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Compression Garments: Influence on Muscle Fatigue

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Reference Data

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ABSTRACT

This study assessed whether opposing compression forces produced by commercially available "compression shorts" affect the repetitive force production capabilities of the thigh muscles during repetitive open- and closed-kinetic-chain exercise tests. Twenty healthy young adults (10 men, age 25.2 ± 3.8 yrs; 10 women, age 23.2 ± 4.8 yrs) volunteered to take part in the study. All were recreationally trained and participated in both weight training and endurance training programs in their weekly exercise routines. Testing was conducted using a balanced and randomized treatment design with two experimental conditions consisting of compression shorts (CS) and control (no compression) shorts; thus all subjects served as their own controls. Testing consisted of 3 sets of 50 maximal isokinetic knee extension/flexion movements at 180° · sec^{-1} on a Cybex 6000 dynamometer and the maximal number of reps at 70% 1-RM using a Tru-squat exercise machine. No significant differences were found between the CS and control conditions in peak torque or total work performed in the isokinetic knee extension/flexion exercise or in max number of reps performed with the Tru-squat. The results indicate that compression garments made for long-term wear and commonly worn by athletes and fitness enthusiasts during training and competition do not contribute to any additional fatigue in repetitive high-intensity exercise tasks.

Key Words: isokinetic, squat, ergonomics

Introduction

The use of compression shorts has become popular in sportswear. Recent investigations have demonstrated that compression shorts can enhance repetitive jump power (11, 12). Mechanisms that mediate performance gains appear to be related to a myriad of variables stimulated by compression including enhanced proprioception, reduced muscle oscillation, enhanced lactate removal, and/or psychological factors (i.e., subjects like the feel of the garments and perceive that they help) (1, 2, 11, 12, 15). Whether the higher levels of compression add significant external resistance to the actions of the contracting musculature while exercising has not been studied. To date, the added opposing resistance created by the compression garment against the contracting hip and thigh muscles has not affected repetitive maximal jump performance (11, 12). In fact, the use of compression shorts has been shown to enhance repetitive maximal jump performance in both men and women of different training backgrounds (11, 12).

In order to support a potential hypothesis, we created a general mathematical model to predict how much of an opposing force a compressive garment made for long-term wear might exert on the contracting musculature. We used a cylinder to represent a muscle. This model was conservative and did not consider the energy returned to the system with the elastic recoil of the garment. The contribution to the total amount of work performed in repetitive resistance exercise was also calculated. From these calculations the garments were predicted to contribute only a small percentage to the total work performed in a resistance exercise protocol ranging from 0.004 to 0.020% of the actual total work completed in different loading schemes (% of 1-RM).

We then designed an in vivo study to directly evaluate the changes in total work and force production capabilities in repetitive exercise tasks to determine if our calculations were supported. Based on our prior work and mathematical calculations, we hypothesized that the use of compressive shorts typically made for long-term wear (11, 12) would not have a negative influence on the total work capacity or force production capability of the lower body musculature. This was primarily due to the fact that the predicted compression forces do not contribute a significant external workload to the shortening muscle. Thus the purpose of this study was to directly examine the influence of compressive shorts on total work capacity and force production capabilities in repetitive, high-intensity, open- and closed-kinetic-chain exercise movements in the lower body.

Methods

Experimental Design and Procedures

We wanted to examine a distinct range of motion to evaluate whether or not compression forces contribute to fatigue in an exercise protocol. We used a fixed range of motion (ROM) that partially eliminated some of the proposed mechanisms which are thought to help mediate any performance benefits (e.g., proprioception) (11, 12). Two specific thigh exercise movements with fixed ranges of motion (i.e., removing any decision-making on the part of the subject as to when to start and finish a joint ROM) were used to isolate the fatigue to the thigh musculature. It was theorized that these exercise models would allow us to observe the impact of the garment's compression specifically on the thigh muscles. We used repetitive and exhaustive high-intensity exercise protocols in order to magnify the effects of any additional work, as small as it might be, that might be produced by the garment and affect performance under conditions of extreme fatigue.

A compressive garment condition and control garment condition were used in the design of this study. The compression shorts covered the area from the waist to just above the knee. They were individually fitted by waist size and hip size according to manufacturer guidelines. The compressive shorts garment consisted of a fabric weight of 6.2 oz/yd^2, Tricot fabric type, and Lycra® brand spandex content of 16%. The control garment conditions (no compression) were regular gym shorts with no tight fitting undergarments worn.

Subjects. All subjects were informed of the benefits and risks of the investigation. Each then signed an institutionally approved informed consent document in accordance with federal and university guidelines for use of human subjects in research. Each subject was medically screened and had no medical or orthopedic problem that might compromise his or her participation in the study. One group of men ($n = 10$) and one group of women ($n = 10$) were used in this study. All were considered healthy, active men and women who were involved with various physical training programs including both cardiovascular and weight training. Operationally, we classified these subjects as being recreationally trained. In addition, the difference in contracted and no-contracted thigh circumference was at least 0.2 cm for all subjects, which allowed for significant movement of the muscle from relaxed to contracted. Subject characteristics were as follows: Women—age 25.2 ± 3.8 yrs; height 168.3 ± 10.8 cm; body mass 62 ± 12 kg; body fat 22.1 ± 4.2%, Men—age 23.2 ± 4.8 yrs; height 176.7 ± 6.8 cm; body mass 85 ± 10 kg; body fat 12.8 ± 9.2%.

Strength Testing Procedures

Prior to the study, all subjects were completely familiarized over several weeks with all laboratory testing procedures. Experimental test days and tests were counterbalanced and randomized over several weeks with at least 48 hours rest between test sessions to provide for adequate recovery. Test-retest reliability of the experimental tests used in this investigation demonstrated an intraclass R of 0.97 or greater.

Squat Testing. A bilateral, closed-kinetic-chain novel squat exercise movement which takes the load stress off the back and focuses it to the thigh was used in order to eliminate confounding effects of upper body fatigue in this exercise (6, 7). Each subject's 1-RM was determined using this squat exercise performed on a Tru-Squat machine (Southern Xercise Inc., Cleveland, TN) according to previously published methods (13). This machine allows for a very structured squat form in a fixed and repeatable position biomechanically. Foot placements were marked on the platform and body position was set for each individual, thus increasing the reliability of the test protocol.

The squat test consisted of a 70% 1-RM load with audible cues to mark the bottom part of the squat, letting the subject know when the proper range of motion was achieved. The squat movement was performed to the parallel position of the thighs with the floor. Using their own volitional pace, subjects performed as many repetitions as they could in a continuous set. When a subject could no longer perform a complete repetition, the test was stopped. Similar verbal encouragement was given at all test sessions. To guard against the Valsalva maneuver and associated symptoms on test results, all subjects were encouraged to use proper breathing and not hold their breath during any of the testing.

Isokinetic Testing. A dominant-leg, unilateral, open-kinetic-chain movement of knee extensions and knee flexions was chosen to isolate the stress of exercise to the thigh musculature. A Cybex 6000 isokinetic dynamometer (Cybex, Ronkonkoma, NY) with a graphic recorder and computer software was used to measure peak torque. The dynamometer was calibrated prior to each testing session according to manufacturer guidelines. During testing, subjects were stabilized by thigh, chest, and waist straps. Similar verbal encouragement was given at all test sessions. Subjects could view their performance on the computer monitor to further enhance performance (13). The isokintetic test consisted of voluntary maximal isokinetic knee extension and flexion movements for the 3 sets of 50 reps at 180° · sec^{-1}. Subjects performed maximal knee extension and flexion as fast as possible (no pacing) for the entire 50-rep set. A 2-min rest period was allowed between sets.

Statistical Analyses. A two-way analysis of variance or a two-way ANOVA with repeated measures were used to analyze these data. Tukey post-hoc tests were used to determine pairwise differences when appropriate. Statistical power calculations ranged from 0.78 to 0.80. Significance was set at $p \leq 0.05$.

Results

Tru-Squat® test results at 70% 1-RM can be seen in Figure 1. No differences were observed between the CS and the control conditions. Nor were any differences observed between men and women. As expected, 1-RM squat strength was significantly different (men 144 ± 69 kg vs. 74 ± 41 kg) between men and women.

The isokinetic results for total work are shown in Figures 2 and 3. No significant differences were found between garment conditions. In general, the same pattern of responses can be observed for both knee flexion and extension in peak torque and total work in men and women. The results for peak torque (data not shown) were identical to the pattern of response for total work in all comparisons. In men, significant and consecutive reductions in peak torque and total work were observed from Sets 1 to 2 and from Sets 2 to 3. In women, however, there was a significant reduction from Sets 1 to 2, but no differences between Sets 2 and 3 for knee extension and for knee flexion. A significant reduction in peak torque and total work was not observed until Set 3.

All of the corresponding values for men, whether for peak toque or total work, were significantly greater than the corresponding values for women. As expected, peak torque and total work values for knee extensions were significantly greater than for knee flexion (4). The force production capabilities for each of the 150 repetitions were evaluated and no significant differences were observed between garment conditions for men or women.

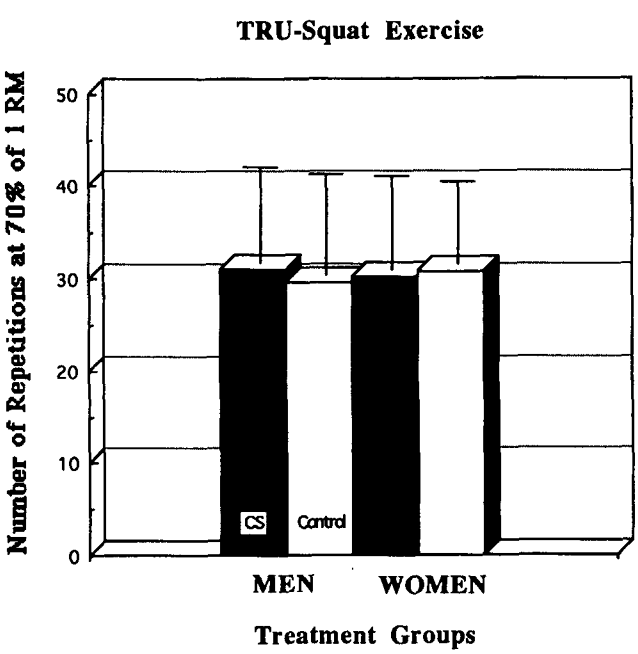

Figure 1. Tru-squat endurance performance of max no. of reps at 70% 1-RM in 10 men and 10 women. CS = compression shorts; control conditions = no compression with the undergarments worn with gym trunks.

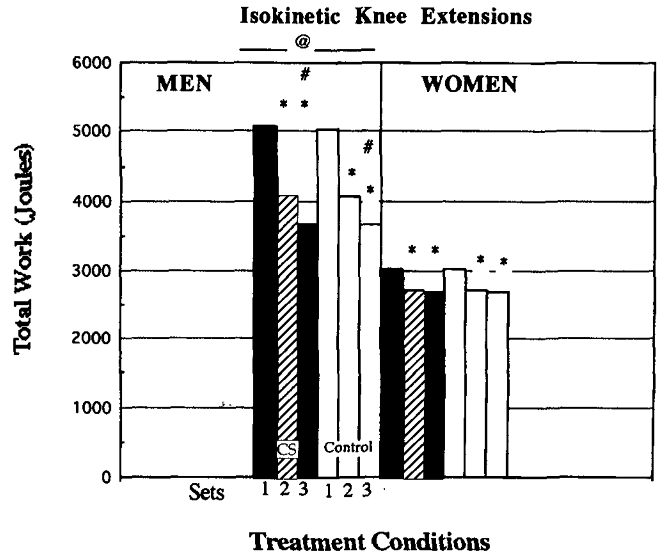

Figure 2. Three sets of 5 isokinetic reps at 180° · sec^{-1} knee extensions with 2 min rest between sets in 10 men and 10 women. CS = compression shorts; control conditions = no compression with the undergarments worn with gym trunks. *$p \leq 0.05$ from corresponding Set-1 value; #$p \leq 0.05$ from corresponding Set-2 values; @$p \leq 0.05$ from corresponding values for women.

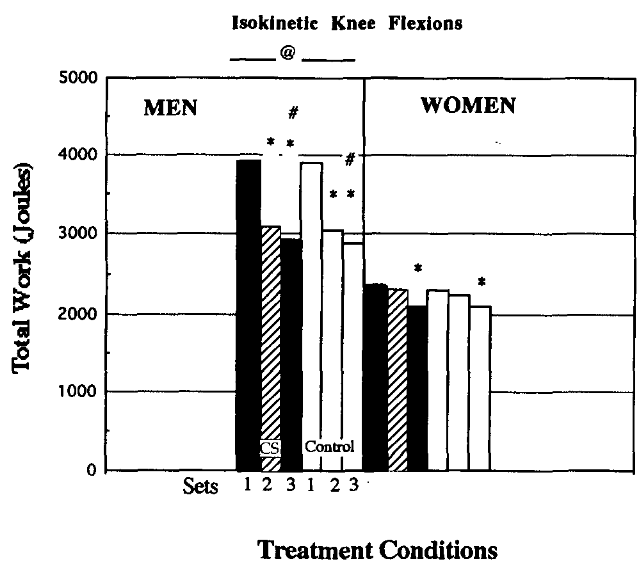

Figure 3. Three sets of 5 isokinetic reps at 180° · sec^{-1} knee flexions with 2 min rest between sets in 10 men and 10 women. CS = compression shorts; control conditions = no compression with the undergarments worn with gym trunks. *$p \leq 0.05$ from corresponding Set-1 value; #$p \leq 0.05$ from corresponding Set-2 values; @$p \leq 0.05$ from corresponding values for women.

Discussion

This study addressed the question, "What is the impact of the added opposing force observed when wearing compression shorts on total work and force production capabilities under conditions of fatigue?" Important to this study was the fact that we removed perceptual decisions regarding the joint ROM by fixing these in the exercise protocols. The primary finding was that our hypothesis was supported and the use of compression shorts does not have a negative effect on repetitive, high-intensity, force-production performance of the lower body musculature. The influence of the comfortable compression levels found in such commercial garments (e.g., Lycra® Power) was not predicted to produce enough mechanical force against the contracting muscles during exercise. Thus these types of compression shorts are different from the mechanical mechanisms engaged with the use of high pressure garments (e.g., super bench shirts and high pressure wraps) which have much more dramatic compression in their opposing support and force.

These higher compression garments have not been studied but, anecdotally at least, appear to mediate their ability to enhance maximal force-production capability in power-lifting movements. However, they have limited use for most sports which require long-term wear for a training session or game. Power lifters see benefits in wearing tightly bound wraps around various joints such as the knees to enhance force production and help support the load. For example, it has been shown that knee wraps increase vertical force at the feet (mean 11.4 ± 2.7 kg) and thus contribute to a greater 1-RM in the squat (8). Anecdotally, it appears that the use of "super" suits (considered extreme compression as lifters can only tolerate them for a few minutes) in power lifting enhances high force development and structural support for 1-RM power lifts in the bench press, squat, and deadlift.

The garments used in this study did not have such extreme levels of compression, as they are marketed for long-term wear in sports and training. These types of compressive shorts (e.g., Lycra® Power) do not provide the high mechanical forces needed to enhance maximal force production in such lifts. Furthermore, the design of the study was focused upon the contracting thigh muscles and determining whether this level of compression affects the force production or work capacity due to the muscles having to shorten against an external compressive force.

A lack of mechanical support for the knee joint also removed the confounding effect of joint support beyond the hip in these tests. It appears there is a dynamic continuum ranging from the extreme mechanical support compression levels to lower compression levels that engage other biological mechanisms (1, 2, 8, 11, 12, 14, 15). The use of different types and amounts of compression in garment construction could be sport-specific. Future garment construction may well try to elicit the stimulation of specific biological mechanisms (e.g., proprioception or reduced oscillation) in the body which are vital to performance in certain sport or training tasks.

Interestingly, no performance benefits were observed in this study with the removal of some proprioceptive skill mechanisms which have been shown to facilitate performance (e.g., proprioceptive signals for deciding when to start and stop movements) (11, 12). Also, there was no evidence that the compression shorts had any impact on other biological mechanisms such as enhanced lactate removal (1, 2). It may be that covering only the hip and thigh does not assist the muscle pumping for venous return of blood or enhance the circulatory clearance of lactate. Furthermore, the removal of lactate from the exercising muscle has been one proposed mechanism for performance enhancement with exhaustive exercise, especially in the recovery period (1, 2). However, the high percentage of maximal effort, short recovery period, and seated position used in isokinetic testing may have prevented this mechanism from becoming operational. Without any lactate data, we can only speculate as to the apparent lack of influence on lactate concentrations in the muscle from the force-production results. A more formal evaluation of this mechanism remains to be studied. The lack on any impact force in these tasks also removes the influence on muscle oscillation that may enhance performance of some activities as well (12).

Ultimately, the focus on the experimental question of the shortening muscle action working against opposing compression forces did not allow for the development of a performance enhancement strategy in this experiment. However, we found that wearing such compression shorts does not create any significant observable negative effects on force production and total work capacity of the thigh muscles.

The differences in muscle strength between men and women as observed in this study support the classically understood gender differences reported in the literature, and a detailed discussion is beyond the question addressed in this study (for review, see Ref. 5). However, the maximal number of repetitions at 70% 1-RM for both men and women were almost identical. Data comparing squat endurance capacity in men and women are scarce. Hoeger et al. (9, 10) found the maximal number of repetitions at 60 and 80% 1-RM in the leg press to be more similar for untrained men and women than for trained men and women. In general, women also appear to be superior at lower percentages (e.g., 60%) of 1-RM for the leg press (e.g., TW > TM > UTW > UTM).

Our data show that men and women are similar in their relative fatiguability in a dynamic upright modified squat exercise. The use of Lycra® compression shorts did not have a negative effect on these performances and, interestingly, a trend toward improved performance with the compression garment was observed in men ($p = 0.09$). We might speculate that the compression shorts had a positive effect on proprioception related to the speed of descent, which in the squat was not controlled (volitional speed). It has been shown that the eccentric phase of the squat is slower in elite power lifters, at least during maximal lifts (5). Further study of this potential role in speed control of movement as it relates to compression garments is needed.

In this study we tried to remove any proprioceptive decision-making process by fixing the endpoints of the ROM by structure (e.g., standing start in the lockout position), having an audible cue at the bottom of the squat, and having fixed movement patterns in the knee extension/flexion test, thus removing one of the proposed important mechanisms for performance enhancement with such garments (12).

In general, the concentric isokinetic force production results in men and women followed the expected pattern: men were stronger than women, knee extension was greater than knee flexion, and the fatigability of the women with repetitive sets of exercise was less dramatic than in the men (3, 4, 5). Key to this study was the fact that the garments did not add any noticeable fatigue factor to the exercise task of the quadriceps and hamstrings. In fact, the force reproduction in both knee extension/flexion were remarkably similar, indicating that the compression garment had no impact on the performance of the thigh muscles even under conditions of extreme fatigue (e.g., last set of 10 reps in the 3rd set of 50 reps).

Practical Applications

The purpose of this study was to determine whether the use of commercial compression shorts would add any significant amount of resistance to repetitive muscle actions, thereby adding an additional fatigue factor that would lead to diminished performance. Our results showed that the compression shorts do not add any significant resistance to hip and thigh movements that might have a negative effect on repetitive, high-intensity force-production capabilities. Thus, the use of commercially available compressive shorts (e.g., Lycra® Power) does not contribute to any additional fatigue in repetitive high-intensity exercise tasks.

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