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# Acute hemodynamic, electrocardiographic, and hematological responses to high-velocity low intensity concentric and low-velocity high intensity eccentric resistance exercises in healthy young adults

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**Abstract**

**Background:** High-velocity low-intensity actions result in reduced hemodynamic responses. Additionally, eccentric actions are associated with reduced hemodynamic and metabolic responses.

**Aim:** This study aimed to investigate acute hemodynamic, hematological, and electrocardiographic responses to high-velocity low-intensity concentric resistance exercise (HVLICRE) and low-velocity high-intensity eccentric resistance exercise (LVHIERE) in healthy young adults.

**Materials and Methods:** In this study, 16 healthy young men were divided into two groups (HVLICRE: 40% 1RM, LVHIERE: 80% 1RM). The exercise protocol consisted of five sets of 10 repetitions, with 90 sec of rest between the sets and a two-second interval between actions. For data analysis, repeated measures ANOVA, one-way ANOVA, and Bonferroni's post hoc test were performed at a significance level of $P \leq 0.05$.

**Results:** LVHIERE led to greater RPE ($P \leq 0.05$), compared to HVLICRE. Also, LVHIERE was associated with a significant increase in the activity of the sympathetic nervous system and a significant decrease in the parasympathetic nervous system as compared to HVLICRE ($P \leq 0.05$).

**Conclusion:** HVLICRE and LVHIERE produced similar effects on blood glucose, serum lactate, hematocrit, systolic and diastolic blood pressure and heart rate. LVHIERE can be investigated as part of the strategy of rehabilitation programs in future studies.

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## 1. Introduction

Resistance exercises play an essential role in physical activity programs and are recommended by international health organizations to improve health and physical fitness [1]. During resistance exercises, different types of muscle actions may be used simultaneously, or a specific type of action may be used in a particular joint [2]. Today, manipulation of different types of muscle action during resistance training is considered important, as most training and rehabilitation programs involve the repetition of both concentric and eccentric actions [1].

Studies on the physiological responses to different types of muscle actions have reported varying results [3, 4]. During submaximal isokinetic exercises of knee extension in the dominant leg, a greater increase in hemodynamic factors has been observed in concentric actions compared to eccentric actions [5]. Also, hemodynamic factors appear to increase more significantly after concentric actions compared to eccentric actions in the elbow joint [6]. Evidence suggests that the intra-muscular pressure, mechanical load, muscle fiber damage, and inflammatory response are greater in eccentric actions than in concentric actions [7, 8]. Moreover, fast-twitch muscle fibers are selectively recruited during eccentric actions [9].

According to previous research, while eccentric activity is metabolically less demanding than concentric exercise, it can result in greater muscle tissue damage and more pronounced inflammatory responses [7, 8]. Studies have also shown that changes in growth hormones and lactate are greater in concentric actions [10, 11, 12]. In this regard, Hollander et al. (2003) found that heart rate, cortisol levels and perceived exertion are significantly higher in concentric actions compared to eccentric actions [12]. Generally, acute responses to resistance activity are affected by several factors, including active muscle mass, relative intensity of exercise, number of repetitions, type of resistance exercise (i.e., isometric, isotonic, and isokinetic), duration, and rest periods between activities [6].

During exercise, the stimulation of the sympathetic nerve increases depending on the intensity of the exercise. This sympathetic stimulation leads to the release of epinephrine and norepinephrine hormones from the adrenal gland, which also increases with the intensity of the activity [13]. An acute resistance exercise (ARE) may have a significant effect on the modulation of the autonomic nervous system [14, 15]. Cardiac autonomic modulation after an ARE session can be assessed based on heart rate variability (HRV). However, there are limited reports on autonomic recovery following ARE [14, 16, 17, 18, 19, 20].

It has been reported that vagal activity decreases after ARE in healthy young men and women [14, 16, 19, 20]. Research indicates vagal withdrawal between 15 and 90 min after ARE at 40-80% of one repetition maximum (1RM) in healthy young sedentary individuals [14, 20]. In this regard, Chen et al. (2011) showed a significant decrease in high-frequency (HF) power and a significant increase in low-frequency (LF) power after an ARE session involving four different exercises in trained young men [19]. Overall, factors, such as the release of catecholamines, the accumulation of metabolites (e.g., lactate, hydrogen ions, and inorganic phosphate), and changes in plasma volume, can all play a role in autonomic recovery [21].

According to the size principle, motor

units (MUs) are recruited based on their threshold. High-intensity resistance exercise (HIRE) is recommended for older adults, because it is necessary to activate type II fibers. However, this type of resistance training is contraindicated for people with hypertension and chronic heart failure, as blood pressure usually increases significantly during a HIRE session [22]. Recent studies have shown that high-velocity resistance exercise (HVRE), which involves performing resistance exercise at high velocities and low intensities, can produce similar responses to HIRE in recruiting type II fibers [23]. Some studies have reported that HVRE is more effective than HIRE in improving muscle strength and performance [24].

In this regard, Miyamoto et al. (2017) conducted a study to investigate the effects of several sets of HVRE and HIRE exercises on cardiovascular responses in healthy adult men. One session consisted of HIRE performed at low velocity, while the other session consisted of HVRE performed at low intensity. This study found that the increase in blood pressure, heart rate, and cardiac output during HVRE was less significant than HIRE [25]. Additionally, some studies suggest that increasing the time under tension (TUT) can increase muscle activation and lactate response [26, 27, 28]. In some studies, the group with the lowest movement speed had the lowest lactate levels [29, 30]. Meanwhile, in a study by Calixto et al. (2014), it was found that slow eccentric (3 sec) produced higher lactate levels compared to fast eccentric (0.5 sec) [31]. It has been proposed that the difference in hemodynamic responses is related to the duration of the activity rather than its intensity [32].

In this regard, Kambic et al. (2021) conducted a study examining the hemodynamic responses of two groups performing high-intensity (eight reps at 80%) and low-intensity (16 reps at 40%) resistance exercises. The results showed that hemodynamic changes were similar in the two groups. The heart rate was higher in the third set for the low-intensity group, while the RPE in the first set was higher for the high-intensity group [33]. Moreover, a study conducted in 2022, evaluating eccentric resistance exercises at two different intensities, showed no significant difference in blood pressure between the two groups [34]. Overall, if blood pressure control is important for exercise performance, resistance exercises with high intensity and fewer repetitions should be prioritized [35].

According to our literature review, the results of research investigating the effects of exercise intensity on hemodynamic factors appear to be contradictory. However, many studies suggest that eccentric action produces lower metabolic and hemodynamic stress than concentric action. Also, these responses increase with an increase in TUT. Since both high-velocity exercises and eccentric actions induce less stress individually, it prompts the question of which elicits fewer responses: low-velocity high-intensity eccentric actions or high-velocity low-intensity concentric actions?

The findings of the present study can serve as a foundation for designing research and exercise protocols for cardiovascular and metabolic patients. This study aimed to explore acute hemodynamic, hematological and electrocardiographic responses to high-velocity low intensity concentric resistance exercise (HVLICRE) and low-velocity high intensity eccentric resistance exercise (LVHIERE) in healthy young adults.

## 2. Materials and Methods

### *2. 1. Participants*

This study was conducted on 16 healthy non-athlete young man, with age of 26.87±3.11 years, height of 177.44±5.96 cm, weight of 72.64±6.64 kg, and body mass index (BMI) of 23.10±2.26 kg/m$^2$, who resided in Rasht (Guilan Province, Iran) and voluntarily participated in this study. The inclusion criteria for participating in the study were as follows: no history of high blood pressure, no lower limb injuries, no medication use, regular exercise habits, no alcohol or tobacco consumption, and cardiac health. To check the eligibility to enter the study, height and weight measurements were taken in one session. The McGill medical and sports history questionnaire was also completed. During the same session, a cardiologist performed blood pressure measurements and electrocardiography tests to confirm the cardiovascular health of the participants. The participants were randomly divided into two groups of HVLICRE and LVHIERE.

The participants were provided with necessary information on the research method, the risks and benefits of the project, and the guidelines they needed to follow to participate in the study, both in written and verbal formats. Before the onset of the study, they received and signed a consent form to indicate their willingness to participate in the research. All research processes and methods have been approved by the Ethics Committee in the Research of the Zanjan University (ethics code: IR.ZNU.REC.1402.002).

### *2. 2. Research method*

#### *2. 2. 1. Training session*

The participants were trained on how to properly use the leg extension machine, polar belt monitor, and digital pressure gauge and were instructed to follow the guidelines for using these devices in all stages of the study. They were also fully informed about the occurrence of possible injuries. Additionally, the participants practiced the exercise protocol for the day of implementation in a schematic manner and learned the schedule for carrying out the protocol. In the same session, the 1RM test was performed to determine the maximum number of repetitions.

#### *2. 2. 2. Main exercise session*

At least one week after the training session, the participants returned to the laboratory to perform the exercises. Hemodynamic and electrocardiographic indicators were measured before exercise, during each of the five sets, and also, 5, 15, 30, and 60 min after the exercise. Hematological indicators were also measured before, immediately after, and 5 and 15 min after exercise, and the RPE was measured at the end of each set.

After arriving at the laboratory in a fasting state, the participant changed into appropriate clothing and to measure heart rate and heart rate variability (HRV) had a polar chest belt (H10) attached. During the entire session, the data was monitored and saved through the Elite HRV application. The subject then sat on a chair for 20 min to record baseline data before exercise. At the conclusion of this stage, blood pressure measurements and blood samples were taken. The subject was then positioned on the leg extension machine and proceeded to perform the protocol. A metronome was used to adjust the speed and rhythm of the movements to maintain consistent timing. Blood pressure and perceived exertion were measured immediately after each set. After the completion of the fifth set, a blood sample was immediately taken for the second stage. The subject then sat on a chair, and subsequent measurements were taken up to 60 min after the activity. Throughout this time, the subject remained in a fasting state. All measurements were taken between 8 am and 10 am.

### *2. 2. 3. Exercise protocol*

The actions were performed on the quadriceps muscles using the leg extension machine. The exercise consisted of five sets of 10 repetitions, with 90 sec of rest between the sets. Within each set, there was a two-second interval between actions. In the HVLICRE group, the TUT per action was one second with an intensity of 40% of 1RM, and in the LVHIERE group, the TUT per action was 3 seconds with an intensity of 80% of 1RM. As a result, the total TUT (TTUT) of the quadriceps muscle during exercise was 50 sec in the HVLICRE group and 150 sec in the LVHIERE group.

### *2. 3. Data collection method*

Height was measured using a tape measure, and weight was calculated using a Camry scale (model EB9003) with an accuracy of 0.1 kg. The 1RM was determined based on the following formula [33].

1RM= ([Number of repetitions until fatigue × 0.0278] - 1.0278)/ Moved weight (kg)

A laboratory technician collected blood samples from the antecubital vein in the forearm while the subject was seated. In each sampling, 3.5 mL of blood was collected. Serum lactate levels were measured in mg/dL using a Zist Shimi kit (Iran), and blood glucose was measured in mg/dL using the Pars Azmoon Kit (Iran) and the Irma Photometer (Japan) following the photometric method in accordance with the protocol of the International Federation of Clinical Chemistry (IFCC) and the German Society for Clinical Chemistry (DGKC) standard.

Additionally, hematocrit was measured using the centrifuge method (Hettich Centrifuge, Germany) and a special ruler. The RPE was also evaluated based on a 10-point scale [36]. Blood pressure was determined using an Omron HBP-1120 monitor (Germany). Moreover, a Polar H10 heart rate sensor was used to measure heart rate and heart rate variability (HRV) in order to assess the sympathetic and parasympathetic nervous system activity. The Sympathetic Nervous System (SNS) and Parasympathetic Nervous System (PNS) indices were computed in Kubios HRV software (https://www.kubios.com/hrv-ans-function/). The collected data were also analyzed using Kubios software (Kubios HRV Standard ver. 3.5.0).

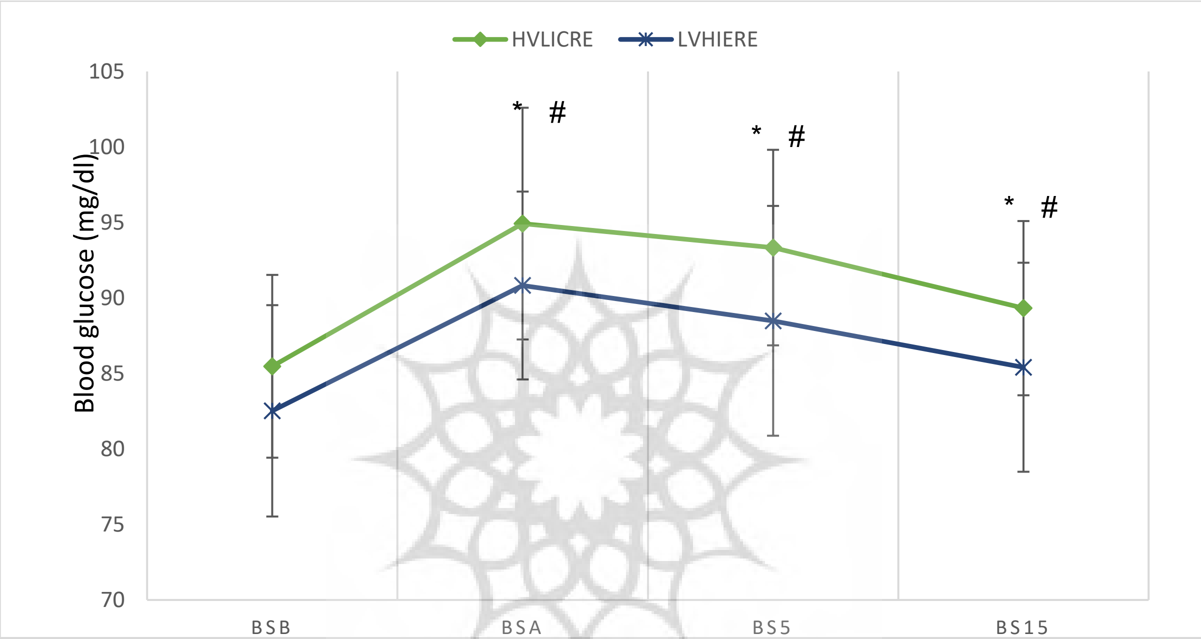
### *2. 4. Statistical methods*

Shapiro-Wilk test was used to determine the normal distribution of data. For descriptive statistics, indicators, such as mean and standard deviation (SD), were measured, and for inferential statistics, repeated measures analysis of variance (ANOVA) was employed to determine any differences in the average of each variable across different stages of measurement. Additionally, one-way ANOVA test was performed to compare the research variables between the two groups. If the F-test was significant, Bonferroni’s post-hoc test was carried out to examine the differences between the group means. The level of statistical significance was set at *P*≤0n05n

## 3. Results

### *3. 1. Blood glucose*

In the HVLICRE group, blood glucose levels significantly increased in all three stages after exercise, including immediately after exercise (*P*=0.001), 5 min after exercise (*P*=0.003), and 15 min after exercise (*P*=0.021) when compared to the pre-exercise levels. Also, in the LVHIERE group, there was a significant increase in blood glucose levels in all three stages after exercise, including immediately after exercise (*P*=0.006), 5 min after exercise (*P*=0.001), and 15 min after exercise (*P*=0.003) as compared to the pre-exercise levels. The observed changes were similar across all repetition of measurement in both groups, with no significant differences detected (Figure 1).




*Significant difference compared to the pre-exercise level in the HVLICRE group. #Significant difference compared to the pre-exercise level in the LVHIERE group. mg/dl: milligram/deciliter; HVLICRE: high-velocity low intensity concentric resistance exercise; LVHIERE: low-velocity high intensity eccentric resistance exercise; BSB: Bood suger Before exercise (pre-exercise); BSA: Bood suger immediately After exercise; BS5: Bood suger 5 min after exercise; BS15: Bood suger 15 minutes after exercise

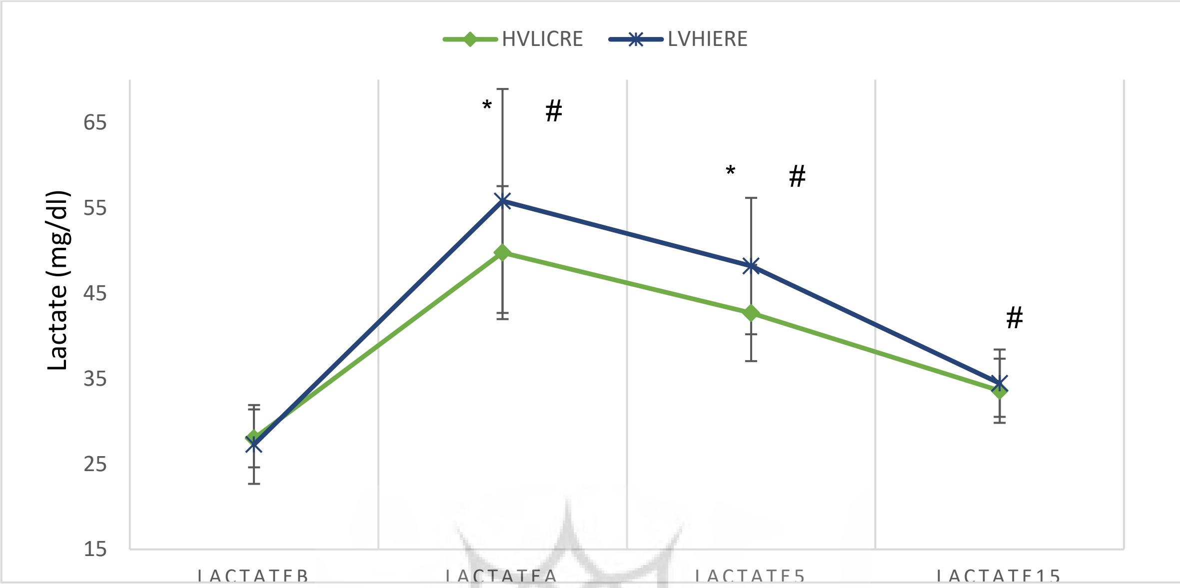
**Figure 1.** Changes in blood glucose levels in the two groups at different stages of the study and the differences between the groups

### *3. 2. Serum lactate*

In the HVLICRE group, there was a significant increase in serum lactate levels immediately (*P*=0.001) and 5 min (*P*=0.003) after exercise, compared to the pre-exercise levels. Also, in the LVHIERE group, serum lactate levels increased significantly in all three stages after exercise, including immediately (*P*=0.003), 5 min (*P*=0.002), and 15 min (*P*=0.028) after the activity when compared to the pre-exercise levels. The changes in the groups were similar across all repetition of measurement, and no significant difference was observed (Figure 2).

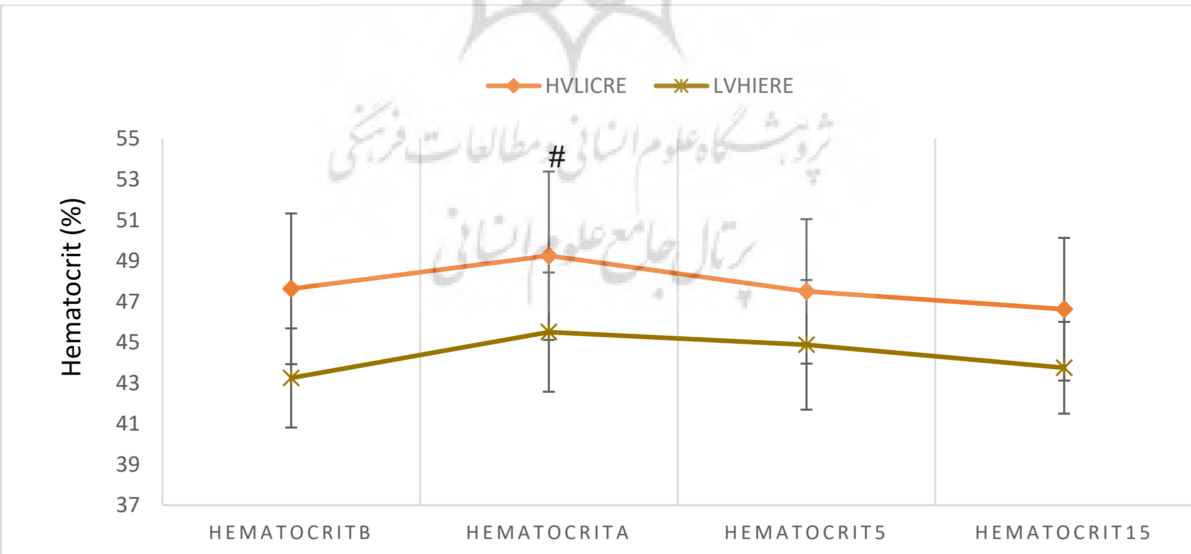
### *3. 3. Hematocrit*

In the HVLICRE group, there was no significant difference in hematocrit levels in any of the repeated of measurement (F=2.62). In the LVHIERE group, there was a significant increase in hematocrit levels immediately after exercise compared to the pre-exercise levels (*P*=0.001). The changes in the groups were similar across all repetition of measurement, and no significant difference was observed (Figure 3).




*Significant difference compared to the pre-exercise level in the HVLICRE group; # Significant difference compared to the pre-exercise level in the LVHIERE group. mg/dl: milligram/deciliter; HVLICRE: high-velocity low intensity concentric resistance exercise; LVHIERE: low-velocity high intensity eccentric resistance exercise; lactate B: lactate Before exercise (pre-exercise);. lactate A: lactate immediately after exercise; lactate 5: lactate 5 minutes after exercise; lactate 15: lactate 15 minutes after exercise.

**Figure 2.** Changes in serum lactate levels in the two groups in different stages of the study and differences between the groups

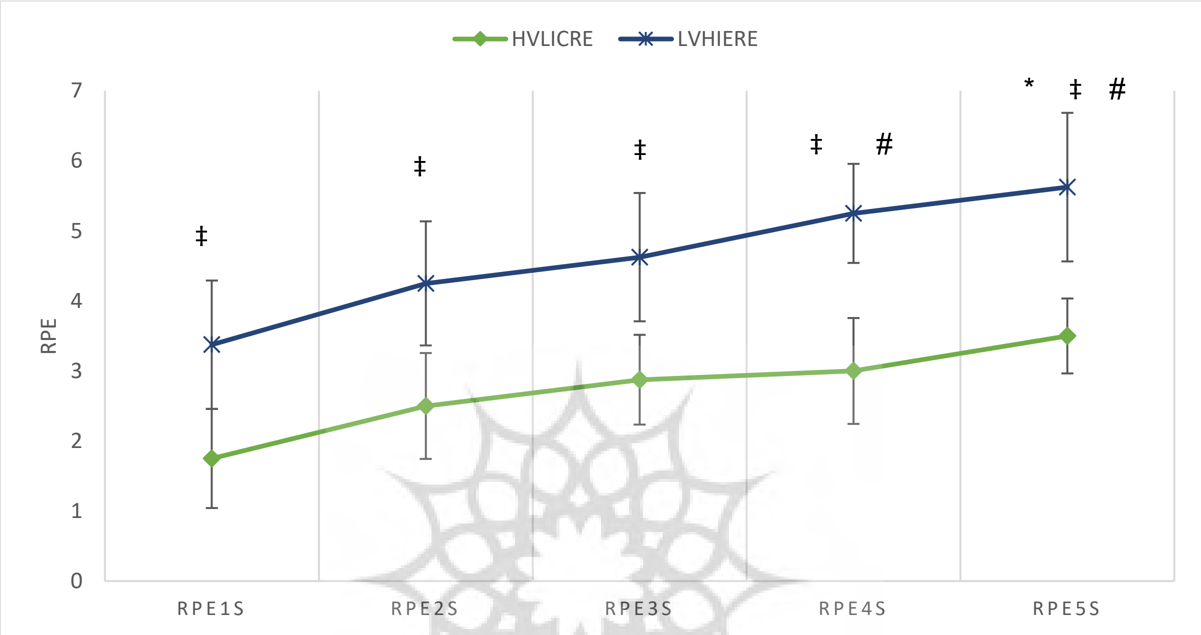



# Significant difference compared to the pre-exercise level in the LVHIERE group; HVLICRE: high-velocity low intensity concentric resistance exercise; LVHIERE: low-velocity high intensity eccentric resistance exercise; Hematocrit B: Hematocrit before exercise (pre-exercise); Hematocrit A: lactate immediately after exercise; Hematocrit 5: Hematocrit 5 min after exercise. Hematocrit 15: Hematocrit 15 min after exercise.

**Figure 3.** Hematocrit changes in the two groups in different stages of the study and differences between the groups

***3. 4. RPE***

According to Figure 4, RPE increased significantly in the HVLICRE group in the fifth set of exercise compared to the first set (*P*=0.008). Also, in the LVHIERE group, there was a significant increase in RPE in the fourth (*P*=0.022) and fifth (*P*=0.037) sets, compared to the first set. In all five sets, RPE was significantly higher in the LVHIERE group compared to the HVLICRE group (first set, *P*=0.010; second set, *P*=0.013; third set, *P*=0.05; fourth set, *P*=0.001, and fifth set, *P*=0.002).




*Significant difference compared to the first set in the HVLICRE group; #Significant difference compared to the first set in the LVHIERE group; ‡Significant difference between the two groups; HVLICRE: high-velocity low intensity concentric resistance exercise; LVHIERE: low-velocity high intensity eccentric resistance exercise; 1S: set 1; 2S: set2; 4S: set 3; 4S: set 4; 5S: set 5.

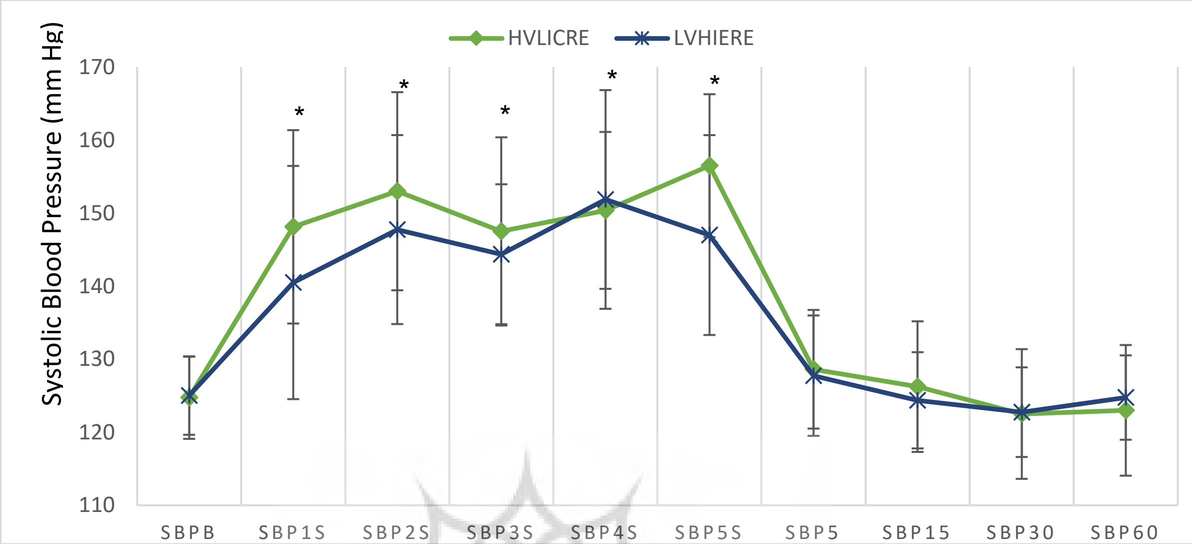
**Figure 4.** Changes in rate of perceived exertion (RPE) in the two groups in different stages of the study and the differences between the groups

***3. 5. Systolic blood pressure (SBP) and diastolic blood pressure (DBP)***

Based on the results, DBP was not significantly different in any of the groups during different repetition of measurement (F=0.619 in the HVLICRE group and F=3.116 in the LVHIERE group). Similarly, DBP did not show any significant differences between the groups in any of the measurement stages. As shown in Figure 5, SBP increased significantly in the HVLICRE group during exercise (in all five sets) (*P*□0.05). However, no significant difference was observed after exercise (5, 15, 30, and 60 min after exercise), compared to the pre-exercise levels. In the LVHIERE group, SBP increased during exercise, but the increase was not significant. Overall, there were no significant differences in SBP at any of the measurement points after exercise (5, 15, 30, and 60 min) when compared to the pretest levels. Similarly, there was no significant difference in SBP between the two groups in any of the repetition of measurement.

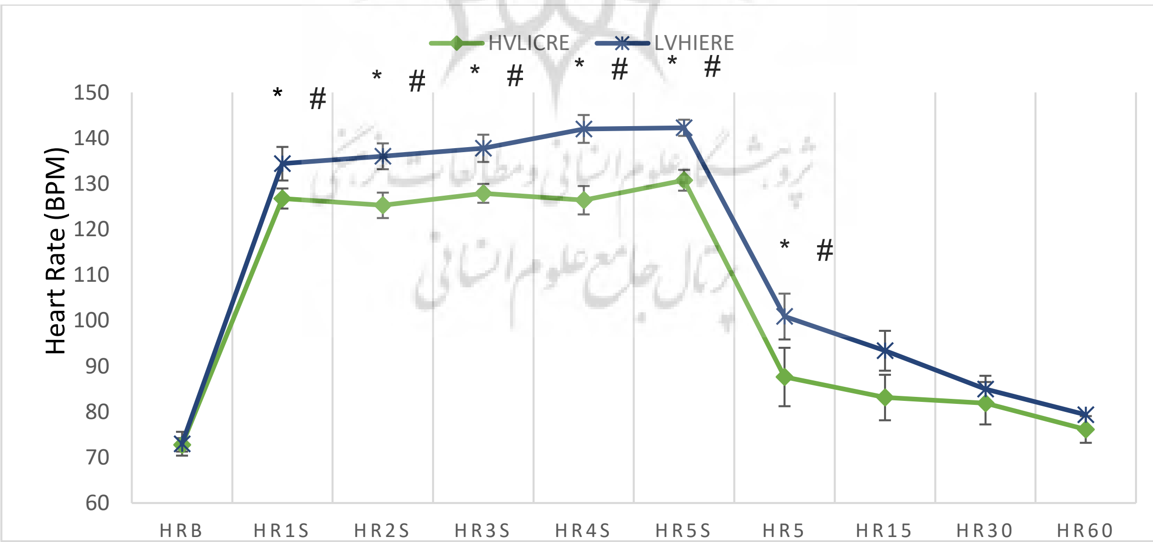
***3. 6. Heart rate***

In both groups, heart rate significantly increased during exercise (in all five sets) and 5 min after exercise (*P*□0.05). However, no significant differences were observed in heart rate at 15, 30, or 60 min after exercise as compared to the pre-exercise levels. Also, there was no significant difference in heart rate between the two groups in any of the measurement stages (Figure 6).




*Significant difference compared to the pre-exercise level in the group; mm Hg: millimetres of mercury; HVLICRE: high-velocity low intensity concentric resistance exercise; LVHIERE: low-velocity high intensity eccentric resistance exercise; B: Before exercise (pre-exercise); 1S: set 1; 2S: set2; 4S: set 3; 4S: set 4; 5S: set 5; 5: 5 min after exercise; 15: 15 min after exercise; 30: 30 min after exercise; 60: 60 min after exercise

**Figure 5.** Changes in systolic blood pressure (SBP) of the two groups in different stages of the study and differences between the groups

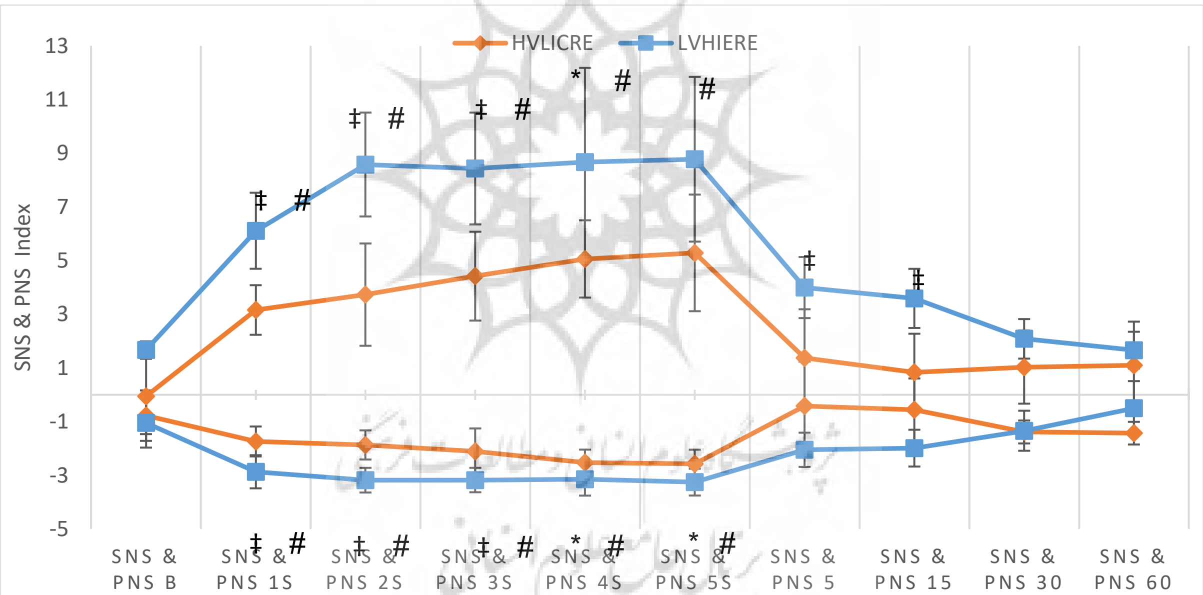



*Significant difference compared to the pre-exercise level in the HVLICRE group; #Significant difference compared to the pre-exercise level in the LVHIERE group; BPM: Beats per min; HVLICRE: high-velocity low intensity concentric resistance exercise; LVHIERE: low-velocity high intensity eccentric resistance exercise; B: Before exercise (pre-exercise); 1S: set 1; 2S: set 2; 4S: set 3; 4S: set 4; 5S: set 5; 5: 5 min after exercise; 15: 15 min after exercise; 30: 30 min after exercise; 60: 60 min after exercise

**Figure 6.** Heart rate changes in the two groups in different stages of the study and differences between the groups

### *3. 7. SNS and PNS measurements*

In the HVLICRE group, the SNS index significantly increased compared to the pre-exercise level only in the fourth set (*P*=0.037), whereas in the LVHIERE group, there was a significant increase during exercise in all five sets (first set, *P*=0.010; second set, *P*=0.013; third set, *P*=0.05; fourth set, *P*=0.001; and fifth set, *P*=0.002). No significant differences were observed at other measurement points in the two groups. Additionally, in the HVLICRE group, the PNS index significantly decreased in the fourth (*P*=0.032) and fifth (*P*=0.029) sets when compared to the pre-exercise levels. In the LVHIERE group, the PNS index significantly decreased in all five sets (first set, *P*=0.010; second set, *P*=0.008; third set, *P*=0.011; fourth set, *P*=0.025; and fifth set, *P*=0.011), compared to the pre-exercise levels. In both groups, no significant differences were observed at other measurement points. Overall, the SNS index was significantly higher in the LVHIERE group compared to the HVLICRE group in the first set (*P*=0.001), second set (*P*=0.001), third set (*P*=0.009), 5 min after exercise (*P*=0.015), and 15 min after exercise (*P*=0.002). Moreover, the PNS index in the LVHIERE group was significantly lower than that of the HVLICRE group in the first (*P*=0.025), second (*P*=0.002), and third (*P*=0.020) sets (Figure 7).




*Significant difference compared to the first set in the HVLICRE group; #Significant difference compared to the first set in the LVHIERE group; ‡Significant difference between the two groups; PNS: parasympathetic nervous system indices; SNS: sympathetic nervous system indices; HVLICRE: high-velocity low intensity concentric resistance exercise; LVHIERE: low-velocity high intensity eccentric resistance exercise; B: Before exercise (pre-exercise); 1s: set 1; 2s: set2; 4s: set 3; 4s: set 4; 5s: set 5; 5: 5 min after exercise; 15: 15 min after exercise; 30: 30 min after exercise; 60: 60 min after exercise

**Figure 7.** Changes in the sympathetic and parasympathetic nervous system indices of the two groups in different stages of the study and the differences between the groups

## 4. Discussion

In a study by Monroe et al. (2020), the capillary blood glucose levels were compared between high- and moderate-intensity resistance exercise. Their findings showed a significant decrease in blood glucose levels post-exercise and 10 min after exercise compared to the pre-exercise levels in both groups. However, these results are not consistent with the findings of the present study. Also, the high-intensity group experienced a greater reduction in blood glucose levels when compared to the moderate-intensity group. Meanwhile, in this study, no significant difference was observed between the two groups [37].

It is important to note that in their study, the pre-exercise measurements were taken 30 min after a warm-up exercise and the consumption of a 100g sugary drink, while in the present study, the subjects were in a fasting state. The findings of the present study, which showed no significant difference between the two groups, are consistent with the results of other studies that also found no significant difference between groups at different intensities of resistance exercise [38, 39]. When interpreting the blood glucose results, it is important to keep in mind that the blood glucose levels remained within the euglycemic range during all measurements in this study. Also, the increase in blood glucose levels within the euglycemic range could be attributed to the activation of the sympathetic nervous system and its associated increase in catecholamine levels [37].

In the present study, serum lactate levels significantly increased in both groups immediately and 5 min after exercise when compared to the pre-exercise levels; nevertheless, no significant difference was observed between the two groups. These findings contradict the results of other studies, which showed an increase in muscle activation and lactate response with increasing TUT [26, 27, 28]. On the other hand, Gentil et al. (2006) found that the group with the lowest movement speed had the lowest lactate levels [29, 30], which is not consistent with the present results. Although differences in the characteristics of the participants and their physical fitness levels can be an effective factor [28], the difference between concentric and eccentric exercise may decrease as TUT increases and lactate levels rise [28].

In a study by Calixto et al. (2014), a comparison was made between blood lactate levels at different velocities of eccentric exercise. The results indicated that a lower velocity (3 sec) produced higher lactate levels when compared to a higher velocity (0.5 sec) [31]. In the present study, the TUT of eccentric action was three times longer than that of concentric action, and its intensity was twice higher. However, no significant difference was observed between the groups, which could be attributed to the effect of the type of muscle contraction.

In research by Durand et al. (2003), changes were observed in growth hormone and lactate levels. Similarly, a study by Hollander et al. (2003) revealed that the level of lactate was higher in concentric actions [10, 11, 12]. Meanwhile, in our study, no significant difference was observed between the concentric and eccentric exercises, which could be related to the difference in TUT and the higher intensity of eccentric actions.

It has been reported that lactate levels and RPE are correlated [12, 40]. Fast-twitch muscle fibers and increased glycolytic activity are expected to result in higher lactate concentrations [40], and the higher RPE appears to be partially induced by lactate levels. Therefore, available evidence confirms that differences in lactate levels between concentric and eccentric exercises are related to differences in RPE [12]. In our study, RPE showed a significant increase in both groups in the fifth set compared to the first set. Also, in both groups, RPE increased with each set, with the highest RPE observed in the fifth set and the lowest in the first set. Overall, RPE from the first to fifth sets was significantly lower in the HVLICRE group compared to the LVHIERE group. As previously described, the longer TUT and higher intensity of exercise require greater efforts [28, 31]. In this regard, Kambic et al. (2021) conducted a study on two groups performing eccentric resistance exercises with different intensities. One group performed 8 repetitions at 80% intensity, while the other group performed 16 repetitions at 40% intensity. They found that RPE in the first set was higher in the high-intensity group [33]. Both young and older adults reported significantly greater perceived exertion after performing concentric exercises compared to eccentric exercises, despite the fact that the eccentric protocol was performed with the same torque output [12, 36].

Additionally, a higher number of repetitions was associated with a greater perception of exertion [28]. Many factors influence perceptual responses to exercise, including the combination of impulses from chemical receptors, mechanical receptors, baroreceptors, and pain receptors [10]. Since eccentric exercises produce less metabolic stress, it seems that the greater torque-producing capacity during eccentric contractions results in lower perceptual responses [36, 41]. Nonetheless, due to a lack of similar research, it is difficult to compare the results. One might expect lower perceived exertion given the type of eccentric contraction in the LVHIERE group. However, the combination of high intensity with longer TUT results in a greater increase in perceived exertion.

In a study by Durand et al. (2003), the hematocrit level was significantly different between the concentric and eccentric groups immediately after exercise [10]. However, no significant difference was observed in our study. The increase in hematocrit levels can be attributed to the fact that hematocrit is influenced by the movements of electrolytes and medium-sized molecules, which are regulated by factors, such as capillary permeability, intravascular pressure, and oncotic pressure. Previous research indicates that maximum voluntary eccentric actions generate less intramuscular pressure per unit of torque compared to concentric and isometric ractions [42]. Also, during resistance exercise, the increase in arterial blood pressure results in a greater pressure difference, creating conditions that facilitate the transmission of electrolytes and molecules. Increased contractile activity and heat production raise the core body temperature, resulting in a subsequent increase in skin blood flow and fluid loss to transport heat away from the body; these effects can lead to unequal changes in the plasma and interstitial volume. Also, during exercise, the increase in intracellular metabolites, such as lactate, which was also observed in our study, induces osmotic water flow. This leads to a decrease in plasma volume and an increase in hematocrit levels [42]. Since there was no significant difference in lactate levels and blood pressure between the groups in this study, the lack of significant difference in hematocrit levels can be justified.

In a study by Caminiti et al. (2022), no significant difference was observed in terms of SBP between low- and medium-intensity eccentric actions. Also, DBP did not increase significantly [34], which is in line with the results of our study. Some studies consider exercise intensity to be an important factor in hemodynamic responses [5], while others have suggested that intensity is not a determining factor [33]. Since there was no significant difference between the two groups in our study, our findings confirm that the intensity of exercise is not a determining factor. Furthermore, in a study by Miyamoto et al. (2017), low-intensity high-velocity actions resulted in a smaller increase in blood pressure. This suggests that the intensity of action was not sufficient to trigger the Valsalva maneuver in the high-velocity, low-intensity group [25]. In several studies, lower SBP and DBP have been reported in the eccentric group compared to the concentric group [5, 6]. Some research on healthy people and patients with ischemic heart disease indicate that the main determinant of blood pressure response is the number of repetitions [32, 33, 34, 35]. Our study protocol, which examined the interaction between the action type, exercise intensity, and TUT, revealed that both groups exhibited optimal hemodynamic responses.

In the present study, both groups exhibited a significant increase in heart rate during exercise and up to 5 min after exercise compared to the pre-exercise levels. The observed increase in heart rate can be attributed to elevated lactate levels and the increased activity of the sympathetic nervous system, which were observed in both groups. There was no significant difference between the groups in terms of heart rate before and after exercise. However, the sympathetic nervous system activity was significantly higher during exercise in the LVHIERE group compared to the HVLICRE group. Despite the greater activity of the sympathetic nervous system in the LVHIERE group, the increase was not accompanied by a corresponding increase in heart rate.

Our findings are in line with the results reported by Caminiti et al. (2022), which indicated an increase in heart rate during eccentric actions of both high and low intensities, with no significant difference between the two groups [34]. On the other hand, our results differ from those reported by Durand et al. (2003), who found that heart rate increased significantly only during the concentric exercise (both in the middle and after exercise) [10]. Our findings also diverge from those of other studies, which reported lower heart rates during isokinetic eccentric exercises [43]. Contrary to our findings, Miyamoto et al. (2017) [25] and Rezk et al. (2006) found that a higher intensity of exercise is linked to a greater increase in heart rate [14]. Moreover, in a study by Overend et al. (2000), no significant difference was found between isokinetic concentric and isokinetic eccentric actions in terms of their effect on heart rate [5]. Also, Kambic and colleagues (2021) showed that heart rate in the third set was higher in the low-intensity group [33]. The results of these two studies are in line with our study.

Resistance exercise protocols are associated with higher heart rates during concentric exercise compared to eccentric exercise at the same absolute workload [5, 43]. Factors, such as increased recruitment of motor units, muscle activity, muscle metaboreflex, and activation of the sympathetic system, can be also effective factors [10, 25]. Generally, resistance exercises activate the sympathetic nervous system, which is accompanied by an increase in heart rate. Although Miyamoto et al. (2017) did not assess the activity of the nervous system, they hypothesized that the sympathetic nervous system is probably more active in the group with higher intensity [25]. Our study, which evaluated the activity of the sympathetic nervous system and found a significant difference between the groups, confirms the prediction made by Miyamoto et al. (2017). Despite the increased sympathetic nervous system activity in the LVHIERE group, no significant difference was observed in heart rate between the two groups.

The SNS index in the LVHIERE group was significantly different from that of the HVLICRE group during the first, second, and third sets, as well as 5 and 15 min after exercise. Also, in the LVHIERE group, the PNS index showed a greater reduction during the first, second, and third sets compared to the HVLICRE group. In the study by Rezk et al. (2006) that investigated HRV, there was an increase in LF power and a decrease in HF power in both groups [14]. Although we used indices of the sympathetic and parasympathetic nervous systems index in our study rather than LF and HF power, the results of the two studies can be considered consistent. Meanwhile, Rezk et al. (2006) did not observe a significant difference between the groups, which is inconsistent with the present study [14]. It should be noted that the results of these two studies are not comparable because the intensity, duration, and type of actions are different in their protocols.

Chen et al. (2011) also demonstrated a significant decrease in HF power and a significant increase in LF power after a two-hour resistance exercise session in trained young men. In this study, the exercise intensity ranged from 60% to 95% of 1RM, with a 90-second rest period between the sets [19]. In their study, the increase in the activity of the sympathetic nervous system was in line with the increase in heart rate, which is not in line with our results. In this study, RPE in LVHIERE group was higher than HVLICRE group. It seems that higher RPE associated with longer TUT and higher intensity lead to higher SNS activity and greater inhibition of PNS activity.

## 5. Conclusion

The present study showed no significant difference regarding the effects of HVLICRE and LVHIERE on blood glucose, lactate, hematocrit, heart rate, SBP, and DBP. Although LVHIERE was associated with a greater perceived exertion, it was accompanied by a larger increase in the sympathetic nervous system activity and a greater decrease in the parasympathetic nervous system activity. Based on the present findings, these two types of resistance exercises can serve as alternatives to each other for groups with special considerations and can be incorporated into rehabilitation program strategies. Therefore, if the level of activity of the nervous system and the level of pain perception are not important, and there is a limitation in the speed of movement, LVHIERE can be a substitute for HVLICRE. It is recommended that future research investigate the acute and long-term effects of these two types of actions in patients with cardiovascular diseases.

## Highlights

- The HVLICRE and LVHIERE can lead to an increase in blood glucose, lactate, hematocrit, heart rate, and systolic blood pressure, although there is no significant difference in the effects of these two types of exercise.
- LVHIERE requires greater perceptual efforts.
- The LVHIERE is associated with a significant increase in the activity of the sympathetic nervous system and a significant decrease in the

parasympathetic nervous system activity, compared to HVLICRE.

## Limitations

Although the necessary recommendations were given to the subjects about nutrition, sleep and stress. However, there was no control over the mentioned items.

## Summary

According to previous studies, high-velocity low-intensity actions are associated with reduced hemodynamic responses. Eccentric actions have been also shown to elicit fewer hemodynamic and metabolic responses. The aim of this study was to investigate the acute hemodynamic, hematological, and electrocardiographic responses to high-velocity low-intensity concentric (HVLICRE) and low-velocity, high-intensity eccentric (LVHIERE) resistance exercises in healthy young adults. Sixteen healthy young men were divided into two groups. One group performed HVLICRE exercises (action duration of one second and an intensity of 40% of 1RM), while the other group performed LVHIERE exercises (action duration of three seconds and an intensity of 80% of 1RM). The exercise protocol consisted of five sets of 10 repetitions with 90 sec of rest between sets and a two-second interval between each action. Both HVLICRE and LVHIERE caused an increase in blood glucose, lactate, hematocrit, heart rate, and SBP. However, there was no significant difference in the effects of these two types of action. Based on the results, LVHIERE involved more perceptual efforts. LVHIERE compared to HVLICRE were associated with a significant increase in the sympathetic nervous system activity and a significant decrease in the parasympathetic nervous system activity. The present results suggest that the effects of these two exercises are similar on blood glucose, serum lactate, hematocrit, systolic and diastolic blood pressure and heart rate. Therefore, LVHIERE can be investigated as part of the strategy of rehabilitation programs in the future studies.

## Conflict of interest

The authors declared no conflicts of interest.

## Authors' contributions

All authors contributed to the original idea, study design.

## Ethical considerations

The authors have completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc. This research was approved under the ethics code IR.ZNU.REC.1402.002.

## Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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