate the sensations during a 90-minute exercise period. The four garments were sold on at retail as sportswear and were described as long-sleeved, high collar jerseys. Subjects were asked to evaluate the ten sensory perceptions on an eleven-point scale at four different time periods during the exercise. The sensation rating was then converted to a 100 point scale while the sensations of garment fit and thermal sensations were rescaled to the range between -50 to +50. The reason the scale range of fit and thermal is different from other sensory perceptions is that the wording used in the scales two ends to describe the perception of fit (from too loose to too tight) and thermal (from too hot to too cold) were different from the other sensory perceptions such as damp. Both garments and sequences of subjects wearing them were randomized to eliminate systematic errors. Each sensation is generated from different signals at the skin surface. Formulating, weighting combining and evaluating against past experiences, the brain makes a conclusion on overall comfort status. This study has concluded that these ten sensory perceptions (clammy, clingy, damp, sticky, heavy, prickly, scratchy, fit, breathable and thermal) all can help predict the comfort of a garment through the neural network. This neural network is an effective technique for modeling the psychological perceptions of clothing sensory comfort.

Comfort is a very broad term and difficult to explain but easy to personally distinguish. Slaters (1985) definition of comfort also refers to the physical comfort of the wearer and the environment they are in. Textiles interaction with the body plays a key role in how the wearer feels (warm or cold) in a certain environment. Therefore, literature discussing how textiles and certain climates affect the comfort of the wearer is reviewed.

The current trend in athletic apparel uses a combination of specific fiber blends and fabric knits. Current research on the topic of sports material in athletics is focused on the fiber content, structural knits, breathability, wickability, amount of clothing worn (body surface area covered) and special finishes. Each of these factors contributes to keeping the athlete comfortable.

Picking the appropriate fiber content for a sports related activity is critical to the comfort of the wearer. Fabrics for athletic and recreational uses should have the ability to transport moisture to the fabric surface for evaporation (Cotton Inc., 2002). In research conducted by Cotton Inc., they compare 100% cotton and Nike Dri-Fit®. The benefits and disadvantages of both fibers and knits were discussed. Cotton is perceived as too heavy when wet, sags when wet due to the extra weight, takes too long to dry, sticks to the skin that restricts movement and after an activity the wearer often feels cold (Cotton Inc., 2002). When referring to water evaporation and fabric absorption, the most important factor in determining how much water (or perspiration) can be absorbed by a fabric is its fabric thickness. The drying time depends on how much water is absorbed by the fabric. A largely reported benefit of cotton is of its comfort and

combination of properties that create the comfort. People report cotton as being soft, good fitting and good moisture transfer. The cotton fabric naturally wicks moisture away from the body but in contrast will absorb more liquid. To increase comfort of recreational apparel the fabric must allow vapor and liquid to pass to the surface of the fabric for evaporation. Moisture vapor transmission is the speed or rate at which moisture vapor moves through fabric. Too much absorbency can have a negative effect in recreational fitness apparel and lead to poor moisture vapor transmission. The fabric becomes too heavy, takes too long to dry and after an activity, the wearer often feels cold. This is where the application of synthetic fibers comes into play. Synthetics absorb less liquid due to the thin construction and natural water resistance and have a much less drying time. The synthetic Nike Dri-Fit® reported the lowest fabric weight, fabric thickness, absorbent capacity and lowest drying time, thus making it an ideal fabric for active wear.

Aside from choosing the appropriate fiber content, a designer must take into account the fabric structure that is chosen. Gavin (2003) studied individual fiber, fabric structure and the amount of airflow effects on mean skin temperature in different climates. For an athlete in a warm climate it is desired to stay cool as for an athlete in a cold environment it is desired to stay warm. His purpose was to understand the effects of clothing on thermal balance. Gavin states that the following six factors must be considered when evaluating clothing; 1:“Wind speed: increased speed disturbs the zone of insulation. 2: Body movements: pumping action of arms and legs disturb the zone of insulation. 3: Chimney effect: loosely hanging clothing ventilates the trapped air layers

from the body. 4. Bellows effect: vigorous body movements increase ventilation of air layers for conserving body heat. 5: Water Vapor transfer: clothing resists the passage of water vapor and this decreases body heat loss by evaporative cooling. 6: Permeation efficiency factor: how well clothing absorbs liquid sweat by capillary action (wicking)" (Gavin, 2003 pp.942). Gavin is explaining a few different ways of heat loss and how they affect the body temperature. In technical terms convention, conduction and evaporation are the three major ways for an athlete to lose heat (Parsons, 2004).

Convection heat loss occurs when warm air next to the body and trapped air between the clothing and the skin is replaced by cooler air from the environment. Wind is the biggest factor contributing to convective heat loss. The event of wind is referred to as "forced" convection. Whereas "passive" convection occurs via the "chimney effect" briefly discussed above by Gavin (2003). The chimney effect draws cool, dense air into the clothing from any opening. For example; pants cuffs, open sleeves, waist hems and then replacing the warm air that exits out of our neck hems and other vents with the cooler air.

Conduction heat loss takes place when a warmer object comes in contact with a cooler object and the warmer objects heat is transferred. For example, cool air streams against the warm skin. The airflow is cooler than the skin and the heat from the skin is transferred to the surrounding air. This is another example of how wind and body movement contribute to heat loss.

Evaporation heat loss occurs when the body sweat changes phase to a vapor (sweat vapor). This phase change requires heat. Unfortunately, the body's heat drives

this phase change. “Evaporative heat loss may be most noticeable in context of the “flash-off” effect, which occurs after a period of intense physical activity and sweating in cold conditions, followed by rapid evaporation and chill after stopping to rest” (Sanders, 2005). Evaporative heat loss from sweat can occur in two different ways. Sensible or also called “active” perspiration is caused by the configuration of liquid sweat droplets on the skin surface in response to excess heat. This excess heat is usually a result of being dressed too warmly for the given activity. The second type of evaporative heat loss is insensible or also called “passive” perspiration. This is the direct emission of sweat vapor from the skin surface in response to a humidity gradient. For example the skin is drying out. Insensible perspiration is most prevalent while at rest, or while sleeping, while sensible perspiration is most significant during periods of activity (Sanders, 2005).

Gavin explores the impact of airflow in different environments and concludes that more airflow would increase convective heat dissipation and promote evaporation by reducing water vapor surrounding the individual. The first study in a hot environment, evaluated the effect of clothing fabric on exercise during 30° C, 35% relative humidity and simulated wind of 11-km/h. There were three separate outfits. One outfit was semi-nude, the second was a synthetic material and third a cotton outfit. The trail consisted of a 30-minute treadmill run. The synthetic material outfit was found to have higher sweat efficiency and clothing regain reduced. Subjects were asked to evaluate their thermal and sweating sensation rates at 5 intervals through the warm-up, run and cool down. Temperature sensations in the synthetics were reported the coolest

except for stage four of the experiment. Sweating sensation was also reported the lowest in the synthetic throughout the entire exercise. When he compared the weave structure for physical exercise he compared underwear from 1 x 1rib knit, fleece, fishnet, interlock and double-layer rib. Recording mean skin temperature, he found that the more open a weave structure; the more airflow to the skin will result in a cooler mean skin temperature. Therefore, the fishnet construction allowed the most air to sweep over the skin and kept the athlete the coolest. Keeping moisture off the skin assists the athlete is staying cool and is ideal for physical exercise. Wearing a fabric that is not breathable during physical exercise will increase heart rate and rectal temperatures much faster than fabrics that are breathable (Umbach, 2001, 2002). When fabrics are more breathable, the skin has more access to air therefore staying cooler and the athlete was able to withstand longer periods of activity. Therefore, having a breathable fabric is critical.

Wickabililty is the fabric's ability to move liquid or sweat from the skin and penetrate through the fabric by capillary action (Slater, 1985 pp.189). Capillary action is the force of a liquid being pulled up and through a tube. Synthetic fibers with a fiber crimp, the way in which the individual fibers zig zag along their length, influence the ability to move moisture. With the crimp in the fiber, it creates a tube or tunnel for the moisture to flow to the surface of the fabric, through capillary action.

For example, Slater (1985) describes the difference between cotton and polyester responses to sweat. Suppose it is a hot day and a shirt or blouse is being worn. Areas of high perspiration (under the arms, for instance) in a cotton fabric will absorb

moisture and transport or spread it to other areas where it can evaporate from the cloth surface. A crimped polyester garment in the same location would soon become saturated, because the water produced isn't absorbed and because of the specific crimp in the fibers the moisture would be pulled away from the skin and evaporate at a faster rate.

Zou and McCullough (2004) researched the heat transfer of individual sports apparel. Heat transfer occurs when a warm object comes in contact with a cooler object and the warmer is transferred to the cooler to attempt equilibrium of the two. In this case, the warmth of the human body, it's clothing and its interaction with the cooler exterior temperature. The purpose of the study was to measure the thermal resistance (insulation value) and evaporative resistance of eighteen sports ensembles using a heated, sweating manikin in an environmental chamber" (Zou, 2004). Among these eighteen uniforms were football, basketball, baseball, soccer, track, tennis, golf and cycling. Each garment was chosen by considering applicable National Collegiate Athletic Association (NCAA) attire requirements. Since each of these sports is played during different seasons, the ambient room temperature for the study was held consistent for tests to get an accurate and comparable measure of each outfit. Descriptions of the individual garments, their individual fabrics, textiles thickness and weight were reported. "Ensembles for a given sport often vary with respect to the amount of body surface covered by garments, the number of fabric layers on different parts of the body, the looseness or tightness of the fit, the type of garments to be worn (e.g., knee-length socks versus ankle-length socks), seasonal differences, and the

thickness and permeability of the fabrics" (Zou, 9). Results showed that football uniforms provided the highest insulation values in the data set. It is concluded from this study that clothing insulation increases as the amount of body surface area covered by garments increases and as the thickness of the garment layers increases. The evaporative resistance of an ensemble depends on the moisture permeability characteristics and wicking properties of the component materials used in the clothing and the amount of skin surface that is covered.

In the Zou, (2004) study to evaluate the thermal properties of sports uniforms, they found that the fiber content has little to do with the moisture permeability of textiles. It is the openness of the fabric structure and type of surface treatments that have more of an impact. Fiber content has some impact on moisture permeability but is not as significant as the openness of the fabric weave structure.

Other studies have concluded the same finding as well. For example, Zhang and Gong (2002), "investigated the combined effects of the properties of clothing materials and wind on human thermoregulatory responses by studying the effects of air permeability during exercise in controlled environments with and without wind". They used two sets of experimental clothing, type A and type B, both consisted of underwear, outerwear and socks, both type made from 100% cotton. Type A was reported at a thickness of 0.18mm and type B reported thickness of 0.23. Each subject cycled on an ergo-meter for one hour. One group was tested with wind and the other without wind during exercise. They recorded rectal temperature, skin temperature, body mass loss, salivary lactate and clothing microclimate relative humidity. Their study concluded that

physiological responses to heat are influenced by wind and the air permeability of clothing materials. During the exercises, skin temperature, clothing microclimate temperature, body mass loss and salivary lactic acid concentrations are significantly lower for the clothing with higher air permeability in the environment with wind.

Looking at another research article by Ciesielska, Mokwinksi and Orlowska-Majdak (2001), their study analyzed the influence that clothing material may have on human physiology and thermal comfort both at rest and during physical effort to answer the question, which fabric is better, a natural or synthetic. The study involved twenty young healthy volunteers, (6 females and 14 males, between the ages of 21-29). They performed a 15-minute treadmill exercise test two times. The first time they were asked to wear a 100% coarse wool clothing set. The second test they wore 100% acrylic clothing set. Physiological parameters, perceived comfort, psychomotor skills and well-being questionnaire were asked before and after each exercise. Perceived comfort data was collected in a qualitative method. Before exercise: Subjects reported that the course wool set of clothing was extremely unpleasant in contact with the skin and they felt uncomfortable wearing it. Subjects reported the opposite with the acrylic set before exercise. However, after exercise, their opinions changed. Subjects reported feeling cooler and dryer in the 100% course wool set and felt discomfort in the acrylic set of garments. According to this research, this is due to the yarn and fiber structure of the two materials. Acrylic has a lower air and liquid permeability then the woolen textiles. This article concludes that clothing materials, whether made from natural or synthetics, has an impact on physiological parameters in humans during physical exercise. “The

type of material for the clothes to be worn during physical effort should ne selected depending on the type, intensity and duration of the effort and talking into account the potential effects on human physiology" (Ciesielska, 2009).

This study by Purvis and Tunstall (2004) demonstrates that fabric and material type impact skin temperature, whole body thermoregulation, energy expenditure, perceived comfort and fabric preference. This study researched two sock types, a standard running sock and an ergonomic asymmetrical fitted sock. Subjects included 16 healthy athletes who were highly active and participated in structured training programs. There were 6 males and 6 females that participated. Each participant visited a lab, on two separate occasions, one week apart and conducted the experiment. They were asked to perform 30 minutes of continuous exercise on a treadmill. Each visit they wore a different sock, once the standard and once the ergonomic. The order of socks tested was randomized. Participants provided their own shoes and running attire that was worn on both visits. The standard sock was 76% cotton, 24% nylon and the ergonomic sock was 44%cotton, Coolmax© 86% polypropylene and 14% nylon. Coolmax© content claims to be a sweat wicking material. Mean skin temperature, heat rate, rate of perceived exertion and following each test, subjects were asked to fill out a questionnaire describing their sock preference. The study used a thermal perception scale to evaluate comfort and sock preference. The results conclude there is no statistical difference in heart rate when wearing either sock. Core temperature was not significantly influenced by wearing either sock. The ergonomic sock showed a slight increase in skin temperature compared to the standard sock although the increase was

not statistically significant. The perceived rates of exertion were identical for both sock conditions. Thermal body perception and thermal foot perception was also identical for both sock conditions. The participant questionnaire shows that they perceived the ergonomic sock as having more cushioning while the standard socks were more comfortable to wear. When asked what type you would purchase, 10 out of 16 indicated they would purchase the ergonomic sock. "When asked to rate the socks on a scale from 1 to 5, with 5 being excellent and 1 being poor, the ergonomic socks were rated higher than the standard sock. Sock types examined here do not significantly affect thermal or physiological responses during exercise. The ergonomic sock was perceived to be cooler and was preferred which suggests that subjective perceptions may be more important than the objective measurements" (Purvis, 2004).

There has been extensive research in the regulation of comfort among athletes depending on the textile used. However, there is no research found on the garment construction or style and it's influence on body temperature. The only study that refers to style garment and its influence on body temperature is the Zou and McCulla (2004) study that examined the amount of clothing worn and how that affects the thermal temperature. It does not however refer to the style of the garments just the articles of clothing. The Purvis and Tunstall (2004) sock study provides us with information explaining that the human perception of comfort can be stronger than the subjective data collected. The majority of people perceived the Coolmax© sock to be cooler when data recorded of foot temperature revealed it to be warmer than the perceived temperature. To further explore the area of perceived comfort and objective data,

literature was reviewed comparing thermal manikin results to subjective human perception results.

Thermal Manikin Results Compared to Human Perception

Tsang and Fan (2008) conducted an experimental investigation on the effect of clothing thermal properties on the comfort sensations of wearers during sport activities. They used a sweating manikin to measure the clothing's thermal properties of five separate tracksuits. They had 5 men wear each of the track suits and found the average comfort sensations of each that were then correlated with the thermal properties of the track suit measured from the manikin. The 5 sets of track suits were purchased from the commercial market and consisted of one long sleeved tracksuit and long trousers, which varied in style, material composition and function to the other samples. All sets were polyester except for 1 shirt. The special functions included on the tags indicated the garments were breathable, thermal insulated and of aerodynamic design. Subjects were asked to dress in the provided tracksuit, rate the comfort sensations for each suit then proceed to play badminton for 30 minutes. After the exercise they were asked to evaluate comfort sensations again. Comfort sensations were rated on a 1(no)-5 (extremely) scale. Comfort sensation evaluation terms were different before and after playing badminton. Before playing badminton, the comfort sensations subjects were asked to evaluate included: warmth, prickliness, stiffness, roughness and overall comfort. After playing badminton, the comfort sensations the subjects were asked to evaluate were: warmth, permeability, skin dryness, stickiness, clinginess, prickliness,

stiffness roughness and overall comfort. Fan and Tsang (2008) found the comfort sensations before exercising were not related to the thermal properties of the clothing, but very much related to the tactile sensations, such as prickliness, roughness and stiffness. The comfort sensations after exercising were very much related to the moisture vapor resistance of the clothing and amount of moisture accumulation within clothing measured from the sweating manikin. This study shows that the measurements from the sweating manikin can provide reliable and accurate evaluation of the comfort of sportswear.

Further research comparing thermal manikin and human subjects indicates that there is a strong correlation between human perceived comfort and thermal manikin data collected. Thermal manikins have proven to be accurate in other types of thermal environments. A trial conducted by Meinander (2004) compared thermal manikin insulation values to human perception in sub zero temperatures. They used four cold-protective clothing ensembles that were intended for use in a temperature range of 0° to -50° C. The clothing chosen had been previously tested to ensure safety in the wearers. The four separate temperature ensembles were protective down to a certain temperatures, 0°C, -10°C, -25°C, and -50°C., three participants wore the ensembles and performed mild to moderate activities in the appropriate climate. The thermal insulation was collected from the thermal manikin in four separate institutions. Results concluded that the thermal manikin insulation values defined with thermal manikin correspond well with the wear trail values in the temperature range of 0°C to -10°C. Knowing that

thermal manikin data is accurate and comparable to subjecting human data provides a basis for the comparison or subjective data to the objective data.

CHAPTER III

METHODS

The purpose of this study is to determine if the style of running pant affects the comfort. In this study, comfort has been defined as the interaction between the textile/material used in the garment, the fit, the environment in which the garment is used, and the style. The methods chapter will explain how each of these variables was controlled, how only the style of pant was changed, and how comfort was measured.

The measurement of comfort was the subjective evaluation of the pant. The objectives have been developed to define perceived comfort as three components: the fit, skin sensation, and thermal properties. Each subject answered a questionnaire related to each of these components.

Protocol

Three male subjects were recruited. Subjects were informed of the research topic through the student researcher, who works at Dixon Recreation Center as a fitness instructor. The study consisted of four separate meetings. The first meeting was to collect demographic information and to take body measurements. (Appendix A). Measurements include waist, hips, thigh, knee, ankle and outseams. The following three sessions lasted one-hour long occurring over a two-week period. There were at least 2 days between each visit. The 2-day break between running sessions gave the subject time to rest and give a legitimate assessment of the pant style without recalling the previous pant style worn.

The subjects were asked to engage in jogging at 5.5 MPH on a treadmill for duration of 40 minutes. This is a moderate to slow pace and the subject will complete less than 4 miles of distance. This includes a 5-minute warm up and a 5-minute cool down walking on a treadmill at 3.0 MPH. During a heavy constant running exercise, a rise in oxygen uptake occurs after about 2 to 3 minutes and onsets a rise in core body temperature and perspiration (Bringard, 2005). A 40 minute run was felt appropriate because athletes begin perspiring at different time points during running and when running it can take an individual anywhere from 5 to 30 minutes to perspire (Porcari, 2007). This time frame was found in the following experimental design studies that used apparel and exercise (Wong 2007, Trenell 2006, Duffield 2007, Bringard 2005, Purvis 2004 and Gavin 2003). With a warm up and cool down, a total of 40 minutes gives the opportunity for all participants to attain perspiration. During the activity, the participant was asked subjective questions before and after the exercise. Questions asked directly related to the comfort of the running pant. Each session, the subject was wearing a different fit of running pants. The first pair, Style A, fit on legs without any pressure or room for airflow to the skin on the legs. The second pair, Style B, was slightly baggier and allowed for more airflow between the fabric and skin of the leg. The third pair, Style C, was a snug fit and did not allow any airflow directly to the skin. The unidentified style of pant was provided to the participant before the study. Throughout the study heart rate (HR) was monitored to ensure the participant is within a normal HR range for jogging. HR is used to understand how much blood is being pumped through the heart in one unit of time, such as Beats per Minute. HR increases as

the need for oxygen changes, such as during exercise or sleep. HR is measured by finding the pulse of the body. For moderate exercise, HR should stay 40 beats per minute (BPM) below the individuals maximum HR. The individual's HR was determined through the standard calculation for maximum heart rate. Example: 220-(age) = maximum HR recommended for males while running. A resting HR was taken prior to exercise to establish each individuals HR range. Monitoring HR range will ensure the safety of the participant during the study. Protocol stated that, if at any time the subjects HR went over or under their HR range, the study would be stopped immediately.

Subjects

Adult male trainers who are employee fitness trainers at Dixon Recreation Center took part in this study. They were invited to participate in this study because they are male fitness trainers currently working at the Dixon Recreation Center. As a fitness trainer it is assumed they are able to perform the required exercise and are able to evaluate the fit of the running pants. Subjects were recruited from Dixon Recreation Center at Oregon State University. The researcher, who works at Dixon, recruited male trainers through word of mouth and all subjects self identified to participate. A chart showing the overview of age, height weight and years of training is in Table 1.

Table 1: Subjects Overview

	Subject #1	Subject # 2	Subject # 3
Age	25 years	29 years	26 years
Height	5’9”	5’11”	6’3”
Weight	160 lbs.	180lbs.	165 lbs.
Years Training	5 years	8 years	2 years

Procedure

Subjects were instructed to drink 10 oz of water, 30 minutes prior to the exercise and were instructed to refrain from alcohol for 24 hours prior to the test. Alcohol is shown to raise blood pressure. Alcohol is a diuretic and can lead to dehydration. Dehydration means your body does not have as much water and fluids as it should. Dehydration is the most commonly overlooked source for endurance. The body uses fluids to help regulate body temperature via sweat and to maintain blood pressure. With alcohol in the bodies system it can lead to dehydration and high blood pressure (Porcari, 2007). For safety of the subjects they were asked to refrain from alcohol 24 hours prior to each session and consume 10oz of water 30 minutes before running. This was duplicated from protocol of Duffield (2006), and Ciecielska (2009). Each session the subjects were handed either style type A, B or C, without knowledge of the style type they were given. The random order of style was given because by randomizing treatment assignment, the group attributes for the different treatments will be roughly equivalent. Both garments and sequences of subjects wearing them were randomized to

eliminate systematic errors. Each running session was within 14 days with at least 2 days between each visit. The 2-day break between running sessions gave the subjects time to rest and give a legitimate assessment of the pant style without recalling the previous pant style worn.

Every 5 minutes throughout the exercise, a digital sensor connected to the treadmill-recorded heart rate. Heart rate was monitored to insure the safety of the subjects. According to IRB approval the tests would be discontinued if a subjects HR went over the calculated maximum HR for their specific age.

Equipment used is a Precor 9.35 Treadmill with Patented Integrated Footplant Technology adjusts belt speed at microseconds to support stride, Patented Ground Effects Impact Control System cushions your joints, Touch and Telemetry (Wireless) heart rate with Smart Rate and included chest strap transmitter, ranges in Speed: 0.5 - 12 mph, Decline -2%, Incline 15%, 23 programs, 4 User IDs, Workout Log and Pacer.

Pant Style

Material

To control the influence of the textile and materials, each style pant is made from the same fabric and construction techniques was identical. The fabric was a moisture wicking material. The fiber content of the fabric was a blend of 88% polyester and 12% spandex. The fabric structure was a single knit plain jersey. The fabric was made of two types of yarns. One yarn was 100% polyester, microfiber and X1 Denier. The term micro-denier is used to describe filaments that weigh less than one gram per 9,000

meter length. The yarn was manufactured to be delustered to reduce, but not completely, eliminate the shine. It was also produced with a false twist, which certain synthetic yarns are given stretch characteristics. The yarns are wound under heat to eliminate the twist, but because of the yarns natural tendency to retain its twist, fabrics made from the false twist have a tendency to stretch. The fiber is round due to the synthetic production and was yarn dyed. The second yarns are untwisted and 100% Lycra-Invista Spandex= Elastine. Lycra is the generic name and Spandex® in the brand name. The term micro-denier is used to describe filaments that weigh less than one gram per 9,000 meter length. The yarn was manufactured to be delustered to reduce, but not completely, eliminate the shine. The fiber was flat on one side and rounded on the other. It had a 3mm absorbent capacity. The entire fabric was finished with a MM chemical finish on face and back. The polyester is a synthetic fabric and was dispersed dyed by immersion in an aqueous dispersion of insoluble dyes, whereby the dye transfers into the fiber and forms a solid solution. The technical Jersey back side of fabric is the fashion face of fabric. Fabric width measures 157 centimeters and weighs = 288 grams per square-meter.

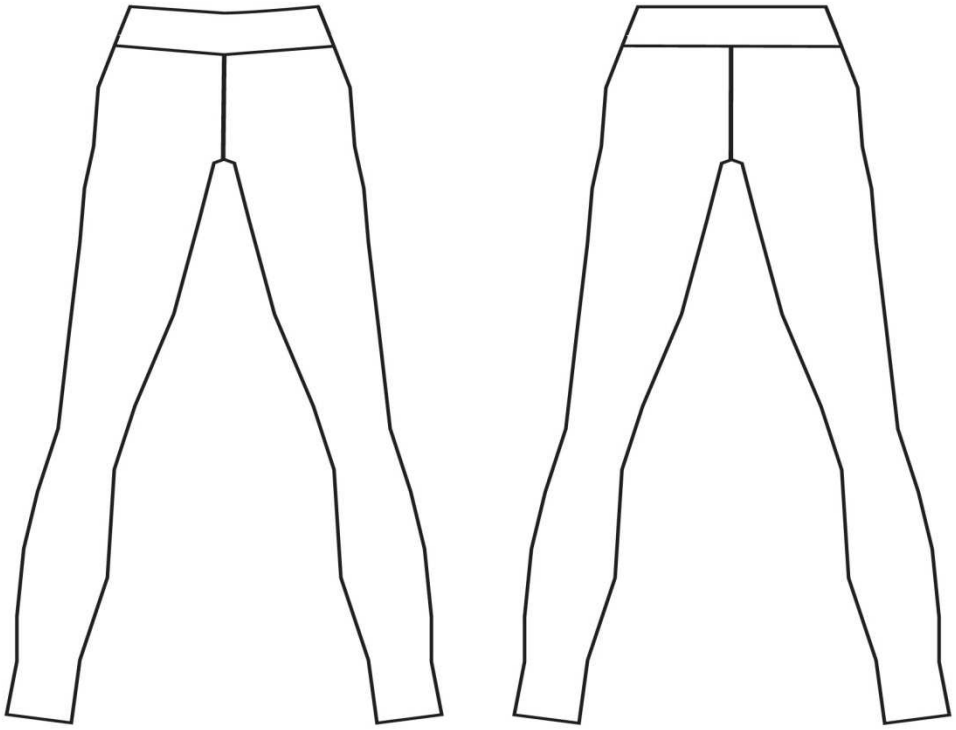
Garment Design and Fit

Each subject was measured. For the human subjects these measurements were taken at the first meeting and process approved by IRB. Appendix A shows the location and procedure used to measure each subject. The measurements for each subject and pant are given in Tables 1, 2 and 3.

The design of the pant was developed through flat pattern and drafting techniques. Each pant was made of the same fabric and used the same construction techniques. The design of the pant was the same, only the amount of ease was changed. Figure 1 illustrates the basic design.

There were three pant styles, Style A, Style B and Style C. Style A will rest at 0% from the body, sitting on the leg without any pressure. Style B will have an additional 5% of fabric added to the width of the leg. Style C will consist of a 20% reduction in material causing it to compress the legs. This Style C, and smaller representation of the subject's lower body, would expand to almost 100% of the original measurements of Style A. The most important factor of our investigation is the amount of ease in each style and how that affects the subject's perceived comfort. Tightness was measured as a percentage.

Figure 1: Basic Pant Style



In order to develop the three different style pants the basic pant pattern was altered to develop a compression garment and a looser fitting pant. To achieve identical level of ease on each subject, Style A, B, and C was made to custom fit each subject. Table 2, 3 and 4 report the amount of design ease, which was incorporated to develop the three different styles for each subject.

Each total ensemble consisted of underwear, athletic top, socks, and provided pants. Participants provided their own running shoes, socks, underwear and top.

Table 2: Subject #1 Body and Pant Measurements

Subject #1	Body Measurements	Style A 0%	Style B + 5%	Style C – 20%
Waist	36.5”	36.5”	37.825”	31 ½”
Hips	40”	40”	42”	32”
Distance from waist line*	5.5”	5.5”	5.5”	5.5”
Thigh	20.5”	20.5”	21.525”	16.4”
Upper Knee	16”	16”	16.8”	13.625”
Knee	15”	15”	15.75”	13.125”
Calf	15.125”	15.125”	16.625”	13.3125”
Ankle	7.75”	7.75”	8.1375”	6.2”
Outseam*	36.5”	36.5”	36.5”	36.5”
Inseam*	29.5”	29.5”	29.5”	29.5”

* Vertical measurements stay same across treatments

Table 3: Subject #2 Body and Pant Measurements

Subject #2	Body Measurements	Style A 0%	Style B + 5%	Style C – 20%
Waist	37.5”	37.5”	39.375”	30”
Hips	42.75”	42.75”	44.887”	34.2”
Distance from waist line*	4.5”	4.5”	4.5”	4.5”
Thigh	25”	25”	25.5”	30”
Upper Knee	19”	19”	19.95”	15.2”
Knee	16.75”	16.75”	17.5875”	13.4”
Calf	16”	16”	16.8”	13.625”
Ankle	10”	10”	10.5”	8”
Outseam*	38”	38”	38”	39”
Inseam*	29”	29”	29”	29”

* Vertical measurements stay same across treatments

Table 4: Subject #3 Body and Pant Measurement

Subject #3	Body Measurements	Style A 0%	Style B + 5%	Style C – 20%
Waist	33.5”	33.5”	35.175”	26.8”
Hips	39.75”	39.75”	41.7375”	31.8”
Distance from waist line*	5”	5”	5”	5”
Thigh	22”	22”	23.1”	17.6”
Upper Knee	17”	17”	17.85”	13.6”
Knee	15.75”	15.75”	16.5375”	12.6”
Calf	15”	15”	15.75”	12”
Ankle	18”	18”	18.9”	14.4”
Outseam*	42”	42”	42”	42”
Inseam*	33”	33”	33”	33”

* Vertical measurements stay same across treatments

Pant Clo Value

Because the present study investigates subjective human thermal comfort of the three pant styles, the researcher was also interested in objective measures of the three styles’ thermal comfort. Therefore, the three pant treatments were submitted to the Department of Design and Human Environment’s Textile and Apparel Performance Testing Laboratory for objective thermal testing by a faculty researcher. The faculty researcher followed guidelines outlines in ASTM F1291- Standard Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin. Using a thermal manikin, data were collected and results were provided in the form of a dry (non-sweating) thermal resistance value for reach pants style under two conditions at an average temperature of 71.126°F and an average relative humidity of 49.501%. Under

the first condition, the manikin was hanging from a frame in a stationary position. Under the second condition, the manikin was hanging from a frame and walking at a speed of 50 strides per minute. In all cases, although the sweating function was disabled, the manikin wore a sweat skin. Results suggest that there are no significant differences in thermal resistance across the three treatments under the first stationary condition. Furthermore, results suggest that there are no significant differences in thermal resistance across the three treatments under the second walking conditions, results provided by the faculty member are displayed in Table 5.

Table 5: Thermal Manikin Rct Values:

Pant	**Stationary**		**Walking (setting = 50)**	
	Rct	**sd**	**Rct**	**sd**
Skin only	0.118	0.003	0.078	0.002
A & skin	0.141	0.004	0.097	0.010
B & skin	0.141	0.002	0.1	0.002
C & skin	0.139	0.005	0.96	0.022

When using the manikin for apparel thermal insulation testing, the size and design of the garment on the manikin are critical in obtaining valid data (Mullet and Chen, 2005). To ensure consistent fit and garment ease between manikin and the human subjects, the fit and size of the garments submitted for testing followed the same procedure as used for pant style development for the human subjects.

After obtaining results from the Textile and Apparel Performance Testing Laboratory, the researcher converted the provided thermal resistance values (Rct) into

Clo values. To do so, the researcher multiplied each thermal resistance value by 6.45. Thermal resistance values are often used in the building and construction market as a measure of thermal insulation for materials. The Clo value is a measure of thermal resistance value of clothing, especially as it relates to relative human comfort within that clothing at given conditions. (Parsons, 2003) The Rct value was converted to Clo value to get a more comparable value to that of other clothing insulation values. The conversion is in Table 6.

Table 6: Converted to Clo value:

Pant	Stationary		Walking (setting = 50)	
	Clo	**sd**	**Clo**	**sd**
Skin only	0.761	0.01935	0.531	0.0129
A & skin	0.90945	0.0258	0.62565	0.0645
B & skin	0.90945	0.0129	0.645	0.0129
C & skin	0.89655	0.03225	0.6192	0.1419

The Clo values of the three pant styles when tested in a stationary position did not differ significantly. Furthermore, the Clo values of the three pant styles when tested in the walking setting did not differ significantly.

Questionnaire Development

A questionnaire was developed to obtain information concerning the perceived comfort of the three pants styles. The questionnaire was modeled after Wong's (2003) study on human sensory perception. The questions were based on fit, skin sensation and thermal properties of the pants. (Appendix B)

The subjects were asked to report on an 11-point scale how they felt about a description of the pants. A Likert Scale was used and broken into three sections: Fit perception, skin perception and thermal comfort perception. Ten fit questions included rating the tightness on a scale of (0 = very loose- 11= extremely tight), chafing/ rubbing on a scale of (0 = no rubbing - 11= extreme), rating overall fit on a scale of (0 = very poor- 11 = very good) and comfort of the waist, crotch, thigh, knee, calf, ankle, overall fit on a scale of (0 = very uncomfortable- 11= extremely comfortable). Seven questions were used in the skin perception section. Subjects were asked to rate the following questions about feeling damp, prickly, clammy, sticky, itchy on a scale of (0 = not at all – 11 = extremely) describing the weight of the pants on a scale of (0 = light – 11 = heavy), and overall breathability on a scale of (0 = extremely – 11= not at all). The third section was one question which asked the subjects to rate the perception of their body temperature at that time on a scale of (0 = very cool - - 11 = very hot). The last question on the questionnaire was an open-ended question asking subjects if they had any additional comments. The open-ended question was intended for the subjects to address anything that might not have been addressed in the questionnaire, give opinions, and expand on anything they felt necessary.

Questions were asked once before and once after. The mean scores and range of all questions, for each treatment, was reported.

A pre-test on the questionnaire was conducted to remove errors or any confusion. One male subject was asked to complete the exercise and complete the questionnaire. No pant treatment was provided. It was discovered that it was not needed to do the survey questions throughout the run unlike Wong (2003) who had the subjects fill out the questionnaire during the exercise. It was determined that the questionnaire be administrated twice, once before running and once after. There was also slight confusion about the definition of 'clinginess'. Therefore, the clinginess sensation was replaced with chafing/rubbing sensation due to literature that supports that common event in athletic apparel. Otherwise all sensations were replicated from Wong (2003).

Data Collection and Objectives

The questionnaire was developed to collect information about the perceived comfort of the pant styles. The objectives of this study were then used to focus on specific components of the perceived comfort.

Objective 1: To determine human subjects' perceived fit comfort of three pants styles with varying levels of ease.

In the questionnaire, questions 1-10 are related to fit comfort of the pant style treatment. Each question based on an 11 point Likert Scale. The 10 questions were added up across all subjects, with the highest possible fit score equaling 110 points. To find the mean fit score, the researcher divided the highest possible fit score (110) by the

amount of subjects. In this case, there were 3 subjects equaling the highest mean fit score of 36.6. This 36.6 indicates the most comfortable fit score possible. The higher the mean fit score, the higher perceived comfort of the pant style. The lowest possible score for fit equals 0, indicating the style is very uncomfortable.

Objective 2: To determine human subjects' perceived skin sensation of three pants with varying levels of ease.

In the questionnaire, questions 11-17 are related skin sensations. Each question based on an 11 point Likert Scale. The 6 questions were added up across all subjects, with the highest possible skin sensation score equaling 77 points. To find the mean skin sensation score, the researcher divided the highest possible skin sensation score (77) by the amount of subjects. In this case, there were 3 subjects equaling the highest mean skin sensation score of 25.6. This 25.6 indicates the most experienced skin sensation. The higher the skin sensation score, the lower perceived comfort of the pant style. The lowest possible score for skin sensation equals 0, indicating the style has very little skin sensation and is therefore very comfortable.

Objective 3: To determine human subjects' perceived thermal comfort of three pants with varying levels of ease.

In the questionnaire, question 18 is related perceived thermal comfort. This question was based on an 11 point Likert Scale. The single question was added up across all subjects, with the highest possible thermal score equaling 33 points. To find the mean thermal score, the researcher divided the highest possible fit score (33) by the

amount of subjects. In this case, there were 3 subjects equaling the highest mean thermal score of 11. This 11 indicates the highest thermal score possible. The higher the mean perceived body temperature score, the warmer perceived thermal temperature of the pant style. The lowest possible score for perceived body temperature equals 0, indicating the style is very cool.

The questionnaire also included an open-ended question for additional comments during each session. This open-ended question was used to provide information on experiences during exercise that may have been left unanswered in the questionnaire. Individual comments per pant style were reported in the results section.

Data Analysis and Procedure

The data were analyzed according to the objectives stated in the previous section. The program STATA version 11.0, a general-purpose statistical software package created in 1985 by Stata Corp was used to statistically analyze the quantitative subjective data. All quantitative subjective data was entered into STATA. The Likert Scale scores were analyzed using means for each of the individual criteria per section on the questionnaire. The mean and standard deviation of all questions, for each treatment and subject were calculated. Each section of the questionnaire produced an overall fit, skin sensation and thermal comfort score for each subject and each pant style. The running test response for perceived comfort was evaluated with a Repeated Measures ANOVA with repeated-measures across each style, subject and time, followed by a post ANOVA contrast analysis used to isolate differences among

conditions. The four assumptions of Repeated Measures ANOVA include independence of observations within and between samples, normality of sampling distribution, equal variance and homogeneity of covariance. The independence assumption is based on the way data are collected. The normality assumption concerns the sampling distribution. The equal variance assumption addresses variances in the populations. Under the null hypothesis, the "within-groups" and "between-groups" variance both estimate the same underlying population variance and the F ratio is close to one. If the between-groups variance is much larger than the within-groups, the F ratio becomes large and the associated p-value becomes small. This leads to rejection of the null hypothesis, thereby concluding that the means of the groups are not all equal. The homogeneity of covariance refers to the requirement that the effect of the treatment is consistent for all of the subjects and no carry-over effects exist. Data was reported as mean +- SD for each of the measures, unless otherwise specified. The level of significance was set at $p < 0.05$ for all analysis. The researcher chose to use Repeated Measures ANOVA because there were 3 or more independent groups. The three independent groups were pant styles, subjects, and time. The researcher decided not to conduct a series of t-tests (one for each pair of sample means) because it would lead to an inflated Alpha. To conclude more precise results, the researcher used Repeated Measures ANOVA.

CHAPTER IV
RESULTS

The purpose of the research was to investigate perceived comfort between men's athletic running pants. In this chapter, the results of the questionnaire are presented and will follow the objectives of the study. Three respondents participated, resulting in a response rate of 100%. All statistical tests were interpreted at 0.05 probability level.

Objective 1: To determine human subjects' perceived fit comfort of three pants styles with varying levels of ease.

In the questionnaire, questions 1-10 are related fit comfort of the pant style treatment. These were analyzed and compared across subjects, across styles, and before and after each session. A fit score was calculated for subjects by adding up their total scores for each pant style. There were 10 questions that ranged from a scale of 1-11 totaling a mean maximum of 36.6 points for extremely comfortable fit. Scale ranged from 0-very uncomfortable to 11-exteremly comfortable. Table 7 shows that mean perceived fit scores across all three subjects before and after exercising. Following that, Table 8 shows the ANOVA statistical data. Figure 2 shows a bar graph of the mean fit scores by subject and style.

Table 7: Mean Perceived Fit Comfort Score

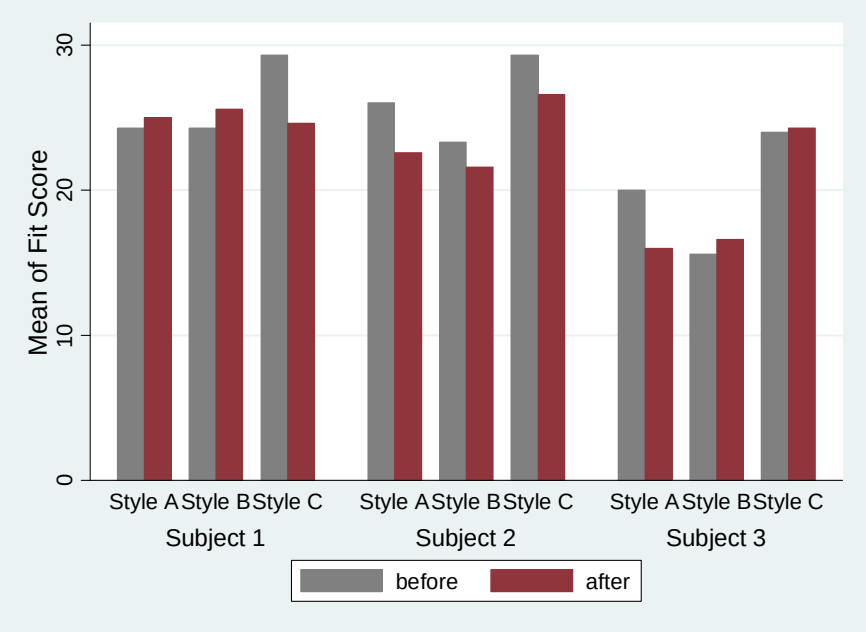
Fit Comfort Score	Style	Time	Mean	SD
Tight no pressure	A	Before	23.43	+ - 3.092
Tight no pressure	A	After	27.53	+ - 4.664
Baggy	B	Before	21.06	+ - 4.760
Baggy	B	After	21.26	+ - 4.509
Compression	C	Before	27.53	+ - 3.742
Compression	C	After	25.16	+ - 2.459

Table 8: ANOVA of Perceived Fit Comfort Score

Source	Partial SS	d.f	M.S.	F-Value	P	R-squared= 0.9538
Model	262.554	13	20.1964	6.35	0.0439*	
id	135.314	2	67.6572	13.88	0.0159*	
style	88.9144	2	44.4572	9.12	0.0323*	
id*style	19.4922	4	4.87305			
time	9.67999	1	9.67999	6.70	0.1225	
Id*time	2.88999	2	1.44499			
style*time	6.26333	2	3.13166	0.99	0.4489	
Residual	12.7166	4	3.17916			
Total	275.271	17	16.1924			

*Significant at $p < .05$

Figure 2: Graph of Mean Fit Scores:



The overall model for the fit scores is significant f (13) = 6.35, p=0.0439. R-squared = 0.9538 and can explain 95% of the variance.

Within this model (Table 8), there is a significant difference in style, f (2,4) = 9.12, p=0.0323. After discovering the subjects significantly identified styles as fitting differently, there was an ANOVA Contrast run to examine the difference between each style. Table 8 shows the ANOVA contrast between Style A and Style B. It reports no significant difference between Style A and Style B. Table 10 reports the difference between Style A and Style C. Table 10 explains there is a significant different between Style A and Style C f (1,4) = 39.93, p=0.032, and Table 11 shows there is also a significant difference between Style B and Style C f (1,4) = 65.96, p= 0.0013.

Table 9: ANOVA CONTRAST of Perceived Fit Comfort Score between Style A and B

Source	SS	df	MS	Contrast =	1.15
contrast	3.96749956	1	3.9675	F =	3.25
error	4.88888889	4	1.2222	Prob > F =	0.1459
				t =	1.80

* Significant at p > 0.05

Table 10 : ANOVA CONTRAST of Perceived Fit Comfort Score between Style A and C

Source	SS	df	MS	Contrast =	-4.03
contrast	48.8033287	1	48.8033	F =	39.93
error	4.88888889	4	1.2222	Prob > F =	0.0032*
				t =	6.32

*Significant at p > 0.05

Table 11: ANOVA CONTRAST of Perceived Fit Comfort Score by Style between B and C

Source	SS	df	MS	Contrast =	-5.18
contrast	80.6008254	1	80.6008	F =	65.95
error	4.88888889	4	1.2222	Prob > F =	0.0013*
				t =	8.12

* Significant at p > 0.05

Objective 2: To determine human subjects' perceived skin sensation of three pants with varying levels of ease.

In the questionnaire, questions 11-17 are related skin sensations. These were analyzed and compared across subjects, styles, before and after each session. Perception of skin sensation was described as 0-not at all to 11 extremely. Table 12 reports the mean scores across all subjects before and after exercise. Highest mean skin sensation score is 25.6. Mean scores across all style ranged from (3.067 to 7.734) (Table 12). The results indicate there was no statistical difference between pant style, skin sensation and

time (before and after). The following Table 13 is the ANOVA of perceived skin sensation. Figure 3 shows a bar chart of mean skin sensation scores by subject and across styles. It is shown that there is not statistical difference between pant style.

Table 12: Mean Skin Sensation Score

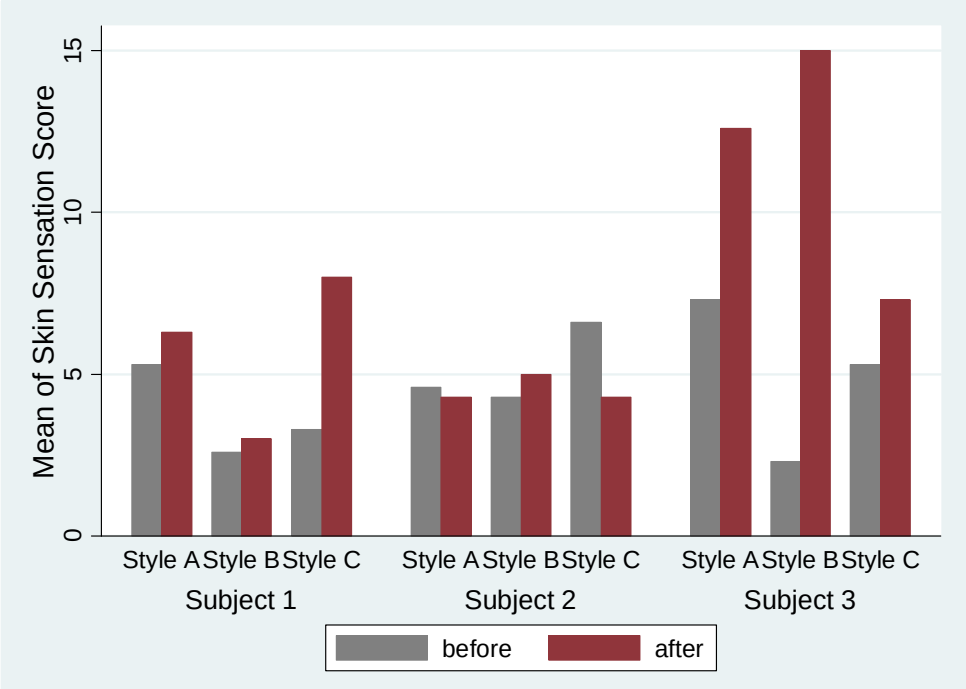
Skin Sensation	Style	Time	Mean	SD
Tight no pressure	A	Before	5.734	+- 4.3
Tight no pressure	A	After	7.734	+- 3.3
Baggy	B	Before	3.067	+- 1.6
Baggy	B	After	7.667	+- 4.3
Compression	C	Before	5.067	+- 3
Compression	C	After	6.533	+- 2.5

Table 13: ANOVA of Perceived Skin Sensation Score

Source	Partial SS	d.f.	M.S.	F-Value	P	R-squared= 0.8427
Model	157.171	13	12.0900	1.65	0.3353	
id	49.0300	2	24.5150	4.81	0.0863	
style	5.85333	2	2.92666	0.57	0.6036	
id*style	20.3866	4	5.09666			
time	32.5355	1	32.5355	1.59	0.3345	
Id*time	40.9344	2	20.4672			
style*time	8.43111	2	4.21555	0.57	0.6035	
Residual	29.3488	4	7.33722			
Total	186.5200	17	10.9717			

* Significant at $p > 0.05$

Figure 3: Mean Skin Sensation Scores:



Objective 3: To determine human subjects' perceived thermal comfort of three pants with varying levels of ease.

In the questionnaire, question 18 is related perceived thermal comfort. This was analyzed and compared across subjects, treatments and before and after each session. Table 14 shows the mean scores across all subjects before and after exercise. Highest mean score is 11 points. Ranging from 0-very cool to 11 very hot). Across all pant styles the scores ranged from 2.666 to 7.667.

In Table 15, the ANOVA of perceived thermal comfort, the results indicate that the overall model is approaching significant f (13, 4) = 5, p=0.0662. There is a significant difference between time and perceived levels of thermal comfort (1, 2) =

27.13, p=0.034. Figure 4 shows a bar chart of mean thermal perception scores by subjects, across styles, before and after exercise.

Table 14: Mean Thermal Perception Score

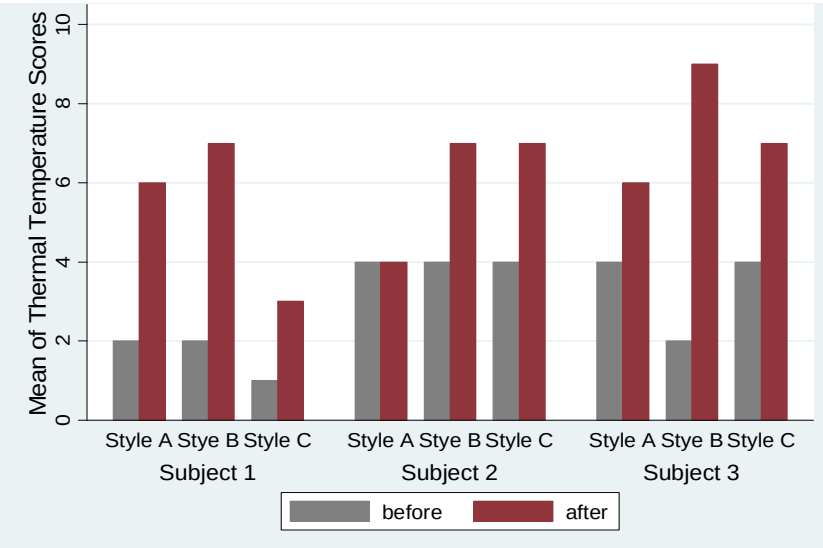
Thermal Score	Style	Time	Mean	SD
Tight no pressure	A	Before	3.333	+- 1.67
Tight no pressure	A	After	5.333	+- 0.77
Baggy	B	Before	2.667	+- 1.33
Baggy	B	After	7.667	+- 2.0
Compression	C	Before	3	+- 0
Compression	C	After	5.667	+- 1.33

Table 15: ANOVA of Perceived Thermal Comfort Score

Source	Partial SS	d.f.	M.S.	F-Value	P	R-squared= 0.9420
Model	79.388	13	6.10687	5.00	0.0662	
id	11.444	2	5.7222	3.03	0.1581	
style	2.7778	2	1.3889	0.74	0.5346	
id*style	7.5556	4	1.8889			
time	46.722	1	46.7222	27.13	0.0349*	
Id*time	3.4444	2	1.72222			
style*time	7.4444	2	3.7222	3.05	0.1571	
Residual	4.88889	4	1.22222			
Total	84.2777	17	4.95751634			

* Significant at $p > 0.05$

Figure 4: Mean Thermal Perception Score



Overall Subjective Evaluation

At the very end of the survey there was an open-ended question where the subjects could comment on the overall comfort of the pant. Open-ended question responses are reported by style.

Comments- Style A:

“Thighs are loose”

“Very comfortable waistband”

“Thighs felt a little loose for my taste.”

“Very comfortable waist band but felt a little loose”

“Pants are itchy at the calf’s”, “Felt a chill, sort of”

“Pants feel slightly breathable but too loose in crotch”

Comments- Style B:

“Feels good”

“Comfy loose fit”

“Very comfortable waist band”

“Comfy loose fit”

“Felt a lot warmer in these today”

Comments- Style C:

“Pants feel very nice”

“Very breathable/ comfy”

“Very comfortable waist band”

“Just thought the knees were a little restrictive. Other than that I thought they were comfortable.”

“Really liked the comfort of the waistband”

“I would run in these pants”

CHAPTER V

CONCLUSIONS AND DISCUSSION

In this chapter, the results are discussed and the hypotheses which were developed for each objective will be accepted or rejected. The general findings, limitations, and recommendations for further study are presented.

Hypotheses

Objective 1: To determine human subjects' perceived fit comfort of three pants with varying levels of ease.

HI. There is a significant difference between perceived fit comfort between Style A and Style B. *This hypothesis was rejected.*

H2. There is a significant difference between perceived fit comfort between Style A and Style C. *This hypothesis was accepted.*

H3. There is a significant difference between perceived fit comfort between Style B and Style C. *This hypothesis was accepted.*

Objective 2: To determine human subjects' perceived skin sensation of three pants with varying levels of ease.

H4. There is a significant difference between perceived skin sensation comfort between Style A and Style B. *This hypothesis was rejected.*

H5. There is a significant difference between perceived skin sensation comfort between Style A and Style C. *This hypothesis was rejected.*

H6. There is a significant difference between perceived skin sensation comfort between Style B and Style C. *This hypothesis was rejected.*

Objective 3: To determine human subjects' perceived thermal comfort of three pants with varying levels of ease.

H7. There is a significant difference between perceived thermal comfort between Style A and Style B. *This hypothesis was rejected, although the overall model is approaching significant.*

H8. There is a significant difference between perceived thermal comfort between Style A and Style C. *This hypothesis was rejected, although the overall model is approaching significant.*

H9. There is a significant difference between perceived thermal comfort between Style B and Style C. *This hypothesis was rejected, although the overall model is approaching significant.*

Findings

The following are the major findings of the study:

1. There is a significant difference in the overall model of perceived fit comfort scores between all styles. This tells the researcher that the subjects identified significant differences between the pant styles.

2. There is a significant difference of fit comfort between Style A and Style C. Style A and Style C is similar in overall appearance style when worn on the body, but very different ease fit. The amount of design ease from Style A to Style C results in a

variation of pressure on the body from 0% to -20%. This design ease reduction in fabric compresses the legs and therefore produces a completely different comfort of fit than any other style that is not compressing the body muscles.

3. There is a significant difference between perceived fit comfort between Style B and Style C. Style B and Style C have the largest difference in fabric weight and ease fit. There is a 25% difference in fabric. Style B is baggy and Style C compressed the leg muscles.

4. There is a significant difference in perceived thermal temperature before and after exercise. This was expected and is not a surprise to the researcher. As activity increases the human heart rate increased therefore producing heat (Parsons, 2004).

Conclusions and Discussion

The purpose of this study is to determine if the style or design ease of a man's running pants influences the subject's perceived comfort of the garment. For each style treatment, the fabric, fitting ease, environment, and construction remained the same, only the design ease was changed. The majority of studies on clothing comfort have usually dealt with the fit of the garment or the influence of different textile properties. Few studies have evaluated the design ease and style of garments as it relates to comfort.

When looking at the significance between styles, the human subjects found a significant difference between Style A and Style C. Style A and Style C has a 20% difference in ease. Style C had a higher fit score than Style A. The mean fit scores for Style C was (27.5, 25.167) before and after exercise. Compared to Style A, the mean fit scores was (23.433, 21.2) before and after (Table 6). Successfully completing all elements of this study fulfilled objective 1: *To determine human subjects' perceived fit comfort of three pants with varying levels of ease. H1: There was a difference between the perceived comfort of Pant Style A and Pant Style C.*

The results of this study cannot be applied to the general public or to running pant styles that have not been tested, yet the analysis revealed a significant difference between pant Style B and C, supporting *H3: There was a difference between the perceived comfort of Pant Style B and Pant Style C.* Style B was the baggiest style out of the three and had a mean fit score of (21.06, 21.2) (Table 6) before and after exercise. There is an insignificant difference between the before and after fit scores for Style B.

However, when comparing the overall fit scores between Styles B to Style C there is a significant difference. This significant different can be due to a few reasons. First possibility is due to the lack of 'chimney effect". The chimney effect occurs when loosely hanging clothing ventilates the trapped air layers from the body (Gavin, 2003 pp.942). With the lack of this effect, the air between the fabric and the body is heated up during exercise and has no way of escape. The longer the duration of the exercise, the warmer the trapped air will get. Second, it is possible that the weight of the fabric had some type of contribution to the overall fit score of the pants. The lighter fabric weight, the less amount of clothing worn and more airflow to the skin result in a cooler athlete (Zou and McCulla, 2004, Gavin, 2003). Compression garments provide all of these factors, therefore making them an ideal pair of running pants. This confirms the hypothesis *that there was a significant difference between Styles C to B.*

Pant Weight

Table 16 indicates the mean pant weight perception score across all subjects before and after exercise. Style B to Style C has the largest variation in amount of yardage used. On the survey, subjects perceived Style B as feeling the heaviest, while perceiving Style C as feeling the lightest in weight. Below is a chart showing the differences in before and after scores across subjects for perceived weight of the fabric used.

Table 16: Pant Weight Perception Score Before and After Exercise.

Style	Before	SD	After	SD
A	9	+- 0	9	+- 0.6
B	9	+- 1	16	+- 2.7
C	6	+- 0.5	7	+- 1.7

As shown, Style A has no change across subjects in perceived weight of the garment before and after exercising. While, Style B has the largest variation in score, jumping from 9 to 16 points in perception of weight, Style C only has a 1-point increase in perception of weight. Table 16 shows the actual fabric weight in grams.

Table 17: Actual Pant Weight

Style	Grams
A	279.248 g
B	315.9 g
C	219.588 g

Comparing the perceived fabric weight to the actual fabric weight reinforced the perception of fabric weight is accurate. Style B is the heaviest at 315.9 grams. Style A is the second heaviest at 279.248 grams. Style C is the lightest pair of pants at 219.588 grams. This concludes that humans are capable of perceiving fabric weight before and after exercise.

Perceived Skin Sensation

In Objective 2, this was to determine human subjects' perceived skin sensation of three pants with varying levels of ease. The hypothesis that we would find a significant difference in skin sensation across treatments was rejected. During the planning stages of the study, no consideration to leg hair and skin perception revealed itself during a literature review. However, looking at the data a bit closer we find an interesting difference across subjects. Scores were added up across all the skin sensation scores by subject. The questions included, do you feel prickly, clammy, damp, itchy etc, and there was a noticeable large difference between subject 1 and 3 and subject 2 and 3. Subject 3 had much higher skin sensation scores then the others. I wanted to know what could contribute to this finding. After consideration, I recalled that Subjects 1 and 2 ritually shave their legs and Subject 3 does not. When looking at the difference in scores between the shavers and non-shaver we find an interesting difference. Below, Table 18, shows the total scores of skin perception by subjects before and after exercise.

Table 18: Skin Sensation Perception Scores by subject before and after exercise.

Subject	Before	SD	After	SD
1	29	+- 2.6	56	+-3.4
2	37	+- 4.21	39	+- 2.43
3	44	+- 4.16	113	+- 4.1

By reviewing the scores of skin perception across subjects, it is clear that there is a large difference between Subject 3's after score and the other 2 subject's scores

after exercise. Upon further research, it has shown that repeated rubbing on a hair follicle can lead to increased skin sensations and even infection. The most common hair infection is called folliculitis. Folliculitis is inflammation surrounding a hair follicle. Symptoms of follicultitis include pain, itching, swelling and puss development. One of the factors contributing to the development include rubbing of tight clothing or hats (Freiman, 2004). This leads the researcher to believe the leg hair on subject 3 influenced the increase in his skin sensation score compared to the other subjects.

Objective 3 was to determine human subjects' perceived thermal comfort of three pants with varying levels of ease. There was no statistical difference found between perceived thermal comforts of the three pant styles. The room average temperature and relative humidity range for each pant style is shown in Table 19. There is an interesting range of scores across pant styles and room temperature/ relative humidity during the tests.

Table 19:Temperature/ relative humidity range/ average by pant style:

Style	Temp. Range F	Relative Humidity Range	Temp Average F	RH Average
A	68° – 75.2°	31%-50%	71.6°	40.5%
B	66.2°-73.7°	31% - 50%	69.95°	40.5%
C	69.6° – 74.5°	32% - 46%	72.05°	39%

The relative high humidity in each test is seen as a limitation of the study. However, the room with the highest average temperature was during the test in which

Style C pant was being evaluated. Style C pant was evaluated by the subjects as being the coolest even thought the room was not. The room with the lowest average temperature was during the test in which Style B was being evaluated. Style B was evaluated by the subjects as being the warmest even thought the room was not.

Although there is no significant difference between styles and perception of thermal temperature, Table 20 shows that Style C has the coolest perceived thermal temperature, both before and after exercising. I believe this is because of the openness of the knit fabric. As the fabric is stretched, so is the openness of the fabric structure that allows more airflow to the skin. The more airflow to the skin will result in a cooler mean skin temperature (Gavin, 2003). The higher level of compression may result in more airflow. The designer will have to account for fabric structure, percentage of fabric stretch and the size of the athlete. Depending on the levels of compression, the percentage of compression will impact the amounts of airflow to reach the skin. The higher the compression level the more openness of the fabric, the lower levels of compression the more closed the fabric structure will be.

Style A is rated as having no change in perception of thermal temperature before and after exercise. Lastly, Style B was perceived to be the same thermal temperature as Style A before exercising and the overall hottest, by 7 points, after exercise. There is reason to believe that this is due to the lack of “chimney effect”. The chimney effect occurs when loosely hanging clothing ventilates the trapped air layers from the body (Gavin, 2003 pp.942). With the lack of this effect, the air between the

fabric and the body is heated up during exercise and has no way of escape. The longer the duration of the exercise, the warmer the trapped air will get.

Table 20: Total Percption of Thermal Temerature

Style	Before	SD	After	SD
A	9	+- 1.6	9	+- 1.4
B	9	+- 1.4	16	+- 0.6
C	6	+-1	7	+-1.4

This is interesting when compared to the Temperature and relative humidity of the exercise portion. Style B was perceived to be the warmest style even though the ambient room temperature was the lowest of all exercise sessions (Table 19). Style C was perceived to be the coolest pair of running pants while the ambient temperate was measured the highest. These temperatures are not significantly different but do bring up an interesting observation.

Although not statistically supported, there appears to be a trend that warrants further testing. Style B had the highest overall Clo value (Table 6) and was perceived to be the hottest pair of running pants across all subjects. Even thought there is not a statistical difference, this finding is interesting. Referring to (Table 14), we can tell that the lowest Thermal Temperature perception scores was for pant Style C. Table 21 shows a comparison between the average Clo value and the perception of thermal temperatures. The lowest averaged Clo Value (Table 21) was for pant Style C as well. The middle score for thermal temperature perception was pant Style A. The Clo value

for pant Style A matches the middle rated of perceived thermal score. Lastly, Style B was perceived as the hottest pair of running pants and that matches with the Clo average for Style B on the thermal manikin.

Table 21: Walking Clo Value Compared to Human Thermal Temperature Perception

Style	Clo Value	sd	Thermal Perception Score
A	.625	0.0645	18
B	.645	0.0129	25
C	.619	0.1419	13

Reviewing the overall subjective comments by individual style, we find two themes that relate to the findings. Supporting Objective 3 hypotheses: there was a difference between thermal perceptions of pant styles. Style B received the highest overall mean score for perception of thermal comfort. A comment for Style B supporting that is, “Felt a lot warmer in these today”. Not only do scores reflect this but the additional comment reinforces that Style B was perceived to be the warmest during exercise.

Another important comment that appears across all styles is about the comfort of the waistband. The majority of waistbands, that I have worn on athletic apparel, range from 1” - 2”. With a band this thin there is more pressure on less surface skin area. As a designer and athlete, I have a person preference for a wider waistband and I incorporated this into my running pant design for male subjects. With a wider waistband there is less pressure concentrated on one area. This width distributes pressure evenly over a larger surface area. In using this design technique, it can prevent unsightly curves

or rolls around the abdomen area. Waistband width on each subject's pants was a 5" band. Under each style there is a comment that states, "Very comfortable waistband". I think it is important to note that each style, although different in ease throughout the legs, was very comfortable at the waist.

Limitations

This section will describe the limitations of the study.

1. The large range of relative humidity across running sessions limits the accuracy of the results. The relative humidity contributes to perception of body temperature. With the large range in relative humidity it may have influences the perception of body temperature.

2. Another limitation of the study is the difference in leg shaving routines. Two of the three subjects regularly shaved their legs and one subject did not. This resulted in a large difference between subject's skin sensation scores. This limits the accuracy of our skin sensations results and data.

3. The use of only three subjects was also a limitation of the study and the results may not be generalized to the larger population.

Implications and Recommendations

The results indicate that humans have a different perception of thermal comfort as opposed to the measured Clo value. This confirms Purvis's (2004) study of sock comparison. They discovered that "subjective perceptions might be more important than the objective measurements" (Purvis, 2004). All though there is no significant difference in skin perception, thermal temperature perception and Clo value results; there is a significant difference in perceived fit comfort. This reinforces that subjective perceptions may be more important to designers and retailers than the objective measurements. Developing a more sophisticated questionnaire and integrating them with a larger sample size may yield to more statically significant results.

The comparison of subjects indicate that amount of hair on the legs has a large influence on perception of skin sensation. To gain further insight on creating an 'ideal' pair of running pants, future studies might investigate the use of subjects with similar hair grooming rituals to see if there is a linear relationship for perceived skin sensation.

Having a larger sample of pant styles with a more dramatic difference in ease across each style, may lead to more statically different results based on thermal perception. Testing a larger sample of pant styles with a more dramatic difference in ease across each style may also yield to a statically difference in Clo values from a thermal manikin.

From a design stand point, it is recommended for athletic design companies to incorporate a larger waistband for men's running apparel. The subjective comments revealed that a wider waistband is comfortable. Further research may benefit from

experimental design research exploring different width of waistbands and preference of width.

Further research may include exploring different textiles, knits and additional pant styles. It would be interesting to compare different pant styles with more dramatic ease variations. Exploring the impact of different textiles in running pants would also be valuable. Instead of comparing three styles of the same fabric, compare six styles of pants with three different textiles.

This data is valuable to designers and retailers in the athletic apparel field. From the review of literature, we learned that compression pants are beneficial of overall athletic performance. They are proven to reduce soreness, increase jump height and increase squat depth. From this study, it was found that male trainers find them more comfortable compared to two other pant styles. Gaining more knowledge about consumer's preferences may yield higher sales, happier consumers and a lower return rate.

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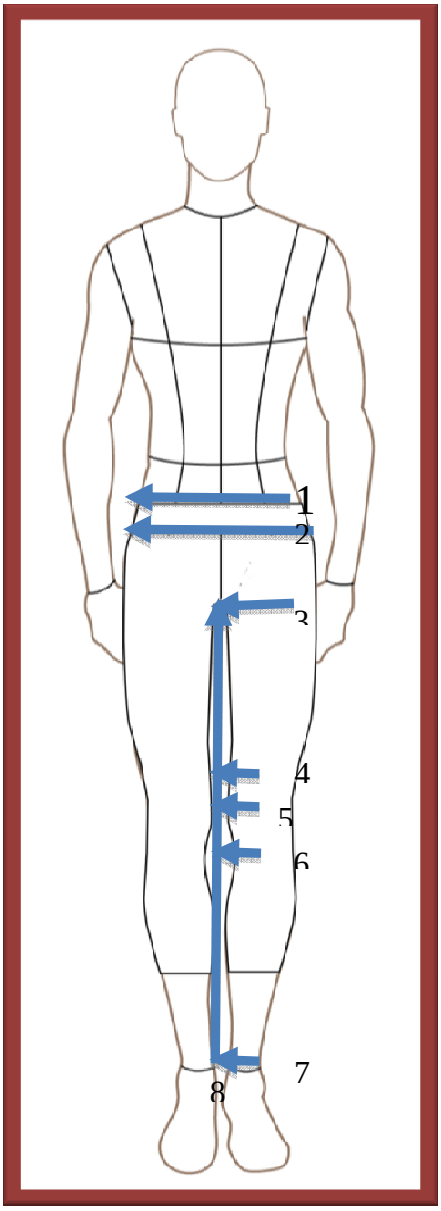
APPENDICES

APPENDIX A HUMAN SUBJECT GUIDE



Waist	1
Hips@6” down from waist	2
Upper thigh center crotch- all around	3
Above the Knee @3” from Knee	4
Knee	5
Below knee @ 3” below center knee	6
Calve @ 14” up from bottom of foot	7
Inseam length @ 9” up from ground	8

APPENDIX B HUMAN SUBJECT APPROVAL LETTER

OSU
Oregon State

Institutional Review Board • Office of Research Integrity
B308 Kerr Administration Building, Corvallis, Oregon 97331-2140
Tel 541-737-8008 Fax 541-737-3093 IRB@oregonstate.edu
http://oregonstate.edu/research/ori/humansubjects.htm

NOTIFICATION OF APPROVAL

[illegible]

Principal Investigator:	Dr. Kathy Mullet	Department:	Design and Human Environment
Study Team Members:			
Student Researcher:	Deborah Christel		
Study Number:	4492		
Study Title:	Perceived Comfort in Men's Running Pants		
Funding Source:	N/A		
Submission Type:	Initial Application – received 12/03/09		
Review Category:	Expedited	Category Number:	7
Waiver(s):	None	Number of Participants:	10
Risk level for children[1]:	N/A		

The above referenced study was reviewed and approved by the OSU Institutional Review Board (IRB).

Approval Date: 02/09/2010
Expiration Date: 02/08/2011

Annual continuing review applications are due at least 30 days prior to expiration date

Documents included in IRB approval:

- [x] Protocol
- [x] Consent forms
- [ ] Assent forms
- [ ] Grant contract
- [ ] Recruiting tools
- [x] Test instruments
- [ ] Attachment A: Radiation
- [ ] Letters of support
- [ ] External IRB approvals
- [ ] Translated documents
- [ ] Attachment B: Human materials
- [ ] Other:

- [ ] Project revisions:

Principal Investigator responsibilities for fulfilling the requirements of approval:

- All study team members should be kept informed of the status of the research.
- Any changes to the research must be submitted to the IRB for review and approval prior to the activation of the changes.
- Reports of unanticipated problems involving risks to participants or others must be submitted to the IRB within three calendar days.
- Only consent forms with a valid approval stamp may be presented to participants.
- Submit a continuing review application or final report to the IRB for review at least four weeks prior to the expiration date. Failure to submit a continuing review application prior to the expiration date will result in termination of the research, discontinuation of enrolled participants, and the submission of a new application to the IRB.

If you have any questions, please contact the IRB Office at IRB@oregonstate.edu or by phone at (541) 737-8008.

[1] Where parental permission is to be obtained, the IRB may find that the permission of one parent is sufficient for research to be conducted under §46.404 or §46.405. Where research is covered by §§46.406 and 46.407 and permission is to be obtained from parents, both parents must give their permission unless one parent is deceased, unknown, incompetent, or not reasonably available, or when only one parent has legal responsibility for the care and custody of the child.

[illegible]

APPENDIX C INFORMED CONSENT

OSU Oregon State University

Department of Design and Human Environment
Oregon State University 226 Milam Hall, Corvallis, Oregon 97331-5702
T: 541-737-3796 | F: 541-737-3385 | http://www.hhs.oregonstate.edu/dhe

Informed Consent Document:

Project Title: **Perceived Comfort in Men's running pants**

Principle Investigator: **Dr. Kathy Mullet, Design and Human Environment**

Co-Investigator(s): **Deborah Christel, Masters Student, Design and Human Environment**

What is the purpose of this study?

The purpose of this study is to determine the perceived comfort levels of three different styles of running pants. You will have 3 running pants made specifically to your body measurements. The student researcher is making these pants for you because they need to fit each individual participant the same.

What is the purpose of this form?

This consent form gives you the information you will need to help you decide whether to participate in the study or not. Please read the form carefully. You may ask any questions about the research, the possible risks, benefits and anything else that is not clear. When all of your questions have been answered, you can decide if you want to participate in this study or not.

Why am I being invited to take part in this study? Adult males who are employee fitness trainers at Dixon Recreation Center can may take part in this study. You are being invited to participate in this study because you are a male fitness trainers currently working in the Dixon Recreation Center. As a fitness trainer, it is assumed that you are able to perform the required exercise and are able to evaluate the fit of your running pants.

What will happen during this study and how long will it take?

If you agree to take part in this study, your involvement will consist of 4 separate sessions. The first session lasting 15 minutes and will consist of taking participants measurements. Measurements include: waist, hips, thigh, knee and outseams. The following three sessions, each last 1 hour long. You will be asked to jog on a treadmill for duration of 40 minutes, including a 5-minute warm-up and a 5-minute cool down. During that time, you will be asked questions about how comfortable the clothing is. During that time Heart Rate (HR) will be monitored to ensure you are within your normal HR range for jogging.. A Precon

Oregon State University • IRB Study #:4492 Approval Date: 02/09/10 Expiration Date: 02/08/11

OSU Oregon State University

Department of Design and Human Environment
Oregon State University 224 Milam Hall, Corvallis, Oregon 97331-5702
T 541.737.3796 | F 541.737.3689 | http://www.dhe.oregonstate.edu/dhe

9.35 treadmill with a digital sensor connected to the treadmill will record heart rate at 5-minute intervals throughout the study. If at anytime the subjects HR exceeds their maximum calculated HR the study will be stopped immediately.

·What are the risks of this study?

There are minimal risks to participating in this study. These are the same as any risks involved with aerobic exercise that lasts for 40 minutes. These injuries include but are not limited to sprains and moderate fatigue.

There is possibility for breach of confidentiality if you choose to participate in this study. However, the data collected and the identity of the subjects will be securely stored and not be published so as to identify the individual subjects.

Oregon State University has no fund to pay for medical treatment of research related injuries. If you think you have been injured as a result of this study, please contact the researcher immediately.

·What are the benefits of this study?

You will not benefit from being in this study.

·Will I be paid for participation?

You will not be paid for participating in this research study. You may choose to keep the running pants used in this study.

·Who will see the information?

The data and information you provide during this research study will be kept confidential to the extent permitted by the law. If the results of this project are published your identity will not be made public.

·Do I have a choice to be in the study?

If you decide to take part in this study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at anytime during the study and still keep the benefits and rights you had before volunteering. If you choose to withdraw from the study, your benefits and membership with Dixon Recreation Center will not be affected. Participation in this study is in no way connected to your employment with Dixon Recreation Center. You will not be treated

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differently if you decide to stop taking part in the study. You are free to skip any questions that you would prefer not to answer. If you choose to withdraw from this project before it ends, the researchers may keep information collected about you and this information may be included on study reports.

<u>What if I have questions?</u>

If you have any questions about this research project, please contact: Dr. Kathy Mullet, at (541) 737-3818 or the Oregon State University Institutional Review Board (IRB) Office, at (541) 737-8008 or by email at IRB@oregonstate.edu.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant's Name (printed):

. . . .

. . . .

(Signature of Participant) (Date)

APPENDIX D PRE- TEST QUESTIONAIREE

Perceived Comfort in Apparel HHS- DHE Research Study:

Subjects General Information:

1.Name:_____

2. Gender:_____

3. Age:_____

4. Height:_____

5. Have you had any recent injuries:_____ If no, continue on to question 8.

6. If yes, have they been examined by a doctor?_____

7. If yes, do you have physician approval or permission to endure aerobic exercise?_____

Contact information

8. Email:_____

9. Cell phone:_____

10. Preferred Method of communication:_____

11. Best time to contact:_____

12. Best days/ times to participate in study:_____

APPENDIX E QUESTIONAIRRE

Perceived Comfort in Apparel- Fit assessment
Subject: _____
Treatment: _____
Date: _____
Visit #: _____

Questionnaire:
The following questions was asked twice, once before the exercise and once after.

Please rate perceptions of fit comfort on a scale from 0-11. Circle your answer.

1. How tight would you rate the pants?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Loose - Slightly loose - Not loose or tight Slightly tight Extremely Tight

2. How would you rate the chafing/ rubbing of the pants?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Not at all Slightly Somewhat Very Much Extremely

3. How would you rate the fit?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Poor Poor Acceptable Good Very Good

4. How comfortable does the waist fit feel?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Uncomfortable - Slightly Uncomfortable - Comfortable - Quite Comfortable - Extremely Comfortable

5. How comfortable does the crotch/ rise feel?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Uncomfortable - Slightly Uncomfortable - Comfortable - Quite Comfortable - Extremely Comfortable

6. How comfortable does the thigh area feel?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Uncomfortable - Slightly Uncomfortable - Comfortable - Quite Comfortable - Extremely Comfortable

7. How comfortable does the knee feel?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Uncomfortable - Slightly Uncomfortable - Comfortable - Quite Comfortable - Extremely Comfortable

8. How comfortable does the calf are feel?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Uncomfortable - Slightly Uncomfortable - Comfortable - Quite Comfortable - Extremely Comfortable

9. How comfortable does the ankle area feel?

0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Uncomfortable - Slightly Uncomfortable - Comfortable - Quite Comfortable - Extremely Comfortable

10. How comfortable is this garment?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------ 9 ---- 10 ----- 11
Very Uncomfortable - Slightly Uncomfortable - Comfortable - Quite Comfortable - Extremely Comfortable

Please rate perceptions of skin sensation on a scale from 0-11. Circle your answer.

11. Do you feel damp?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7------ 8------9 -------- 10 ----- 11
Not at all Slightly Somewhat Very Much Extremely

12. Do you feel prickly?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7------ 8------9 -------- 10 ----- 11
Not at all Slightly Somewhat Very Much Extremely

13. Do you feel clammy?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7------ 8------9 -------- 10 ----- 11
Not at all Slightly Somewhat Very Much Extremely

14. Do you feel sticky?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7------ 8------9 -------- 10 ----- 11
Not at all Slightly Somewhat Very Much Extremely

15. Do you feel itchy?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7------ 8------9 -------- 10 ----- 11
Not at all Slightly Somewhat Very Much Extremely

16.How would you describe the weight of the pants?
0 -----1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8------ 9--------10 ----- 11
Light Light Med. Medium Medium-Heavy Heavy

17.Do these pants feel breathable?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------9 --------- 10 ----- 11
Not at all Slightly Somewhat Very Much Extremely

Please rate perceptions of thermal comfort on a scale from 0-11

18. How would you rate your body temperature?
0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 ----- 6 ---- 7 ------ 8 ------9------- 10 ----- 11
Very cool Cool Average Hot Very Hot