The Effect of Graduated Compression Tights, Compared With Running Shorts, on Counter Movement Jump Performance Before and After Submaximal Running

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Abstract

Rugg, S and Sternlicht, E. The effect of graduated compression tights, compared with running shorts, on counter movement jump performance before and after submaximal running. *J Strength Cond Res* 27(4): 1067–1073, 2013–The purpose of this study was to determine if wearing graduated compression tights, compared with loose fitting running shorts, would increase and or help sustain counter movement jump (CMJ) height after submaximal running. Fourteen competitive runners (6 women and 8 men) participated in this study. The subjects' mean (±*SD*) for age, height, body mass, percent body fat, resting heart rate, and maximal heart rate were 28.2 ± 14.0 years, 174.7 ± 8.6 cm, 70.2 ± 14.9 kg, 15.5 ± 8.1%, 67.2 ± 7.4 b.min^{-1}, and 186.5 ± 9.5 b.min^{-1}, respectively. During testing, subjects wore a Polar RS400 heart rate monitor. Each trial consisted of 15 minutes of continual treadmill running with 5 minutes performed at 50%, 70%, and 85% of the subject's heart rate reserve. Using a Vertec vertical leaper, each subject performed 3 CMJ, both pre- and postrun trials, with the mean value used to measure relative leg power. In addition to the CMJ height data, each subject rated their level of perceived exertion (RPE), and their comfort level, after the postrun trials. The mean postrun CMJ height in graduated compression tights of 60.3 ± 19.4 cm was significantly greater (at the $p < 0.05$ level) than both the prerun with tights of 57.7 ± 19.4 cm (4.5% increase) and the postrun running shorts of 57.7 ± 19.6 cm (4.5% increase). In addition, the subjects reported a significantly lower level of perceived exertion and greater comfort values while wearing the graduated compression tights. The results of the present study support the use of graduated compression tights for maintenance of lower limb muscle power after submaximal endurance running.

Key Words compression garments, vertical jump, athletic apparel, leg power, muscle oscillation and damage

Introduction

An increasing number of athletes are using compression garments to hopefully improve performance or recovery or both. Although most studies (1–3,5,12–15,23,30,34,35,40,42–44) have shown no significant improvements in either sprint or endurance performance while wearing compressive garments, several studies have shown a decrease in muscle oscillation (8,9,13,29,32), an increase in maximal repetitive jump height (28,29), an increase in counter movement jump (CMJ) height (13), and a greater maintenance of CMJ height after endurance exercise (3). Wearing compression garments, particularly during recovery, have also been shown to produce greater maintenance of CMJ height after exercise-induced muscle damage (26), decrease creatine kinase (12,15,17,31,32), improve lactate removal (6,38), and decrease delayed onset of muscle soreness (1,12,14,15,26,31,32). Several studies have also reported favorable comfort ratings when wearing compression garments (2,3,18,32,33).

Counter movement jump height was analyzed in this study because it is not only a popular training exercise to gauge anaerobic leg power, but it is also a critical skill for many sports including volleyball, basketball, and high jumping. Numerous factors influence CMJ height including somatotype, fiber type, skill, motivation, and training. However, most of the research has focused on how different training protocols can affect CMJ performance. For example, studies have looked at plyometric training (21,22,36), strength and power training (4,11,36,37,44), and how they might improve CMJ height. Based on the findings of this and other studies (2,3,13,26,28,29), compressive garments may also be a factor in helping some athletes sustain CMJ performance.

The running protocol used in this study was designed to more closely match sports, such as basketball, where running

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and vertical jumps are used throughout practice and competition. The purpose of this study, therefore, was to investigate if wearing graduated compression tights, compared with loose fitting running shorts, help improve and sustain CMJ height after submaximal endurance running.

Methods

Experimental Approach to the Problem

Because CMJ height is a popular test for predicting anaerobic leg power, and it is used as a training exercise for numerous sports, we wanted to see if graduated compression tights would increase and help sustain CMJ height after submaximal running. Each subject performed 3 CMJs, both pre- and postrun trials, with the mean value used to represent relative leg power. Each trial consisted of 15 minutes of continual running with 5 minutes performed at each of the following intensities: 50%, 70%, and 85% of the subject's heart rate reserve (HRR). Two complete trials of the CMJ plus the running protocols were performed by each subject, one while wearing graduated compression tights and one while wearing loose fitting running shorts. Trial order was randomized to prevent data "order" bias.

Subjects

Fourteen healthy subjects (6 women and 8 men) participated in this study. The subjects were trained, competitive runners. Of the 14 subjects, 10 were collegiate-level track and field athletes, 1 subject was a national-level age-group triathlete, and 3 subjects were recreational 10K runners. The track and field athletes competed in 2 or more of the following events: 100 m, 200 m, 400 m, 4 × 100 m, 4 × 400 m, 100-m hurdles, long jump, high jump, and heptathlon. The subjects' mean (±*SD*) for age, height, body mass, percent body fat, resting heart rate, and maximal heart rate were 28.2 ± 14.0 years, 174.7 ± 8.6 cm, 70.2 ± 14.9 kg, 15.5 ± 8.1%, 67.2 ± 7.4 b.min^{-1}, and 186.5 ± 9.5 b.min^{-1}, respectively. Anthropometric (circumference) measures of our subjects are listed in Table 1.

Table 1. Anthropometric values for 8 male and 6 female subjects.*

Circumferences (cm)	Females	Males
Waist	74.9 ± 5.8	78.9 ± 9.3
Hips	99.2 ± 7.9	96.2 ± 10.8
Thigh	53.1 ± 4.4	54.5 ± 3.2
Knee	34.6 ± 1.7	35.9 ± 2.3
Calf	34.3 ± 0.5	35.5 ± 2.7
Ankle	20.9 ± 1.3	22.2 ± 1.5

*Thigh, knee, calf, and ankle circumferences represent the average of the right and left legs together. Values are represented as mean ± *SD*.

Two clothing conditions were used in this study. The compression clothing condition consisted of having the subjects wear C3fit graduated compression tights (Table 2) that extended from each subject's waist to their ankle. The tights were individually fitted based on the manufacturer's guidelines for gender, waist (men), hip (women), thigh, calf and ankle circumferences, and total body height. However, based on feedback from our female subjects the C3fit tights that were the best fit, and therefore the most comfortable, were those that best matched their hip circumference instead of their height. The noncompression control condition required each subject to wear traditional loose fitting running shorts.

All experimental procedures, with any potential risk, were discussed with each subject, and university-approved informed consent forms were signed before testing. All subjects were free of acute or chronic injury before the study. Subjects were instructed on how to properly perform the CMJ and the structure of each workout before recording data. If at any time the subjects felt tired or were unable to continue with the workout, they were free to stop and rest and discontinue working out further.

Procedures

Body Composition. Body composition testing was performed using an electronic Skyndex System 1 body fat Skinfold caliper (Caldwell Justiss & Co., Inc., Fayetteville, AR, USA). For men, the generalized equation by Jackson and Pollock (24) was used with the 3-fold sites located at the chest, abdomen, and thigh. For women, the generalized equation by Jackson et al. (25) was used with the 3-fold sites located at the triceps, suprailium, and thigh.

Heart Rate Measures. During testing, subjects wore a Polar RS400 heart rate monitor (Polar Electro USA, Lake Success, NY, USA). Each watch was preprogrammed with the subject's date of birth, gender, height, weight, and resting and maximal heart rate values. The heart rate monitor strap was placed over their chest at the level of the xiphoid process of the sternum. To assure continuous signal

Table 2. Compression applied by C3fit graduated compression tights (Goldwin, Inc., Japan), for both men and women, based on the manufacturer's guidelines when fitted correctly.

Measured region	Pressure (hPa)	Compression (mm Hg)
Ankle	24.0	18.0
Calf	16.8	12.6
Thigh	9.6	7.2

C3fit compression data were listed in hectopascals (hPa). Conversion was performed using 0.75 mm Hg = 1 hPa.

transduction, the inside surface of each strap was coated with Spectra 360 electrode gel (Parker Lab, Inc., Fairfield, NJ, USA). Each subject's heart rate was recorded every 5 seconds throughout each workout. Maximal heart rate was calculated using the method of Robergs and Landwehr (39). Resting heart rate was obtained averaging the waking heart rate value of the subjects on 3 consecutive days. The data were downloaded onto an HP EliteBook 8540p laptop computer. The data were further analyzed using the Polar ProTrainer 5 program (Polar Electro USA).

Running Protocol. Before data collection, each subject performed a dynamic warm-up that consisted of a minimum of 5 countermovement jumps. Exercise intensity for the running trials, with and without tights, was determined using the Karvonen formula and maintained at intensity levels of 50%, 70%, and 85% of HRR for each subject. These intensity levels were selected because they span the American College of Sports Medicine's training intensity guidelines, as prescribed in their 2011 position stand (16).

Each trial consisted of 15 minutes of continuous running with 5 minutes performed at each of the following intensities: 50%, 70%, and 85% of the subject's HRR. Each subject's heart rate was continuously monitored during the run to assure appropriate exercise intensity for each workload and trial. Trial order was randomized to prevent data order bias. A Life Fitness Treadmill Model 95Ti (Life Fitness, Schiller Park, IL, USA) was used throughout the experiment. For all the running trials, room temperature was kept constant between 20.6 and 21.6°C. Each subject performed both the running and CMJ protocols in their training, self-selected, running shoes.

Counter Movement Jump Protocol. Each subject performed 3 CMJs, both pre- and postrun trials, with the mean value used to measure relative leg power. Before the prerun and postrun CMJ trials, subjects performed a minimum of 5 practice jumps. All CMJ efforts were separated by at least a 10-second rest. A Vertec Vertical Leaper was used to record the CMJ heights.

Subjective Rating Measures. In addition to the CMJ height data, each subject rated their level of perceived exertion (RPE) and their level of comfort after 15 minutes of running in loose fitting shorts and after 15 minutes of running in graduated compression tights. Perceived exertion was rated using the modified Borg scale (7) that ranges from 0 (no exertion) to 10 (maximum exertion). Comfort was rated using a Feeling scale (19) that ranges from −5 (very bad) to 0 (neutral) to +5 (very good).

Statistical Analyses

The PASW Statistics version 18 (IBM Corporation, Armonk, NY, USA) was used to perform all statistical tests. Mean CMJ height values were analyzed using a repeated measures 2-way analysis of variance test to determine if any significant differences existed among clothing (tights vs. no tights) or timing (prerun vs. postrun) jump trials. Data were also evaluated for interaction effects between clothing and timing. Any significant interaction effect was followed by a test of simple main effects test using the Bonferroni confidence interval adjustment for multiple comparisons. Intraclass correlation coefficients were used to measure the degree of similarity between sets of data. A significance level of 0.05 was chosen for all statistical methods.

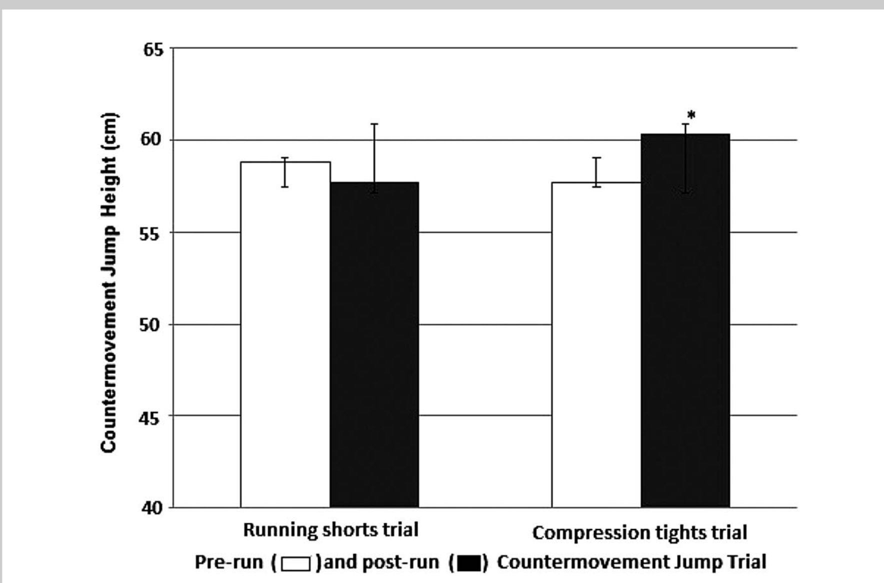

Figure 1. Pre- and postrun counter movement jump (CMJ) height with loose fitting running shorts or graduated compression tights ($N = 14$). *Significant differences in postrun CMJ height from the prerun with tights and the postrun with no tights values ($p < 0.05$).

Results

The mean postrun graduated compression tights CMJ height of 60.3 ± 19.4 cm was significantly greater (at the $p < 0.05$ level) than both the prerun with tights value of 57.7 ± 19.4 (4.5% increase) and the postrun no tights value of 57.7 ± 19.6 cm (4.5% increase). Although the mean postrun with tights value of 60.3 ± 19.4 cm was greater than the prerun no tights jump height of 58.8 ± 20.0 cm (2.6% increase), these values were not

TABLE 3. Pre- and post-run counter movement jump height averaged over 3 jumps for 14 subjects.

Trial	Pre run (cm)	Post run (cm)
Running shorts	58.8 ± 20.0	57.7 ± 19.6
C3fit tights	57.7 ± 19.4	60.3 ± 19.4*

*Value statistically significant from the pre-run with tights and the post-run no tights values, $p < 0.05$.
Values are mean ± *SD*.

significantly different. The results of the CMJ height data showed a mean decrease of 1.9% in CMJ height after 15 minutes of running without tights and an increase in CMJ height of 4.5% after 15 minutes of running with tights (Figure 1; Table 3). In addition, only 3 subjects increased their postrun CMJ height when not wearing tights, whereas 12 subjects increased their postrun CMJ height when wearing tights.

Comparison of intraclass correlation coefficients (>0.90) determined by clothing and timing demonstrate that there was strong tester reliability for all experimental conditions. No main effect of clothing (tights vs. no tights) or timing (prerun vs. postrun) was found ($F_{1,13} = 2.16$ and $F_{1,13} = 3.45$, $p > 0.05$, respectively). However, clothing and timing did demonstrate an interaction effect ($F_{1,13} = 42.15$, $p < 0.05$). A test of simple main effects determined that tights significantly increased jump height during postrun trials ($F_{1,13} = 20.61$, $p < 0.05$) but had no effect during prerun trials ($F_{1,13} = 3.27$, $p > 0.05$). These results suggest that the performance benefit of compression tights are isolated to conditions in which an athlete runs before completing a CMJ.

The subject's RPE were significantly higher after their run without tights compared with the run with the compression tights, with values of 5.1 ± 1.6 and 3.9 ± 1.4, respectively (Table 4). Of the subjects, 10 gave a lower RPE, 1 the same, and only 3 gave a higher RPE when running and jumping in graduated compression tights compared with loose fitting running shorts. Finally, the subject's comfort values were 2.6 ± 1.2 when wearing tights compared with a reference value of zero while running without tights (Table 4). This average comfort rating reflects that 13 of the subjects rated the graduated compression tights more comfortable than loose running shorts during both the run and jump portions of the experiment.

TABLE 4. Postrun rating, RPE, and feeling scale ratings, for 14 subjects.

Postrun rating	RPE	Feeling scale
Running shorts	5.1 ± 1.6	Neutral (0)
C3fit tights	3.9 ± 1.4*	2.6 ± 1.2

*Value statistically significant from the running shorts RPE value, $p < 0.05$. Values are mean ± S.D. RPE = rate of perceived exertion.

DISCUSSION

Numerous performance wear manufacturers and athletes claim that compression garments improve athletic performance. For example, improvement claims include increased power, increased endurance, and better recovery after high-intensity exercise. Although compression garments did not significantly increase maximum jump height in volleyball players (28), runners (2,3), and track athletes (13), these studies did show that compression garments resulted in greater repetitive jump heights and, therefore, helped maintain higher mean jumping power. One possible explanation for these results may be enhanced proprioception provided by the compression garments (28,29,32). Even if the recoil within the garment's fabric appears insignificant compared with what takes place within the muscle (e.g., titin strands being stretched and recoiling during the stretch-shorten cycle), the fabric's recoil coupled with the garment's pressure may enhance proprioception and, therefore, improve and help sustain power output. Several research groups have suggested that there may also be a psychological component associated with improved performance (18,27,30,32,34). In the present study, based on the Feeling scale values and subjective feedback, most of the subjects liked the feel and extra support provided by the graduated compression tights. Therefore, this positive association with the tights may have helped improve postrun CMJ performance.

Not all studies that looked at the effect of compression garments on CMJ height, however, reported improvements in performance. For example, Kraemer et al. (32) studied 11 male and 9 female athletes wearing full-body compression garments both during heavy resistance training and for 24 hours after training. Although no significant differences in CMJ height were reported, they did find a significant increase in power for the bench press throw.

One of the challenges of comparing data across studies is the diversity of compression garments tested. For example, researchers have tested socks, stockings, tights, shorts, or full-body garments on performance. As expected, not only are different manufacturer's garments used, which have different levels of compression, but also there is the distinction between compression vs. graduated compression garments. However, several studies attempted to address this challenge. For example, Duffield and Portus (15) studied 10 male cricket players and found that 3 different full-body compression garments still produced no improvements in either throwing or repeat-sprint performance. Sperlich et al. (42)

used 15 well-trained endurance athletes to test different types of compression clothing on submaximal and maximal running performance. Each subject performed running trials with and without compression stockings, tights, and full-body compression suits. In summary, there were no significant improvements in running performance when wearing any of the compression garments.

Another challenge of comparing data across studies is the variation in fitness of the subjects tested. Although most of the studies reviewed used athletes, they ranged from moderately trained to elite athletes. Kemmler et al. (27) tested 21 moderately trained men running at a submaximal pace and at their anaerobic threshold. When compared with traditional running socks, they found that compression stockings produced significant improvements in running at both metabolic thresholds. In contrast, Sperlich et al. (42) tested 15 well-trained endurance runners and, as mentioned previously, reported no improvements in either submaximal or maximal running performance when wearing compression stockings, tights, or full-body garments. These differences may be due, in part, to the different fitness level of the subjects. In the present study, we used collegiate track athletes, a competitive triathlete, and older 10K runners and found that graduated compressive tights helped sustain CMJ height performance after submaximal running, independent of our subject's fitness. However, it is clear that more research needs to focus on the specific mechanisms of how compression garments may enhance the maintenance of power.

If wearing compression garments can increase CMJ height, then they may also produce better performance in other anaerobic tasks. An increase in power is not only beneficial for power and strength athletes but also important for endurance athletes. For example, endurance athletes often need to maintain muscle power for sustained pacing, a surge, and a final kick during competition. Although only a few studies have shown compression garments to improve running performance (27,45) or prolonged high-intensity intermittent running (20,41), the greater maintenance of leg power reported in this study, and of others (2,3,13,26,28,29), may prove beneficial for some endurance athletes. However, it is clear that more research is needed to test the potential benefits of wearing compression garments during endurance events of different intensities and durations.

Although most studies have shown no significant improvements in athletic performance while wearing compressive garments, the prevailing research still supports the use of compression garments for reducing muscle damage during high-intensity efforts and for recovery after training. For example, wearing a compression garment immediately after exercise has been shown to decrease creatine kinase (12,15,17,31,32), reduce muscle swelling (18,31–33), and decrease delayed onset muscle soreness (DOMS) (1,12,14,15,26,31,32). In addition, numerous studies have reported a decrease in muscle oscillation during exercise while the athletes were wearing compression garments (8,9,13,29,32). This decrease in muscle oscillation helps support the decrease in creatine kinase, muscle swelling, and DOMS reported in the literature. Because muscle and connective tissue injury typically occurs during forced lengthening, or eccentric, muscle actions used to decelerate high-velocity movements (e.g., initial contact with the ground during running or jumping), compression garments may help to reduce muscle damage during and after intense training and, therefore, reduce the recovery time between training sessions.

Based on the CMJ data from this study, graduated compression tights maintained and increased power output after submaximal endurance running when compared with loose fitting running shorts. Although there was no significant difference in prerun CMJ height between the no tights and the postrun with tights groups, the tights group's postrun CMJ height was significantly greater than that of both the postrun without tights and prerun with tights.

This study also found that compared with running in loose fitting running shorts, our subjects reported significantly lower levels of perceived exertion and greater comfort values while wearing the graduated compression tights.

Practical Applications

Counter movement jump height is not only a popular exercise to predict anaerobic leg power but also a critical skill for many sports including volleyball, basketball, high jumping, and many dancers, specifically ballet. Counter movement jump ability is also used to assess explosive (anaerobic leg) power in track athletes (4), soccer players (10), and American football (44). The increased maintenance of CMJ height reported in this study, and in previous studies (2,3,13,26,28,29), could, therefore, be beneficial for any athlete who uses CMJ and explosive power in training or during competition.

In the present study, we used collegiate track athletes, a competitive triathlete, and recreational 10K runners and found that graduated compressive tights helped sustain CMJ height performance after submaximal running independent of the fitness our subjects. As stated in Methods, the running intensity levels were selected because they span the American College of Sports Medicine's training intensity guidelines as prescribed in their 2011 position stand (16). However, the authors acknowledge that the running protocol used in this study does not match a specific sport in intensity, such as sprinting, or duration, such as a 10K. Because other studies have already focused specifically on sprint or 10K times, we selected a running protocol that would more accurately represent an average training intensity, and duration, for our diverse subjects.

More studies are still needed to see the range of potential performance and recovery benefits provided by wearing compression and graduated compression garments. This information will not only help athletes and nonathletes but also coaches, athletic trainers, strength and conditioning specialists, and physical therapists in deciding when to use compression garments in hopes of enhancing performance, training, and recovery.

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