Technical Report

A Detailed Investigation of the AntiBody Lower-Body Compression Garments on Athletic Performance

The Human Performance Laboratory

Ball State University, Muncie, IN 47306

by

William J. Kraemer, Ph.D., Professor/Director, The Human Performance Laboratory
Robert U. Newton Ph.D., Associate Professor/Director, Biomechanics Laboratory
Young-Hoo Kwon, Ph.D., Assistant Professor, Biomechanics
Ball State University, Muncie, IN 47306
Phone: 765-285-1158
Fax: 765-285-3238

EXECUTIVE SUMMARY

The purpose of this research project was to determine how custom fit compression shorts might affect athletic performance. Further, the mechanical properties of the shorts were investigated to help explain the performance enhancements. Ten men and ten women varsity track athletes specializing in sprint or jump events were recruited for this investigation. Testing utilized the AntiBody neoprene-cloth compression shorts, which run from the knee to just above the waist, and loose fitting gym shorts as the control garment. Both conditions for each of a series of performance tests were conducted on the same day using a balanced, randomized block design to remove day-to-day variation. Several significant and important effects were revealed for the AntiBody garment.

- Importantly 60m sprint speed was not reduced and in fact hip flexion angle was lower suggesting stride rate was increased.
- Skin temperature increased more during a warm-up protocol and was achieved more rapidly for the Antibody garment condition compared to gym short control.
- Muscle oscillation was significantly decreased during vertical jump landings when the subjects wore the Antibody garment.
- Countermovement vertical jump height increased when the subjects were wearing the Antibody garment.
- Elasticity of the Antibody 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. Further, at the completion of the propulsive phase this effect may also assist the hips flexors in accelerating the limb and so may contribute to reducing groin injuries as well as hamstring.
- In the materials testing the Antibody garment significantly reduced impact force compared to football pants alone and this has relevance to any and all impact sports.

Through various mechanisms, these findings may translate into an effect on athletic performance and reduction of injury.

Introduction

The use of compression garments in athletics and fitness activities is becoming more and more popular. Style, reduced chaffing, injury prevention, anecdotal and research-supported evidence of performance enhancement are all reasons cited for wearing these compressive garments. A look at 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 (Ghandhi et al., 1984, O'Donnell et al., 1979; Perlau et al., 1996; Sigel et al., 1975). 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. Additionally, it has been shown that the added opposing resistance against contracting muscles due to a compressive garment does not impede muscle performance (Kraemer et al., 1997).

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 ergometric 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 3/16th inch thick. This garment is much more compressive, elastic and impact absorbing than previously studied compressive garments and also, the garment has a tacky inner surface designed to maximize adhesion and prevent it sliding over the skin. These features may illicit different or additional benefits to athletic performance.

Methods

Subjects

Subjects included ten men (mean height, 179.1 cm; mean age, 20.0 years; mean body mass, 74.1 kg) and ten women (mean height, 168.9 cm; mean age, 19.2 years; mean body mass, 60.23 kg) varsity track athletes 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 (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 the knee to just above the waist and is a 15 to 20% smaller representation of the subject's lower body, but will expand to almost 100% of its original size. 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 3/16th inch thick.

Experimental Approach

Testing utilized the compression shorts and loose fitting gym shorts as the control garment. Both conditions for each of a series of performance tests were conducted on the same day using a balance, 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 an adequate time period and then crossed over and completed the other testing condition. Individual performance test means were calculated and compared within subjects for the with and without compressive garment conditions. Subjects performed a standardized warm-up protocol prior to each testing session

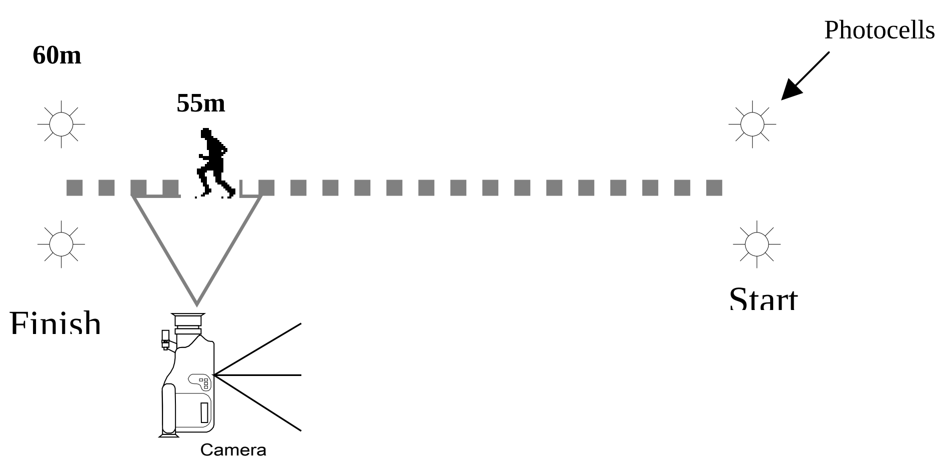
Testing Procedures

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. A

Berkey Colortran Multi-10A (model number 100-301) spotlight in line with the axis of the camera was used to illuminate the markers during the testing sessions.

A 486 Gateway 2000 computer equipped with a BCD Associated video controller board, a Sony PVM1341 video monitor, Panasonic AG-7300 VCR along with Kwon 3D, version 2.1 (Kwon, 1994) motion analysis software were 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. 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 time. Athletes rested for a minimum of 10 minutes between conditions. See figure 1.

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



testing.

Muscle Oscillation: Subjects were filmed performing countermovement jumps to measure thigh muscle oscillation between with and without the compressive shorts conditions. One 60Hz video camera (Panasonic WV-D5100HS) interfaced with a video recorder 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. A Berkey Colortran Multi-10A (model number 100-301) spotlight in line with the axis of the camera was used to illuminate the markers during the testing sessions.

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

A 486 Gateway 2000 computer equipped with a BCD Associated video controller board, a Sony PVM1341 video monitor, Panasonic AG-7300 VCR along with Peak Performance (Peak Performance Technologies Inc., Englewood, CO), version 5.3.0, motion analysis software were 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. Maximum longitudinal and anterior displacement of the thigh marker was calculated relative to the hip and knee markers and compared between conditions. See figure 2.

Fatigue-Agility Test: A modified T-Test (Seminec, 1990) was used to assess the athlete's agility and performance under fatigue. Two sets of four cycles through the course were performed with 2 minutes rest in between sets and a minimum of 10 minutes rest between testing conditions. Four touch mats (Control Mat #5510, Tapeswitch Corp., Farmsdale, NY) were used to measure intervals and ground-contact time. Kinematic Measurement System (Innervations, Muncie, IN) software was used to link mats and record times.

Figure 3. Subject completing the modified T-Test.

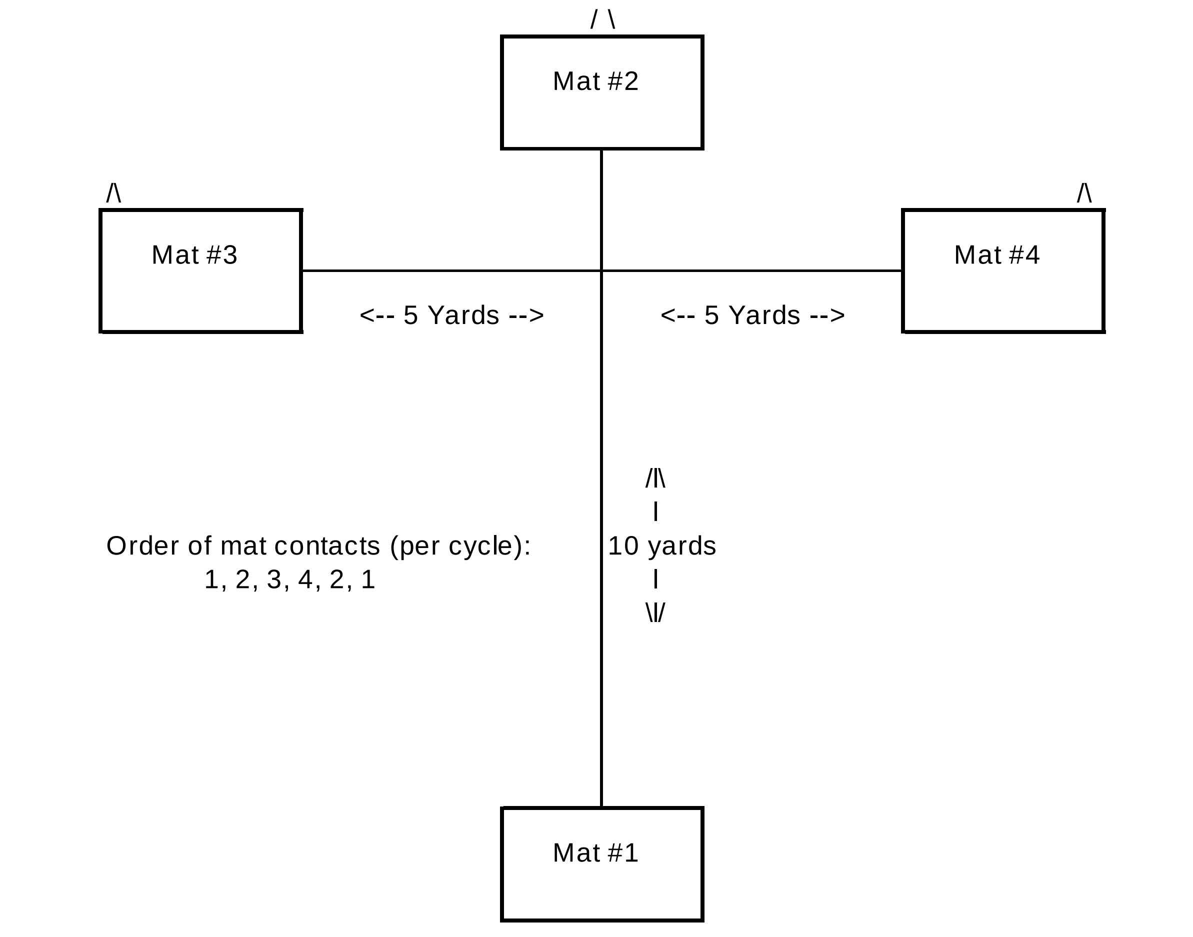


Figure 4. Schematic diagram of modified T-Test.

Total time, interval time, and contact times were summed and compared between conditions. Total time was calculated as time from start to finish of the entire trial. Interval time was calculated as the sum of the times between each individual mat. Contact time was calculated as the sum of all the times the subject's foot was in contact with each mat. See figures 3 and 4.

Jump-Power Test: Three maximal efforts (hands on hips) at: .61 m (24 in.) drop jump, .30 m (12in) drop jump, and countermovement jump were performed on a force plate. Subjects practiced each mode of jump until they were comfortable and consistent. Jump heights were measured with a Celesco cable

Figure 5. Experiment setup for the Jump-Power Testing.

transducer (Celesco, CA) attached to the subject's waist. Vertical ground reaction force data was recorded at 500 Hz with a Kistler force place (model number 9281B) interfaced with a Pentium II computer and analyzed with Ballistic Measurement System (Innervations, Muncie, IN) computer software. The force plate was connected to a Kistler 8 channel charge amplifier (type 9865A) (Kistler Instrument Corporation, Amherst, NY). The same measurement system was used for the drop jump trials and subjects were instructed to minimize ground contact time and maximize jump height (Young et. al, 1995). Subjects repeated jumps until two consistent trials were recorded for each condition on each jump (see Figure 5).

Shock Attenuation Test: Each subject ran for on a treadmill for at least 5 minutes or until they were comfortable and able to maintain a consistent gait pattern. Subsequently, each subject ran on the same treadmill for two minutes at 2.7 m/s (6 mph). Tibial and forehead acceleration was recorded with a 17.0g (gravitational acceleration) triaxial accelerometer (Biopac model TSD109F) interfaced with a Pentium II computer, and analyzed with Biopac Acq*Knowledge* (version 3.5.2) computer software (Biopac Systems, Inc.). The accelerometer was placed on the anteromedial aspect of the tibia, 5cm below the distal border of the patella with the vertical axis aligned parallel to the longitudinal axis of the bone. The accelerometer was held firmly in place with athletic tape and a Velcro strap that was tightened to the pain tolerance of each subject**.** The vertical component of acceleration was sampled at 2000 Hz and recorded for the last 30 seconds of the trial. Subjects rested for a minimum of five minutes between conditions. Each subject's skin was marked between conditions to ensure

Figure 6. Experimental setup for the head and tibial shock attenuation measurement.

consistent placement of accelerometers. Peak values for tibial and forehead acceleration and head to tibia shock attenuation ratios were compared between conditions (Derrick et al, 1998)

Skin Temperature: Subjects pedaled on a bicycle ergometer (see Figure 7) for five minutes with 1.5 W/Kg of bodyweight resistance. Two type-T copper-

Figure 7. Experimental setup for the skin temperature measurement during stationary cycling.

constantin thermocouples were secured under the compressive shorts and loose fitting control shorts with breathable tape (Kendall, Polyskin II, Mansfield, MA) 24 cm (9 inches) 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.

Mechanical characteristics of garment:

Impact: Standard impact testing was conducted on the garment material to assess the impact attenuation properties of the garment. A collegiate football helmet weighted to a total mass of 5.44 kg (12 lbs) was repeatedly dropped on a force plate from 38.1 and 76.2 cm. The helmet was dropped onto a normal pair of football pants for the control condition and onto a swatch of the compressive garment material for the experimental condition. Vertical ground reaction force data was recorded at 7000 Hz with a Kistler force place (model number 9281B) interfaced with a Pentium II computer and analyzed with Bioware (Kistler

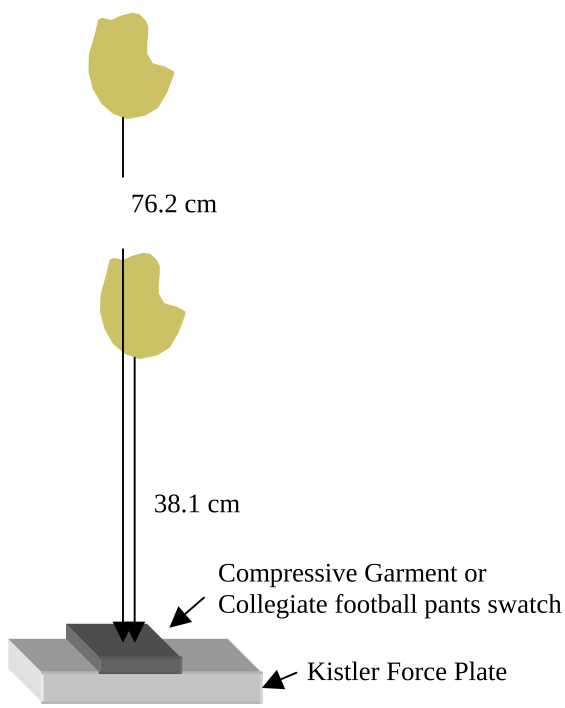


Figure 8. Compressive Garment Impact Testing Diagram

Instrument Corporation, Amherst, NY) computer software. The force plate was connected to a Kistler 8 channel charge amplifier (type 9865A) (Kistler Instrument Corporation, Amherst, NY). Peak force values were compared between conditions.

Elasticity: The garment was fitted to a mannequin to measure the elastic properties of the garment. Force data was collected at 200 Hz on Biopac Acq*Knowledge* (version 3.5.2) computer software (Biopac Systems, Inc.) using an Entran (Fairfield, NJ) force transducer. A life-size mannequin cast from a human specimen with full joint range of motion (Gatesville Doll, MA56237) 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. Force was measured with and without the compressive garment on the mannequin and the amount of torque at the joint was calculated.

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 an alpha of $p \leq 0.05$.

Results

A summary of the results is contained in Tables 1, 2, and 3. A significant reduction with the garment was noted in both vertical and horizontal thigh musculature oscillation during vertical jump landing for men and women ($p = 0.013$ for all groups and conditions)(Figure 9). 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. A significant ($p = 0.04$) reduction for the total group only in hip range of motion during a sprint was noted. However, the individual groups of men and women hip range of motion and men knee range of motion for all groups was not significantly reduced. No significant difference was found when comparing 60-meter sprint times. The agility test revealed a trend towards a reduction in ground-contact times, however the difference was not significant. No significant difference was found in agility test interval times. Comparison of head to tibia shock attenuation ratios also showed no significant difference between conditions. 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. The elasticity of the garment increased torque at the hip joint by 53.1% to 90.8% during flexion and by 190.5% to 284.63% during extension. Single maximal countermovement vertical jump height significantly ($p = 0.015$) increased from 0.461m to 0.485m for the pooled group of subjects. 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 pooled subject group ($p = 0.016$).

Table 1. Summary data for the effects of compressive shorts. Significant differences between with and without compressive garment conditions are highlighted in bold type.

VARIABLE		Without Garment		With Garment		%	
		Mean	*SD ±*	Mean	*SD ±*	Difference	P Value
Horizontal Muscle Oscillation (cm)	**Total**	**1.12**	***0.44***	***0.72**	***0.29***	**-35.30%**	**0.000167**
	Women	**1.07**	***0.52***	***0.73**	***0.33***	**-32.24%**	**0.010341**
	Men	**1.18**	***0.35***	***0.72**	***0.27***	**-38.88%**	**0.007501**
Vertical Muscle Oscillation (cm)	**Total***	**0.66**	**0.32**	***0.34**	***0.13***	**-48.71%**	**0.000187**
	Women	**0.65**	**0.40**	***0.35**	***0.16***	**-46.55%**	**0.012967**
	Men	**0.66**	**0.20**	***0.32**	***0.10***	**-51.51%**	**0.010081**
Change in Skin Temperature (°C)	**Total**	**0.07**	***0.30***	***1.04**	***0.49***	**1361.97%**	**0.000001**
	Women	**0.13**	***0.31***	***0.96**	***0.41***	**651.26%**	**0.000106**
	Men	**0.08**	***0.31***	***0.96**	***0.60***	**1111.21%**	**0.003042**
Hip Range of Motion (degrees)	**Total**	**76.85**	**9.28**	***71.77**	***6.44***	-6.61%	**0.041111**
	Women	77.86	9.62	72.66	*6.33*	-6.68%	0.058950
	Men	75.93	9.28	70.89	*6.77*	-4.31%	0.240363
Knee Range of Motion (degrees)	Total	119.22	*7.84*	115.97	*8.16*	-2.72%	0.157471
	Women	116.61	*7.49*	113.66	*7.21*	-2.53%	0.411749
	Men	121.57	*7.75*	118.05	*8.76*	-2.90%	0.356275
60m Sprint Time (sec)	Total	7.96	*0.61*	7.95	*0.59*	-0.02%	0.968988
	Women	8.48	*0.41*	8.47	*0.42*	-0.14%	0.787008
	Men	7.48	*0.25*	7.49	*0.18*	0.11%	0.908137
Agility T-Test - Contact Time (sec)	Total	2.35	*0.57*	2.21	*0.47*	-6.18%	0.104457
	Women	2.56	*0.64*	2.34	*0.60*	-8.48%	0.124443
	Men	2.55	*0.44*	2.37	*0.28*	-7.32%	0.506655
Agility T-Test - Interval Time (sec)	Total	29.68	*2.51*	29.94	*2.42*	0.89%	0.093135
	Women	28.49	*1.80*	29.02	*1.81*	1.88%	0.074788
	Men	30.75	*2.65*	30.77	*2.68*	0.06%	0.877686
Shock Attenuation Ratio (Head to Tibia)	Total	0.79	*0.27*	0.83	*0.34*	6.01%	0.206593
	Women	0.74	*0.26*	0.77	*0.27*	4.65%	0.226454
	Men	0.85	*0.30*	0.92	*0.43*	8.04%	0.454406
Impact Force at 38.1 cm drop ht. (N)		**2427.00**	**13.05**	**1780.80**	**20.47**	**-26.63%**	**0.000000**
Impact Force at 76.2 cm drop ht. (N)		2894.00	112.65	2559.40	270.80	-11.56%	0.065641
Mannequin Hip Joint Torque (Nm)							
127° flexion		**7.49**		***11.47**		**53.10%**	
158.5° flexion		**2.32**		***4.43**		**90.83%**	
200° extension		**1.99**		***5.77**		**190.52%**	
195° extension		**1.17**		***4.51**		**284.63%**	

Table 2. Countermovement Jump Comparison. Significant differences between with and without compressive garment conditions are highlighted in bold type.

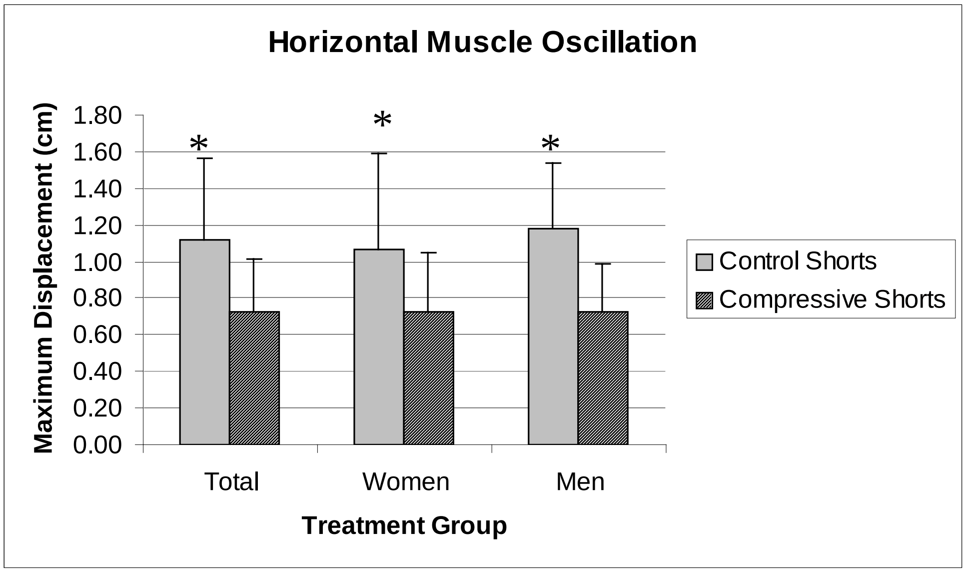
COUNTERMOVEMENT JUMP VARIABLE		Without Garment		With Garment		%	
		Mean	*SD ±*	Mean	*SD ±*	Difference	P Value
maximum distance (jump height) (m)	**Total**	**0.461**	***0.083***	***0.485**	***0.085***	**5.21%**	**0.015**
	Women	0.417	*0.050*	0.431	*0.042*	3.48%	0.118
	Men	0.517	*0.087*	0.553	*0.076*	6.99%	0.071
minimum distance (squat depth) (m)	**Total**	**-0.270**	**0.077**	***-0.288**	***0.071***	**6.65%**	**0.024**
	Women	-0.264	0.069	-0.280	*0.062*	5.96%	0.231
	Men	**-0.279**	**0.091**	***-0.299**	***0.085***	**7.49%**	**0.016**
peak velocity (m/s)	Total	2.709	*0.366*	2.761	*0.369*	1.89%	0.084
	Women	2.513	*0.263*	2.554	*0.210*	1.66%	0.178
	Men	2.962	*0.332*	3.026	*0.368*	2.15%	0.288
minimum (squat) velocity (m/s)	Total	-2.327	0.348	-2.396	*0.323*	2.98%	0.184
	Women	-2.167	0.262	-2.230	*0.186*	2.90%	0.444
	Men	-2.529	0.353	-2.606	*0.349*	3.05%	0.124
peak force (N)	Total	1595	*314*	1562	*288*	-2.12%	0.581
	Women	1472	*333*	1394	*199*	-5.33%	0.481
	Men	1719	*260*	1730	*272*	0.63%	0.869
Peak Power (W)	Total	3344	*704*	3456	*677*	3.35%	0.079
	Women	**2781**	***376***	***2884**	****341***	**3.68%**	**0.043**
	Men	3907	*442*	4028	*337*	3.11%	0.332

Table 3. High Drop Jump Comparison

HIGH DROP JUMP VARIABLE		Without Garment		With Garment		%	
		Mean	*SD +*	Mean	*SD +*	Difference	P Value
Flight to Contact Time Ratio	Total	1.594	0.247	1.651	0.291	3.57%	0.372
	Women	1.576	0.176	1.665	0.257	5.68%	0.287
	Men	1.617	0.145	1.632	0.178	0.91%	0.891
maximum distance (jump height) (m)	Total	0.477	0.105	0.468	0.097	-1.72%	0.550
	Women	0.449	0.058	0.455	0.081	1.34%	0.118
	Men	0.504	0.122	0.482	0.111	-4.45%	0.629
minimum distance (squat depth) (m)	Total	-0.379	0.211	-0.370	0.217	-2.57%	0.817
	Women	-0.411	0.223	-0.390	0.238	-5.26%	0.667
	Men	-0.348	0.217	-0.350	0.204	0.61%	0.977
peak velocity (m/s)	Total	2.708	0.262	2.620	0.331	-3.25%	0.378
	Women	2.648	0.165	2.564	0.203	-3.14%	0.548
	Men	2.769	0.298	2.676	0.413	-3.36%	0.559
minimum (squat) velocity (m/s)	Total	-3.027	0.157	-3.006	0.166	-0.69%	0.652
	Women	-3.051	0.098	-2.976	0.170	-2.44%	0.444
	Men	-3.004	0.196	-3.036	0.168	1.08%	0.626
peak force (N)	Total	2126	*300*	2116	*205*	-0.46%	0.904
	Women	2391	*250*	2286	*183*	-4.40%	0.482
	Men	2299	*342*	2355	*222*	2.43%	0.664
Peak Power (W)	Total	3342	*891*	3164	*704*	-5.32%	0.303
	Women	3356	*550*	3320	*157*	-1.07%	0.781
	Men	3683	*1066*	3622	*810*	-1.65%	0.810

Table 4. Low Drop Jump Comparisons

LOW DROP JUMP VARIABLE		Without Garment		With Garment		%	
		Mean	*SD* ±	Mean	*SD* ±	Difference	P Value
Flight to Contact Time Ratio	Total	1.569	0.382	1.562	0.505	-0.41%	0.941
	Women	1.531	0.336	1.535	0.435	0.25%	0.977
	Men	1.617	*0.336*	1.598	0.392	-1.21%	0.875
maximum distance (jump height) (m)	Total	0.432	0.111	0.437	0.095	1.34%	0.588
	Women	0.391	0.100	0.410	0.100	4.70%	0.721
	Men	0.478	0.111	0.469	0.089	-1.82%	0.885
minimum distance (squat depth) (m)	Total	-0.259	0.110	-0.285	0.112	-9.80%	0.049
	Women	-0.245	0.092	-0.295	0.123	-20.62%	0.280
	Men	-0.276	0.133	-0.273	0.108	1.17%	0.967
peak velocity (m/s)	Total	2.615	0.281	2.628	0.321	0.50%	0.741
	Women	2.551	0.311	2.625	0.338	2.89%	0.676
	Men	2.687	0.246	2.631	0.317	-2.10%	0.741
minimum (squat) velocity (m/s)	Total	-2.485	0.265	-2.476	0.262	-0.36%	0.824
	Women	-2.443	0.241	-2.421	0.206	-0.92%	0.843
	Men	-2.532	0.302	-2.539	0.315	0.25%	0.975
peak force (N)	Total	2120	*345*	2128	*349*	0.38%	0.825
	Women	1939	*363*	1942	*373*	0.13%	0.959
	Men	2301	*221*	2315	*252*	0.60%	0.933
Peak Power (W)	Total	3753	*890*	3669	*687*	-2.26%	0.363
	Women	3443	*1056*	3428	*755*	-0.42%	0.973
	Men	4064	*611*	3909	*564*	-3.81%	0.688



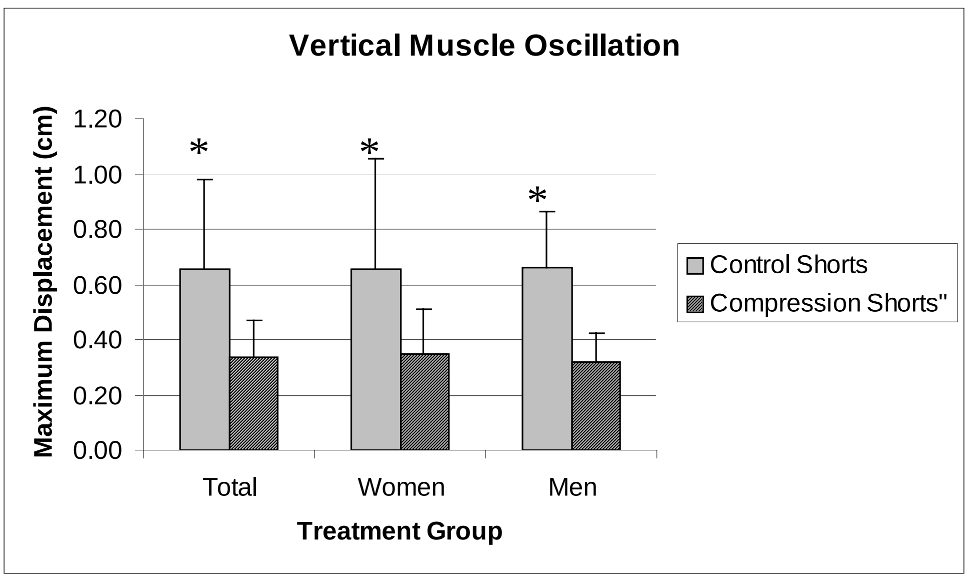


Figure 9. Muscle Oscillation Charts.
* Compression shorts condition significantly (p = .05) lower maximum oscillatory displacement.

Discussion

From the performance test results of this study we observed several possible positive enhancements 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 yet running velocity was not effected suggesting an increase in stride frequency. Through various mechanisms, these findings may translate into an effect on athletic performance and reduction of injury.

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, and maintain skin/muscle temperature, thereby enhancing muscle performance. Additionally, studies have shown that increased musculotendinous temperature may reduce injury potential (Agre, 1985 and Kujala et al, 1997).

According to the kinematic results of this study, the garment slightly decreases the hip joint range of motion during sprinting. The subjects ran the same speed, however, with decreased hip range of motion, which may mean the garment increases stride frequency however this was not measured in the current study and is hypothetical 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 interfere with the motion. This is an important finding because a theoretical prediction could be that the high compression and elasticity of the garment would interfere with normal sprint mechanics and reduce running velocity. Empirical evidence refutes such a claim. In fact, the elasticity of the garment may increase the acceleration of the leg coming down and has the potential to increase running velocity. However, additional kinematic analysis would be necessary to confirm this. Testing of sprint velocity was limited to 60m because of the size of the indoor track used. Contribution of the garment to running velocity may be more apparent when tested over longer distances of 100-400m in which the cumulative effect of the garment may be quantifiable using electronic timing systems. Additionally, the garment may reduce injury by assisting the eccentric action of the hamstrings at end of recovery phase (Kujala, 1997) and the hip flexors at the start of the recovery phase.

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, according the countermovement vertical jump test results from this study, the maximum jump heights of the athletes under the compressive garment condition was significantly higher than the control condition. 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) squat depth to be performed, resulting in a greater impulse in the concentric phase of the jump. Additionally, previous studies have shown an increased proprioception with compressive garments (Barrack et al., 1989; Kraemer et al., 1998; Perlau et al., 1995), 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.

This investigation found significantly reduced longitudinal and anterior 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).

The agility test revealed a trend towards a reduction in ground-contact times, however the difference was not significant. Improved hip stability and/or proprioception may improve agility and reduce the time the athlete is in contact with the ground. Additionally, previous studies have shown a reduction in fatigue due to a compressive garment, which may be due to increased muscle pump (increased venous return) and removal of lactate from the working muscles (Kraemer et. al, 1998).

Mechanical testing revealed some further potential benefits the garment may have on 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 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. In the situation of the groin muscles (hip flexors) they are maximally stretched at the start of the recovery phase as the support leg leaves the ground. The groin is also a common site for injury and most likely occurs at this phase of the running stride. There is a considerable contribution of elastic recoil of the garment at the end of the hip extension and beginning of leg recovery and this extra flexion torque about the hip will assist the hip flexors and may reduce groin strains. Also, the compression and elastic resistance to joint movement may reduce extraneous movement about the hip such as rotation and abduction. This may provide benefits in terms of injury risk reduction during sprinting as well as keeping the athlete more stable by reducing movements other than those in the sprint direction.

The garment may also aid the athlete in the propulsive phases of sprinting and jumping. Impact testing revealed that the garment is effective at significantly attenuating impact forces. This may be valuable information for impact-related injury prevention in contact sports and sports associated with a high incidence of falling (e.g. football).

Although not evaluated, the material is designed with a 'tacky' inner surface with the goal of providing increased adhesion to the skin. This is important to provide a mechanical mechanism to transmit forces from the garment to the body. If the garment simply slipped over the skin surface, particularly when wet with sweat, the biomechanical effects discussed would not be as evident.

In conclusion, wearing the Antibody compressive shorts:

- contributes elastic energy to hip flexion and extension which appears to improve vertical jump performance and may increase stride frequency in sprinting;

- compresses the underlying muscle which should improve the muscle pump and venous return as well as reducing muscle oscillation. This has the physiological potential to reduce fatique and improve recovery;
- increases the rate of temperature increase with warm-up and maintains the temperature. Such an effect might lead to less warm-up time and therefore less fatigue and the maintenance effect is important for keeping athletes warm on the sideline without the necessity for continuous exercise;
- reduces the forces exerted during impacts and thus might protect the athlete from such injuries.

All of these mechanisms combined should have a positive influence on performance, reduction of injury, and extension of an athlete's playing career.

Summary

Wearing Antibody compressive shorts does not reduce sprinting speed over 60 meters and it may have an enhancement effect over longer distances but this needs to be experimentally determined. It is clear that wearing the Antibody garment improves warm-up and maintains muscle warmth 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 risk 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. Further, the elastic tension developed at the end range of hip extension would assist the hip flexor muscles in accelerating the leg forward during the swing phase and this contribution may reduce groin injuries. In addition, the material used in the Antibody garment is capable of attenuating impact forces and this may have some benefit when worn during contact sports.

References

Agre, J.C. (1985) Hamstring injuries. Proposed aetiological factors, prevention, and treatment. *Sports Medicine.* Jan-Feb;2(1):21-33.

Astrand, P.O. and K. Rodahl. (1977) *Textbook of work physiology*, 2nd ed, New York, McGraw-Hill, Inc.

Barrack, R.L., Skinner, H.B., and Cook, S.D. (1983) Effect of articular disease and total knee arthroplasty on knee joint position sense. *J. Neurophys.* 50:684-687.

Bergh, U. and Ekblom, B. (1979) Influence of muscle temperature on maximal muscle strength, power output in human skeletal muscles. *Acta Physiol. Scand*. Sep; 107(1):33-37.

Berry, M.J., S.P. Bailey, L.S. Simpkins, and J.A. TeWinkle. (1990) The effects of elastic tights on the post-exercise response. *Can. J. Sport Sci.* 15:244-248.

Derrick, T.R., Hamill, J., and Caldwell, G.E. (1998) Energy absorption of impacts during running at various stride lengths. *Medicine and Science in Sports & Exercise* 30(1), 128-135.

Gandhi, DB., J.D. Palmer, B. Lewis, and I.G. Schraibman. (1984) Clinical comparison of elastic supports for venous diseases of the lower limp. *Postgrad. Med J.* 60:349-352.

Isaji, S., Yoshimura K., and Amano T.. (1994) The regional skin temperature of hand under different clothing conditions. *Ann Physiol anthropol*. Nov; 13(6):375-81.

Kraemer, W.J. , Bush, J.A., Bauer, J.A., Triplett-McBride, N., Paxton, N. J., Clemson, A., Koziris, P.L., Mangino, L.C., Fry, A.C., Newton, R. U. (1998). Influence of compressive garments on vertical jump performance in NCAA Division I Volleyball Players. *Sports Med., Training and Rehab.* 8, 163-184.

Kraemer, W.J. , Bush, J.A., Newton, R. U. Duncan, N.D., Volek, J.S., Denegar, C.R., Canavan, P., Johnston, J., Putukian, M., and Sebastianelli, W.J. (1998). Influence of a compressive garment on repetitive power output production before and after different types of muscle fatigue. *Sports Med., Training and Rehab.* 8, 163-184.

Kraemer, W.J., Newton, R.U., Bush, J.A., Duncan, N.D., Volek, J.S., Nindl, B., Harman, F., Hakkinen, K., Denegar, C.R., Canavan, P., Putukian, M.,Johnston, J., and Sebastianelli, W.J. (1997). Influence of a compressive on muscle function and soreness after maximal eccentric exercise. *Abstract, 1997 NSCA Conference.*

Kuster, M.S., Grob, K., Kuster, M., Wood, G.A., and Gachter A. (1999) The benefits of wearing a compression sleeve after ACL reconstruction. *Med Sci Sports Exerc* 31(3): 368-71.

Kujala UM, Orava S, Jarvinen M. (1997) Hamstring injuries. Current trends in treatment and prevention. *Sports Med.* Jun;23(6):397-404.

McComas, A.J. (1996) *Skeletal Muscle: Form and Function.* Human Kinetics, Champaign, IL.

O'Donnell, T.F., D.A. Rosenthal, A.D. Callow, and B.L. Ledig. (1979) Effect of compression on venous hemodynamics in postphlebitic limbs. *J. Am. Med. Assoc.* 242:2766-2768.

Perlau, R., C. Frank, and G. Fick. (1995) The effect of elastic bandages on human knee proprioception in the uninjured population. *Am. J. sports Med*. 23:251-255.

Sargeant, A.J. (1987) Effect of muscle temperature on leg extension force and short-term power output in humans. *Eur J Appl Physiol*. 56(6):693-8.

Semenick, D. (1990) Tests and measurements: The T-Test. *NSCA J*. 12(1)36-37.

Sigel, B., A.L. Edelstein, L. Savitch, J.H. Hasty, and R. Felix. (1975) Types of compression for reducing venous stasis: A study of lower extremities during inactive recumbency. *Arch Surg*. 110:171-175.

Young, W.B., Pryor, J.F., and Wilson, G.J. (1995) Effect of instructions on characteristics of countermovement and drop jump performance. *Journal of Strength and Conditioning Research,* 9(4): 232-36.