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Original Research Article

Effects of Various Recovery Modalities on Lactate Clearance and Subsequent Exercise Performance

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Abstract

Introduction: Recovery following exercise plays a vital role in allowing individuals to realize the benefits of exercise training. Clearance of blood lactate (BLa) is considered an important marker of the speed of recovery. Manufacturers of intermittent pneumatic compression (IPC) devices claim that their products help clear BLa more quickly than passive recovery. As such, IPC devices have become increasing popular recovery tool used by athletes. **Purpose:** The purpose of this study was to compare BLa clearance and subsequent exercise performance following 30 minutes of passive recovery, active recovery, or IPC (NormaTec Pulse 2.0 Recovery System) usage. **Methods:** Fourteen subjects completed baseline vertical jump, agility, and Wingate testing. On three separate days, separated by a minimum of 72 hours, subjects completed a Tabata workout on a cycle ergometer (8 x 20s @ 125% PPO; 10s recovery). Each Tabata workout was immediately followed by a 30-minute recovery period (i.e., NormaTec, active recovery, or passive recovery), in random order. BLa was measured immediately post exercise and every 5-minutes during each 30-minute recovery condition. Subjects returned to the laboratory 24 hours after each recovery trials to repeat the performance tests. Two recovery questionnaires were also completed to assess subjective recovery. **Results:** Active recovery and NormaTec resulted in faster BLa clearance during 30 minutes of recovery compared to passive recovery. There was no difference between active recovery and NormaTec during the first 10 minutes post exercise, but thereafter active recovery was superior to NormaTec. There were no significant differences in exercise performance for any of the tests, regardless of the recovery modality. Subjects felt significantly more recovered immediately following the active recovery compared to the passive recovery condition. **Conclusion:** Active recovery and the NormaTec Pulse 2.0 Recovery System were significantly more effective at clearing BLa than passive recovery during 30-minute recovery sessions. None of the recovery techniques had any significant effect on exercise performance 24-hours later

Key Words: Agility, Anaerobic Power, NormaTec.

Introduction

An athlete's ability to maximize their training is at least partially based upon their ability to fully recover between consecutive training sessions. Recovery is important because it is the period where all exerciseinduced adaptations occur.[1] Recovery periods can be broken down into three distinct phases. The shortest period of recovery is between consecutive repetitions within a set of exercises. The second period is short-term recovery between sets, which could be the time between resistance sets or interval bouts. The third period is the recovery period between workouts, which has received the most research focus.

One of the measures used to gauge the speed of recovery is blood lactate (BLa) clearance. Although there is not a cause and effect relationship between BLa and fatigue, BLa clearance can be used as an indirect measure of the build-up and clearance of metabolites associated with fatigue. Active recovery, which is the use of submaximal exercise in the immediate post-exercise period, has been shown to be the most effective method for BLa clearance.[2,3] Previous studies have shown that performing active recovery at or near lactate threshold is the most efficient way of clearing BLa.[4-6] Not only has active recovery at lactate threshold been linked to BLa clearance, but it has also been shown to improve subsequent performance.[4]

Intermittent pneumatic compression (IPC) devices are an increasing popular modality used by athletes to accelerate recovery. Intermittent pneumatic compression devices are typically worn on the extremities and incorporate chambers that are sequentially inflated from distal to proximal and then deflated.[7] The pressure gradient created by the compression collapses the lumen of the vessel, pushing blood toward the heart, facilitating venous return.[8] This action has been termed "biomimicry," since it mimics the body's natural muscle pump which occurs in skeletal muscle during exercise.[9] Originally, IPC devices were used in a hospital setting to reduce blood pooling in the lower extremities, which in turn reduced the incidence of deep vein thrombosis.[10]

Research on the ability of IPC devices to effectively accelerate BLa removal and improve performance is inconclusive. Several studies have shown that various IPC devices facilitate BLa removal better than passive recovery,[11,12] while others have not.[13-15] The ability of IPC devices to improve performance is also inconclusive. A study by Zelikovski et al.[15] found a 45% improvement in time to exhaustion on a constant load cycle ergometer test (performed at 80% of VO_2max) immediately after IPC usage compared to passive recovery in the supine position. Conversely, studies by Thorp[16] and Overmayer and Driller[14] found that IPCs did not improve performance in either distance or track cyclists, respectively. Previous studies have shown that IPC devices may reduce muscle swelling, peak pain, and delayed onset muscle soreness (DOMS) following a muscle-damaging protocol.[17,18] However, there was no change in peak isokinetic knee extension strength following IPC or sham treatment.[17]

A relatively new and increasingly popular IPC device on the market is the NormaTec Pulse 2.0 Recovery System (Watertown, MA).[9] The NormTec System used in this study incorporated a compressive boot and sleeve that extended to the upper thigh. The purpose of this study was to evaluate BLa clearance and exercise performance following the usage of the NormaTec Pulse 2.0 Recovery System in comparison to passive and active recovery. Exercise performance was assessed using tests for vertical jump height, agility, and anaerobic power.

Methods

Participants

Fifteen apparently healthy male college students between 20-27 years of age were recruited for this study. Subjects were required to be relatively fit (i.e., currently exercising at least five times per week, including high-intensity training at least once per week) and could not have had any lower extremity or back injuries within the last 6 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

Each subject initially 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 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). The gas analyzers were calibrated 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) and the pneumotach was calibrated with a 3-liter calibration syringe. Heart rate (HR) was measured every minute using radiotelemetry (Polar Vantage XL, Polar Instruments, Port Washington, NY) and ratings of perceived exertion (RPE) were assessed each minute using the 6-20 Borg Scale.[19] Maximal HR was determined as the highest HR observed during the test. Ventilatory threshold was determined using a combination of the V-slope and ventilatory equivalent methods.[20] Ventilatory threshold was defined as when VCO_2 increased disproportionately to VO_2 and when VE/VO_2 increased relative to VO_2, without VE/VCO_2 increasing. Oxygen consumption was summated every 30 seconds, and the highest 30-second value was accepted as VO_2max value. Peak power output was defined as the highest PO recorded during the test.

A minimum of 24 hours after 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[21], which includes forward, lateral, and backward movements (See Figure 1). 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, side step from cone C to cone D, side step 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.

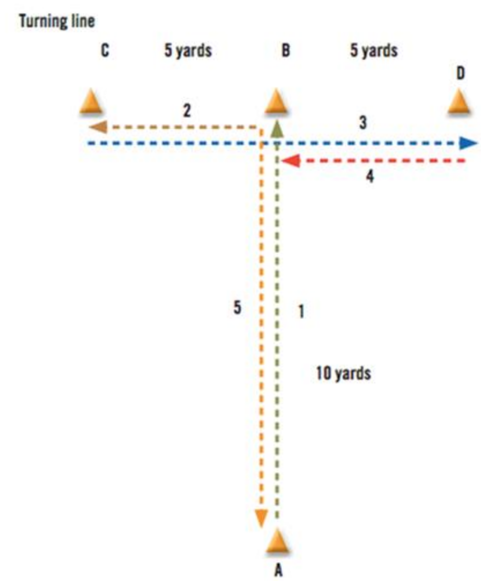

Figure 1. Diagram of the T-Test movement pattern.

Anaerobic power was assessed using the Wingate test on a cycle ergometer as described by Franco et al.[22] 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 pedaled 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. Power decline was the percentage of power lost from the beginning to the end of the test and was calculated as PP-LP/PP. Mean power was calculated as the average power over the 30-second testing period.

A minimum of 48 hours after the baseline performance testing, subjects reported back to the Human Performance Laboratory to perform a Tabata training session 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 125% of PPO from the maximal cycle ergometer test, paired with 10 seconds of unloaded pedaling (50 Watts), for a total of 8 sets, or 4 minutes.[23] Subjects continued cycling for 3 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. 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 Pulse 2.0 Recovery System and the maximal setting was used for all subjects (Setting 7). The active recovery was performed on the cycle ergometer at a PO calculated to be 10% below the subject's VT. Blood lactate was measured before exercise, immediately after the cool-down, then in 5 minute increments post-exercise (5, 10, 15, 20, 25, 30 minutes) using a capillary blood sample (Accusport Lactate Analyzer, Accusport, Hawthorne, NY).

At the conclusion of the 30-minute recovery period, subjects filled out two subjective recovery questionnaires. One questionnaire utilized a Visual Analog Scale (VAS). Subjects placed a mark on a 10-cm line, with verbal anchors at 0 cm (not recovered at all) and 10 cm (fully recovered). The marks distance from the left was quantified as a percentage of the line length.[24] The subject's recovery was also quantified using the 6-20 Total Quality Recovery Scale (TQRS).[25] On the TQRS scale, a rating of 6 represents very, very poor recovery whereas a rating of 20 represents very, very good recovery.

Subjects reported back to the Human Performance Laboratory 24 hours later. They filled out the two recovery questionnaires, were retested for vertical jump height, agility, and anaerobic power, and then completed the questionnaires once again. During the 24-hour intervening period, they were instructed not to exercise or consume alcohol.

The entire testing sequence was repeated three times. There was a minimum of 72 hours between conditions and the three recovery conditions were presented in random order.

Statistical analyses

Repeated measures ANOVA were used to compare changes in all variables across time and between recovery conditions. If there was a significant F ratio, Tukey's post-hoc tests were used to detect pairwise differences. Alpha was set at $p < .05$ to achieve statistical significance. Data are presented as mean ± standard deviations. All analyses were conducted using SPSS Version 26.0 (Chicago, IL).

Results

Fourteen subjects completed the protocol. One subject dropped out of the study prior to completing all the trials due to an orthopedic injury unrelated to the study protocol. Descriptive statistics of the 14 subjects who completed the study are presented in Table 1.

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

	Mean ± SD	Range
Age (yr)	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 ± 9.3	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

VT = ventilatory threshold; PPO = peak power output.

Blood lactate values at each time point for each of the three recovery modalities are presented in Table 2 and Figure 2, respectively. Blood lactate clearance for both the NormaTec and active recovery conditions was significantly faster than passive recovery at the 5, 10, 20, 25, 30-minute measurement periods. Active recovery cleared BLa significantly faster than NormaTec at the 15, 20, 25, and 30-minute measurement periods. There was no significant difference between active recovery and NormaTec at the 5 and 10-minute time points.

Table 2. Blood lactate values for the Passive, NormaTec, and Active recovery conditions.

	Pre	Post	5	10	15	20	25	30
Passive	1.6 ± .64	14.4 ± 2.46	13.9 ± 3.03	12.7 ± 3.26	11.0 ± 3.14	9.6 ± 3.04	8.7 ± 2.78	7.4 ± 2.67
NormaTec	1.4 ± .43	14.6 ± 2.43	12.6 ± 2.45[a]	11.2 ± 2.63[a]	10.1 ± 2.35	8.4 ± 2.16[a]	7.4 ± 2.03[a]	6.3 ± 1.81[a]
Active	1.6 ± .68	14.4 ± 2.10	12.8 ± 2.13[a]	10.5 ± 2.69[a]	8.4 ± 2.80[ab]	6.9 ± 2.32[ab]	5.6 ± 2.39[ab]	4.5 ± 1.94[ab]

[a] Significantly lower than Passive recovery (p<.05).
[b] Significantly lower than NormaTec recovery (p<.05).

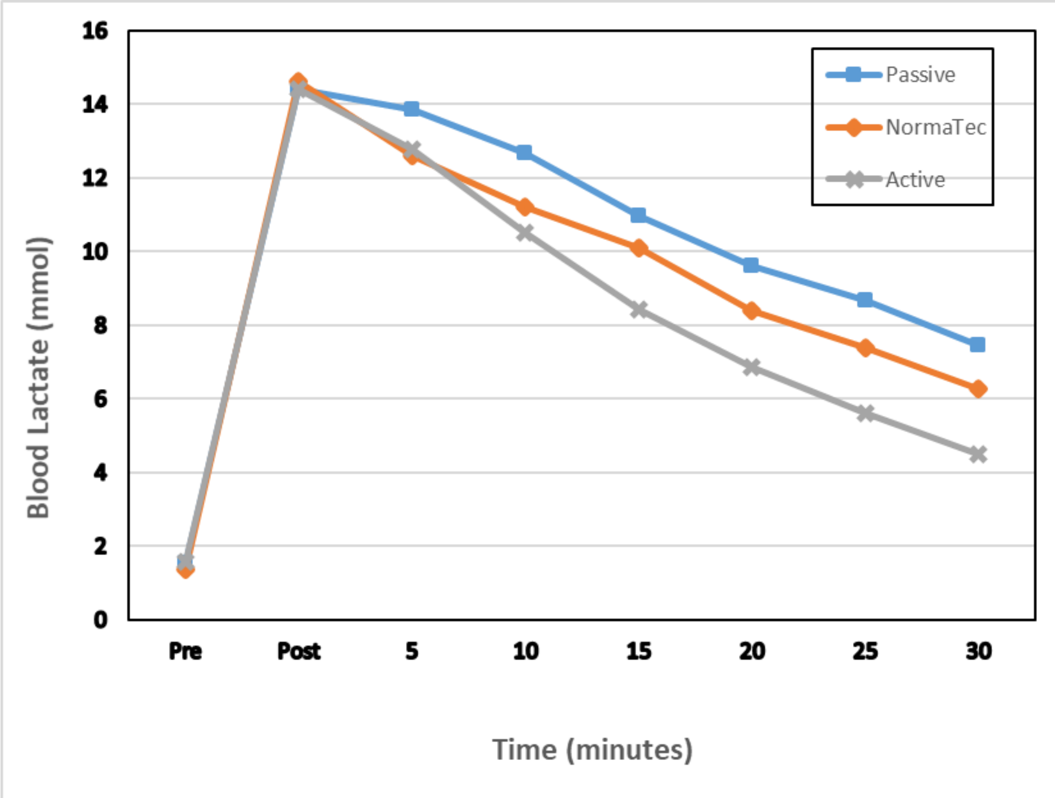

Figure 2. Blood lactate clearance between the Passive, NormaTec, and Active recovery conditions.

The performance results following each recovery condition are presented in Table 3. 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 for the two recovery scale questionnaires (TQRS and VAS) between the three different recovery modalities are presented in Table 4. On both the TQRS and VAS recovery questionnaires, subjects felt significantly more recovered immediately following the active recovery compared to the passive recovery condition.

Table 3. 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
Lowest 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

Table 4. 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
	NormaTec	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

TQRS = Total Quality Recovery Scale; VAS = Visual Analog Scale

[a] Significantly greater than Passive Recovery ($p<.05$).

Post – measurements were taken immediately after each recovery condition.

Pre24 – measurements were taken before the performance tests 24 hours after each recovery condition.

Post24 – measurements were taken after the performance tests.

Discussion

The purpose of this study was to evaluate BLa clearance and assess exercise performance after using the NormaTec Pulse 2.0 Recovery System compared to passive and active recovery. It was found that both NormaTec boots and active recovery cleared BLa significantly faster than passive recovery over a 30-minute recovery period. During the first 10-minutes of recovery, there was no difference in BLa clearance between the NormaTec boots and active recovery. However, from the 15-minute measurement point onward, active recovery was more effective at clearing blood lactate than the NormaTec boots.

These findings are consistent with results from other studies. Hanson, Stetter, Li, and Thomas[26] had female student-athletes complete a Wingate Test followed by a 20-minute recovery session. Comparing the same three modalities (i.e., IPC, active recovery, passive recovery), they found that using an IPC device was more effective at clearing BLa than passive recovery and just as effective as active recovery. The use of the NormaTec boots in our study was just as effective at clearing BLa for the first 10 minutes of the recovery period, but after 10 minutes, active recovery cleared BLa significantly faster than the NormaTec boots. Martin et al.[12] also compared the rate of BLa clearance between IPC devices and passive recovery. They had subjects complete two Wingate Tests followed by 30-minutes of treatment. They found that IPC devices cleared BLa significantly faster than passive recovery.

Increased clearance rate of BLa with active recovery is a result of the muscle pump increasing venous return, which would increase blood flow to the working muscles.[3] This increase in blood flow would help to distribute the lactate more quickly to the rest of the body, where is can be metabolized. Oxidative muscle fibers are designed to oxidize lactate and use it as a fuel source, which is the primary method hypothesized for increases in BLa clearance with active recovery. Glycolytic tissue also has the ability to metabolize lactate through its conversion to glycogen.[27] Similarly, the faster BLa clearance with the NormaTec boots is most likely due to an increased venous return, consequent to the sequential, pulsating compression provided by the boots. It has previously been shown that both low and high pressure pneumatic compression can increase venous return velocity,[28] which would increase blood flow to other tissues in the same manner as active recovery. Why active recovery resulted in faster BLa clearance than the NormaTec boots after 10 minutes can only be speculated upon. It is plausible that because the muscles of the leg were still working relatively hard during the active recovery condition (i.e., at 90% of VT), lactate could have been used as a fuel source which would remove it from the blood stream more quickly. During the NormaTec recovery period, subjects were not exercising, thus muscle metabolism was relatively low.[29]

The three exercise 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. These results were consistent with a study by Martin et al.[12] which also found no difference in anaerobic power immediately after 30 minutes of IPC treatment. Similarly, studies by Northey et al.[7] and Cochrane et al.[30] did not find a significant difference in vertical jump performance or strength 24 hours following the use of IPCs compared to the passive recovery. There was no change in agility following any of the recovery modalities. To our knowledge, no studies have evaluated changes in agility following IPC usage.

The question arises as to why there no difference in performance following both the active recovery and IPC conditions. Both conditions resulted in faster BLa clearance, indicating a faster rate of recovery. At least one study supports the relationship between faster lactate removal and improved performance. A study by Greenwood et al.[4] 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 when the subsequent trials were performed relative to when the recovery conditions were completed. In the study by Greenwood et al.,[4] the 200 m swims were performed *immediately* after the different recovery conditions. In the current study, subjects completed the performance tests *24 hours later*. This suggests that different recovery strategies may be more important in athletic competitions that have multiple heats per day (e.g., track meets that have qualifying heats prior to the finals).[31]

Subjectively, based on the results of the TQRS and VAS questionnaires, subjects only felt significantly more recovered immediately following the active workout. There was a trend for subjects to feel more recovered immediately after the NormaTec condition compared to passive recovery, but it was not statistically significant. Hoffman et al.[24] did find that subjects felt significantly more recovered following 20 minutes of IPC compared to passive recovery and Winke and Williamson[19] saw a non-significant improvement in TQRS scores which were similar in magnitude to the current study. Anecdotally, subjects in the current study commented that the NormaTec treatment "felt good," like getting a massage. There were no significant differences in the recovery scores on either questionnaire prior to performance testing the next day (24 hours later) or after completion of the performance tests.

The results of this study have several limitations. Because this study only tested apparently-healthy, male subjects, who were highly fit, the results have limited application for older or less fit individuals, or females. Another limitation of this study was that we used a single, high-intensity exercise bout in order to accumulate BLa quickly. The subjects were also asked to refrain from strenuous exercise and other forms of recovery during the study. However, because we used highly 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 influenced the results of the study. Even though subjects were supposed to go "all out" during all 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. Future research could utilize different exercise protocols to accumulate BLa in subjects and see if that alters the subjective benefits of the different recovery modalities. Finally, this study used the highest pressure setting (Setting 7) on the NormaTec system, in an attempt to maximize results. In practical terms, individuals who purchase and use the NormaTec system may use lower settings, which could influence results.

Conclusion

Both active recovery and the NormaTec Pulse 2.0 Recovery System cleared BLa more quickly post-exercise compared to passive recovery. The NormaTec boots also cleared BLa as quickly as active recovery in the first 10-minutes following an intense exercise session. None of the recovery techniques resulted in significant benefits in terms of vertical jump, agility, or anaerobic performance. However, because the performance tests were all performed 24 hours after each recovery condition, this may have negated some of the potential benefits of enhanced recovery strategies. Future studies may want to consider evaluating different recovery strategies in between repeat exercise sessions in the same day (e.g., when multiple heats are completed in the same day).

Disclosure

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