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Original Research

The Effects of Exercise Training in a Novel Full-Body Compression Garment on Anaerobic Performance in Healthy Men

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Abstract

International Journal of Exercise Science 18(8): 836-851, 2025. https://doi.org/10.70252/DKHN4431 Although acutely donning compression garments improves several markers of athletic performance, the effects of training in compression garments remains largely unexplored. Thus, this study aimed to determine the effects of exercise training while donning a novel full-body compression garment on multiple measures of anaerobic performance. Sixteen sedentary males (age: 21±3 y; BMI: 25±3 kg/m^2) completed 4 weeks of training with (CG; n=8) or without (CON; n=8) a novel full-body compression garment. Subjects performed a 40m sprint (time and velocity), a 5-repetition maximum barbell back squat (barbell weight and serratus anterior activity), a countermovement vertical jump (VJ; displacement, force, power, velocity, and acceleration), and a Wingate Anaerobic Test (WAnT; peak power, mean power, and fatigue index) before (PRE) and after (POST) training. Data are presented as mean ± SD changes from PRE and were analyzed via two-way repeated measures ANOVAs. CG showed a significant increase when compared to CON for the change in sprint velocity (-0.68±0.26 m/s, P = 0.014), VJ velocity (+0.15±0.07 m/s, P = 0.033), WAnT relative peak power (+0.88±0.49 W/kg P = 0.018), WAnT absolute mean power (+62.37±52.11 W, P = 0.006), and WAnT relative mean power (+0.83±0.53 W/kg, P = 0.004). While there were statistically significant improvements from PRE to POST in other measures, only the aforementioned five variables demonstrated intergroup significance. Overall, donning this novel full-body compression garment during training led to enhanced performance in specific anaerobic measures when compared to not training in the garment.

Keywords: Anaerobic power, axial loading, core muscle activation, anti-gravity kinetic chain, Wingate Anaerobic Test

Introduction

The field of kinesiology is continually evolving in an attempt to improve human performance. Wearable ergogenic aids, such as compression garments, are commonly used to improve performance, alleviate pain, and/or enhance recovery.[1] The usage of compression garments during exercise has been shown to have many physiological benefits[1], primarily concerning circulatory assistance.[2] These benefits do not appear to be due to the placebo effect, as an augmented blood flow to the active muscles, induced via the compression garments, improves post-exercise recovery.[2] In fact, these enhancements are likely due to acute adaptations of venous and muscular blood flow.[3] In addition, compression promotes lymphatic clearance by impeding inflammatory responses and minimizing further muscle damage.[4,5] Such responses and adaptations support the usage of compression garments during and after intense exercise.

Recently, a novel compression garment emerged and is purported to facilitate core muscular activation via axial loading.[6] Previous findings demonstrate that gravitational loading enhances human performance through the activation of deep core muscles.[6] By mimicking the effects of gravity, the deep postural muscles (i.e., multifidus and transversus abdominis) are activated[6] to maintain the stability of the spine and pelvis[7] while also preventing postural deformation.[8] Furthermore, the kinetic chain experiences less compressive and shearing forces when the spine and pelvis are placed in a mechanically favorable position[9], which is typically ensured through proper bracing. In turn, this elicits optimal force distribution for functional movements.[9] Additionally, gravitational loading, or lack thereof, induces physiological adaptations within the skeletal and muscular systems since these systems are mechanosensitive to gravity.[6] In sum, the inciting factor of postural muscle tone is gravity, as gravity elicits prolonged exposure to load.[10] The activation of the core muscles correspondingly increases intra-abdominal pressure, ergo increasing lumbar stability.[11] Thus, it is plausible that an augmented axial load during exercise training will improve performance aside from the demonstrated effects of compression garments in previous studies.

Exercise training alone has been shown to enhance exercise performance.[12] However, speculation remains regarding the effectiveness of training while wearing compression garments when compared to not wearing compression garments.[1,13] Despite scant research on this topic, Baum et al provided promising findings in 2020. After four weeks of lower-body resistance training, their findings indicated that donning a novel lower-limb compression garment during training augmented performance variables (seated leg press, jump height, peak and average power) when compared to training without it.[14] This device, a Restrictive Compression Garment by Blueprint Phoenix, provides patterned, internal resistance when stretched via layers of elastic bands within the device. They suggested that the increase in muscular strength and power may be credited to the addition of the lower limb restrictive compression garments during training.[14] These improvements are indicative of the effects of variable resistances applied to the anterior and posterior chains of musculature.[14] Additionally, training in similar garments has been shown to play a protective role concerning injuries compared to training without them.[15] According to Lucas-Cuevas et al, donning compression stockings during three weeks of running-based training was shown to reduce impact acceleration, thus decreasing the likelihood of injury.[15]

However, it is unknown if training in the G-Suit by Gravity Fit enhances human performance when compared to a control group that does not train in the garment. To this end, the purpose of our investigation was to determine the effects of exercise training while donning a full-body compression garment on multiple measures of anaerobic performance. We hypothesized that training in the compression garment would improve performance measures of the sprint, barbell back squat, vertical jump, and Wingate Anaerobic Test (WAnT) when compared to training without the compression garment.

Methods

Participants

Sixteen sedentary males (age: 21 ± 3 y; BMI: 25 ± 3 kg/m^2) voluntarily participated in this investigation. Recruitment was coordinated via word of mouth. All subjects completed a written informed consent followed by a health history questionnaire. Subjects self-reported to be healthy and free from major health conditions including cardiovascular disease, cancer, diabetes, pulmonary disorders, coronary and peripheral artery disease, and cognitive disorders. Despite their general health, all subjects were deemed sedentary as they did not meet the criteria to be considered physically active according to the American College of Sports Medicine.[16] The study was administered in accordance with the ethical standards of the Declaration of Helsinki and was approved by the Cornerstone University Institutional Review Board (Study ID: 2101.001). This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[17]

Protocol

Instruments and Measurements.

Height and weight were measured using a stadiometer and digital scale (Health o meter, Glenwillow, OH, USA). The Dashr laser timing system accompanied by the Dashr smartphone application (Dashr, Omaha, NE, USA) was utilized to measure sprint time and velocity during a sprint test. A surface electromyographic device called, the Somaxis Cricket accompanied by the Chirp smartphone application (Somaxis, Morgan Hill, CA, USA) recorded raw signals of the right serratus anterior (SA) at 1,000 Hz during a 5-repetition maximum (5-RM) barbell back squat. With the subject's arm abducted to 90°, the Somaxis Cricket was placed vertically along the mid-axillary line at ribs 6-8. Muscular activation of the SA was expressed as a percentage of maximal voluntary isometric contraction (MVIC). To determine the MVIC, subjects abducted their right arm to 120° and resisted a downward force applied by a researcher for five seconds. This procedure has been documented as the optimal angle to obtain maximal activation of the SA and is described in detail elsewhere.[18] The MVIC value obtained served as a baseline reference against which the muscle's activity during the squat test was compared. As a superficial postural core muscle, the SA was selected because the Somaxis Cricket is a surface electromyographic device and cannot measure deep muscles. A generic squat rack with a barbell and weights was used for squat testing (TAG Fitness, Chicago, IL, USA). The PUSH Band 2.0 (PUSH, Toronto, ON, Canada) was used to measure the force, power, velocity, and acceleration of the countermovement vertical jump test. While the PUSH Band 2.0 has been deemed reliable for measuring the variables of the vertical jump, users must be mindful of its occasional tendency to overestimate power variables.[19] The Vertec Vertical Jump Trainer (JumpUSA, Sunnyvale, CA, USA) was used to assess displacement. The Monark Ergomedic 828E and accompanying computer software were used for the Wingate Anaerobic Test (WAnT) (Monark Exercise, Vansbro, Sweden). The G-Suit by GravityFit was worn during exercise training in the experimental group (GravityFit, Peregian Beach, QLD, AUS).

Protocol Overview.

This investigation was a randomized, controlled, experimental trial, which consisted of a pre- (PRE) and post-test (POST) that were separated by four weeks of exercise training. Randomization was ensured via coinflip by the present researcher. The study consisted of a control group (CON) that donned normal exercise attire during exercise training and an experimental group (CG) that donned the G-Suit, a novel full-body compression garment equipped with a hood, stirrups, and thumb holsters, during exercise training. The experimental subjects solely donned the G-Suit during training and no other compression garment variations were utilized in this experiment. All subjects performed a supervised, periodized, 4-week full-body plyometric-based exercise training program in the Human Performance Laboratory at Cornerstone University. Training sessions occurred thrice weekly (i.e., 12 total training sessions) and were preceded by PRE and concluded by POST. There were no significant differences between the number of training sessions completed for subjects in the two experimental conditions (CON: 11.6 ± 0.70 sessions, CG: 11.16 ± 0.70 sessions; $P > 0.99$). PRE included familiarization, fitting of the G-Suit, and a standardized warmup followed by the testing routine. POST was identical to that of the PRE, minus the familiarization and fitting of the compression garment. All subjects performed PRE and POST in normal exercise attire (i.e., shorts and a t-shirt) and at the same time of day. PRE and POST were conducted in a quiet, private, and climate-controlled laboratory.

PRE and POST Testing.

For PRE and POST, a standard warmup preceded the testing protocol. The warmup consisted of 20 meters of high knees, butt kicks, walking lunges, skips, ten body weight squats, and two 40-meter jogs.

The 40-meter sprint test immediately followed the warmup. This test included two trials, each assessing time and velocity, which were separated by a 2-minute rest period. The sprint was self-initiated by each subject as they assumed a forward-facing position between the laser and the reflector of the laser timing system. The time began when the subject moved, and the time ended when the subject broke the end laser. Each trial was recorded, and the best time and velocity of the two sprints was used for analysis.

The 5-RM barbell back squat followed the sprint, after a 10-minute rest period. The 5-RM squat test was selected because it is a safer alternative compared to a 1-RM squat test. The Subjects performed a high-bar back squat with the oversight of a spotter. This test began with a warmup set of five repetitions at an undemanding, subject-selected weight. The maximum number of sets permitted for this test were set at five to ensure ample attempts to achieve the 5-RM, but not so much as to induce unintended fatigue. Ultimately, each subject achieved the 5-RM test within 2-4 sets, not including the warmup set. Measures of barbell weight (kg) and SA activation

(%) were assessed during each set. Two-minute rest periods followed each set. The final set which contained five full repetitions was used for analysis. Subsequent sets that did not include 5 repetitions due to failure prior to achieving five repetitions were not considered for analysis. Baseline MVIC was collected before the squat testing.

The countermovement vertical jump test followed the squat test, after ten minutes of rest, with three maximal jumps, and the highest jump being used for analysis. Reach height was evaluated by measuring the height of the subjects' reach while standing with both feet flat on the ground under the Vertec. Then, jump height was recorded using the Vertec, and force, power, velocity, and acceleration were measured using the PUSH band. After brief instruction, each subject utilized a countermovement arm swing and loading phase during the vertical jump to achieve maximal jump height.

Finally, the WAnT was performed at the end of the visit, after ten minutes of rest. A formal cycling warmup was not given to subjects; however, subjects were allowed to briefly familiarize themselves with the Monark cycle ergometer by cycling against no resistance. The WAnT is a maximal exertion test assessing anaerobic power and capacity.[20] It was performed only once during each test. Subjects cycled on a stationary Monark bike for 30 seconds at maximal exertion against a constant resistance of 7.5% of their recorded body weight (kg). Resistance was immediately and automatically applied to the flywheel once the subject reached 120 revolutions per minute, thus initiating data collection. Data collected during the WAnT included peak power (absolute and relative), mean power (absolute and relative), and fatigue index.

Experimental Training.

A distinct standardized warmup routine preceded the regular training sessions, each consisting of 30 seconds of butt kicks, high knees, skips, side shuffles, and jumping jacks. The warmup routine was designed to prepare the body for movement by targeting all major muscle groups and inducing a light perspiration. Subjects in the CG group performed both the warmup and training program while wearing the G-Suit. Subjects in the CON group performed both the warmup and training program without the G-Suit (i.e., in regular exercise attire). However, both groups performed the same exercises, sets, and repetitions throughout the entire training program. Table 2 depicts the training protocol. The training protocol exercises (Table 1), drawing inspiration from Owen et al, were designed to activate core musculature via the movement of hypaxial muscles with the conditional presence of the G-Suit.[6] The training protocol consisted of an exercise circuit with three super sets, each followed by a standardized rest period. Each superset consisted of two or three individual exercises and subjects moved on to the next superset only upon the completion of the previous superset. Sessions lasted roughly 30 minutes, and subjects adhered to the training protocol via instruction from a trained researcher or independently. CG and CON subjects were allowed one independent training session per week, while the other two training sessions were overseen by a trained researcher. The training schedule remained this way for the entirety of the 4 weeks. Subjects who trained independently confirmed the adherence to training through the completion of a handwritten exercise log. Exercise logs were reviewed weekly to ensure appropriate adherence. Subjects were encouraged and motivated to complete all exercises at maximum intensity while maintaining proper form.

It is also important to note that repetitions per set increased weekly for each group to ensure that the sessions were progressively overloaded.[21] No cool-down was required of any subjects following the conclusion of daily training sessions.

Table 1. Training Protocol Outline

Skater Jumps: Subjects performed lateral bounds, propelling themselves sideways from one foot to the other, emphasizing dynamic balance and power.
I, Y, T's: Subjects executed shoulder abduction and scapular retraction movements by raising the arms into I, Y, and T positions while maintaining back extension in a prone position.
Glute Bridges: Subjects performed hip extensions in the supine position by elevating the pelvis until full hip extension was achieved, targeting the gluteal musculature.
Lunges: Subjects executed forward stepping lunges by flexing the hip and knee joints to approximately 90 degrees, focusing on lower extremity muscular strength and stability.
Push-ups: Subjects performed a closed kinetic chain exercise involving elbow flexion and extension while maintaining a prone plank position to engage the pectoralis major, triceps brachii, and core muscles.
Squat Jumps: Subjects executed explosive concentric movements from a squat position to vertical jump, emphasizing lower limb power generation.
Triceps Dips: Subjects performed elbow extension exercises in a supported seated position by lowering and raising the body using the triceps brachii muscles.
Dead Bugs: Subjects engaged in contralateral limb extension while maintaining lumbar stabilization in the supine position to target core musculature and neuromuscular control.

a. *Exercise descriptions highlight the primary movement patterns and targeted muscle groups used in the training protocol.*

Statistical Analysis

As previously mentioned, there is limited literature providing insight into the effects of axial loading as it relates to donning compression garments. Resultantly, pilot data from a study by Baum et al was utilized to confirm the feasibility and validity of our study. A statistical power analysis (G*Power 3.1) was performed to estimate the required sample size. The effect size (0.3) for preliminary data from Baum et al[14] (n=12) evaluating the effect of four weeks of training in compression garments vs. sham for vertical jump height was 1.72. With an alpha of 0.05, power of 95%, two conditions (CON and CG), and two measurements (PRE and POST), the projected sample size needed to observe a within-between group interaction was six subjects. To this end, we collected data on 16 subjects, with eight in each group.

Data were recorded and uploaded to a Microsoft Excel spreadsheet. A change score (i.e., change from PRE) was calculated from the raw data, which were then transferred to statistical analysis software (GraphPad Prism v.10.2.0, San Diego, CA, USA), where data were compared between groups (CON vs. CG) and across time (PRE vs. POST). An outlier analysis was utilized to mitigate the effects of erroneous data that might otherwise skew the results. Outliers were identified and removed using the ROUT method,[22] in which the Q value, or the false discovery rate, was set conservatively (i.e., 0.1%) so that only definitive outliers were removed. Outliers were removed from statistical analysis for sprint time (n=1), sprint velocity (n=1), and peak vertical jump velocity (n=1). Data were analyzed via a two-way repeated measures ANOVA. If a significant main effect was found, Sidak's multiple comparisons test was used to analyze pairwise comparisons between conditions or across time, respectively. Effect sizes are expressed as the F-statistic which was calculated by dividing the mean square between groups by the mean square within groups. Data were analyzed as mean and standard deviation, and the alpha level was set *a priori* at $P = 0.05$. Mean and standard deviation of each measure at PRE are presented in Table 3. All other data are expressed as changes from PRE.

Table 2. Experimental Training Protocol

Super Set	*Exercise*	*Sets*	*Repetitions*			
			Wk. 1	***Wk. 2***	***Wk. 3***	***Wk. 4***
1.	Skater Jumps	3	10	12	13	15
	I, Y, T's	3	5 ea.	6 ea.	7 ea.	8 ea.
	Glute Bridges	3	10	12	13	15
Rest			3 min.		2 min.	
2.	Lunges	3	10 ea.	12 ea.	13 ea.	15 ea.
	Push Ups	3	10	12	13	15
Rest			3 min.		2 min.	
3.	Squat Jumps	3	10	12	13	15
	Triceps Dips	3	10	12	13	15
	Dead Bugs	3	10 ea.	12 ea.	13 ea.	15 ea.

a. *Exercises were performed as supersets in the order listed.*
b. *Repetitions progressed weekly to facilitate progressive overload.*
c. *Rest periods between supersets decreased after week 2 to increase training intensity.*

Results

Subject Height and Weight

Subject weight data can be found in Table 3. POST height was deemed negligible and therefore not considered for analysis. Weight was measured at PRE and POST. No differences were observed from PRE to POST for CON or CG, nor were there significant differences between CON and CG at POST.

40-Meter Sprint

Sprint data can be found in Table 3. The change in sprint time from PRE to POST ($F_{1,13} = 0.306$) was not statistically different for CON or CG. Moreover, there were no differences between conditions for the change in sprint time at POST ($F_{1,13} = 0.306$). Similarly, the change in sprint velocity from PRE to POST ($F_{1,13} = 0.008$) was not significantly different for CON or CG. However, the change in sprint velocity in CG was significantly greater ($F_{1,13} = 4.320$) than CON.

Table 3. Outcome Variables at PRE and POST

	Group	PRE	POST	Change	P-within†	P-between†
Weight	CON	76.20±13.31	76.34±13.02	0.14±0.87	0.863	
(kg)	CG	76.21±12.45	76.44±12.68	0.23±0.86	0.723	0.999
Sprint Time	CON	5.72±0.47	5.68±0.37	-0.04±0.17	0.958	
(sec)	CG	6.08±0.78	6.20±0.54	0.12±0.54	0.682	0.471
Sprint Velocity	CON	7.20±0.29	7.16±0.20	-0.12±0.10	0.297	
(m/s)	CG	6.37±0.66	6.48±0.56	0.11±0.27	0.310	0.014*
Squat Barbell Weight	CON	94.32±18.50	101.42±17.31	7.10±6.92	0.019*	
(kg)	CG	88.64±18.66	98.01±17.96	9.38±6.48	0.003**	0.509
Squat SA Activity	CON	38.52±29.59	32.23±22.84	-6.29±23.86	0.873	
(a.u.)	CG	35.81±26.02	44.69±44.19	8.88±47.44	0.765	0.433
VJ Displacement	CON	196.79±15.92	199.74±15.32	2.95±3.93	0.151	
(cm)	CG	192.42±9.72	195.35±10.51	2.93±4.83	0.156	0.990
VJ Force	CON	2012.89±244.59	1901.92±216.47	-110.97±164.10	0.114	
(N)	CG	2033.22±500.98	1943.45±372.66	-89.77±139.78	0.222	0.785
VJ Power	CON	5460.76±1139.45	5232.55±1144.71	-228.21±828.87	0.633	
(W)	CG	5977.76±2241.65	5566.33±1986.23	-411.43±625.79	0.252	0.626
VJ Velocity	CON	2.95±0.28	2.99±0.34	0.04±0.17	0.738	
(m/s)	CG	2.83±0.26	3.02±0.31	0.19±0.15	0.015*	0.033*
VJ Acceleration	CON	15.92±2.03	14.86±1.95	-1.06±2.02	0.183	
(m/s^2)	CG	16.29±3.06	15.54±2.02	-0.75±1.23	0.402	0.719
WAnT Peak Power	CON	828.30±131.34	814.59±130.20	-13.71±124.53	0.906	
(W)	CG	657.96±137.54	718.10±106.60	60.14±55.30	0.189	0.148
WAnT Peak Power	CON	10.70±1.60	10.41±0.98	-0.29±1.55	0.511	
(W/kg)	CG	8.74±1.80	9.53±1.48	0.79±0.70	0.085	0.018*
WAnT Mean Power	CON	356.30±82.90	349.10±97.33	-7.20±42.43	0.918	
(W)	CG	255.57±71.23	310.74±29.50	55.17±64.15	0.025*	0.006**
WAnT Mean Power	CON	4.59±0.94	4.48±1.18	-0.11±0.57	0.886	
(W/kg)	CG	3.45±1.07	4.17±0.70	0.72±0.77	0.020*	0.004**
WAnT Fatigue Index	CON	56.69±8.84	57.05±9.76	0.36±8.08	0.990	
(W)	CG	60.32±10.51	56.12±5.72	-4.22±8.13	0.302	0.279

a. *Values are mean ± SD.*
b. *SA = Serratus Anterior; VJ = Vertical Jump; WAnT = Wingate Anaerobic Test; CON = Control; CG = Compression Garment; †after correcting for multiple comparisons; *p<0.05; **p<0.01*

Barbell Back Squat

Barbell back squat data can be found in Table 3. From PRE to POST ($F_{1,15}$ = 21.410), the change in barbell weight was significantly greater for both CON and CG. However, the change in barbell weight was not statistically different between conditions ($F_{1,15}$ = 0.136). Moreover, SA activation was not significantly different from PRE to POST ($F_{1,14}$ = 0.019) for CON or CG, nor was the change significantly different between conditions ($F_{1,14}$ = 0.652).

Countermovement Vertical Jump

Vertical jump data can be found in Table 3. Displacement was not significantly different from PRE to POST ($F_{1,14}$ = 7.131) for CON or CG, nor was the change significantly different between conditions ($F_{1,14}$ < 0.001). Peak force was not significantly different from PRE to POST ($F_{1,14}$ = 6.937) for CON or CG nor was the change significantly different between conditions ($F_{1,14}$ = 0.077). Peak power was not significantly different from PRE to POST ($F_{1,14}$ = 3.034) for CON or CG, nor was the change significantly different between conditions ($F_{1,14}$ = 0.294). Similarly, peak velocity was not significantly different from PRE to POST ($F_{1,13}$ = 7.759) for CON. However, the change in peak velocity was significantly greater for CG from PRE to POST ($F_{1,13}$ = 7.759) and between conditions ($F_{1,13}$ = 3.279). Lastly, peak acceleration was not significantly different from PRE to POST ($F_{1,14}$ = 4.654) for CON or CG, nor was the change significantly different between conditions ($F_{1,14}$ = 1.135).

WAnT

WAnT data can be found in Table 3. Absolute peak power was not significantly different for CON or CG from PRE to POST ($F_{1,14}$ = 0.929), nor was the change significantly different between conditions ($F_{1,14}$ = 2.351). Similarly, relative peak power was not significantly different for CON or CG from PRE to POST ($F_{1,14}$ = 0.693). However, the change in relative peak power for CG was significantly greater than CON ($F_{1,14}$ = 3.188). Absolute mean power was not significantly different for CON from PRE to POST ($F_{1,14}$ = 3.112) but was significantly greater for CG from PRE to POST ($F_{1,14}$ = 3.112). The change in absolute mean power for CG was significantly greater than that of CON ($F_{1,14}$ = 5.261). Relative mean power was not significantly different for CON from PRE to POST ($F_{1,14}$ = 3.184) but was significantly different for CG from PRE to POST ($F_{1,14}$ = 3.184). Moreover, the change in relative mean power for CG was significantly greater than for CON ($F_{1,14}$ = 5.835). Fatigue index was not significantly different for CON or CG from PRE to POST ($F_{1,14}$ = 0.899), nor was the change significantly different between conditions ($F_{1,14}$ = 1.270).

Discussion

To our knowledge, no studies have examined the effects of wearing the G-Suit during exercise training on anaerobic performance in healthy males. The main findings of our investigation are that sprint velocity, vertical jump velocity, relative peak power, and mean power during the WAnT were augmented for the group that trained in the compression garment when compared to the control group. Despite significant improvements following training in sprint velocity, barbell weight during a back squat, and absolute peak power during the WAnT for CG, these improvements were also augmented for CON. Given the lack of research depicting the effects of training in a full-body compression garment on performance, we conclude that training with the G-Suit, may improve sprint velocity, relative peak power, mean power (i.e., anaerobic capacity), and vertical jump velocity in healthy males. This is likely because training in the G-Suit augments core strength, more than training alone (i.e., without the garment), thus improving anaerobic performance. Although this improvement is subtle, it may be biologically significant and beneficial for athletes, where winning a competition is constituted by the smallest margins.

Performance improvements for sprint time from PRE to POST were not induced by training with the G-Suit. This can likely be attributed to the specificity required when aiming to improve sport-specific performance.[23] While core activation is important to maintain balance and stability and while axial loading may improve lower extremity strength[24], sport-specific exercises, such as sprinting, require a more specific training protocol to enhance performance.[23] Since sprinting is a multiplanar exercise, augmenting core activation via vertical loading is insufficient for improving performance.[25] Notably, training-induced benefits may not have been achieved because of the multi-faceted nature of improving sprint time because the G-Suit provides axial loading in only the sagittal plane.[26] Moreover, the training program utilized in this investigation was a body weight-based plyometric program and did not include sprints. Although no significant difference was found in sprint time from PRE to POST in either group, there were differences between the two groups at POST. At POST, CG subjects may have had a greater top velocity but a slower acceleration time. This would account for the lack of evidence for a difference in sprint time, as the two variables of velocity and acceleration would have offset each other. This, however, is merely speculative, as there was no definitive measurement of acceleration for the sprint test.

Although improvements were evident in both conditions for the barbell back squat from PRE to POST, these improvements were not elicited by the G-Suit alone. The matched training protocol targeted and strengthened the rectus femoris, vastus lateralis, vastus medialis, triceps surae, gluteus maximus, and gluteus medius to improve squat capability.[27] Since the G-Suit is supposed to activate the deep core muscles[6], it possibly also triggered a proper brace during training for experimental subjects, theoretically leading to greater lumbar stability.[28] However, since core activation during testing was nearly the same amongst groups, as reflected by SA activation, the G-Suit provided no additional effects that would compound improvements to squat performance. It is unclear why muscular activation was not greater in CON vs. CG in the present study. Future research is required to explore if wearing the G-Suit improves muscular activation of the other muscles in the core. Moreover, it is worth mentioning that verbal cues may have augmented core activation when used in conjunction with the G-Suit, as demonstrated previously.[6,29] In this context, the employment of verbal cues during testing may have resulted in significant improvements for the squat in CG vs. CON. However, we did not employ verbal cues to isolate and identify the physiological effects of the G-Suit alone.

Although vertical jump displacement, force, power, and acceleration were not different between CG and CON at any time point, vertical jump velocity was greater during CG vs. CON at POST. Vertical jump performance is dictated, in part, by spinal and muscle fiber alignment.[30] Also referred to as muscle architecture, proper fiber alignment produces optimal force and explosiveness, enough to have a significant impact on performance when lacking such.[30] Additionally, core muscle activation aligns and stabilizes the spine[30], theoretically enabling movements such as the vertical jump to be carried out optimally.[31] Studies have reported the positive effects of mechanical pressure from lumbo-abdominal compression garments on jump performance.[31] Such mechanisms include muscle vibration suppression[32], reduced muscle soreness[33], and rate of fatigue.[31] The novel mechanism offered by the G-Suit is its ability to vertically load the spine to activate deep core muscles.[6] It is possible that greater core activation during CG vs. CON led to quicker movements (i.e., velocity) during vertical jumping. However, the augmented core activation during CG vs. CON may not have been great enough to improve overall vertical jumping performance. According to Ikeda et al, while compression garments may improve jump performance, improvements cannot be solely designated to devices that cue proper spinal alignment.[31] To this end, the augmented axial load and stabilization of the spine specifically provided by the G-Suit are likely not the primary contributors to improvements in vertical jump performance. While the program certainly required a degree of core strength for each exercise, only a nominal portion of the program was devoted specifically to core strengthening. Because of this, the core strengthening that occurred during training was insufficient in improving overall vertical jump performance when comparing CG to CON.

The change in relative mean and peak power as well as absolute mean power for CG was significantly greater when compared to CON during the WAnT. Improvements in core and postural stability from plyometric training have been shown to improve anaerobic performance variables.[34] Just as plyometric training improves anaerobic performance, greater isokinetic trunk strength is strongly associated with greater WAnT mean power.[35] Appropriate abdominal recruitment ensures trunk stability and postural control which subsequently enables a synchronized muscle contraction that buttresses the powerful spinal flexion contractions during anaerobic exertions such as the WAnT.[35] Our findings are consistent with the findings of previous studies and further highlight that full-body compression garments worn during plyometric training augment anaerobic capacity more than just plyometric training alone.[34] Since plyometric training has been proven to improve anaerobic performance, the integration of additional axial loading throughout training explains why CG displayed greater changes in mean power when compared to CON.

Full-Body vs. Lower-Body Compression Garments

The emergence of the G-Suit has brought a new mindset to performance enhancement and its designers claim that it may do so via a divergent mechanism known as axial loading.[6] While typical compression garments provide adequate external counterpressure for improved circulation[36] and stabilization[37], GravityFit is more interested in designing the G-Suit to load the spine and other anti-gravity kinetic chains throughout the body.[6] To this end, this device is atypical compared to other compression garments as it features a hood, stirrups, and thumb holsters. While certain exercises activate deep core muscles[6], novel strategies such as cues and devices have been shown to have a similar effect.[6] In fact, Owen et al found that pairing exercise cues with a novel resistance band-based exercise device that loads the spine, lower limbs, and upper limbs during upper limb extension, augmented transverse abdominis and multifidus muscular activation.[6] By mimicking the effects of this resistance device, they concluded that the G-Suit may be capable of activating deep core muscles when it is donned.[6] Since greater activation of the deep core muscles has been shown to enhance performance[23], it is plausible that donning this novel compression garment during exercise will exacerbate an increase in performance when compared to exercising without it.

Even so, there exists a wide variety of compression garments including compression socks, sleeves, pants, shirts, and full-body garments.[1] Partial garments are generally used for stabilizing tissues and enhancing blood circulation through compression.[37] Specifically, lower limb compression garments are typically used by endurance athletes and runners[36] whose aim is to improve performance through cardiorespiratory and peripheral physiological factors related to venous flow.[36] In contrast to lower extremity compression garments, full-body compression garments have predominantly been shown to provide physiological augmentation during recovery[24], rather than performance.[13] However, both types of garments function via a similar physiological mechanism: augmented venous flow.[24,36]

Perspectives

Through the incorporation of compression garments into training and competition, both competitive and recreational athletes possess the potential to improve their performance. The findings of this study, along with other studies of the like, highlight the benefits of full-body and segmental compression garments in various disciplines, as well as their futility. Specifically, the design and production of the G-Suit represents an innovative approach that supposedly leverages the concept of axial loading, thus activating deep core muscles and stabilizing the spine and pelvis. Although further research is warranted, the idea of augmenting axial loading to enhance performance is noteworthy.

Although small, the various and scattered performance improvements induced by the G-Suit may prove beneficial depending on the user. For elite athletes, these slight enhancements have the potential to be the difference between victory and defeat. For the general population, this study and others indicate that while full-body compression garments and the G-Suit alike have a limited impact on most performance measures, they may be more beneficial for recovery.[1,13] Although no compounding enhancements were discovered in the majority of the variables that we measured, no significant hindrances were found either. This allows for further study to be considered and conducted on distinct populations such as geriatrics, females, and sport-specific athletes who may experience benefits from other mechanisms of full-body compression such as circulation, muscle and joint proprioception, and inflammation.

Given the wide variety of performance atmospheres available and unmarked by full-body compression garments, the opportunity for further study is approachable. One of the primary topics that lacks research is regarding compression garments and exercise recovery. Notably, compression garments have shown a promising effect on recovery from resistance training.[4] These compression garment studies, however, only consider recovery from distinct regions of the body[3,33], unlike full-body compression garments such as the G-Suit. A novel study displays a distinct recovery effect of full-body compression garments, but these findings are the first of their kind and require further observation.[38] However, the trivial findings in our study raise questions about the specific contributions of the garment, especially when compared to the contrasting results in Nguyen's work.[38] Despite these nuances, the scattered improvements observed draw attention to the potential of the G-Suit and similar full-body compression garments.

This study has various considerations worth mentioning. First, the intervention duration was relatively short compared to other training studies.[8,39] The 4-week training period may not have been long enough to dramatically reveal the trending improvements of training with compression garments compared to ordinary exercise attire.[40] However, previous findings indicate that a 4-week training program can improve certain aspects of physical fitness in sedentary individuals.[14] Secondly, numerous measures were statistically different at PRE between groups. To address this concern, data were analyzed as a change from PRE and a progressive resistance series was incorporated into the training protocol. These measures were taken in attempt to statistically and physiologically nullify this complication. Additionally, subjects and researchers needed to be adequately blinded. Without a sham or control garment, awareness of assignments may have resulted in assessment or training bias from the researchers and subjects, respectively. Non-compressive garments and blinding techniques have been designed and used to combat this limitation.[15] Despite this, all subjects were made aware of the health benefits that come from plyometric training regardless of their assigned group. To this end, subjects exhibited signs of genuine effort and were coached throughout the study, potentially mitigating bias. Since some subjects completed some of the training independently, the presence of dishonesty in effort and completion of the protocol was possible; however, this is unlikely as performance improvements were present in both groups. Moreover, the outcome measures from the study were categorically limited. Although the design gave us an in-depth understanding of the effects of training with the G-Suit on anaerobic performance, the study lacked an assessment of other performance measures such as aerobic capacity, agility, and/or motor control. The design compensated for this by considering the primary anaerobic components and validating it as an extensive research study; however, further research is warranted to draw concrete conclusions.

To conclude, training in the G-Suit for four weeks may lead to subtle, but significant, improvements in sprint velocity, anaerobic capacity, and vertical velocity when compared against a control after training. These improvements, although minute, show potential for elite athletes where small advantages in these areas may be the difference in competitive outcomes. Despite these findings, there was an evident lack of exceedingly perceptible findings that favored one condition over the other, thus warranting further research on similar devices and their effects compared to what is normally worn during exercise. In this respect, devices such as these present emergent findings that spark curiosity for the future of human performance.

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