DEVELOPMENT AND EVALUATION OF
A PROTOTYPE ATHLETIC
SPORTS GIRDLE

By

KATHLEEN M. WALDE

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SPORTS GIRDLE

Thesis Approved:

Donna H. Branson

Thesis Advisor

Peggy D. Fair

Cheryl Ann Farr-Popelka

Thomas C. Collins

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

The advent of protective items developed for football has made it possible for athletes in a variety of contact sports to have protection from muscle injuries in the quadriceps, gluteals, and hamstrings (Zylks,1989). This new protection involves wearing a sports girdle, a garment made of fabric that allows the garment to fit and perform in a fashion similar to that of bicycle pants. Bicycle pants were designed to act as a muscle conditioner and insulation to the body, helping athletes to warm up more quickly and maintain that temperature without overheating (Freedman, 1985). Athletic girdles offer additional protection with pockets for the insertion of thigh pads for use during football, basketball, or soccer (Zylks, 1989).

Sports medicine personnel (Cooper & Fair, 1976) at Oklahoma State University first developed the idea of this garment by modifying a woman's knee-length panty girdle to accommodate the physical structure of a football player. This modified garment was used to support the hamstrings, gluteals, and quadriceps. The panty girdle offered better support than elastic wraps, and became especially valuable for the rehabilitation of pulled hamstring muscles. The panty girdle was also used to protect against further injury in athletes who notice early twinges or light pulls in the hamstring.

Athletic girdles developed in recent years and manufactured by various athleticwear companies are proported to support the groin, hamstring, abdomen, and quadriceps. This is accomplished through the combination of design and fabric which offers benefits of flexibility, comfort, support, and steady uniform pressure to these muscle groups. Other proported benefits of the athletic girdle include its ability to fight fatigue by preventing vascular pooling (a decrease in blood circulation to the heart), decrease swelling which may occur from a blow or injury, and act as a second skin to help prevent abrasions (Manufacturer Information).

Justification

The prevention of injuries to the lower extremities such as abrasions, contusions, hematomas, and strains is of vital importance to coaches, trainers, and athletes in physical contact sports such as football. Each of these injuries can be severely debilitating to the athlete (Kulund, 1988).

Many studies indicate a higher rate of injury in late game or practice competition when muscles enter a state of general fatigue. This fatigue is caused by a reduced blood supply to muscle; fibers become devitalized and easily torn, leaving an individual susceptible to injury. Fatigue also reduces movement efficiency and performance, thus, an athlete becomes an easier target in contact sports and may place himself or herself in a mechanically unsound position when contact occurs (Unitas & Dintiman, 1979).

The National Sports Injury Surveillance System collected data during the 1986 football season regarding injuries to both high school and collegiate football players. Injuries were classified by anatomical part, with injuries to the knee by far the most frequent, followed by ankle, shoulder, quadriceps muscle group, head, neck, hamstring, lower back, fingers, pelvis-hip, and lower-leg. Sprained ligaments account for nearly one third of these injuries, followed by strained muscle, contusion, fracture, concussion, ligament rupture, nerve injury, and torn cartilage. Of all players, 32.1 percent were injured at least once per season and there was an average of four lost days as a result of the injury. Surgical repair was required for 8.5 percent of the injuries and 8.3 percent of the injuries removed the player from competition for the remainder of the season (Zemper, 1989).

A study of high school football injuries in the chapel Hill, North Carolina area by Blyth and Mueller (1974) found that 46 percent of all injuries to high school football players were injuries to the lower extremity; 24 percent to the upper extremity; 13 percent to the head and neck; and less than 1 percent internal.

Background Information

Interest in athletic girdles began in the spring of 1991 during a functional design class during which the researcher investigated various characteristics of athletic girdles currently being used by athletes at Oklahoma State University. Informal interviews conducted with various coaches, equipment managers, and athletes identified critical problems with the girdles currently available. It became apparent that although several types of girdles are available to athletes, functional problems regarding comfort and fit had been noticed during wear. After considering information obtained through market analysis, user interview, survey analysis, and fabric testing, two alternative designs were developed to provide a more comfortable garment that would assist in maximum performance. This project stimulated the author's interest in pursuing the influence of comfort on athletic performance.

The concept of clothing comfort is defined by Branson and Sweeney (1991) as: "a state of satisfaction indicating physiological, social-psychological and physical balance among the person, his/her clothing, and his/her environment". It is expected by the researcher that clothing comfort will have some influence on athletic performance.

Purpose

The purpose of this study was to determine athletes' comfort and athletic performance while wearing a prototype athletic girdle, a girdle currently being used by the university football team, and a non-girdle. Also, the relationship that exists between comfort and performance was investigated.

Objectives of the Study

Specifically, the study determined:

1. the athlete's thigh circumference measurements prior to and following a specific exercise protocol while wearing each of the three garment treatments.
2. skin temperature over the athlete's hamstrings, quadriceps, hamstrings, and gluteals while wearing each of the three garment treatments.
3. comfort perceptions of the athlete while wearing each of the three garment treatments.
4. the athlete's athletic performance while wearing each of the three garment treatments.
5. the relationship between comfort perceptions and athletic performance of the athlete while wearing each of the three garment treatments.

Hypotheses

Ho1A: There will be no significant difference between pre- and post-circumference measurements of the upper thigh.

Ho1B: There will be no significant difference between pre- and post-circumference measurements of the upper thigh by garment treatment.

Ho2: There will be no significant difference in skin temperature by garment treatment.

Ho3: There will be no significant difference in percieved comfort by garment treatment.

Ho4: There will be no significant difference in athletic performance by garment treatment.

Ho5: There will by no significant relationship between athletic performance and perceived comfort by garment treatment.

Limitations of the Study

1) The number of subjects will be limited to six male athletes on a volunteer basis only.

2) The testing will be administered at the Oklahoma State University Sports Medicine Department because of the location of the testing equipment, thus limiting regulation of environmental conditions.

CHAPTER II

LITERATURE REVIEW

This chapter is organized into three major subdivisions. The first section investigates aspects of athletic performance. Following this are sections dealing with clothing and athletic equipment respectively.

Athletic Performance

The elite athlete is a specimen of mankind that is unique in many ways from the rest of us, and whose goal is to perform at the very highest possible level (Zarins, 1985). The athletes of today run and swim faster, throw further, and jump higher than their counterparts of the past. In determining the quality of athletic performance, the components of physical characteristics, ability, and skill, are significant (Smith, 1983).

Physical Characteristics of Athletes

In recent years much attention has been given to those quantitative factors that may distinguish the elite athlete from their less successful counterparts. Some of the most common comparisons often made between athletes and nonathletes has dealt with physique including height and weight, percent of body fat, aerobic power and anaerobic power, and muscle fiber characteristics (Butts, 1985).

<u>Height and Weight</u>

Average heights and weight obtained for groups of female and male elite athletes show that with the exception of volleyball players, rowers, and throwers, the majority of the male athletes are in the middle or average range for height. In contrast, the height of the majority of the female athletes tend to be skewed to the taller end of the spectrum. The total body weights of the athletes, excluding the exceptionally tall groups, appear to be below that of the values reported for the comparison male and female groups of similar ages (Butts, 1985).

<u>Body Fat</u>

Numerous studies have been completed to characterize the relative fat (% body fat) of various groups of athletes. The relative fat of champion athletes is used as a rough guideline for the amount of fat athletes should be expected to carry for the greatest likelihood of success in a given event. For example, good distance runners often have a low percentage of body fat; to carry more fat than necessary will deter performance in distance running and in many other sports where moving the body mass requires a significant expenditure (Lamb,1984).

<u>Aerobic Power</u>

Aerobic power (VO2 max) is defined as the maximal volume of oxygen consumed per unit of time. It is also known as maximal oxygen uptake or maximal oxygen consumption (Lamb, 1984). It has been suggested that to be successful in world competition, endurance athletes must have relatively high VO2max values, but having a high VO2max does not, in itself, predict success among elite athletes (Butts, 1985; Pollock, 1977). In activities such as volleyball, basketball, etc., factors other than cardiorespiratory endurance appear to be more related to success. Some of these factors may include anaerobic power, experience, training, skill, and innate ability, among others (Butts, 1985).

<u>Anaerobic Power</u>

The basic concept of anaerobic power is that during high intensity exercise, a sizeable portion of the energy expended comes from metabolic processes that do not require an immediate consumption of oxygen. For an exercise that requires an energy consumption that is less than maximal, there exists in the early stages of the metabolic adjustment to exercise a delay in the rate of rise in VO2, such that a portion of the energy is derived from "oxygen deficit" mechanisms (Saltin et. al., 1986).

Muscle Characteristics

Finally, muscle fiber characteristics and distribution is a factor in identifying the elite athlete. Human skeletal muscle fibers may be categorized as either fast twitch (FT) or slow twitch (ST). Fast twitch fibers are particularly well adapted for speed and power activities because they contract rapidly. In contrast, ST fibers contract more slowly but are quite fatigue resistant because they possess a well-developed aerobic capability. Individuals vary greatly in the relative distribution of FT and ST fibers. Generally persons who inherit a high percentage of ST fibers possess a greater potential for performing endurance activities. Those who inherit a high percentage of FT fibers are better adapted to high-power activities (Kuland, 1988).

Evaluating Physical Abilities

Athletic evaluation consists of investigating muscle strength, power, and endurance; speed; agility; flexibility; and cardiovascular endurance. For athletes of high school age, athletic evaluation is a good indicator of future potential. Evaluation can consist of simple field tests which measure specific tasks. Some examples include the 50 yard run as a test for speed, the standing long jump as a test of muscle power, and sit-ups for one minute as a test of muscle endurance, along with several others (Smith, 1983).

Muscle Strength

Muscle strength is defined as the maximum force exerted by a group of muscles, and is determined by the size of involved muscles, their chemical characteristics, and the nervous input to the muscle fibers (Smith, 1983). Without muscular contraction, there can be no movement. Muscular contractions may be static, isotonic, or isokinetic (Lamb, 1984).

A static contraction is one in which minimal muscle fiber shortening produces force with no change in the angle of a joint. Isotonic contractions result from muscle fiber shortening that causes a joint to move through some range of motion against a constant resistance. Isokinetic contractions occur as muscle fibers shorten to counteract an "accommodating" resistance developed by a device that allows only a constant rate of movement regardless of the force exerted by contracting muscle throughout the range of motion Lamb, 1984).

Jensen and Fisher (1979) explain that in addition to being an important trait by itself, muscle strength is an element in several other performance traits. Muscle strength is a contributor to muscle power, muscle endurance and agility.

Jensen and Fisher (1979) also state that in addition to its importance in athletic performance, muscular strength is critical in protecting athletes from injury. Strong muscles enable an athlete to move quickly and avoid accidents, while increasing joint stability.

Muscle Power

Muscle power is the combination of speed and muscle strength, or the ability to exert a large force rapidly. Muscle power is an extremely important characteristic for success in any sport. It allows the athlete to start quickly, change direction rapidly, and jump high. Muscle power appears to be specific to the athletic event; a powerful football lineman may not have a powerful tennis serve or be able to hit a long ball on the golf course (Smith, 1983).

Muscle Endurance

Local muscle endurance is the capacity to perform repeated muscle contractions without limiting fatigue (Smith, 1983). A high level of endurance implies that a given level of performance can be continued for a relatively long time. Increased endurance postpones the onset of fatigue. The definition of endurance may apply to the body as a whole, to a particular body system, or to a local area of the muscle system (Jensen & Fisher, 1979).

Muscular endurance is dependent upon 1) the quality of muscles, 2) the extensiveness of their capillary beds, and 3) the nerve mechanisms supplying them. There are three potential sites of muscular fatigue: 1) the synapses in the central nervous system, 2) the myoneural junction, and 3) the muscle tissue. The best available evidence points to the muscle tissue itself as the site of potential fatigue (Jensen & Fisher, 1979).

Speed

Smith (1983) defines speed as the ability to move the body or any one of its parts rapidly. Because speed is directly related to muscle power, it is essential for athletes who are involved in running, jumping, throwing, or striking. How fast the athlete can run or move depends on several factors, most of which are genetically determined: characteristics of the nervous system (how many muscle fibers for each nerve ending), the arrangement of bones and the attachment of bones by ligaments and tendons, and adequate muscle strength. Speed primarily depends on the muscle's fiber type, however.

Agility

Agility refers to the maneuverability of the individual, or the ability to shift the direction of movement rapidly, without loss of balance or sense of position. Agility is a combination of speed, strength, quick reactions, balance, and coordination, and can refer to the total body or to a specific part. Agility reflects the ability of athletes to perform with a smooth, balance, and fluid motion (Smith, 1983).

Cardiovascular Endurance

Cardiovascular endurance refers to the ability of the whole body to sustain prolonged rhythmic exercise. Maximum oxygen uptake (VO2max) is regarded by most as the best single measure of cardiovascular fitness (Smith, 1983). The higher the VO2max, the greater is the rate at which work may be done over extended periods and the longer the work may be done at any submaximal intensity (Kulund, 1988). A major role of the cardiovascular system during exercise is the transport of more oxygen to the exercising muscles as the work load increases. This function is achieved not only by increasing the volume of blood pumped by the heart each minute but also by the redistribution of the blood so that flow is increased to active tissues such as skeletal and cardiac muscle and decreased in the splanchnic region and kidneys (Bar Or & Buskirk, 1980).

Flexibility

Flexibility is defined as the range of movement of a specific joint or group of joints influenced by associated bones and bony structures and the physiological characteristics of muscles, ligaments, tendons, and other collagenous tissues surrounding the joint (Arnheim, 1989). Flexibility depends in part on the structure and alignment of bones and joints and in part on the amount of muscle and fat tissue that may restrict movement (Smith, 1983). Good flexibility usually indicates that there are no adhesions or abnormalities present in or around the joints and no serious muscular limitations. This allows the body to move freely and easily through the full range-of-joint flexion and extension without any unnecessary restrictions in the joints or adjacent tissues (Arnheim, 1989).

Athletic Skill

Skill is the ability to perform a specific task efficiently. Effective performance requires sufficient amounts of several physiological traits, such as strength, speed, endurance, agility, and flexibility, but athletes possessing lesser amounts of these traits often outperform their stronger and faster opponents because of well-coordinated neuromuscular patterns (Jensen & Fisher, 1979). The development of athletic skill depends somewhat on heredity but mainly on many years of repetitive practice (Smith, 1983). Successful participation in athletic activities requires training, which might be described as the systematic participation in physical exercise for the purpose of improving performance in an athletic activity (Kulund, 1988).

Additional Considerations

Suppression of fatigue and pain become increasingly important as task demands require greater effort or duration. Athletes frequently report feelings of well-being and an absence of fatigue and pain even under strenuous conditions of competition resulting in bodily injury (Fobes, 1989; Henry, 1982). Fatigue and pain, however, may work to prevent an athlete from reaching peak performance levels.

While the human is an example of a regulating organism that is able to maintain a relatively constant internal temperature when exposed to a wide range of environmental conditions, in order to maintain thermal equilibrium, the body must quantitatively balance physical avenues of heat exchange in relation to metabolic heat production and environmental stressors. With exposure to higher environmental temperatures, physiological mechanisms that aid the dissipation of body heat come into action. When performing strenuous exercise under climatic conditions that prevent the almost-immediate loss of body heat or that add an external heat load, it is obvious that normal body temperature will rapidly rise above normal levels (Haymes & Wells 1986).

Haymes and Wells (1986) explain that the more stressful the environment, the less blood available for the muscles. This is due to the increased blood supply to the skin and subcutaneous tissues, which means less oxygen, less substrate, and less removal of metabolic waste products from the muscles. The person who is less cardiovascularly fit will first experience the sensation of heavy limbs, then extreme fatigue, dizziness, nausea, tunnel vision, and finally collapse. The more cardiovascularly fit individual will be better able to supply blood to the muscles as well as to the cutaneous layers. In addition, highly trained subjects have an earlier onset of sweating and a heightened sweating response.

Clothing

While the human body is striving to maintain a constant body temperature, clothing interacts with some methods of heat exchange and the thermoregulatory system of the body (Mecheels & Umback, 1977). During heavy exercise in extreme heat, individuals become dependent on the evaporation of sweat for the cooling required to dissipate heat production. The ability of fabric to transport moisture to the environment is vitally important, with several physical properties pertaining to moisture transport that may be considered. These include the following as described by Latta (1977):

1) wettability, or the rate at which liquid moisture applied to a fabric surface is absorbed;

2) wicking, or the rate at which absorbed moisture is dispersed over fabric volume;

3) moisture regain, defined as the amount of water vapor that can be absorbed by fibers.

4) moisture content, or the total water held by a fabric;

5) water vapor permeability, or the rate of passage of water vapor through the construction of a fabric;

6) drying rate, or the rate of evaporation of liquid water from a wet fabric.

Recent trends towards functional sport clothing have used "comfort" as the criterion for development (Buskirk & Bass, 1980). Fabrics have been engineered that provide improved comfort through the modification of fiber polymers, and the differentiation of yarns, blends, and fabric constructions (Thomas, 1990). Fabric technologies have achieved breathability (the diffusion of evaporating sweat through the fabric) in one of two ways: mechanically with hundred of micropores through which the vapor passes, or molecularly through hydrophilic (water-loving) hydrogen groups on the polymer chain that transport water molecules through the fabric (Reagan, 1990).

Athletic Equipment

The problem of heat loss during physical performance is of great concern to both athletes and coaches. The rapid resynthesization of lactic acid and the removal of metabolic heat are critical in the athlete's ability to maintain a high level of mechanical efficiency without undue fatigue throughout an endurance competition. This problem becomes complicated when the performance and recovery is conducted in an environment of high temperature and humidity for long periods of time. The complications increase when protective gear and clothing further reduce heat loss (Cooter, Cundiff, & Courtney, 1975).

Certain pieces of specialized equipment, such as that worn in football, have not been designed with thermal comfort in mind. Many of the items of football "armor" including shoulder pads, rib pads, hip pads, etc., cover areas of the body where considerable evaporative heat loss normally occurs. Since these items are relatively vapor impermeable, they impose a formidable barrier for evaporative cooling. This barrier is supplemented by helmet, jerseys, pants, stockings, shoes, and other items. In addition, these items promote a higher level of metabolic activity, because their weight adds to the player's work load (Buskirk & Bass, 1980).

A study by Teitlebaum & Goldman (1972) demonstrated that multiple-layer clothing systems produced a 16 percent increase in total energy cost. This was attributed to "friction drag" between layers (i.e. the frictional resistance as one layer of material slides over another during movement) and/or a "hobbling" effect of the clothing (i.e., interference with movement at the body joints, produced by the bulk of the clothing).

Fox, Mathews, Kaufman, & Bowers (1964) investigated effects of football equipment on thermal balance and energy cost during exercise. Central core temperature, energy cost, and pulmonary ventilation, heart rate, and sweat loss were measured on five football players while exercising on a motor driven treadmill at 6 mph for 20 minutes. Comparisons were made while subjects wore a football uniform and an hospital scrub suit.

Core temperature, sweat loss, and peak exercise and end recovery heart rates while running in the uniform were significantly elevated compared to the scrub suit controls. Energy cost and pulmonary ventilation were greater in the uniform primarily because of added weight, and to the reduction in available evaporative surface area (Fox, Mathews, Kaufman, & Bowers, 1964).

Mathews, Fox, & Tanzi (1969) investigated physiological responses during exercise and recovery in a football uniform. Results showed that working in a football uniform, even under mild environmental conditions, significantly retards metabolic heat loss. This resulted in marked elevations in rectal temperature, skin temperature, heart rate, and weight loss, as well as alterations in other cardiorespiratory variables.

Mathews, Fox, & Tanzi (1969) further demonstrated that these results are attributable, in part, to an increase in heat production due to the weight of the uniform, but more importantly to a marked decrease in heat dissipation through vaporization of sweat. This was due to a reduction in exposed evaporative surface area.

CHAPTER III

METHODOLOGY

Subjects

Six male subjects were recruited from the Oklahoma State University coaching staff on a voluntary basis. All subjects were ex-athletes in good physical condition and were assumed to be capable of performing maximal physical output. Individuals meeting any of the following criteria were eliminated: those with a history of any cardiac or vascular disorder, stomach or intestinal disorder, high blood pressure (> 140/90 mm/Hg), high resting HR (> 110), currently on medication, or currently ill. This is consistent with a study by Weber (1990). The nature of the experiment was explained to the subjects, and those volunteers who meet the criteria for the experiment were asked to sign an informed consent form (see Appendix A). Approval for all experimental procedures was obtained from the University Institutional Review Board (IRB).

Independent Variables

Three garment treatments were used in the testing procedures. These were: (see appendix C) garment A (athletic shorts : 50% polyester/50% cotton), garment B (girdle prototype with two different fabrics; fabric A: 87% nylon, 13% spandex, fabric B: 85% nylon, 15% spandex with a specialized finish to promote thermal comfort), and garment C (athletic girdle: 92% polyester, 8% spandex). The cross-section of the nylon fiber in fabric A has been developed to promote wicking.

Testing Protocol

Testing was completed at the Oklahoma State University Sports Medicine Department. Prior to testing, the subjects were requested to abstain from strenuous exercise for 48 hours to prevent muscular fatigue. The subjects were also phoned prior to the testing date to ensure attendance. While age, height, and weight was not controlled, it was documented during the initial testing procedure. The testing procedure consisted of a comfort/performance protocol designed to simulate normal wearing conditions of a physical conditioning session while wearing each of the three garment treatments. A Latin Square Repeated Measures experimental design was used.

The subjects were changed into an unidentified garment treatment and were asked to perform a brief 4-minute warmup program on a motor-driven Stairmaster vertical climbing machine, which provided an aerobic workout equivalent to climbing stairs. The machine was set at level 6, equivalent to approximately 40 steps per minute. This warmup was conducted in order to: 1) contribute to greater oxygen consumption, 2) contribute to a increased flow in the vascular beds of the working muscles 3) increase body temperature and induce sweating 4) assist in preventing muscle injury (Jensen & Fisher, 1979). Next, the subjects were asked to perform an 8-minute exercise program on the Stairmaster at level 9, equivalent to approximately 70 steps per minute. This was done to bring subjects to between 60% and 80% of their maximal aerobic capacity and induce moderate to heavy sweating (Jensen & Fisher, 1979). Heart rate of the subjects was monitored by an Oklahoma certified aerobic instructor, with the Oklahoma State University Athletic Department athletic trainer on site. The researcher recorded heart rate at four minute intervals throughout the entire testing protocol.

Following this exercise program, the subjects were asked to perform at maximal level for four minutes. The subjects were asked to manually control the Stairmaster climbing machine to adjust to their preferred level of maximal output. At the end of this period, a brief 4-minute cooldown (again at level 6) was performed to allow the venous pump to continue to work in the legs until the need for blood decreases and the heart can take care of the load by itself. This cooldown was also done to help the muscles rid themselves of the waste products of metabolism more effectively (Jensen & Fisher, 1979). The complete comfort/performance protocol was completed for each of the three garment treatments. A minimum rest period of 48 hours between tests was required to allow proper recuperation of the subjects.

Dependent Variables

The following dependent variables were measured during the exercise protocol. Skin temperature of the quadriceps, hamstrings, and gluteals were recorded with the use of YSI surface thermistors at one minute intervals during the (1) 4-minute warmup period, (2) 8-minute exercise program, (3) 4-minute performance program, and (4) 4-minute cooldown. The researcher questioned the subjects on perceived comfort of each of the garments using a modified version of the Hollies (1977) subjective comfort rating chart (see Appendix B). This rating chart was modified by adding a fifth response category (not at all) to the 1 (totally) to 4 (partially) response scale, and one comfort descriptor was eliminated (picky). This was done once during the warmup, twice during the standard exercise program, once during the maximal performance program, and once during the cool-down.

The researcher also recorded calories burned, floors climbed, and miles climbed at the completion of the exercise program. These data were recorded at the conclusion of each exercise program from the Stairmaster electronic display monitor. Finally, pre- and post- circumference measurements of the right thigh of each subject were recorded using a Limb Accurate Measurement device (L.A.M.) at 8 inches above the superior crest of the patella. This test was completed for each of the specified garment treatments.

CHAPTER IV

MANUSCRIPT I

Development and Evaluation of a Prototype Athletic Sports Girdle

Kathleen M. Walde
Department of Design, Housing, and Merchandising
Oklahoma State University
Stillwater, Oklahoma 74078-0337, U. S. A.

ABSTRACT

The prevention of injuries to the lower extremities is of vital importance to those involved in physical contact sports. Athletic girdles have been developed by various manufacturers who claim that the girdle supports the groin, hamstring, and quadriceps muscle groups via application of steady uniform pressure. The girdle also acts as a muscle conditioner and insulation to the body helping the athletes to warm up quickly and maintain that temperature without overheating. Because of these properties, the girdles are proported to fight muscle fatigue. This study investigated athletes' comfort perceptions and athletic performance while wearing a prototype girdle, a girdle currently being used by the university football team, and a non-girdle. Both girdles maintained a higher skin temperature during exercise and cool down than the non-girdle. The prototype was rated more favorably than the other girdle for several of the comfort descriptors. No significant difference in athletic performance between garment treatments was found.

Development and Evaluation of a Prototype Athletic Sports Girdle

The prevention of injuries to the lower extremities such as abrasions, contusions, hematomas, and strains is of vital importance to coaches, trainers, and athletes in physical contact sports such as football. Each of these injuries can be severely debilitating to the athlete (Kulund, 1988). The National Sports Injury Surveillance System collected data during the 1986 football season regarding injuries to both high school and collegiate football players. Injuries were classified by anatomical part, with injuries to the knee by far the most frequent, followed by ankle, shoulder, quadriceps muscle group, head, neck, hamstring, lower back, fingers, pelvis-hip, and lower-leg. Sprained ligaments account for nearly one third of these injuries, followed by strained muscle, contusion, fracture, concussion, ligament rupture, nerve injury, and torn cartilage (Zemper, 1989).

Many studies indicate a higher rate of injury in late game or practice competition when muscles enter a state of general fatigue. This fatigue is caused by a reduced blood supply to muscle; fibers become devitalized and easily torn, leaving an individual susceptible to injury. Fatigue also reduces movement efficiency and performance, thus, an athlete becomes an easier target in contact sports and may place himself or herself in a mechanically unsound position when contact occurs (Unitas and Dintiman, 1979).

The advent of protective items developed for football has made it possible for athletes in a variety of contact sports to have protection from muscle injuries, particularly to the quadriceps, gluteals, and hamstrings (Zylks, 1989). Sports medicine personnel (Cooper and Fair, 1976) at Oklahoma State University first developed the idea of a sports girdle by modifying a woman's knee-length panty girdle to accommodate the physical structure of a football player. This modified garment improved support for the hamstrings, gluteals, and quadriceps in comparison to elastic wraps. The girdle was also used to protect against injury in athletes who notice early twinges or light pulls in the hamstring, and was especially valuable in the rehabilitation of pulled hamstring muscles.

Today athletic girdles are manufactured by various athletic-wear companies who claim their girdle supports the groin, hamstring, abdomen, and quadriceps. This is proportedly accomplished through the combination of design and fabric which offers benefits of flexibility, comfort, and steady uniform pressure to these muscle groups. Other proported benefits include its ability to fight fatigue by preventing vascular pooling, decrease swelling which may occur from a blow or injury, act as a second skin to help prevent abrasions, and help prevent muscle pulls and strains (particularly to the hamstrings) by warming up the muscles more quickly and maintaining that temperature for a longer period of time.

Recently manufacturers have emphasized "comfort" in the development of new pieces of specialized athletic clothing and equipment. Fabrics have been engineered that provide improved comfort through the modification of fiber polymers and the differentiation of yarns, blends, and fabric constructions (Thomas, 1990). Fabric technologies have achieved breathability (the diffusion of evaporating sweat through fabric) in one of two ways: mechanically with hundred of micropores through which the vapor passes, or molecularly through hydrophilic (water-loving) hydrogen groups on the polymer chain that transport water molecules through the fabric (Reagan, 1990).

The problem of heat loss during physical performance is of great concern to both athletes and coaches. The rapid resynthesization of lactic acid and the removal of metabolic heat are critical in the athlete's ability to maintain a high level of mechanical efficiency without undue fatigue throughout an endurance competition. This problem becomes complicated when the performance and recovery is conducted in an environment of high temperature and humidity for long periods of time. The complications increase when protective gear and clothing further reduce heat loss (Cooter, Cundiff, and Courtney, 1975). In addition, these items promote a higher level of metabolic activity because their weight adds to the player's work load and may prevent an athlete from reaching peak performance levels (Buskirk and Bass, 1980).

Prototype Development

In the spring of 1991 the researcher investigated various characteristics of athletic girdles currently being used by athletes at Oklahoma State University. Informal interviews conducted with various coaches, equipment managers, and athletes identified critical problems with the girdles currently available. It became apparent that although several types of girdles are available to athletes, functional problems regarding comfort and fit had been noticed during wear. Some of the most significant as stated by the athletes included the abrasiveness of the fabric on the inner thigh and groin area, the inability of the waistband to stay in the proper position, and the tightness of the garment in the thigh area, particularly after a workout. After considering this information, the author developed two alternative designs. The evaluation of one of these alternatives is the focus of the present research.

The prototype design that was chosen for the focus of the present research remained similar to the girdle currently available to athletes with some changes in design and fabric. An 85% nylon/15% spandex fabric with a specialized finish chemically processed to promote thermal comfort was used as the foundation fabric for the prototype. An 87% nylon/13% spandex fabric (the cross-section of the nylon was engineered to promote wicking), was used in panels in the groin and inner thigh areas. Textile selections were based on results of textile performance testing of candidate materials such as ASTM D 388-80 for abrasion behavior, AATCC 153-78 for dimensional behavior, colorfastness to laundering, and moisture behavior.

Some structural design features included raising the back length of the short approximately one inch higher than the original girdle and adding a drawstring to the waist to allow for a more snug fit. Pockets for hip pads were eliminated since these protective items are usually now worn in playing pants due to the girdle's inability to keep them in the proper hitting position. Thigh pad pockets were kept in the design of the girdle. Finally, the panels of the girdle were placed along different grainlines (lenthwise and crosswise) to achieve the greatest amount of stretch needed in each area, and all seams were finished on the interior to decrease abrasion.

Purpose

The purpose of this study was to determine athletes' comfort and athletic performance while wearing a prototype athletic girdle, a girdle currently used by the university football team, and a non-girdle. Specifically, the objectives were to determine 1) the athlete's thigh circumference measurements prior to and following a specific exercise protocol while wearing each of the three garment treatments, 2) skin temperature over the athlete's hamstrings, quadriceps, and gluteals while wearing each of the three garment treatments, 3) comfort perceptions of the athlete while wearing each of the three garment treatments, 4) the athlete's athletic performance while wearing each of the three garment treatments and 5) the relationship between comfort perceptions and athletic performance of the athlete while wearing each of the three garment treatments.

Methods and Procedures

Subjects

Six male subjects were recruited from the university coaching staff on a voluntary basis. All subjects were ex-athletes in good physical condition and were assumed to be capable of performing maximal physical output. Individuals meeting any of the following criteria were eliminated: those with a history of any cardiac or vascular disorder, stomach or intestinal disorder, high blood pressure (> 140/90 mm/Hg), high resting HR (> 110), currently on medication, or currently ill. This is consistent with a study by Weber (1990). The nature of the experiment was explained to the subjects, and those volunteers who met the criteria for the experiment were asked to sign an informed consent form.

Independent Variables

Three garment treatments were used in the test sessions. These were (see Figure 1): garment A (athletic shorts: 50% polyester/50%cotton), garment B (girdle prototype with two different fabrics; fabric A: 87% nylon, 13% spandex; fabric B: 85% nylon, 15%) and garment C (athletic girdle: 92% polyester, 8% spandex).

Dependent Variables

The following dependent variables were measured during the test session. Skin temperature over the quadriceps, hamstrings, and gluteals was recorded with the use of YSI surface thermistors at 1-minute intervals during the entire exercise protocol. Perceived comfort was assessed using a modified version of the Hollies (1977) subjective comfort rating chart. This rating chart was modified by adding a fifth response category (not at all) to the 1 (totally) to 4 (partially) response scale, and one comfort descriptor (picky) was eliminated. Subjects responded orally to each descriptor and the researcher recorded the responses at 5-minute intervals. Calories burned, floors climbed, and miles climbed constituted athletic performance measures. These data were recorded at the conclusion of each exercise program from the Stairmaster electronic display monitor. Pre- and post-circumference measurements of the right thigh of each subject were recorded using a Limb Accurate Measurement device (L.A.M.) at 8 inches above the superior crest of the patella.

<u>Testing Protocol</u>

Testing was completed at the Oklahoma State University Sports Medicine facility. Prior to testing, subjects were requested to abstain from strenuous exercise for 48 hours to prevent muscular fatigue. Subjects were also phoned prior to the testing date to ensure attendance. While age, height, and weight were not controlled, these data were obtained at the initial interview, and weight was recorded at each testing session. The testing procedure consisted of a comfort/performance protocol designed to simulate a normal physical conditioning session. A Latin Square Repeated Measures experimental design was used.

Subjects changed into the garment treatment and pre-circumference measurements of the right thigh were recorded. Thermistors were placed on the quadriceps, hamstrings, and gluteals to record skin temperature. The subjects were then asked to perform a brief 4-minute warmup program on a motor-driven Stairmaster vertical climbing machine, that provided an aerobic workout equivalent to climbing stairs. The machine was set at level 6, equivalent to approximately 40 steps per minute. This warmup was conducted in order to: 1) contribute to greater oxygen consumption, 2) contribute to a increased flow in the vascular beds of the working muscles 3) increase body temperature and induce sweating 4) assist in preventing muscle injury (Jensen and Fisher, 1979). Next, the subjects were asked to perform an 8-minute exercise program on the Stairmaster at level 9, equivalent to approximately 70 steps per minute. This was done to bring subjects to between 60% and 80% of their maximal aerobic capacity and to induce moderate to heavy sweating (Jensen and Fisher, 1979). Heart rate of the subjects was monitored by a certified aerobic instructor and recorded by the researcher at 5-minute intervals.

Following this exercise program, subjects were asked to perform at maximal level for four minutes. The subjects were asked to manually control the Stairmaster climbing machine to adjust to their preferred level of maximal output. At the end of this period, a brief 4-minute cool-down (again at level 6) was performed. This allowed the venous pump to continue to work in the legs until the need for blood decreased and the heart could take care of the load by itself. This cooldown was also done to help the muscles rid themselves of the waste products of metabolism more effectively (Jensen and Fisher, 1979). Lastly, post-circumference measurements were taken of the right thigh.

Results and Discussion

Muscle Circumference

A paired T-test for the difference between pre- and post- circumference measurements showed that a significant increase in muscle circumference of the upper thigh occurred over the experiment regardless of the garment treatment (see Table 1). Analysis of Variance tests for mean difference results showed a significant difference by subject but not garment treatment (see Table 2).

The significant increase in muscle circumference of the upper thigh may have occurred due to an increase in blood volume in those working muscles. An increase in physical activity, such as in an intense exercise program, causes certain changes in the rate and volume of blood that may flow to surface vessels. As a result of this increase in volume, vessel expansion or vasodilation takes place (Watkins, 1984). This finding substantiated fit problems of the girdle following an intense workout as previously described by the athletes interviewed.

Skin Temperature

Results of analysis of variance for skin temperature (see Tables 3-5) indicated a significant subject effect for temperature site one but not for temperature site two or three. Also, a significant garment effect was found for temperature site two but not for sites one or three. It is important to note that both the prototype and the girdle kept the skin temperature over the hamstrings significantly higher throughout the course of the exercise protocol than the shorts did for this muscle (see Figure 3). This indicates that while the gluteals and quadriceps may

Figure 3 About Here

stay warm over a period of time without the assistance of a girdle, the hamstrings can be protected more effectively with this garment through its ability to maintain heat. This is particularly important since injuries to the hamstrings are the most the most frequent and debilitating types of injuries an athlete can sustain. Inadequate warm-up and fatigue are two of the major causes of injuries to the hamstrings (Cooper & Fair, 1978).

A significant time effect for all three muscle sites was found. This indicates that there was a change in skin temperature over the course of the exercise protocol for all three muscle sites regardless of the garment treatment. Skin temperature over muscle site ones (quadriceps) and three (gluteals) increased over time regardless of the garment treatment (see Figures 2 & 4).

Figures 2 & 4 about here

Skin temperature over muscle site two (hamstrings) increased over time while the subjects were wearing garments B and C, but decreased over time while wearing garment A (see Figure 3). It should also be noted that both girdle maintained a higher skin temperature than garment A (shorts) during exercise and cool-down for all three muscle sites. Garment C maintained the highest temperature with a mean temperature of 31.79 degrees celsius, followed by garment B with a mean temperature of 31.08 degrees celsius, and finally garment A with a mean temperature of 30.66 degrees celsius. Although the prototype did not keep the skin temperature over the muscles as warm as the other girdle, it did maintain a higher skin temperature than the athletic shorts. This could well be due to the fabrics used in the prototype which were designed to promote thermal comfort.

Figure 3 helps to explain the significant garment by time interaction for temperature site two. In this instance, the temperature over the hamstrings decreased while subjects were wearing garment A (athletic shorts). In contrast, skin temperature over the hamstrings increased while subjects were wearing garments B (prototype) and C (girdle). An explanation for this finding is that both the girdle and the prototype were impairing the body's heat loss mechanisms by reducing the amount of evaporative surface of the skin. This explanation is in agreement with a study by Cooter, Cundiff, and Courtney (1975). On the other hand, the loose nature of the shorts allowed air to circulate around the body, thus allowing evaporation to take place on the skin surface, where it provides the most effective cooling (Watkins, 1984).

Comfort Analysis

Results of analysis of variance for perceived comfort indicated a significant garment effect for 7 of the 14 comfort ballot descriptors: snug, loose, heavy, stiff, clingy, rough, and scratchy (see Table 6). Garment A was rated as the least snug, heavy, staticky, sticky, stiff, clingy, rough, and scratchy of the three garment treatments. Garment A was also rated as the most loose of the three garment treatments. Garment C was rated as the most snug, stiff, staticky, sticky, clingy, rough, and scratchy of the three garment treatments. Garment B was rated as the least nonabsorbent, cold, clammy, and damp. Compared to garment C, garment B was rated less snug, stiff, staticky, sticky, clingy, rough, and scratchy (see Table 6). Overall, the prototype rated more favorably for 11 of the 14 comfort descriptors than the girdle.

There was a significant time effect for eight of the comfort descriptors : lightweight, staticky, cold, clammy, nonabsorbent, clingy, sticky, and damp (see Table 6). For the descriptor lightweight and staticky, there was a slight change in the intensity over the course of the exercise protocol for all three garment treatments with no apparent pattern. There was an increase in the intensity of perceived nonabsorbancy, coldness, clamminess, dampness, and stickiness regardless of garment treatment. This may be explained by the moderate to heavy sweating of the subjects that occurred over the course of the exercise protocol. A slight increase in the intensity of perceived clinginess was also observed for all three garment treatments. This was most likely due to the change in the subjects' pre- and post-circumference measurements of the thigh.

<u>Athletic Performance</u>

Analysis of variance results indicated a significant difference ($p < .05$) by subject but not garment treatment for all of the athletic performance measures. These measures were calories burned, floors climbed, and miles climbed. This indicates that although there may have been a difference between subjects in performance measures, the measures were similar for all three garment treatments.

Clothing Comfort and Athletic Performance

A step-wise regression analysis was performed to examine the impact of the comfort descriptors on the performance variables for each garment. For the performance measure "calories", the best model found was the following with $R^2 = .61$.

Garment A:

$$\text{Calories} = 326.95 - 3.01(X1) + 1.86\ (X2) - 13.32\ (X3) + 3.99\ (X4) + 3.65\ (X5)$$

where X1 = scratchy, X2 = clammy, X3 = stiff, X4 = loose, X5 = snug

Garment B:

$$\text{Calories} = 326.95 + 8.03\ (X1) - 6.60\ (X2) + 2.28\ (X3)\quad 3.99\ (X4) - 12.06\ (X5) - 17.94\ (X6)$$

where X1 = scratchy, X2 = clammy, X3 = stiff, X4 = loose, X5 = snug, X6 = nonabsorbent

Garment C:

$$\text{Calories} = 326.95 + 8.03\ (X1) - 6.59\ (X2) - 13.32\ (X3) + 3.99\ (X4) - 12.06\ (X5)$$

where X1 = scratchy, X2 = clammy, X3 = stiff, X4 = loose, X5 = snug

For the performance measure "floors" the best model was the following with $R^2 = .58$:

Garment B:

$$\text{Floors} = 82.22 - .86\,(X1) - 1.69\,(X2) - 1.05\,(X3) + 1.32\,(X4) + 2.45\,(X5) + .61\,(X6)$$

where X1 = scratchy, X2 = clingy, X3 = cold, X4 = nonabsorbent, X5 = stiff, X6 = snug

Garment C:

$$\text{Floors} = 82.22 - .86\,(X1) - 1.69\,(X2) - 1.05\,(X3) + 1.31\,(X4) + 2.45\,(X5) + .61\,(X6) + 1.90\,(X7) - 3.17\,(X8) + 2.34\,(X9) - .69\,(X10)$$

where X1 = scratchy, X2 = clingy, X3 = cold, X4 = nonabsorbent, X5 = stiff, X6 = snug, X7 = damp, X8 = clammy, X9 = staticky, X10 = lightweight

The relationship between floors and comfort variables is the same for garments A and C.

For the performance measure "miles" the best model found was the following with $R^2 = .56$:

Garment A:

$$\text{Miles} = 1.84 - .03\,(X1) - .04\,(X2) - .09\,(X3) + .02\,(X4) + .02\,(X5) + .02\,(X6) + .03\,(X7) - .01\,(X8) + .09\,(X9) - .04\,(X10)$$

where X1 = scratchy, X2 = clingy, X3 = clammy, X4 = non-absorbent, X5 = sticky, X6 = staticky, X7 = stiff, X8 = loose, X9 = damp, X10 = cold

Garment B:

$$\text{Miles} = 1.84 - .03\,(X1) - .04\,(X2) - .02\,(X3) + .02\,(X4) + .02\,(X5) + .02\,(X6) + .03\,(X7)$$

$- .02 (X8)$

where X1 = scratchy, X2 = clingy, X3 = clammy, X4 = non-absorbent, X5 = sticky, X6 = staticky, X7 = stiff, X8 = loose

The relationship between miles and the comfort variables is the same for garments B and C.

Conclusions

The results of this study clearly indicate that athletic girdles do a better job of warming muscles up more quickly and maintaining that temperature verses a non-girdle. Of particular importance is the non-girdle's inability to keep the hamstrings at a warmer temperature during exercise and cooldown than prior to or during the warmup. The comfort ballot results suggest that the girdle prototype was rated more favorable than the girdle currently in use for the majority of the comfort descriptors.

The pre- and post-circumference data show a significant increase in muscle size after strenuous exercise. While no significant difference by garment treatment was found, this information substantiates athletes' fit complaints. The greater amount of stretch in the prototype may have contributed to the improved comfort perceptions of the subjects.

Results of the performance measures clearly indicate that no difference in performance was found for the three specified garment treatments. Results of the step-wise regression analysis investigating the impact of the comfort descriptors on the performance variables for each garment indicated that certain comfort descriptors are associated with performance results. These findings suggest that while comfort perceptions may be associated with performance, it is possible that clothing may not influence performance to the extent believed by researchers and garment manufacturers. It is also possible that different performance measures might yield different results.

The findings from this study pose several questions in regard to some manufacturer claims of athletic girdles. While it was found that the athletic girdles tested did keep skin temperature over the muscles warmer than non-girdles, this study did not determine what temperature is optimal and safe for the athlete to maintain thermal balance. Further investigation into this issue is suggested.

Due to the lack of research investigating performance of the athlete while wearing a specific article of clothing, performance measures from other areas were investigated. More attention to the measurement of athletic performance would contribute to a better understanding of the influence of garment and fabric on comfort and performance. Some suggestions might include testing the athlete under extreme enviromental conditions, testing the athlete during a conditioning program or competitive situation, and testing the girdle along with other equiptment worn by the athlete during such a situation.

It is anticipated that clothing comfort and athletic performance will continue to be a topic of interest to researchers in a variety of disciplines. Clearly, additional research focusing on these areas would contribute to our understanding of the influence of comfort on performance.

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Table 1. Paired T-Test for Pre- and Post-Circumference Difference Measures for Each Garment Treatment.

Source	N Obs	Mean Diff.	Std Dev	T Value	Prob >T
Garment A	6	.4783	.4515	2.595	.0485
Garment B	6	.6666	.3028	5.393	.0030
Garment C	6	.4367	.1052	10.67	.0002

Table 2. ANOVA for Pre- and Post-Circumference Difference Measures.

Source	DF	Mean Square	F-Value	Prob.>F
Subject	5	6.083	119.07	.0001
Garment	2	0.034	0.67	.5252
Subject* Garment	10	.2215	4.34	.0055
Error	15	.0510		

Table 3. ANOVA of Skin Temperature Values for Temperature Site One (Quadriceps).

Source	DF	Mean Square	F-Value	Prob.>F
Subject	5	7.81333333	3.74	.0360
Garment	2	22.77787367	1.41	.2898
Time	22	13.53021711	36.13	.0001
Garment* Time	41	.11991086	.32	1.000
Error A	10	20.86666667		
Error B	60	15.06666667		

Table 4. ANOVA for Skin Temperature Values for Temperature Site Two (Hamstrings).

Source	DF	Mean Square	F Value	Prob.>F
Subject	5	25.33032120	1.57	.2529
Garment	2	195.34537264	12.14	.0021
Time	22	.68450133	3.37	.0001
Garment* Time	41	.63651068	3.14	.0001
Error A	10	16.09029220		
Error B	292	.20287688		

Table 5. ANOVA for Skin Temperature Values for Temperature Site Three (Gluteals).

Source	DF	Mean Square	F-Value	Prob.>F
Subject	5	43.521997919	2.20	.1357
Garment	2	40.79575570	2.06	.1783
Time	22	7.28454862	11.26	.0001
Garment* Time	41	.28944491	.45	.9987
Error A	10	19.81687140		
Error B	292	.64689966		

Table 6. Overall Means and Standard Deviations of Comfort Evaluations by Garment Treatment.

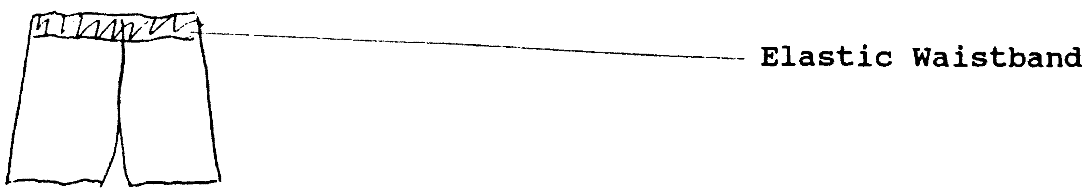
	GARMENTS					
	A		B		C	
DESCRIPTORS	Mean	SD	Mean	SD	Mean	SD
SNUG *	3.40	1.45	2.70	1.02	1.50	.63
LOOSE *	2.40	1.45	4.00	1.11	4.56	.82
HEAVY *	4.80	.55	3.80	.89	3.93	1.11
LIGHTWEIGHT**	2.10	1.35	3.23	.94	2.73	1.31
STIFF *	4.56	.68	4.23	.89	3.26	1.14
STATICKY**	4.70	.70	3.93	.98	3.43	1.41
STICKY**	4.23	1.07	3.90	.96	3.43	1.14
NONABSORBENT**	4.03	1.19	4.50	.63	4.13	.82
COLD**	4.00	1.11	4.33	1.06	4.23	.63
CLAMMY**	4.07	1.08	4.20	1.06	4.10	1.03
DAMP**	4.07	1.11	4.33	.84	3.86	.94
CLINGY *, **	4.33	.84	3.43	1.17	2.44	1.27
ROUGH *	4.66	.71	4.17	.91	3.26	1.05
SCRATCHY *	4.66	.76	4.03	.89	3.10	1.16

* indicates $P < .05$ for garment
** indicates $P < .05$ for Time

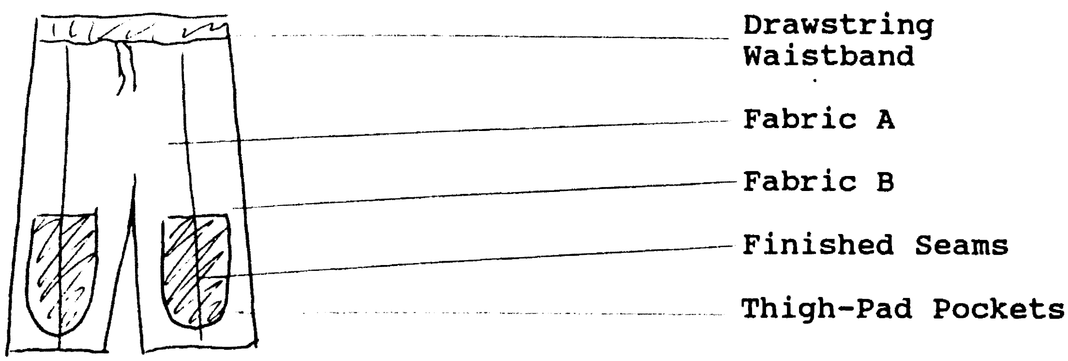
Table 7. Overall Means of Comfort Evaluations Significant Over Time.

		RATING PERIODS				
DESCRIPTORS	GARMENTS	1	2	3	4	5
Lightweight	A	2.83	1.66	1.83	2.50	1.66
	B	3.66	2.66	3.50	3.50	2.83
	C	2.83	2.16	3.00	3.00	2.66
Staticky	A	5.00	4.83	4.66	4.33	4.66
	B	4.16	3.83	3.83	3.83	4.00
	C	3.83	3.00	3.33	3.33	3.66
Nonabsorbent	A	5.00	4.66	3.66	3.33	3.50
	B	4.83	4.66	4.33	4.50	4.16
	C	5.00	4.50	4.00	3.66	3.50
Cold	A	4.33	4.50	3.83	3.50	3.83
	B	4.66	4.33	4.33	4.00	4.33
	C	4.66	4.33	4.16	4.00	4.00
Clammy	A	5.00	4.66	4.00	3.33	3.33
	B	4.66	4.16	3.83	4.16	4.16
	C	4.66	4.16	4.16	3.66	3.83
Damp	A	5.00	4.66	3.83	3.50	3.33
	B	5.00	4.66	4.16	4.16	3.66
	C	5.00	4.16	4.00	3.00	3.16
Sticky	A	5.00	4.50	4.16	3.66	3.83
	B	4.50	4.00	3.66	3.66	3.66
	C	4.00	3.16	3.33	3.16	3.50
Clingy	A	4.66	4.66	4.16	4.00	4.16
	B	3.83	3.50	3.33	3.16	3.33
	C	2.83	2.66	2.00	2.50	2.16

GARMENT A



GARMENT B



GARMENT C

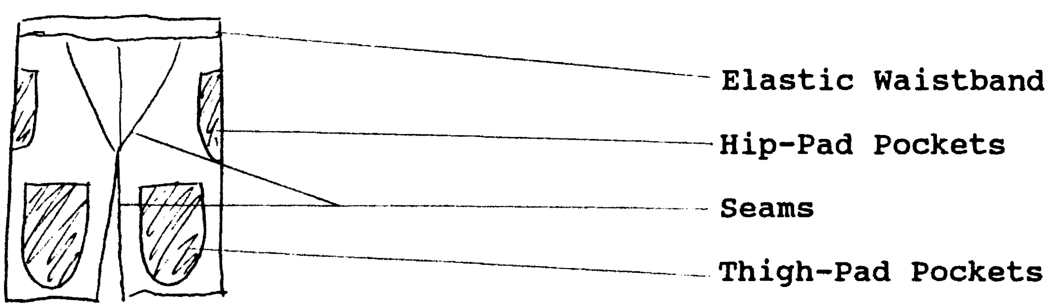


Figure 1. Garments

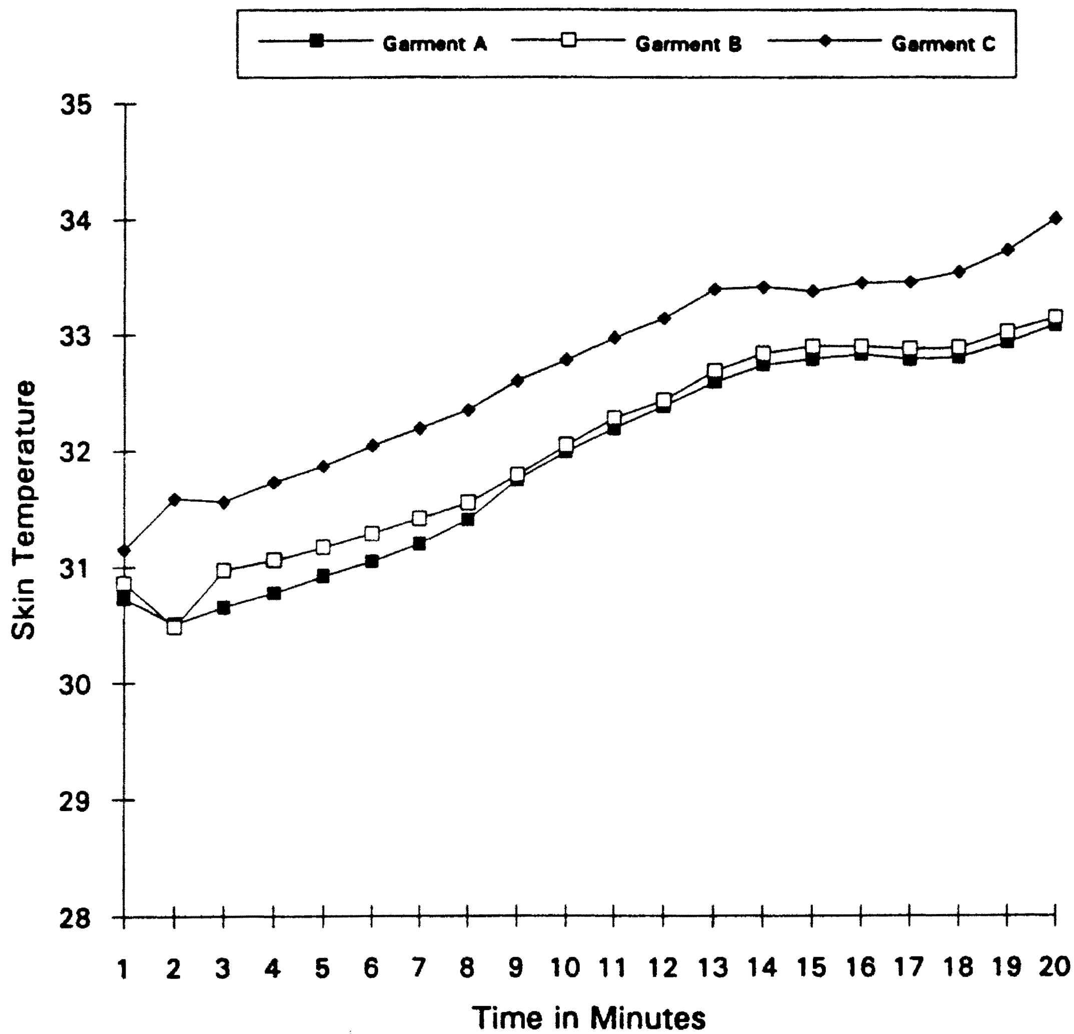


Figure 2. Skin Temperature for Quadriceps Over Time

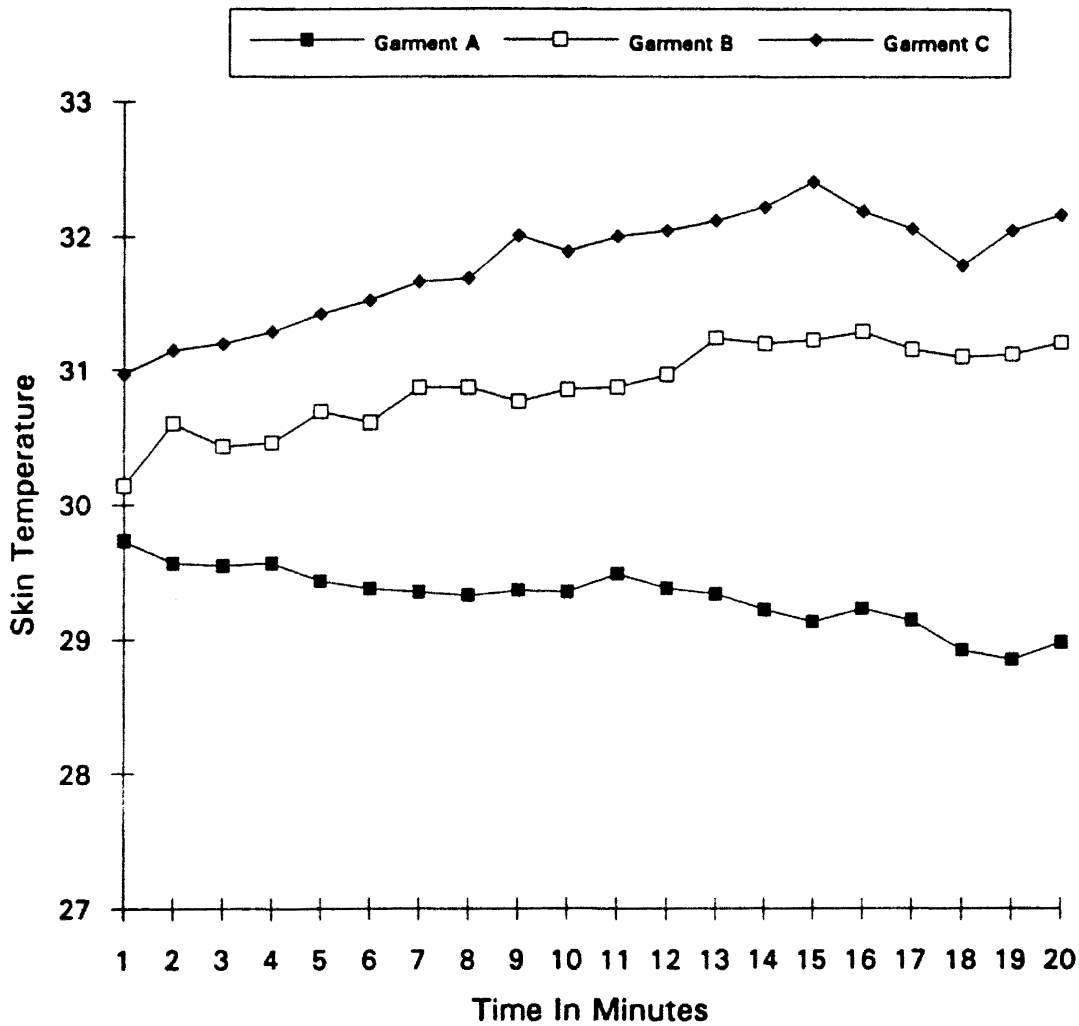


Figure 3. Skin Temperature for Hamstrings Over Time

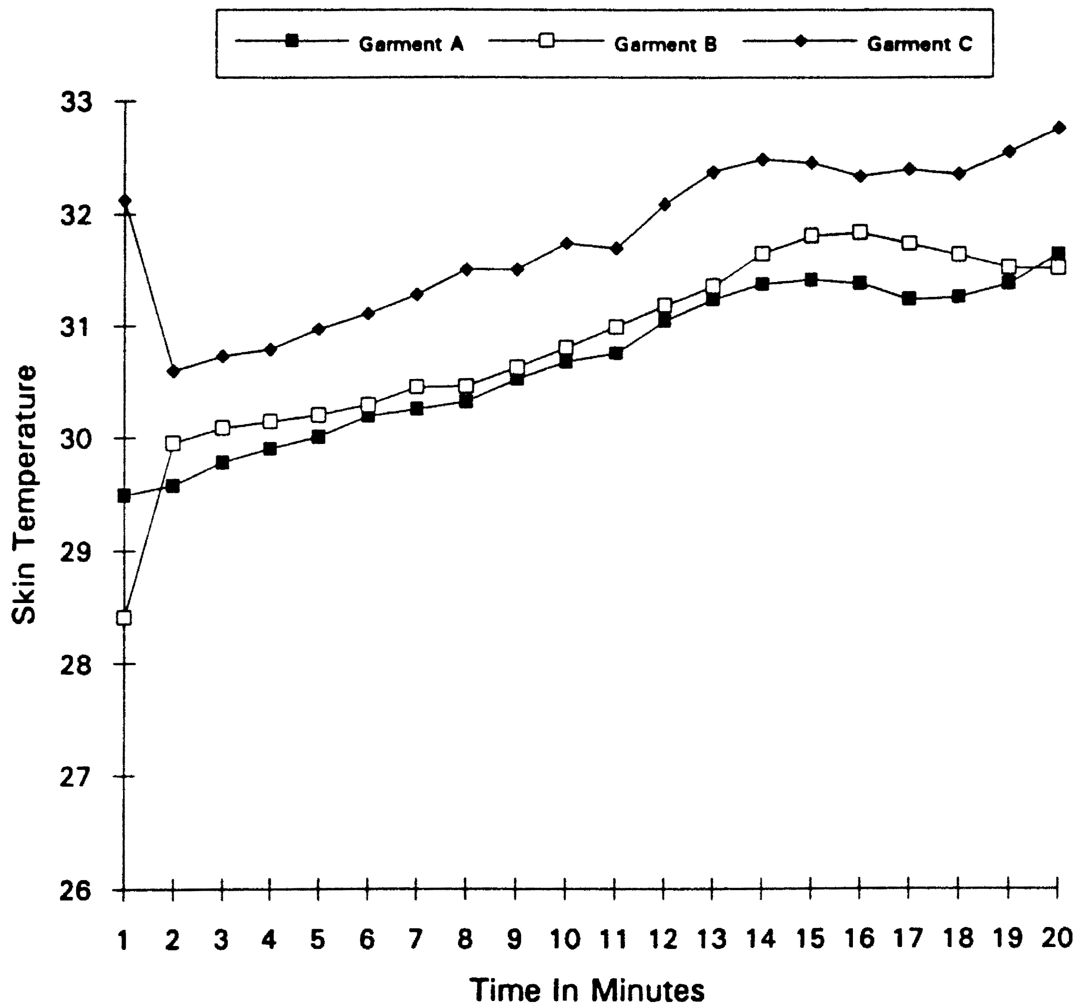


Figure 4. Skin Temperature for Gluteals Over Time

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The prevention of injuries to the lower extremities is of vital importance to those involved in physical contact sports. Many studies indicate a higher rate of injury in late game or practice competition when muscles enter a state of general fatigue. This fatigue is caused by a reduce ed blood supply to muscles, fibers become devitalized and easily torn, leaving an individual susceptible to injury (Unitas and Dintiman, 1979).

The advent of protective items developed for football has made it possible for athletes in a variety of contact sports to have protection from muscle injuries, particularly to the quadriceps, gluteals, and hamstring (Zylks, 1989). Athletic girdles have been developed by various manufacturers who claim that the girdle supports the groin, hamstring, and quadriceps muscle groups via application of steady uniform pressure. The girdle proportedly also acts as a muscle conditioner and insulation to the body helping athletes to warm up quickly and maintain that temperature without overheating.

The purpose of this study was to determine athletes' comfort and athletic performance while wearing an athletic girdle currently used by the university football team, a prototype athletic girdle, and a non-girdle.

Objectives

The objectives of the study were to determine 1) the athlete's thigh circumference measurements prior to and following a specific exercise protocol while wearing each of the three garment treatments, 2) skin temperature over the athlete's hamstrings, quadriceps, and gluteals while wearing each of the three garment treatments, 3) comfort perceptions of the athlete while wearing each of the three garment treatments, and 4) the athlete's athletic performance while wearing each of the three garment treatments 5) the relationship between comfort perceptions and athletic performance of the athlete while wearing each of the garment treatments.

Subjects

Six male subjects were recruited from the university coaching staff on a voluntary basis. All subjects were ex-athletes in good physical condition and were assumed to be capable of performing maximal physical output. Individuals meeting any of the following criteria were eliminated: those with a history of any cardiac or vascular disorder, stomach or intestinal disorder, high blood pressure (> 140/90 mm/Hg), high resting HR (>110), currently on medication, or currently ill.

Independent Variables

Three garment treatments were used in the test sessions. These were: garment A (athletic shorts, 50% polyester/50% cotton), garment B (girdle prototype, fabric A: 87% nylon, 13% spandex, & fabric B: 85% nylon, 15% spandex, and garment C (athletic girdle, 92% polyester, 8% spandex).

Dependent Variables

The following dependent variables were measured during the test session. Skin temperature over the quadriceps, hamstrings, and gluteals was recorded with the use of YSI surface thermistors at 1-minute intervals during the entire exercise protocol. Perceived comfort was assessed using a modified version of the Hollies (1984) subjective comfort rating chart. Subjects responded orally to each descriptor and the researcher recorded the responses at 5-minute intervals. Calories burned, floors climbed, and miles climbed constituted athletic performance measures. These data were recorded at the conclusion of each exercise program from the Stairmaster electronic display monitor. Pre- and post-circumference measurements of the right thigh of each subject were recorded using a Limb Accurate Measurement device (L.A.M.) at 8 inches above the superior crest of the patella.

Testing Protocol

Testing was completed at the Oklahoma State University Sports Medicine facility. Prior to testing, subjects were requested o abstain from strenuous exercise for 48 hours to prevent muscular fatigue. The testing procedure consisted of a comfort/performance protocol designed to simulate a normal physical conditioning session. A Latin Square Repeated Measures experimental design was used.

Subjects changed into the garment treatment and pre-circumference measurements of the right thigh were recorded. Skin thermistors were placed on the quadriceps, hamstrings, and gluteals to record muscle temperature. The subjects were then asked to perform a brief 4-minute warmup program on a motor-driven Stairmaster vertical climbing machine, that provided an aerobic workout equivalent to climbing stairs. The machine was set at level 6, equivalent to approximately 40 steps per minute. Next, the subjects were asked to perform an 8-minute exercise program on the Stairmaster at level 9, equivalent to approximately 70 steps per minute. Heart rate of the subjects was monitored and recorded at 5-minute intervals.

Following this exercise program, subjects were asked to perform at maximal level for four minutes. At the end of this period, a brief 4-minute cool-down (again at level 6) was performed. Lastly, post-circumference measurements were taken of the right thigh.

Findings

Pre-and Post Circumference Measurements. A paired T-test for the difference between pre-and post circumference measurements showed that a significant increase in muscle circumference of the upper thigh occurred over the experiment regardless of the garment treatment. ANOVA tests for mean difference between pre- and post-circumference measurements showed a significant difference by subject but not garment treatment.

Skin Temperature. ANOVA results indicated a significant subject effect was found for temperature site on, but not for temperature sites two or three. Also, a significant garment effect was found for temperature site two, but not for sites one and three. A significant time effect for all three muscle sites was found. Finally, a significant garment by time interaction was noted for temperature site two only. Both garment B and C maintained a higher temperature than garment A during the exercise and cool-down for all three muscle sites. Garment C maintained the highest temperature, followed by garment B and garment A respectively.

Comfort Analysis. ANOVA results for perceived comfort indicated a significant garment effect for 7 of the 14 comfort ballot descriptors: snug, loose, heavy, stiff, clingy, rough, and scratchy. Garment A was rated as the least snug, heavy, staticky, sticky, stiff, clingy, rough, and scratchy of the three garment treatments. Garment C was rated as the most snug, stiff, staticky, sticky, clingy, rough, and scratchy of the three garment treatments. Garment B was rated as the least nonabsorbent, cold, clammy, and damp. Compared to garment C, garment B was rated as less snug, stiff, staticky, sticky, clingy, rough, and scratchy. Overall, the prototype rated more favorably for 11 of the 14 comfort descriptors than the girdle.

There was a significant time effect for eight of the comfort descriptors: lightweight, staticky, cold, clammy, nonabsorbent, clingy, sticky, and damp. For the descriptor lightweight and staticky, there was a slight change in the intensity over the course of the exercise protocol for all three garment treatments. There was a sharp increase in the intensity of perceived nonabsorbancy, coldness, clamminess, dampness, and stickiness regardless of garment treatment.

Athletic Performance. ANOVA results indicated a significant difference by subject but not garment treatment for all of the athletic performance measures.

Clothing Comfort and Athletic Performance. Results of a step-wise regression analysis indicated that certain comfort descriptors are associated with the athletes performance measures.

Conclusions and Implications

Clearly, results of this study indicate that athletic girdles do a better job of warming muscles up more quickly and maintaining that temperature verses a non-girdle. Of particular importance is the non-girdle's inability to keep the hamstrings at a warmer temperature during exercise and cool-down than prior to or during the warm-up. The comfort ballot results suggest that the girdle prototype was rated more favorably than the girdle currently in use for the majority of the comfort descriptors.

The pre- and post-circumference data show a significant increase in muscle size after strenuous exercise. While no significant difference by garment treatment was found, this information substantiates athletes' fit complaints. The greater amount of stretch in the prototype may have contributed to the improved comfort perceptions of the subjects.

Results of the performance measures clearly indicate that no difference in performance was found for the three specified garment treatments. Results of the step-wise regression analysis investigating the impact of the comfort descriptors on the performance variables for each garment indicated that certain comfort descriptors are associated with performance results. These findings suggest that while comfort perceptions may be associated with performance, it is possible that clothing may not influence performance to the extent believed by researchers and garment manufacturers. It is also possible that different performance measures might yield differenct results.

The findings from this study pose several questions in regard to some manufacturer claims of athletic girdles. While it was found that the athletic girdles tested did kepp skin temperature over the muscles warmer than non-girdles, this study did not determine what temperature is optimal and safe for the athlete to maintain thermal balance. Further investigation into this issue is suggested.

Due to the lack of research investigating performance of the athlete while wearing a specific article of clothing, performance measures from other areas were investigated. More attention to the measurement of athletic performance would contribute to a better understanding of the influence of garment and fabric on comfort and performance. Some suggestions might include testing the athlete under extreme enviromental conditions, testing the athlete during a conditioning program or competitive situation, and testing the girdle along with other equipment worn by the athlete during such a situation.

It is anticipated that clothing comfort and athletic performance will continue to be a topic of interest to researchers in a variety of disciplines. Clearly, additional research focusing on these areas would contribut to our understanding of the influence of comfort on performance.

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APPENDICES

APPENDIX A

INFORMED CONSENT

I, ___________________________, voluntarily agree to participate in this study entitles : <u>Development and Evaluation of a Prototype Athletics Sports Girdle</u> which is sponsored by College of Human Environmental Sciences through the Department of Design, Housing, and Merchandising, Oklahoma State University, Stillwater, OK.

I understand that the purpose of this study is to investigate muscular performance and comfort perceptions of individuals while wearing three different items of athletic clothing, and that testing will involve an exercise program to be completed at the Oklahoma State University Sports Medicine Department with each of these items of clothing.

I understand the procedure for assessing muscular performance and comfort perceptions will require my participation in the following ways:

1. <u>Pre-Testing</u> : (Immediately prior to testing) Age, weight, and percent of body fat will be recorded for all of the subjects. A circumference measurement of the gluteals, hamstrings, and quadriceps will also be recorded with the use of a standard tape measure. Subjects will be allowed approximately two minutes to become familiar with the pace of the motor-driven Stairmaster climbing machine, and directions for manipulation of the Stairmaster will be given. Subjects will also be given directions for answering the comfort ballot. Skin thermistors will be placed on each of the muscle groups described (one per group) in preparation for testing.

2. <u>Testing</u> : (Approximately 20 minutes) In the first part, the subjects will be asked to perform a warm-up exercise program on the Stairmaster vertical climbing machine pre-set at level 3 for four minutes. At the beginning of this program subjects will be asked to verbally rate the intensity of a comfort sensation by responding : 1 (totally), 2 (definitely), 3 (mildly), or 4 (partially). In the second part of testing, the subjects will be asked to perform an exercise program on the Stairmaster pre-set at level 6 for eight minutes. Twice during this program the

subject will be asked respond to the comfort ballot verbally. In the third part, the subject will be asked to perform at maximum level for four minutes. The subject will be asked to manually control the level at which exercise will be performed. Once during this exercise program the subject will be asked to respond to the comfort ballot. In the final part, the subject will be asked to perform a cool-down exercise program pre-set at level three for four minutes. Once during this program the subject will be asked to respond to the comfort ballot. Throughout this entire 20 minute period, skin temperature will be recorded at one minute intervals. Also, heart rate will be recorded at five minute intervals. This entire exercise protocol will be completed on three separate occasions while wearing three different articles of athletic clothing.

3. Post-testing : (Immediately following testing) Circumference measurements of the gluteals, hamstrings, and quadriceps will be recorded using a standard tape measure.

I understand that participating in this study presents the following possible benefits to me:
1. knowledge of, and experience in, muscular performance testing, and comfort sensation testing,
2. future improved athletic apparel design

I understand that there are no risks anticipated by the investigators for participants in this study and that records of this study will be kept confidential with respect to verbal reports making it impossible to identify me individually. I also understand that I can withdraw from this study at any time without negative consequences.

I have read this informed consent document and understand its contents. I freely consent to participate in this study under the conditions described here. I understand that I will receive a copy of this signed consent form.

Date/Time Signature of the Research Subject

Date Signature of the Witness

Date Signature of the Principal Investigator

APPENDIX B

SUBJECTIVE COMFORT RATING CHART

Comfort Descriptors	Rating Periods				
	1	2	3	4	5
SNUG					
LOOSE					
HEAVY					
LIGHTWEIGHT					
STIFF					
STATICKY					
STICKY					
NONABSORBENT					
COLD					
CLAMMY					
DAMP					
CLINGY					
ROUGH					
SCRATCHY					

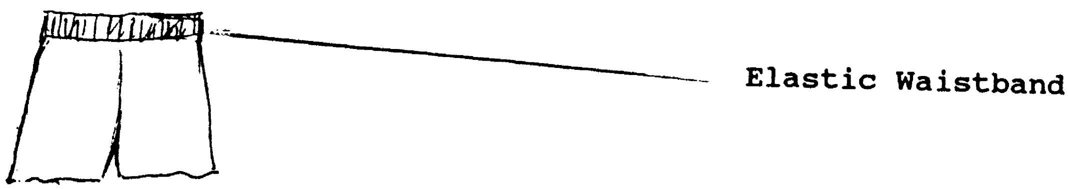
INTENSITY SCALE

1=Totally
2=Definitely
3=Mildly
4=Partially
5=Not at All or N/A

APPENDIX C

GARMENTS

GARMENT A



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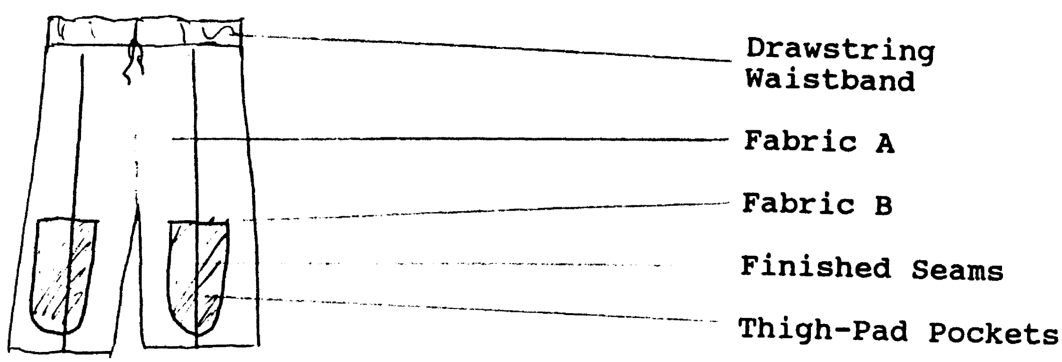

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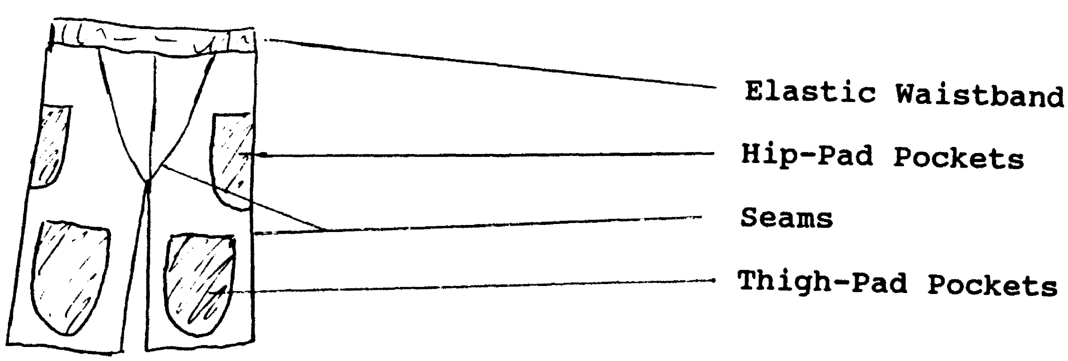

VITA

Kathleen Marie Walde

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT AND EVALUATION OF A PROTOTYPE ATHLETIC SPORTS GIRDLE

Major Field: Design, Housing, and Merchandising

Area of Specialization: Apparel Design

Education: Graduated from Bishop McDevitt High School, Harrisburg, Pennsylvania in June 1984; received Bachelor of Science Degree in Education from Temple University in December, 1989; completed requirements for the Master of Science degree at Oklahoma State University in May, 1993.