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PNEUMATIC COMPRESSION DEVICES: EFFECTS ON RECOVERY AND SUBSEQUENT PERFORMANCE

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ABSTRACT

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Recovery is considered a vital part of sports and exercise performance. The most efficient recovery method following an exercise bout, in order to improve performance, is not fully elucidated or agreed upon. The purpose of this study was to compare the effect of three recovery strategies (passive, active, and pneumatic compression devices) on exercise performance. Fourteen male subjects completed an intense exercise bout using a Tabata protocol. Subsequent performance testing involved completing three performance tests: a vertical jump test, an agility test (T-test), and a Wingate anaerobic power test. All three recovery methods were carried out for 30 minutes immediately following the Tabata protocol. Subsequent performance tests were completed within 24 hours of each recovery method, in random order. There were no significant differences in exercise performance for any of the tests, regardless of the recovery modality. It was concluded following an intense exercise bout, active recovery or the use of pneumatic compression boots are no more beneficial than passive recovery in terms of their effect on performance 24 hours later.

TABLE OF CONTENTS

INTRODUCTION

Recovery is a crucial component of any training program. A device or method that can help to speed recovery could be an incredible tool especially if it could be shown that it improves subsequent performance. One of the new tools on the market that claims to enhance recovery are Pneumatic compression devices (PCDs). The PCDs incorporates a series of compression chambers that sequentially inflate and deflate, in order to increase venous return to the heart. Originally, PCDs used in hospitals to reduce blood pooling in the lower extremities in order to prevent deep vein thrombosis (Maffiodo et al., 2016). The literature on the use of PCDs to enhance performance is inconclusive.

Several studies have found that there is a benefit to using PCDs as a recovery tool. A study by Oakley (2019) found that using PCDs after eccentric contractions of the elbow flexors improved power output during a subsequent arm ergometer test. PCDS have been shown to improve flexibility in the forward split position, in previously trained subjects (Sands et al., 2014). Pneumatic compression devices also were shown to reduce muscle swelling and peak pain after a muscle-damaging protocol of the elbow flexor muscle group (Winke &Williamson, 2018). Even though range of motion (ROM) was decreased following the workout, the reduction in ROM was less in the PCD group compared to the control group. Similarly, Haun and colleagues (2017) found less delayed-onset muscle soreness (DOMS) and an attenuated decrease in knee flexion ROM following PCD usage compared to a passive recovery in subjects who completed a 3-day heavy resistance training protocol. Lastly, Zelikovski et al. (1993) found a 45%

improvement in time-to-exhaustion on a constant load-cycling test following PCD use versus passive recovery.

Conversely, a study by Heapy et al., (2018) randomized ultra-marathoners' post-race to receive either manual therapy or treatment with PCDs. There was no difference in 400-meter performance following either treatment. Studies by Thorp (2015) and Overmayer and Driller (2018) found that PCDs did not improve performance in either distance or track cyclists, respectively. In the aforementioned study by Haun et al. (2017), even though there was less DOMS and an attenuated ROM in knee flexion, there was no change in peak isokinetic knee extension strength following PCD or sham treatment. There was also a decrease in total lifting volume across the three workouts, with no difference between recovery treatments. Because research investigating the use of PCDs to aid recovery is inconclusive, the purpose of this study was to compare the effects of passive recovery, active recovery, and PCDs on agility, vertical jump height, and anaerobic power. This study was part of a larger study which also compared blood lactate removal following either passive recovery, active recovery, or PCD usage.

METHODS

Subjects

Fifteen apparently healthy college students between 19-25 years of age from the University of Wisconsin- La Crosse were recruited for this study. One subject dropped out due to an injury unrelated to our study. Subjects were required to be highly fit (i.e., currently exercising at least five times per week for at least 30 minutes) and could not have had any lower extremity or back injuries within the last six months. Each subject completed a PAR-Q to screen for cardiovascular and orthopedic contraindications to exercise. Eligible subjects provided written informed consent before undergoing any testing procedures. The study was reviewed and approved by the University of Wisconsin–La Crosse Institutional Review Board for the Protection of Human Subjects.

Procedures

Initially, each subject completed a maximal cycle ergometer test to determine maximal oxygen consumption (VO_2max), maximal heart rate (HRmax), ventilatory threshold (VT), and peak power output (PPO). The VO_2max test was performed on an electronically braked cycle ergometer (Lode B.V., Groningen, Netherlands). The test began at 25 W for 3 minutes and power output (PO) was increased by 25 W every minute until volitional fatigue. Respiratory gas exchange was measured using a mixing chamber based, open-circuit spirometry system (AEI Technologies, Naperville, IL). Calibration of the metabolic system was completed before each test using a reference gas mixture

(16.02% O_2 and 4.00% CO_2) and room air (20.93% O_2 and 0.03% CO_2). Calibration of the Pneumotach was completed using a 3 L calibration syringe. Heart rate (HR) was measured every minute using radio telemetry (Polar Vantage XL, Polar Instruments, Port Washington, NY) and ratings of perceived exertion (RPE) were assessed each minute using the 6-20 Borg Scale (Borg, 1982). Maximal HR was determined as the highest HR observed during the test. Oxygen consumption was averaged every 30 seconds and the highest 30-second value was accepted as VO_2max. Peak power output was defined as the highest PO recorded during the test.

Following the VO_2max test, subjects performed baseline testing for vertical jump height, agility, and anaerobic power. Vertical jump was measured using a Just Jump Meter mat (Probotics Inc, Huntsville, AL). The mat was placed flat on a hard surface and was programmed on “1 jump mode.” Subjects were instructed to stand with both feet flat on the mat, shoulder width apart. Instructions were given to jump as high as possible and land with both feet on the mat. The subjects were encouraged to use countermovement of the arms during their jumps. The test was performed three times with a 30-second rest between each jump. The two closest measurements were averaged and used for data analysis.

Agility was measured using a T-test (American Council on Exercise, San Diego, CA), which includes forward, lateral, and backward movements. Cones were set up at four points (A, B, C, D). Subjects were told to start behind the first cone (A). Subjects would sprint from cone A to cone B, sidestep from cone B to cone C, sidestep from cone C to cone D, sidestep from cone D to cone B, and backpedal from cone D to cone A all as fast as they could. The subjects were told to touch each cone and were advised to not cross their feet when sidestepping. Timing was done using an Accusplit 740mx Turbo stopwatch triggered by an IRD Wire (Brower Timing Systems, Draper, UT). The test was performed three times with a 2-minute rest period between trials. The average of the two closest times was used for data analysis. A diagram of the test is presented in Figure 1.

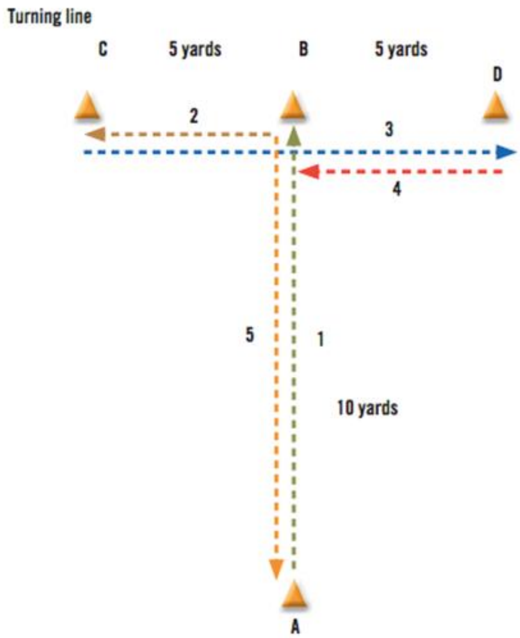

Figure 1. A diagram of the T-Test.

Anaerobic power was assessed using the Wingate test on a cycle ergometer as described by Franco et al. (2012). Subjects completed a 1-minute, self-paced, warm-up with a load corresponding to 2.0% of body mass. Following the warm-up, subjects were instructed to pedal at 60 rpms and were given a 5-second countdown before the resistance was applied to the flywheel. The resistance used was equal to 7.5% of body weight. When the resistance was applied, subjects were to pedal as hard and fast as possible for 30 seconds. After completion of the test, subjects were allowed to continue pedaling against a light load for as long as needed for recovery. Peak power (PP) was calculated as the highest power output seen at any time during the test. Lowest power (LP) was calculated as the lowest power seen at any time during the test. Anaerobic fatigue (AF) was the percentage of power lost from the beginning to the end of the test and was calculated as PP-LP/PP.

Following the baseline data collection, and with at least 48 hours of recovery, subjects reported to the Human Performance Laboratory to perform a Tabata workout on a cycle ergometer. Initially, subjects warmed up for 5 minutes at a self-selected pace. They then completed the Tabata workout. The Tabata workout consisted of 20 seconds of work at a PO calculated to be 120% of PPO (at 90 rpm) from the maximal cycle ergometer test, paired with 10 seconds of unloaded pedaling, for a total of 8 sets, or 4 minutes (Farland et al., 2015). Following the Tabata workout, the subjects continued cycling for 2 minutes at a self-selected pace as a cool-down. Following the cool-down, subjects were randomly selected to recover using either passive recovery, active recovery, or the NormaTec Pulse 2.0 Recovery System for 30 minutes (NormaTec Pulse 2.0 Recovery System, NormaTec, Watertown, MA). The passive recovery modality was performed while sitting in a reclined position with the feet elevated. The NormaTec recovery condition was performed in the identical position as the passive recovery, except subjects wore the NormaTec Pule 2.0 Recovery System. All subjects used the highest setting on the NormacTec system (setting 7). The active recovery was performed on the cycle ergometer at a PO calculated to be 10% below the subject's VT. Subjects were also required to complete two different recovery questionnaires following each recovery condition. Subjects recovery was quantified visually by having subjects place a mark on a 10-cm Visual Analog Scale (VAS), with verbal anchors at 0 cm (not recovered at all) and 10 cm (fully recovered) (Appendix B). The marks distance from the left was quantified as a percentage of the line length (Hoffman, Badowski, Chin, and Stuempfle, 2016). The subject's recovery was also quantified using the 6-20 Total Quality Recovery Scale (TQRS) (Appendix C). On the TQRS scale, a rating of 6 represents very, very poor recovery whereas a rating of 20 represents very, very good recovery.

Twenty-four hours after the Tabata workout, subjects returned to the laboratory to be tested for vertical jump, agility, and anaerobic power, in that order. This sequence was repeated following the remaining two recovery conditions.

Statistical Analysis

Standard descriptive statistics were used to quantify subject characteristics and to summarize the responses under each condition. Comparisons for each variable between each condition were made using a one-way ANOVA with repeated measures. Alpha was set at $p < .05$ to achieve statistical significance.

RESULTS

Fourteen subjects completed the study protocol. One subject dropped out of the study due to an injury unrelated to the study protocol. The physical characteristics of the subjects are presented in Table 1. Performance results following each recovery condition are presented in Table 2. There was no significant difference in vertical jump height, T-Test time, or any of the Wingate performance variables between recovery conditions or compared to baseline. Data from the two recovery questionnaires are presented in Table 3. Subjects felt significantly more recovered following the 30-minute active recovery compared to the passive recovery condition when assessed using both the TQRS and VAS questionnaires.

Table 1. Descriptive characteristics of the subjects (N=14).

	Mean ± SD	Range
Age (yrs)	23.2 ± 1.76	20 - 27
Height (cm)	176.8 ± 6.76	165 - 188
Weight (kg)	84.6 ± 11.33	71 - 106
HR_{max} (bpm)	188 ± 9.29	168 - 203
VT (watts)	132.1 ± 22.85	100 - 175
VO_2max (ml O_2/kg/min)	47.0 ± 6.48	35.9 - 56.4
PPO (watts)	289.3 ± 25.41	250 - 325

Values represent mean ± SD.

Table 2. Performance variables 24 hours after active recovery, passive recovery, or NormaTec recovery boots compared to baseline.

	Baseline	Passive	Active	NormaTec
Vertical Jump (cm)	62.5 ± 8.43	62.0 ± 6.60	62.1 ± 7.69	61.8 ± 7.87
T-test (sec)	9.93 ± 0.548	9.89 ± 0.327	9.89 ± 0.489	9.94 ± 0.368
Peak Power (watts)	1341 ± 340.3	1315 ± 353.1	1338 ± 279.1	1340 ± 310.7
Mean Power (watts)	736 ± 109.6	726 ± 88.9	723 ± 90.7	727 ± 91.3
Low Power (watts)	413 ± 102.9	418 ± 106.4	428 ± 87.9	407 ± 113.9
Power Decline (%)	67 ± 11.1	65 ± 10.5	64 ± 10.3	68 ± 11.5

Values represent mean ± SD.

Table 3. Recovery scale scores immediately following each recovery period (Post), before performance testing conducted 24 hours later (Pre24), and immediately following performance testing (Post24) with Passive, NormaTec and Active recovery

		Post	Pre24	Post24
TQRS				
	Passive	14.8 ± 2.61	17.7 ± 2.79	15.1 ± 2.65
	NormaTec	16.0 ± 2.31	17.4 ± 2.50	15.1 ± 2.87
	Active	16.6 ± 1.56[a]	17.5 ± 2.68	15.1 ± 3.08
VAS				
	Passive	6.6 ± 1.77	8.39 ± 1.90	7.0 ± 1.86
	Normatech	7.2 ± 1.26	8.22 ± 1.62	7.0 ± 1.73
	Active	8.0 ± 1.05[a]	8.35 ± 1.62	7.2 ± 1.76

Values represent mean ± SD.
[a] Significantly greater than Passive Recovery ($p<.05$).

DISCUSSION

This study found that following a vigorous exercise bout, none of the recovery techniques utilized (i.e., active recovery, passive recovery, NormaTec boots) had a significant effect on subsequent exercise performance. The three performance tests used in the current study were chosen to reflect physical attributes that would affect athletic performance, namely strength (vertical jump), agility (T-test), and anaerobic power (Wingate test).

We found no difference in peak power, mean power, or power decline following any of the recovery techniques. Martin, Friedenrich, Borges, & Roberts (2015) tested trained college hockey players and their performance on a Wingate protocol. The researchers had their subjects complete a familiarization session with the Wingate protocol similar to our baseline session. The subjects then came back to the laboratory 72 hours later to complete the testing session. The subjects completed two Wingate tests and wore either compression sleeves with actual compression or compression sleeves without compression. After each condition the subjects completed a third Wingate test. The researchers found no significant differences in peak power, average power, or fatigue index.

Cochrane, Booker, Mundel, and Barnes (2013) evaluated vertical jump height following the use of PCDs compared to passive recovery after subjects completed a strenuous back squat workout. They found no significant difference in vertical jump performance or strength attenuation between conditions. Agility involves quick movements and direction change which is crucial for athletic performance. To our knowledge, no studies have evaluated changes in agility following PCD usage. We found no change in agility following any of the recovery protocols.

A study by Heapy et al. (2018) evaluated 400 m running performance following an ultra-marathon. They found no improvement in 400 m times consequent to the use of PCDs these devices compared to active and passive recovery methods.

The question becomes, why is there no difference in performance following the use of PCDs, which are designed to help people recover more quickly. Pneumatic compression devices have been used for many years in a clinical setting to prevent deep vein thromboses in bed-ridden patients. A study by Malone et al. (1999) found that both low- and high-pressure sequential compression increased venous return velocity, illustrating that PCDs increase venous return. In theory it is this increase in venous return which is suggested to remove lactate more quickly, thus helping athlete's recover faster. If they recover faster, subsequent performance should be enhanced. There has been some research supporting a relationship between improved lactate removal and improved performance. A study by Greenwood et al. (2008) evaluated maximal 200 m freestyle swim times following different active recovery strategies compared to passive recovery. It was found that active recovery for 10 minutes at lactate threshold significantly improved subsequent 200 m performance. A key difference between that study and the current study was the time of testing relative to when the recovery conditions were completed. In the study by Greenwood et al., the 200 m swims were performed immediately after the different recovery conditions. In the current study, subjects completed the performance tests 24 hours later. It is highly likely that this difference between when the testing was completed relative to the different recovery conditions influenced the results. It also suggests that different recovery strategies may be more important in athletic competitions that may have multiple heats or trials per day (e.g., track meets that have qualifying heats prior to the finals). On the contrary a study by O'Donnell & Driller (2015) tested triathletes performing a running and cycling test. Following the cycling session, the athletes wore PCDs. There was no improved performance between the two different events.

One factor to consider may be the relationship to subsequent performance. Using the same study by Martin et al. (2015) as an example, it was shown that although lactate removal may be improved with a certain recovery method, it does not always correlate with improved performance.

Another factor that helps to explain the lack of improvement in performance may be related to the scores on the VAS and TQRS questionnaires. There was no significant difference in the recovery scores on either questionnaire just prior to testing, which was performed 24-hours after each recovery condition. However, subjects did feel significantly more recovered immediately after the active recovery and there was a non-significant trend for subjects to feel more recovered following the NormaTec condition. It is possible that had the performance testing been conducted immediately after each recovery condition, difference results may have been seen.

There are several possible limitations to the current study. The subjects were asked to refrain from strenuous exercise and other forms of recovery during the course of the study. However, because we used relatively trained individuals who normally exercised five or more days per week, it is possible that their regular workouts and associated fatigue levels may have affected their performance on the performance tests.

The vigorous nature of our testing (i.e., repeated Tabata workouts and Wingate tests) may have also influenced the results of the study. Even though subjects were supposed to go "all out" during all of the testing procedures, it is possible that after the baseline testing, subjects knew how difficult the subsequent testing was going to be and paced themselves accordingly.

CONCLUSION

It was found that none of the recovery techniques used in the current study provided any benefit to subsequent performance. However, because the performance tests were all performed 24 hours after each recovery condition, this may have negated some of the potential benefit of the recovery modalities. A study by Greenwood et al. (2008) did see some benefit to performance when testing was undertaken immediately after the recovery modalities, a future study may want to repeat the current methodology, but complete the testing in a shorter timeframe relative to the active, passive, and NormaTec recovery sessions. It may also be beneficial to focus on sport specific testing such as swimmers in their usual event.

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