



Original Article

Recovery levels after eccentric and concentric loading in maximal force

GAMZE ERIKOĞLU ÖRER, PhD^{1)*}, NEVIN ATALAY GÜZEL, PhD²⁾, ERŞAN ARSLAN, PhD³⁾

¹⁾ Department of Sport Sciences, Faculty of Health Sciences, Yıldırım Beyazıt University: Ankara, Turkey

²⁾ Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Gazi University, Turkey

³⁾ Department of School of Physical Education and Sports, Siirt University, Turkey

Abstract. [Purpose] The aim of this study was to compare the differences in recovery periods after maximal concentric and eccentric exercises. [Subjects and Methods] Twenty-two participants voluntarily participated and were divided into two groups: the athlete and sedentary groups. An incremental treadmill running test was performed until exhaustion. During the subsequent passive recovery session, heart rate and venous blood lactate level were determined every 3 minutes until the venous blood lactate level reached 2 mmol/l. The same test protocol was implemented 15 days later. [Results] Both groups showed significantly shorter running durations in concentric exercise, while significant differences were found between the athlete and sedentary groups in terms of venous blood lactate level responses. In addition, there were significant differences between the athlete and sedentary groups in terms of running duration and heart rate in concentric and eccentric exercises. [Conclusion] The present study revealed no difference between the athlete and sedentary groups in terms of recovery durations after eccentric and concentric loadings, although the athletes demonstrated faster recovery in terms of HR compared with the sedentary group. It was thought that concentric exercises cause greater physiological responses.

Key words: Eccentric, Concentric, Recovery

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INTRODUCTION

Recovery is defined as the process of normalization of the organism after workout¹⁾. After maximal exercise, the purpose of the recovery period is to rest the organism or return to conditions before the exercise. Recovery also accelerates the regeneration rate of the organism between training sessions and decreases fatigue and injury risk. Lactic acid accumulation is one of the important factors that causes fatigue. Therefore, recovery or resting starts with the decrease of lactic acid in the body. Removal of lactic acid, which is eliminated in blood and muscle, occurs over a period of approximately 2 hours with passive recovery and over a period of 1 hour on average with active recovery after maximal exercise¹⁾. Skeletal muscle contraction is classified in the literature as isometric contraction, concentric contraction, and eccentric contraction. In eccentric contraction, the load torque is greater than the muscle torque, and the muscle lengthens. In contrast, the muscle torque is greater than the load torque in concentric contraction, and the muscle length shortens²⁾. Some studies in the literature have demonstrated that eccentric exercises lead to strength losses, while, others have shown different results because of the effects of exercise intensity, exercise type (resistance, downhill running), and area where the exercise is implemented^{3, 4)}. Studies have shown that blood lactate levels increase 6–10 folds during eccentric exercise⁵⁾. In addition to this, it can therefore be seen that mechanical stress per fibril during eccentric exercises is higher than that during concentric exercise. However, concentric exercise also causes more energy expenditure, and it leads to more maximal contraction, lactic acid, and heart rate responses

*Corresponding author. Gamze Erikoğlu Örer (E-mail: basketball.08@hotmail.com)

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compared with eccentric loading⁶⁻⁸).

Eccentric contraction has been shown to produce greater muscle hypertrophy than a concentric contraction after resistance training⁹). In addition to greater hypertrophy, eccentric contraction training tends to exert lower stress on the cardiovascular system¹⁰). In contrast to eccentric training, the cardiovascular and metabolic responses show a linear increase in concentric running¹¹). It has been stated that this difference can be associated with the contribution of gravity during eccentric exercise. Furthermore, it is understood that gravitational force increasingly assists with the work of performing the activity as the negative slope becomes steeper, thus reducing the physiologic work required of the body¹¹). As a result of this, negative slope walking e.g., walking downhill may be associated with cardiovascular or metabolic stress¹¹). The aim of this study was to compare the differences in recovery periods after maximal concentric and eccentric exercises between athletes and sedentary individuals.

SUBJECTS AND METHODS

The study was designed as a comparative study. All measurements were performed in the Department of Physiotherapy and Rehabilitation, Gazi University Faculty of Health Sciences, in a temperature-controlled performance laboratory. All participants were notified of the research procedures, requirements, benefits, and risks before giving informed consent. Written informed consent was obtained from all the participants. The study was approved by the research ethics committee of Gazi University and was conducted in a manner consistent with the institutional ethical requirements for human experimentation in accordance with the Declaration of Helsinki. All measurements were performed by the same researchers at a similar time of the day between 8:00 and 12:00 a.m. Participants were asked not to exercise exhaustively on the day prior to assessment and to have eaten and to be hydrated on the day of the test. After excluding chronic or acute health conditions, musculoskeletal system problems, and any drug intake, that might affect performance. Twenty-two participants were voluntarily participated. The participants were divided into two groups: the athlete group and the sedentary group. The athlete group trained on average 2 hours/day a least 4 days/week, whereas the sedentary group performed no training and had no lifestyle changes during the study.

All the players completed an incremental treadmill test on a motorized treadmill (Cosmed, Italy) at an incline of 10% until exhaustion. The test began at 8 km.h⁻¹, and the speed was increased by 1 km.h⁻¹ every 3 minute until exhaustion. The participants were verbally encouraged to give maximal effort during the test. Heart rate was monitored continuously throughout the test and passive recovery session with a Polar RS400 heart rate monitor (Polar, Finland). The heart rate data were transferred to a computer and smoothed (average of 1 second) by the Polar Precision Performance Software (PPP4, Finland). During the passive recovery session, the venous blood lactate level (La) was determined every 3 minutes until it reached 2 mmol/l. The same test protocol was implemented 15 days later. The data are reported as means and standard deviations. Differences in all test performance variables between the athlete and sedentary groups were by nonparametric Wilcoxon signed rank tests for independent samples. All statistical analyses were performed in SPSS version 16.0, and the level of statistical significance was set at p<0.05.

RESULTS

Table 1 shows the descriptive characteristics of the subjects.

Table 2 shows comparisons of the running durations, recovery durations, post-recovery heart rates, and post-exercise lactic acid values within the groups. Significant differences were found between concentric and eccentric loading in the athlete group in terms of running duration (17.1 ± 0.9 vs. 45.0 ± 2.7; z=-2.80, p=0.00) and La values (10.8 ± 1.6 vs. 4.3 ± 1.2; z=-2.80, p=0.00). Similarly, significant differences were found between concentric and eccentric loading in the sedentary group in terms of running duration (10.8 ± 1.3 vs. 26.1 ± 0.9; z=-2.80, p=0.00) and La values (11.0 ± 2.4 vs. 5.7 ± 1.7; z=-2.80, p=0.00).

Table 3 shows comparisons of the running durations, recovery durations, post-recovery heart rates, and post-exercise lactic acid values between the groups. Significant differences in concentric loading were found between the athlete and sedentary groups in terms of running duration (17.1 ± 0.9 vs. 10.8 ± 1.3; z=-3.65, p=0.00) and post-recovery HR responses (80.1 ± 7.7 vs. 101.9 ± 11.9; z=-3.63, p=0.00). Similarly, significant differences in eccentric loading were found between the

Table 1. Descriptive characteristics of participants

	Athlete	Sedentary
Age (years)	22.1 ± 3.3	20.1 ± 1.1
Height (cm)	176 ± 0.5	174 ± 0.0
Weight (kg)	73.4 ± 6.4	65.9 ± 8.6
BMI (kg/m ²)	23.5 ± 1.2	21.8 ± 3.0

athlete and sedentary groups in terms of running duration (45.0 ± 2.7 vs. 26.1 ± 0.9 ; $z=-3.07$, $p=0.00$) and post-recovery HR responses (75.7 ± 6.6 vs. 100.1 ± 20.2 ; $z=-2.82$, $p=0.00$).

DISCUSSION

The aim of this study was to compare the differences in recovery periods after maximal concentric and eccentric exercises. One of the main findings of the present study is that the post-exercise La responses are significantly higher with concentric loading compared with eccentric loadings. However, the athlete group had a significantly lower running duration with concentric loading. Both the athlete and sedentary groups tolerated eccentric loading better in terms of running durations and post-exercise lactic acid levels. As La and H⁺ are removed from blood via oxidation¹²), the type of the recovery significantly affects the elimination of La from blood¹³). Studies have reported that anaerobic energy metabolism, an important part of recovery session, is closely associated with the elimination of La from muscle and blood after high intensity activities^{14, 15}). The elimination of La from muscle and blood after a maximal exercise occurs over a period of approximately 2 hours with passive rest and over a period of 1 hour on average with active rest¹). Several studies have demonstrated that active recovery is a more effective strategy for eliminating of La from muscle and blood and subsequent exercise performance compared with other recovery strategies¹⁶⁻¹⁸). Active recovery allows greater reoxygenation of myoglobin and therefore oxygen delivery to the muscles¹⁹). Therefore, recovery strategies are of crucial importance for subsequent performance or loading after maximal or supramaximal loading.

Our results showed that no significant difference was observed in an intragroup comparison made between +10% and -10% slopes in post-exercise recovery durations and post-recovery HR of the athletes, while significant differences were detected in running durations and post-exercise La values in the athlete and control groups. This may explain why the athlete group tolerated exercise better in both loading types and they recovered more efficiently after the end of the exercise. A previous study showed that passive recovery strategies showed no advantages in recovery except for after high intensity exercise with a recovery period of less than 3 minutes²⁰). For these reasons, active resting is advisable if the recovery period is longer than 3-4 minutes after high intensity exercise. Moreover, many studies have shown that elimination of La and post-exercise HR responses are correlated with aerobic capacity²¹). Low-intensity exercise effectively increases endurance capacity, but it does not effectively induce hypertrophy of the skeletal muscle²²). In contrast, several studies have shown that capacity of the endurance affects muscle lactate concentration and lactate elimination after maximal loading²³⁻²⁵). Another study showed that the ability to eliminate lactate increases in workout endurance exercises during active recovery¹⁸). In addition, endurance exercises reduce lactate production and increase the removal of lactate²⁶). In contrast, no differences were found between trained and sedentary people in terms of La during passive recovery after exhaustive exercise¹⁵). The results of that study are similar our study results. It is known that aerobic training, which improves maximal oxygen uptake and oxidative capacity, increases the activity of aerobic enzymes and mitochondrial and capillary densities in muscles²⁷), is one of the most common and popular activities among adults of all ages, decreasing the resting HR⁵) and shortening the post-exercise

Table 2. Comparison of running durations, recovery durations, post-recovery heart rates, and post-exercise lactic acid values within the groups

	Athlete (Concentric loading) (+10%)	Athlete (Eccentric loading) (-10%)	Sedentary (Concentric loading) (+10%)	Sedentary (Eccentric loading) (-10%)
Running duration (min)	17.1 ± 0.9	45.0 ± 2.7*	10.8 ± 1.3	26.1 ± 0.9*
Recovery duration (min)	40.1 ± 9.5	35.0 ± 18.9	41.3 ± 7.4	36.1 ± 20.3
Heart rate (rate/min)	80.1 ± 7.7	75.7 ± 6.6	101.9 ± 11.9	100.1 ± 20.2
Lactic acid (mmol/l)	10.8 ± 1.6	4.3 ± 1.2*	11.0 ± 2.4	5.7 ± 1.7*

*p<0.05

Table 3. Comparison of running durations, recovery durations, post-recovery heart rates, and post-exercise lactic acid values between the groups

	Athlete (Concentric loading) (+10%)	Sedentary (Concentric loading) (+10%)	Athlete (Eccentric loading) (-10%)	Sedentary (Eccentric loading) (-10%)
Running duration (min)	17.1 ± 0.9	10.8 ± 1.3*	45.0 ± 2.7	26.1 ± 0.9*
Recovery duration (min)	40.1 ± 9.5	41.3 ± 7.4	35.0 ± 18.9	36.1 ± 20.3
Heart rate (rate/min)	80.1 ± 7.7	101.9 ± 11.9*	75.7 ± 6.6	100.1 ± 20.2*
Lactic acid (mmol/l)	10.8 ± 1.6	11.0 ± 2.4	4.3 ± 1.2	5.7 ± 1.7

*p<0.05

recovery phase²⁸). In addition, it was found that the recovery of HR within 30 seconds after exercise is negatively correlated with the pre-exercise levels²⁹).

The present study also showed that running duration and post-recovery HR responses were significantly higher in after concentric loading in the athlete group compared with the sedentary group. Additionally, passive recovery had an effect on running duration and post-recovery HR responses, and the athlete group had a significantly lower running duration and post-recovery HR responses after eccentric loadings. This can be explained by the positive physiological effect on athletes of training for a long time. Many activities of daily living use muscle combinations that require the coordinated use of concentric and eccentric contractions¹¹). However, it is known that long-term eccentric contractions generate acute pains and reduction in functional strength in the sedentary individuals. Nevertheless, it can be possible to continue exercise, especially exercise in the form of downhill running for a long time without tiring with the contribution of gravity¹¹). After two different styles of aerobic loading, that is, walking and jogging for men and women on -5% and -10% and $+5\%$ and $+10\%$ slopes respectively, were found lower heart rates responses found for both groups on the 5% and -10% slopes³⁰). Both the athlete and sedentary groups continued the running exercise on the -10% slopes under eccentric loading for longer and completed running with a lower lactic acid level in our study as well.

In conclusion, athletes continued to exercises for a longer duration at a higher intensity under both concentric and eccentric loading. It was observed that concentric exercise led to more La accumulation and higher HR responses. Although there was no difference between the athlete and sedentary groups as a result of eccentric and concentric loadings in terms of recovery durations, it was observed that athletes recovered faster in terms of HR. In addition, both the athlete and sedentary groups performed eccentric running for longer under all loading conditions. La values were found to be lower in eccentric exercise. This fact demonstrates that athletes tolerate eccentric exercise better due to the contribution of gravity. The contribution of regular aerobic workouts to the recovery period was demonstrated in this study. However, it was observed that these effects were limited with a passive recovery period. Further studies are required to compare different recovery types and different loading programs. The results of this study suggest that people who wish to derive more benefits from training should pay special attention to choosing the exercise type and should consider their health profile. In addition, eccentric exercises are more effective for improving muscle size and gaining strength in healthy individuals.

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