

Evaluation of a Lower-Body Compression Garment

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Key Words: athletic performance, ergonomic aids, injury, sprint, jump,

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ABSTRACT

The purpose of this investigation was to determine how custom-fit compression shorts affect athletic performance and to investigate the mechanical properties of the shorts. Subjects included ten men and ten women track athletes on the university's nationally competitive track team, specializing in sprint or jump events. Testing utilized the compression shorts with loose fitting gym shorts as the control garment. Several significant affects were revealed for the custom-fit compressive garment. Although 60m-sprint time was not effected hip flexion angle was reduced. Skin temperature increased more and at a faster rate during a warm-up protocol. Muscle oscillation was decreased during vertical jump landing. Countermovement vertical jump height increased when the subjects were wearing the custom-fit compression garment. In materials testing, the elasticity of the compressive garment provides increased flexion and extension torque at the end range of extension and flexion respectively and may assist the hamstrings in controlling the leg at the end of the swing phase in sprinting. The compressive garment significantly reduced impact force at forces under 2500 Newtons when compared to American football pants alone. Through various mechanisms, these findings may translate into an affect on athletic performance and reduction of injury.

Introduction

The use of compression garments in athletics and fitness activities are becoming more popular. Style, reduced chaffing, injury prevention, anecdotal and research-supported evidence of performance enhancement are all reasons cited for wearing these compressive garments. An examination of recent elite track and field contests documents the popularity of compressive garments.

Early research on compressive garments focused on increased venous blood flow due to the compression and its positive effects on venous thrombosis in postoperative patients. Compressive stockings and tights caused a reduction of venous stasis in the lower extremities (Sigel et al., 1975; O'Donnell et al., 1979; Gandhi et al., 1984; Perlau et al., 1995). Berry and McMurray (1987) conducted the first exercise-related research on compressive garments, finding lower blood lactate concentrations following maximal exercise when the stockings were worn during the exercise. A series of investigations by Kraemer et al. (1996, 1998) of Lycra-type compression shorts have noted athletic performance enhancement due to compressive garments.

Specifically, compressive shorts have been shown to enhance repetitive jump power (Kraemer et al., 1996, 1998). Possible mechanisms contributing to the increased repetitive vertical jump performance include a reduction in muscle oscillation, improved proprioception, and increased resistance to fatigue.

The compression shorts (Antibody Inc., Abdingdon, MD) used in this investigation were much different than traditional spandex or Lycra compression shorts and may represent the next advancement in sports garments working to

maximize physical performance and the ergonomic interface with the athlete. The garment is custom fit to be hyper-compressive (15% smaller than the athlete's measurements) and is made of 75% closed cell neoprene, 25% butyl rubber and is 4.76 mm thick. This garment is much more compressive, elastic and impact absorbing than previously studied compressive garments and may illicit different benefits or detriments to athletic performance. The purpose of this investigation was to determine how these custom-fit compression shorts affect athletic performance and to investigate the mechanical properties of the shorts. Specific performance and mechanical tests were designed to assess the effect of the garment on muscle oscillation, jump power, skin temperature, impact absorption and elasticity.

Methods

Subjects

Subjects included ten men (mean height, 179.1 ± 7.2 cm; mean age, 20.0 ± 0.9 years; mean body mass, 74.1 ± 8.3 kg) and ten women (mean height, 168.9 ± 3.4 cm; mean age, 19.2 ± 1.3 years; mean body mass, 60.2 ± 5.2 kg) track athletes on the university's nationally competitive (National Collegiate Athletic Association (NCAA), Division I) track team specializing in sprint or jump events. The Institutional Review Board committee of the university approved the investigation. Subjects were fully informed of the purpose and risks of participating in this investigation and signed informed consent documents prior to testing.

The Garment

The compression shorts (Model 950 GH, Antibody Inc., Abdingdon, MD) used in this investigation were much different than traditional spandex or Lycra compression shorts. The garments were custom fit based on girth and inseam measurements of each subject's waist, hip, thigh, and knee. The garment runs from just above the knee to just above the waist and is a 15 to 20% smaller representation of the subject's lower body, while the material will expand to almost 100% of the original measurements while compressing tissues underneath. The garment material is made to be light, strong, compressive and impact absorbing and consists of 75% closed cell neoprene, 25% butyl rubber and is 0.48 cm thick. Additionally, the garment has a sticky inner surface designed to maximize compression and elasticity by preventing the garment from sliding on the skin surface.

Experimental Procedures

Testing utilized the compression shorts with loose fitting gym shorts being the control garment. Both conditions for each of a series of performance tests (60m sprint, jump power, and muscle oscillation) were conducted on the same day using a balanced, randomized block design to remove day-to-day variation. Each subject was allowed several familiarization trials before each performance test. After completing each performance test, the subject rested for 10 to 20 minutes and then crossed over and completed the other testing condition. For the skin-temperature test, however, each condition was tested on different days in the afternoon, still using a balanced, randomized block design. Test results

were compared within subjects for the with and without compressive garment conditions. Subjects performed a standardized warm-up protocol prior to each performance testing session.

60m Sprint (Range of Motion) Test

One 60Hz video camera (Panasonic WV-D5100HS) interfaced with a video recorder was positioned at a right angle to a runner's path at the 55m mark of a 60m sprint to record kinematic data. Highly reflective markers were placed on the left temple-mandibular joint, left leg over the greater trochanter, lateral epicondyle of the femur, and lateral malleolus.

Kwon 3D, version 2.1 (Kwon3D, Muncie, IN) motion analysis software was used to digitize and analyze the kinematic data. Prior to analyses, the data were filtered using a fourth order low-pass Butterworth filter with a cutoff frequency of 6 Hz (Winter, 1990). Hip and knee joint range of motion, calculated as the difference between the maximum and minimum values for the hip and knee, were compared between conditions. Photocells were positioned at the start and finish of the race to measure 60m times. Athletes rested for a minimum of 10 minutes between conditions.

******Figure 1 about here******

Muscle Oscillation

Subjects were video taped performing countermovement jumps to compare thigh muscle oscillation between with and without the compressive

shorts conditions. Subjects were instructed to dip down to a comfortable depth and jump for maximum height, while keeping their hands on their hips throughout the movement. One 60Hz video camera was positioned to record the sagittal plane view of each jumper. Highly reflective markers were placed on the left leg over the 1) greater trochanter 2) lateral epicondyle of the femur, and 3) antero-lateral aspect of the thigh midway between the anterior superior iliac spine and the superior aspect of the patella.

Peak Performance (Peak Performance Technologies Inc., Englewood, CO), version 5.3.0, motion analysis software was used to digitize and analyze the kinematic data. Prior to analyses, the data were filtered using a fourth order low-pass Butterworth filter with a cutoff frequency of 12 Hz (Winter, 1990). Maximum longitudinal and anterior-posterior displacement of the thigh marker was calculated relative to the hip and knee markers and compared between conditions.

******Figure 2 about here******

Jump-Power Test

Maximal effort countermovement jumps were performed as a measure of jump power. Subjects were instructed to dip down to a comfortable depth and jump for maximum height, while keeping their hands on their hips throughout the movement. Subjects practiced jumping until they were comfortable and consistent. Jump heights were measured with a Celesco cable transducer

(Celesco, CA) attached to the subject's waist. Vertical ground reaction force data was recorded at 500 Hz with a Kistler force plate (Kistler Instrument Corporation, Amherst, NY) and analyzed with Ballistic Measurement System (Innervations, Muncie, IN) computer software. Subjects performed three trials, unless the third jump was much higher than first and second jumps, then four or more jumps were performed until jump height stopped increasing. Even though subjects performed a standard warm-up and were trained jumpers, some subjects took more than three jumps to attain maximal height.

******Figure 3 about here******

Skin Temperature

Subjects pedaled on a bicycle ergometer for five minutes with 1.5 W/kg of bodyweight resistance. Two type-T copper-constantin thermocouples were secured under the compressive shorts and loose fitting control shorts with breathable tape (Kendall, Polyskin II, Mansfield, MA) 24 cm above the superior aspect of the patella. Temperature measurements were recorded using an Iso-Thermex (Columbus Instruments, Columbus, OH) system linked to an Apple computer. Measurements were taken immediately before the warm-up protocol, once per minute during the warm-up and immediately following warm-up. The other treatment condition was tested on a different day to ensure return of skin temperature to normal between trials. Ambient temperature was measured and controlled between conditions.

Mechanical characteristics of garment

Impact: Standard impact testing was conducted on the garment material to assess the impact attenuation properties of the garment. An American collegiate American football helmet weighted to a total mass of 5.44 kg was repeatedly dropped on a force plate from 36.1 and 76.2 cm. The helmet was dropped onto a normal pair of American football pants for the control condition and onto a swatch of the compressive garment material for the experimental condition (see figure 4). Vertical ground reaction force data was recorded at 7000 Hz with a Kistler force plate (model number 9281B) and analyzed with Bioware (Kistler Instrument Corporation, Amherst, NY) computer software. Peak force values were compared between conditions.

******Figure 4 about here******

Elasticity: The garment was fitted to a life-size mannequin cast from a human specimen with full joint range of motion (Gatesville Doll, MA56237) to measure the elastic properties of the garment. Force data was collected at 200 Hz on Biopac *AcqKnowledge* (version 3.5.2) computer software (Biopac Systems, Inc.) using an Entran (Fairfield, NJ) force transducer (see Figure 5). The mannequin was tested through a normal sprinter's hip range of motion, as determined in the sprint test of this investigation, with and without the garment. The force transducer was connected at a 90-degree angle to the distal end of the mannequin's thigh segment and to a stationary point at two hip flexion (127 and 158.5 degrees) and two hip extension (195 and 200 degrees) angles. Force was

measured with and without the compressive garment on the mannequin and the amount of torque at the joint was calculated. The garment was made to fit the mannequin, however the skin of the mannequin did not have the same elastic and frictional properties with the garment as human skin. The aim of this test was to produce a reasonable estimate of the human joint torques caused by the garment.

******Figure 5 about here******

Data Analyses

Means and standard deviations were computed for the conditions with and without the compressive garment. A two-tailed, paired t-test was applied to identify whether the means were significantly different. The criterion for statistical significance was set at $p \leq 0.05$.

Results

60m Sprint (Range of Motion) Test

When the men and women were combined into one group, a significant ($p = 0.04$) reduction for the with-garment condition in hip range of motion during a sprint was noted. However, for the men-only and women-only groups hip range of motion did not change. Knee range of motion for all groups was not significantly different between conditions; however there was a trend towards a decrease in range of motion. No significant difference was found when comparing 60-meter sprint times between experimental conditions.

****Figure 6 about here****

****Figure 7 about here****

Muscle Oscillation

A significant reduction with the garment was noted in both longitudinal and anterior-posterior thigh musculature oscillation during vertical jump landing for men and women ($p \leq 0.013$ for all groups).

****Figure 8 about here****

Jump-Power Test

When men and women were combined as one group, single maximal countermovement vertical jump height significantly ($p = 0.015$) increased from 0.461m to 0.485m for the control and compressive garment conditions respectively. Also while wearing the compressive garment, squat depth in single maximal countermovement vertical jumps decreased significantly from 0.279m to 0.299m for men ($p = 0.024$) and 0.270m to 0.288m for the combined-subject group ($p = 0.016$).

****Figure 9 about here****

****Figure 10 about here****

Skin Temperature

The garment also caused a significant increase ($p = 0.003$ for men and women) in skin temperature when compared to loose fitting gym shorts during a 5-minute warm-up session.

******Figure 11 about here******

Mechanical Characteristics of the Garment

According to impact testing performed in this investigation, 26.6% of the impact forces were significantly ($p = 0.000$) attenuated by the garment at a drop height of 38.1 cm, while 11.6% ($p = 0.066$) of the impact forces were attenuated at a drop height of 76.2 cm.

******Figure 12 about here******

The elasticity of the garment increased torque at the hip joint by 53% to 91% during 127° and 158° flexion and by 191% to 285% during 200° and 195° extension respectively.

******Figure 13 about here******

Discussion

From the performance test results of this study we observed several possible effects the customized compression garment may contribute to athletic performance. Skin temperature increased during a warm-up protocol. Muscle oscillation significantly decreased during vertical jump landings. Countermovement vertical jump height increased with the garment. Elasticity of the garment provides increased flexion and extension torque at the end range of extension and flexion respectively. Lastly, hip joint range of motion slightly decreased during a 60-meter sprint. Through various mechanisms, these findings may translate into an effect on athletic performance and reduction of

injury.

60m Sprint (Range of Motion) Test

According to the kinematic results of this study, the garment slightly decreases the hip joint range of motion during sprinting primarily due to a reduction in maximum hip flexion angle. The subjects ran the same speed, however, with decreased hip range of motion (-5.08 degrees), which may mean the garment increases stride frequency. However this was not measured in the current the study is purely conjecture at this time. What is important to note is that there was no dramatic change in the kinematics of sprinting and so the garment does not appear to interfere with the motion of the hip or knee. The elasticity of the garment may increase the acceleration of the leg coming down. Although the garment may be a hindrance near full hip extension, as it is producing a small opposing torque beyond 180° of hip extension. Additionally, the garment may reduce injury by assisting the eccentric action of the hamstrings at end of recovery phase (Kujala et al., 1997).

Muscle Oscillation

This investigation found significantly reduced longitudinal (0.32 cm) and anterior-posterior (0.40 cm) muscle oscillation upon landing from a maximal vertical jump. Similar results have been reported for Lycra-type compression shorts and the reduction in oscillation was speculated to be a contributing factor to increases in repetitive jump performance by enhancing technique and reducing fatigue (Kraemer et al., 1998). The proposed ergonomic mechanism is that a reduction in the oscillatory displacement of the muscle may optimize

neurotransmission and mechanics at the molecular level (McComas, 1996).

Jump-Power Test

Previous studies have found single maximal vertical jump power output was not affected by compressive shorts composed of varying percentages of Lycra® content (Kraemer et al., 1996). The compressive shorts used in this study however, consisting of neoprene and butyl rubber, are much thicker and may provide significant elastic force aiding in single maximal jump performance. In fact, the countermovement vertical jump test results from this study were that the maximum jump height of the athletes under the compressive garment condition was significantly higher than the control condition by 2.4 cm. The elasticity of the garment, as measured in the mechanical testing of the garment, may have increased the propulsive force, resulting in a higher jump. Also, because this investigation found a significantly lower squat depth with the garment, the mechanical support of the garment may have allowed a more optimal (lower by 1.8 cm) squat depth to be performed, resulting in a greater impulse in the concentric phase of the jump. Additionally, previous studies have shown improved proprioception with compressive garments (Barrack et al., 1983; Perlau et al., 1995; Kraemer et al., 1998), which may improve jump technique. A compression sleeve worn on the knee improved the integration of the balance control system and muscle coordination (Kuster et al., 1999). There are many possible mechanisms that may contribute to the increase in single maximal jump performance, determination of the actual mechanisms at play in this research requires further study.

Skin Temperature

An initial increase in skin temperature may translate into increased athletic performance and reduced potential for injury. Bergh and Ekblom (1979) found that performance in short term, power-related athletic events, such as jumping and sprinting, was decreased at below normal and enhanced at above normal muscle temperature. Maximum dynamic strength increased and the force–velocity curve shifted causing a higher velocity of shortening at a given load as a function of muscle temperature (Bergh and Ekblom, 1979; Sargeant, 1987). Studies have also noted that skin temperature is related to blood flow and muscle temperature (Isaji et al., 1994). Muscle function has been proven to be optimal at 38.5°C (Astrand and Rodahl, 1977). According to the results of this study, the garment will decrease warm-up time to this optimal temperature, thereby enhancing muscle performance. Additionally, studies have shown that increased musculotendinous temperature may reduce injury potential (Agre, 1985; Kujala et al., 1997). It should be noted, however, the garment may increase muscle temperature beyond an optimal level in longer duration activities or in hot environments, possibly causing a decrease in performance.

Mechanical Characteristics of the Garment

Mechanical testing revealed some further potential benefits the garment may have for athletic performance. Results of the elasticity testing indicate a significant amount of torque provided by the garment at the hip joint at the tested joint angles. The torque provided by the garment may assist the hamstrings in slowing the leg at the end of the hip flexion phase in running, which may reduce

eccentric activation of the antagonists. The hamstrings are compromised at the end of the swing phase in sprinting as it is being simultaneously lengthened over the hip and knee joints. If the hamstrings cannot provide sufficient force to slow the limb and accelerate it to ground contact, muscle tearing can result. The added hip flexion torque provided by the garment at the end of swing phase may assist in reducing this common sport injury. The garment may also aid the athlete in the propulsive phases of sprinting and jumping. Impact testing revealed that the garment is effective at attenuating some impact forces. This may be valuable information for impact-related injury prevention in contact sports and sports associated with a high incidence of falling.

Conclusions

Wearing custom-fit compressive shorts did not change sprinting speed over 60 meters, however it may have an effect over longer distances, such as 100 to 400 meter distances, but this needs to be experimentally determined. It is clear that wearing the custom-fit compression garment improves warm-up in terms of skin temperature attained, and increases vertical jump height. Muscle oscillation on landing from a jump is considerably reduced and this may have benefit in terms of reduced tissue injury and enhanced performance with repeat jumps. The tight fit and elastic nature of the Antibody garment results in a considerable torque being generated about the hip joint at the flexion and extension ranges of motion encountered during sprinting. This may have a performance enhancement and injury-reduction role by assisting the muscles in

generating torque. In particular, this may assist the hamstrings in limiting hip flexion at the end of the swing phase, a time that is particularly risky for hamstring injuries. In addition, the material used in the custom-fit compression garment is capable of attenuating impact forces and this may have some benefit when worn during contact sports.

Acknowledgements

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Figure 1. Experimental setup of video camera and photocells for 60m sprint testing.

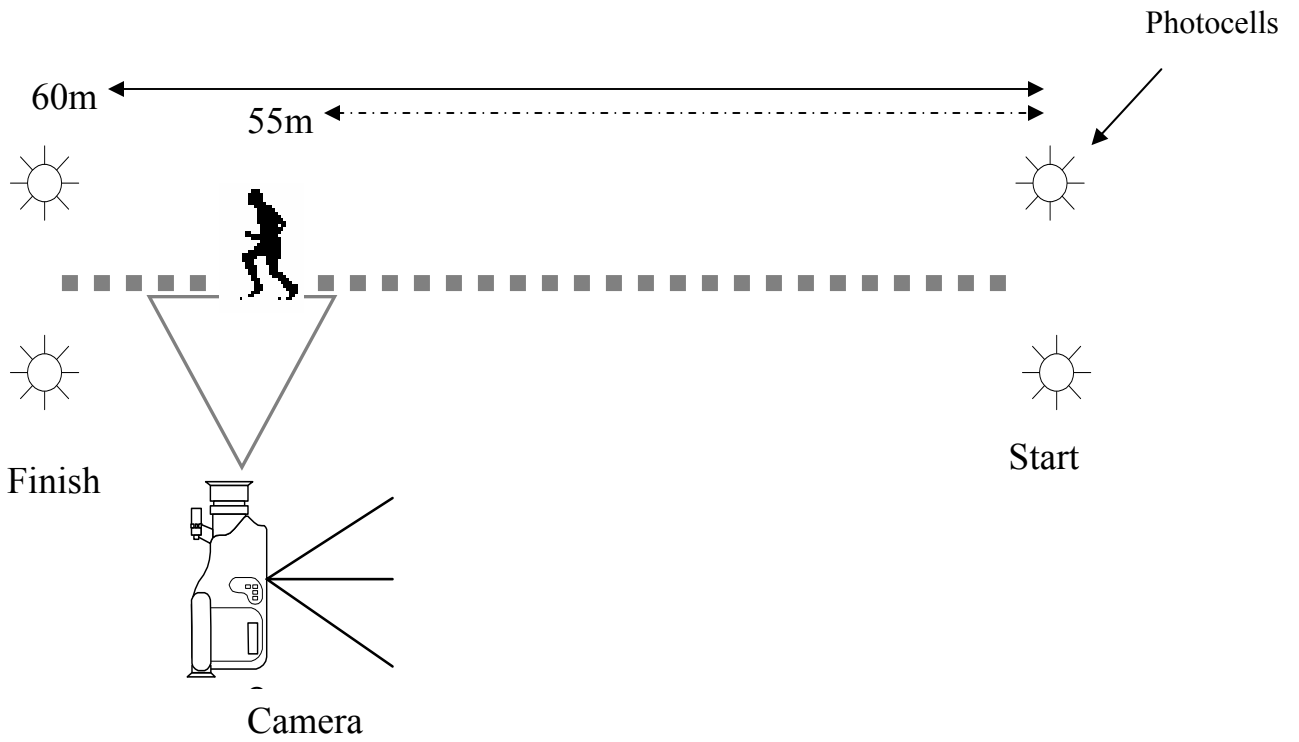


Figure 2. Experimental setup for measurement of muscle oscillation. Reflective markers are shown attached to the hip, knee and mid-thigh.

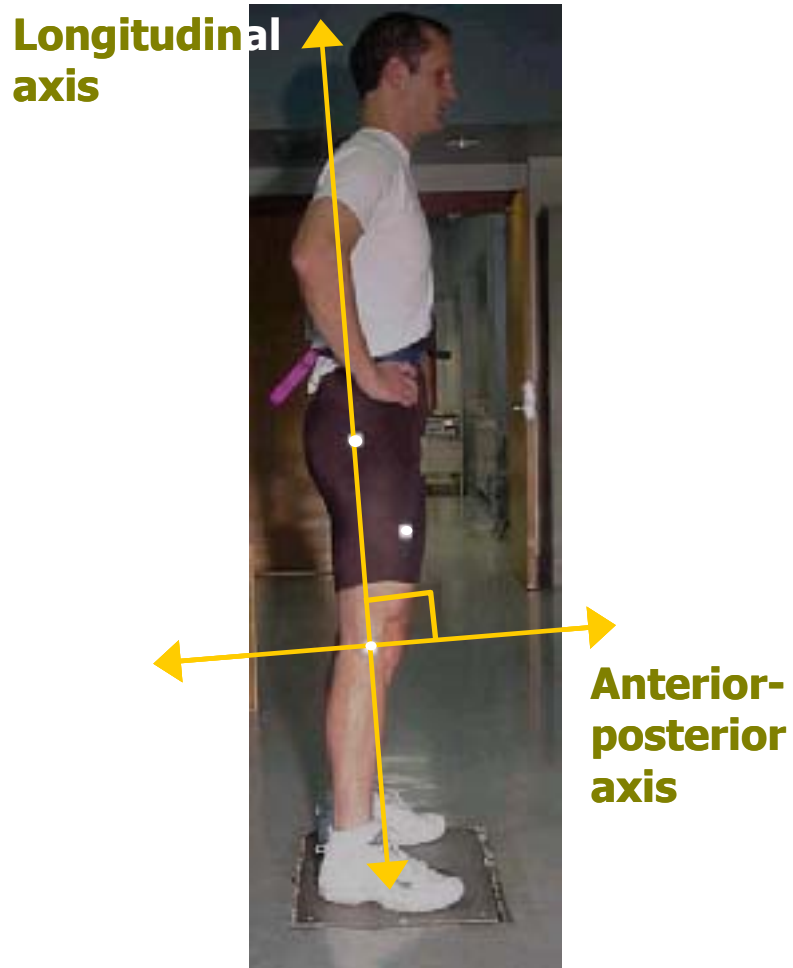


Figure 3. Experimental setup for countermovement jump test

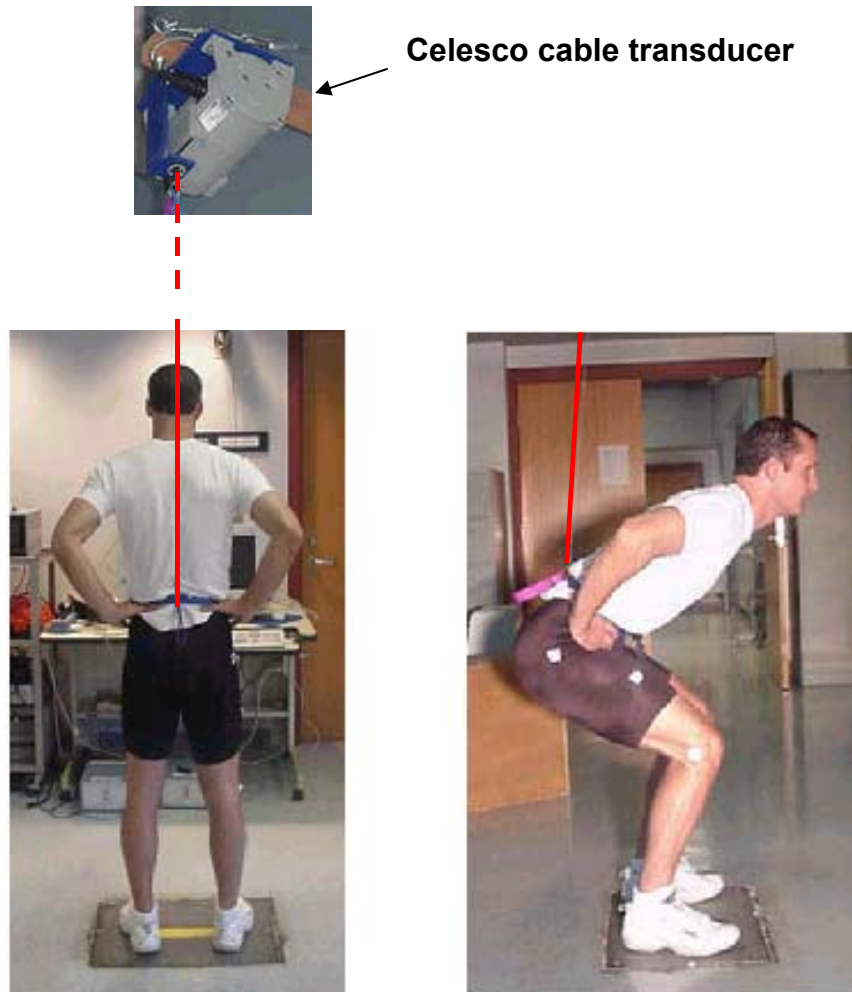


Figure 4: Experimental setup for impact force measurement test

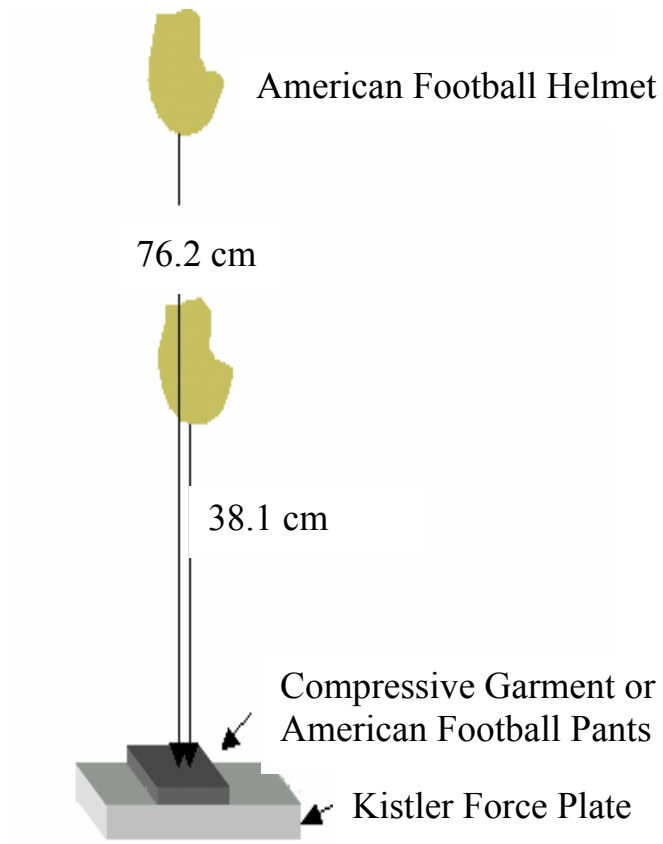


Figure 5. Experimental setup for measurement of effects of garment on hip joint torque.

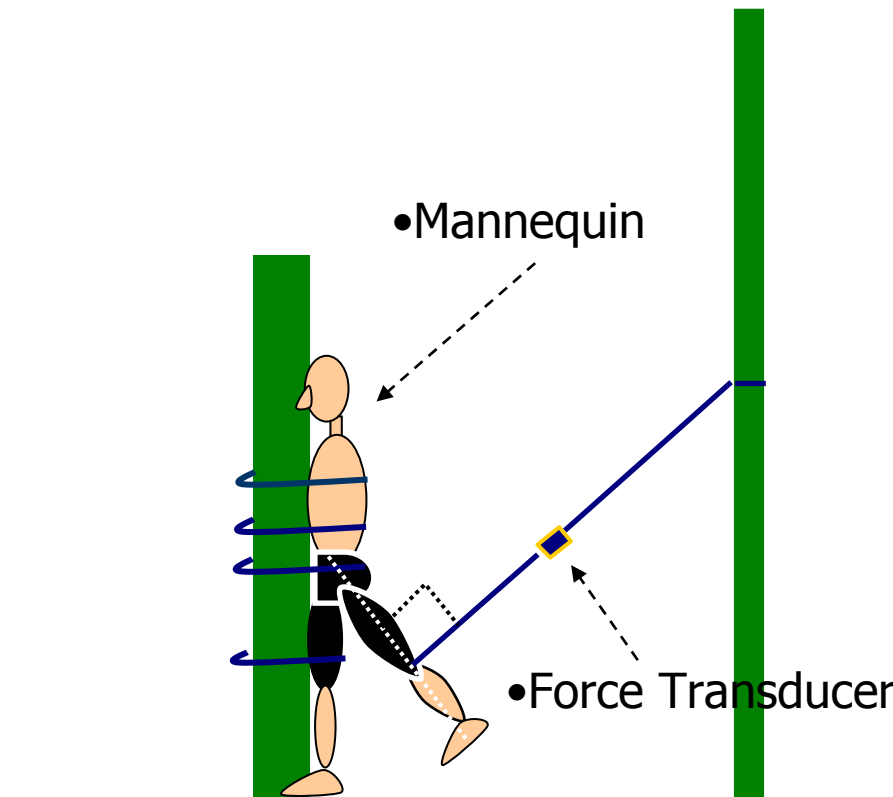


Figure 6. 60-meter sprint time values are means± S.D. * Difference between with and without garment conditions at significance level of $p \leq 0.05$

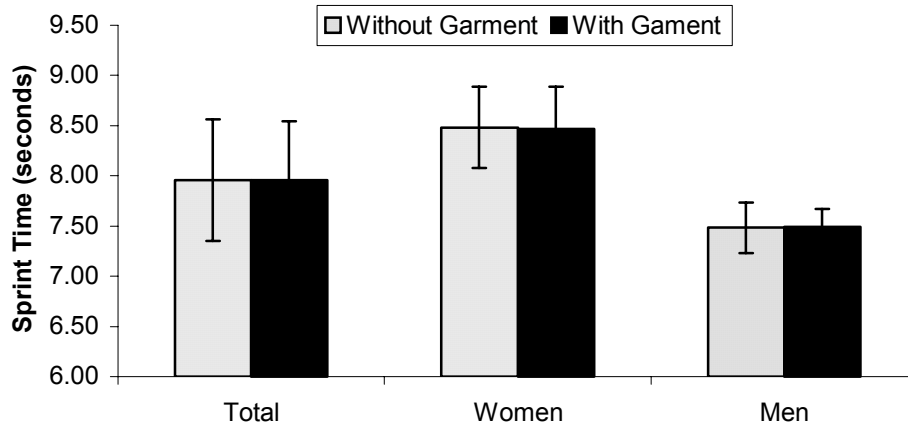


Figure 7. Hip and knee range of motion values in degrees are means \pm S.D.
*Difference between without and with garment conditions at significance level of $p \leq 0.05$

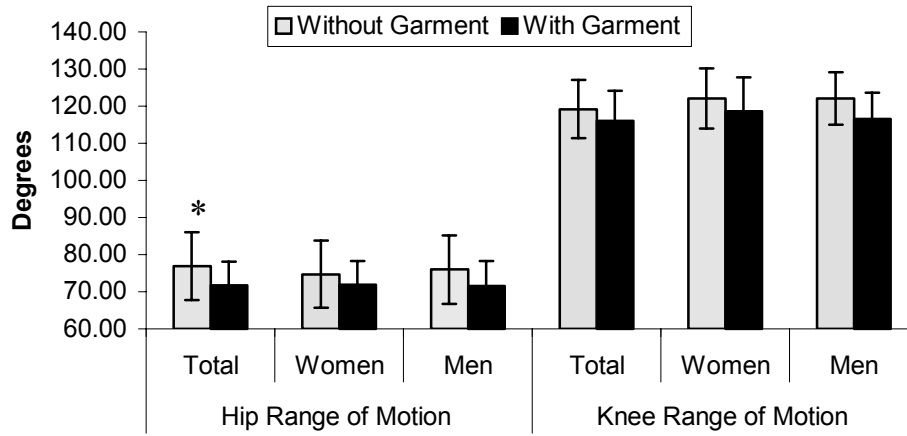


Figure 8. Anterior-posterior muscle oscillation values are means \pm S.D.
* Difference between without and with garment conditions at significance level of $p \leq 0.05$

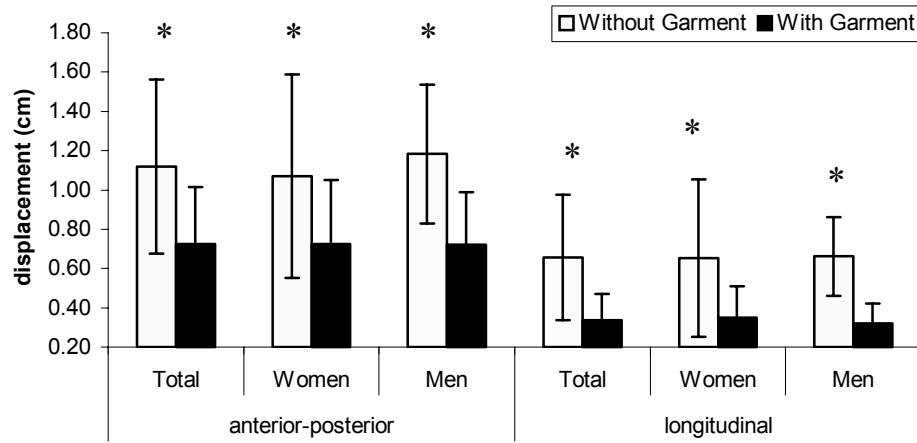


Figure 9. Maximum countermovement jump height values are means \pm S.D.
*Difference between without and with garment conditions at significance level of $p \leq 0.05$

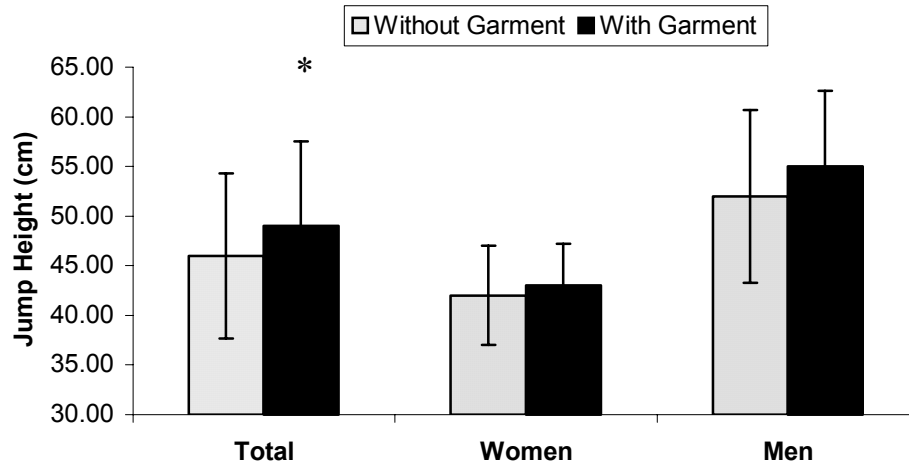


Figure 10. Minimum countermovement jump squat depth values are means \pm S.D. *Difference between without and with garment conditions at significance level of $p \leq 0.05$

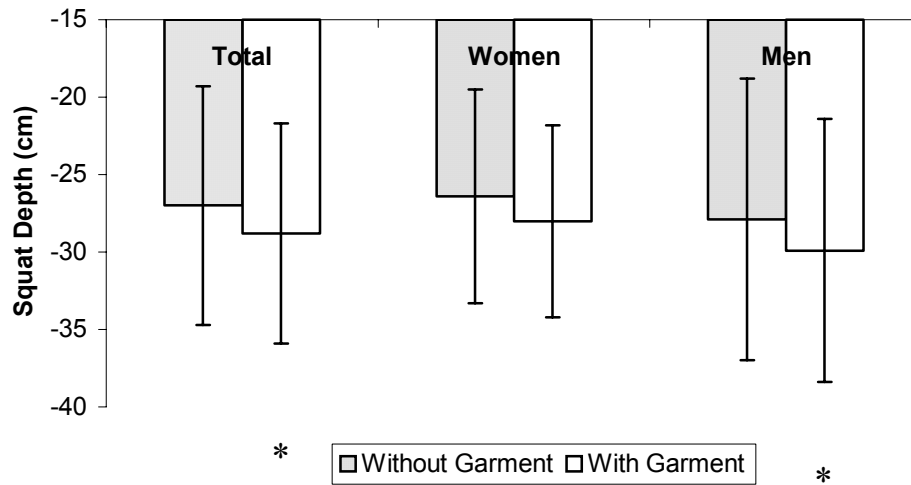


Figure 11. Change in skin temperature values are means \pm S.D. *Difference between without and with garment conditions at significance level of $p \leq 0.05$

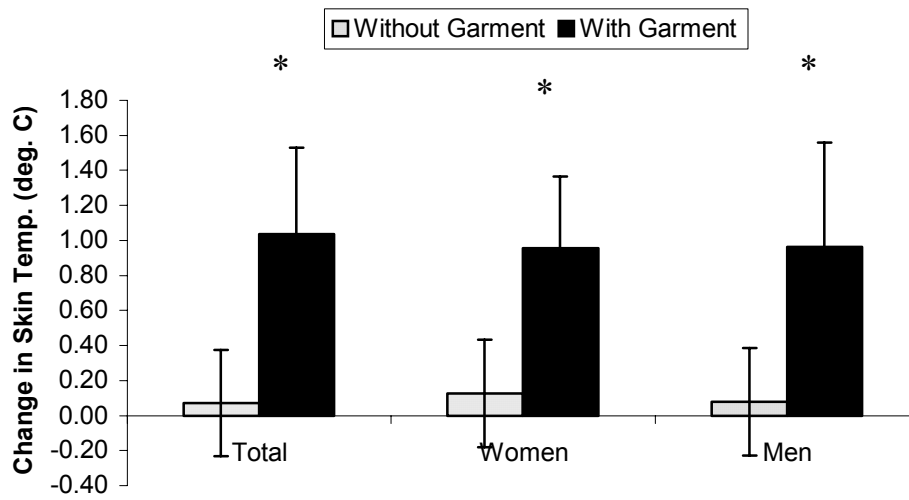


Figure 12. Impact force values measured from a 38.1 cm and 76.2 cm drop height are means \pm S.D. *Difference between without and with garment conditions at significance level of $p \leq 0.05$

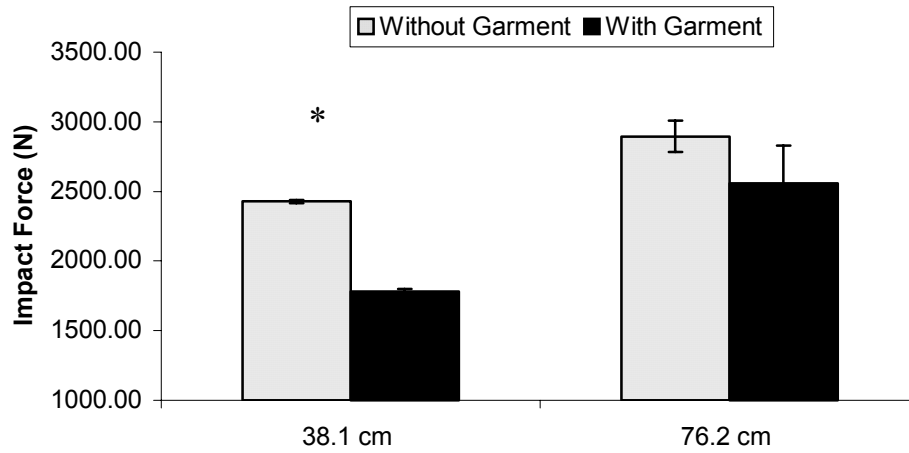


Figure 13. Mannequin hip joint torque values are means \pm S.D. *Difference between without and with garment conditions at significance level of $p \leq 0.05$

