



Alterations in Serum Lactate Dehydrogenase and Creatine Kinase Levels in Relation to Physical Activity Intensity

Nuha Hamza Khedhir¹, Muntaha Mezhir Abbas², Galawesh Norri Taher³

¹Department of Pharmacy, Medical Technical Institute / Kirkuk, Northern Technical University, Iraq.

²Department of Nursing Techniques, Medical Technical Institute / Kirkuk, Northern Technical University, Iraq.

³Department of Nursing Techniques, Medical Technical Institute / Kirkuk, Northern Technical University, Iraq.

Corresponding Author: nuha70hamza@ntu.edu.iq

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Abstract:

The objective of this study was to investigate how muscle-related enzymes, i.e., creatine kinase (CK) and lactate dehydrogenase (LDH), depend on various degrees of physical exercise intensity in apparently healthy individuals. The study participants, 180 in number, between 20 and 50 years old, were selected from Kirkuk city and divided into three groups according to their physical activity: sedentary, moderately active, and highly active. Blood was taken before and 30 minutes after exercise in the active groups, and serum creatine kinase and lactate dehydrogenase levels were determined. In addition, heart rate and blood lactate concentrations were measured.

There was no significant difference between the two groups in terms of initial levels of CK and LDH enzymes, i.e., ($p > 0.05$). However, after exercise, there was a significant increase in levels of CK and LDH enzymes in moderate and high activity groups, i.e., ($p < 0.001$), with higher levels of enzymes in highly active individuals.

The increase in CK levels is related to muscle stress during exercise and is a result of temporary changes in cell membrane permeability, and the increase in LDH levels relates to increased demand during exercise. This combination of markers gives a picture of what happens in terms of structure and metabolism in the muscles.

Keywords: Creatine Kinase (CK), Lactate Dehydrogenase (LDH), Muscle Enzymes, Muscle Stress, Anaerobic Metabolism.

في (CK) وكرياتين كيناز (LDH) التغيرات في مستويات إنزيم لاکتات ديهيدروجيناز المصل تبعاً لشدة النشاط البدني

نهي حمزة خضير¹، منتهى مظهر عباس²، كالأویش نوري طاهر³

¹ قسم الصيدلة، المعهد التقني الطبي / كركوك، الجامعة التقنية الشمالية، العراق

² قسم تقنيات التمريض، المعهد التقني الطبي / كركوك، الجامعة التقنية الشمالية، العراق

³ قسم تقنيات التمريض، المعهد التقني الطبي / كركوك، الجامعة التقنية الشمالية، العراق

الایمیل الرسمي: nuha70hamza@ntu.edu.iq

الخلاصة:

كانت فكرة الدراسة هي معرفة كيف تؤثر مستويات مختلفة من النشاط البدني على إنزيمات العضلات مثل كرياتين كيناز (CK) ولاكتات ديهيدروجيناز (LDH) عند أشخاص يبدو عليهم أنهم بصحة جيدة. شارك في الدراسة ١٨٠ شخصاً تتراوح أعمارهم بين ٢٠ و ٥٠ سنة، جميعهم من مدينة كركوك. قُسم المشاركون إلى ثلاث مجموعات حسب مدى نشاطهم البدني: مجموعة تميل إلى الخمول، وأخرى تمارس نشاطاً متوسطاً، وثالثة نشطة بشكل كبير. تم سحب عينات الدم قبل التمرين وبعده بـ ٣٠ دقيقة لدى المجموعات النشطة، وتم قياس مستويات إنزيمي كرياتين كيناز ولاكتات ديهيدروجيناز في المصل. بالإضافة إلى ذلك، تم قياس معدل ضربات القلب وتركيز اللاكتات في الدم. لم تُسجل فروق معنوية بين المجموعات في المستويات الأساسية لإنزيمي CK و ($p > 0.05$) LDH ومع ذلك، بعد التمرين، لوحظت زيادة معنوية في مستويات كلا الإنزيمين في مجموعتي النشاط المعتدل والعالي ($p < 0.001$)، وكانت هذه الزيادة أعلى لدى الأفراد ذوي النشاط العالي. ترتبط الزيادة في مستوى إنزيم CK بالإجهاد العضلي أثناء التمرين، وهي ناتجة عن تغيرات مؤقتة في نفاذية غشاء الخلية، بينما تعكس زيادة إنزيم LDH ارتفاع الطلب الأيضي خلال النشاط البدني. ويعطي هذا المزيج من المؤشرات صورة واضحة عن التغيرات البنوية والأیضية التي تحدث في العضلات.

كلمات مفتاحية: كرياتين كيناز (CK)، لاکتات ديهيدروجيناز (LDH)، إنزيمات العضلات، الإجهاد العضلي، الأیض

اللاهوائي

1. Introduction:

Exercise is one of the pillars of human health, which aids in the maintenance of metabolic homeostasis, heart performance, and skeletal health[1]. Exercise is characterized by repeated

contracting and relaxation of skeletal muscles causing mechanical, metabolic and oxidative stress to muscle fibres[2]. These stressors may cause temporary structural perturbation of the muscle cells which causes the extraction of intracellular components into the blood[3].

The creatine kinase (CK) and lactate dehydrogenase (LDH) are some of the most frequently studied biochemical markers of muscle stress and damage[4]. Creatine kinase is a mitochondrial and cytosolic enzyme which catalyzes the reversible phosphate group exchange of phosphocreatine to ADP [5]. Damage to muscle fibers is strongly associated with elevated serum CK levels following high-intensity exercise [6]. Lactate dehydrogenase, nevertheless, is a significant enzyme related to anaerobic metabolism[7]. It catalyzes the conversion of pyruvate and lactate to allow glycolysis to take place in the anaerobic state[8]. High level of LDH indicates high metabolic demand and cell membrane permeability changes during as well as after physical exercise[9]. The increase in CK and LDH with exercise is related to several factors including exercise intensity, length and type of exercise (aerobic or anaerobic) and the fitness of the individual[10]. Intensive bouts of vigorous exercise typically cause significant changes in these enzymes but long-term training of the body to exercise leads to adaptation which restricts the amount of leakage of these enzymes[11].

The response of CK and LDH to physical activity is important because it can be used to assess muscle damage and recovery as well as to increase athletic performance and avoid overtraining[12]. Furthermore, these biomarkers have clinical relevance in diagnosing muscle-related pathologies and monitoring rehabilitation processes[13].

Thus, the current research will explore the changes in serum CK and LDH alongside various exercise amounts of physical activity among seemingly healthy adults.

2. Materials and Methods

2.1 Study Design

This study was designed as an analytical cross-sectional study to assess the effect of physical activity intensity on muscle enzyme levels and physiological parameters.

2.2 Study Population and Sampling Site

This study comprised 180 apparently healthy subjects between 20 and 50 years of age. The subjects were selected from private clinics and diagnostic laboratories in Kirkuk city, where routine health check-ups and investigations are carried out.

Participants were recruited with the assistance of medical staff in these institutions, this facilitated access to participants with different physical activity levels.

All the participants were informed of the purposes of the study and informed verbal consent was obtained prior to inclusion.

The physical activity level was used to group the subjects into three groups:

- Group I (Sedentary): Individuals with minimal or no regular physical activity
- Group II (Moderately active): Individuals performing moderate exercise 3–4 times per week
- Group III (Highly active): Individuals engaged in intense physical training or competitive sports

2.3 2.3 Inclusion Criteria

The participants in this study were apparently healthy adults without a history of long-term illnesses. Participants were not taking any medications that could interfere with muscle metabolism., and all individuals were non-smokers to limit the possible confounding variables that may impact the study results.

2.4 Exclusion Criteria

The participants were not allowed to include those whose history included cardiovascular or metabolic diseases, recent infections or inflammatory diseases, or any injury of the muscles during the previous two weeks. Also, the participants taking antioxidant supplements or performance-enhancing drugs were not part of the study in order to eliminate possible interference with the biochemical parameters under study.

2.5 Data Collection

Data from all participants were collected using a comprehensive and standardized method. All the participants were given a structured questionnaire which contained data on age, lifestyle habits, and degree of physical activity. Also, general body composition was measured through anthropometric measurements, body mass index (BMI). Physical activity levels were assessed using a standardized physical activity scoring system to be able to classify the participants in a consistent and reliable way in terms of their activity status.

2.6 Exercise Protocol

Participants in the moderate and high activity groups performed supervised treadmill-based exercise sessions under standardized conditions.

Participants in the moderate activity group performed 30 minutes of moderate-intensity jogging at 60–70% of maximal predicted heart rate.

Participants in the high activity group performed 45 minutes of high-intensity interval running at 80–90% of maximal predicted heart rate.

Heart rate was continuously monitored throughout the exercise sessions to ensure consistency of exercise intensity.

2.7 Blood Sample Collection

Blood samples (5 mL) were collected from participants under standardized conditions. All the individuals were sampled at a rest position (baseline), and the other sample was done 30 minutes after the exercise, in the case of the participants in the active groups. Biochemical analysis was performed on the collected serum samples.; therefore, their samples were centrifuged at 3000 rpm, 10 minutes to separate the serum.

2.8 Biochemical Analysis

Biochemical analysis was performed to evaluate the levels of muscle-related enzymes. Creatine kinase (CK) was measured using an enzymatic UV kinetic method, and the results were expressed in units per liter (U/L)[14]. Lactate dehydrogenase (LDH) levels were determined using a spectrophotometric method, with results also expressed in units per liter (U/L).

2.9 Blood Lactate Measurement

Blood lactate levels were measured using a portable lactate analyzer. Capillary blood samples were obtained from the fingertip under aseptic conditions. Baseline samples were collected prior to exercise, and post-exercise samples were obtained within 5 minutes after exercise completion. Lactate concentrations were expressed in mmol/L.

2.10 Heart Rate Measurement

Measurement of the heart rate was conducted with the aid of a digital heart monitor. Resting heart rates were recorded after a 10-minute resting period in a sitting position, while the post-exercise heart rates were recorded immediately after the completion of the session of exercises. All the values of the heart rates were recorded in beats per minute (bpm).

2.11 Statistical Analysis

Results were presented as mean and standard deviation. One-way ANOVA followed by Tukey's post hoc analysis was used to compare study groups. In addition, Pearson correlation analysis was performed to evaluate the relationships between CK, LDH, heart rate, and blood lactate levels. Differences were considered statistically significant when the p-value is < 0.05 . The selected parameters were CK, LDH, heart rate, and blood lactate.

3. Results and Discussion

3.1 Participant Characteristics

One hundred and eighty apparently healthy adults were used in the study, with equal representation on each of the three groups on the basis of their physical activity levels; low activity ($n = 60$), moderate activity ($n = 60$), and high activity ($n = 60$). Table 1 summarizes the demographics and anthropometric measurements of the participants (Figure 1).

Table 1 summarizes the demographic and anthropometric measurements of the participants.

Parameter	Low Activity (n=60)	Moderate Activity (n=60)	High Activity (n=60)
Age (years)	34.2 ± 7.1	33.8 ± 6.5	34.5 ± 7.0
BMI (kg/m ²)	26.1 ± 3.2	25.5 ± 2.9	24.8 ± 2.7
Gender (M/F)	30/30	30/30	30/30

All values are expressed as mean $\pm$ SD.

The three groups were found not to have statistically significant differences based on age, gender distribution, or BMI ($p > 0.05$), which means that the comparability of the baseline was high. This homogeneity is essential in achieving the internal validity of the study since it reduces the possibilities whereby confounding variables may obstruct the sampled biochemical results[15].

The age is a well-known issue that can impact muscle metabolism and the activity enzymes because physiological aging could influence muscle mass, muscle repair, and exercise-related enzymatic reactions[16]. On the same note, it goes without saying that BMI has a close relationship with body composition and metabolic status, which can influence pre and post exercise levels of muscle related enzymes like CK and LDH[17]. These parameters indicate the lack of notable differences between groups, which implies that the differences in enzyme levels

in the later part of the study could be attributed with greater certainty to the physical activity difference than to demographic or anthropometric differences between groups[18].

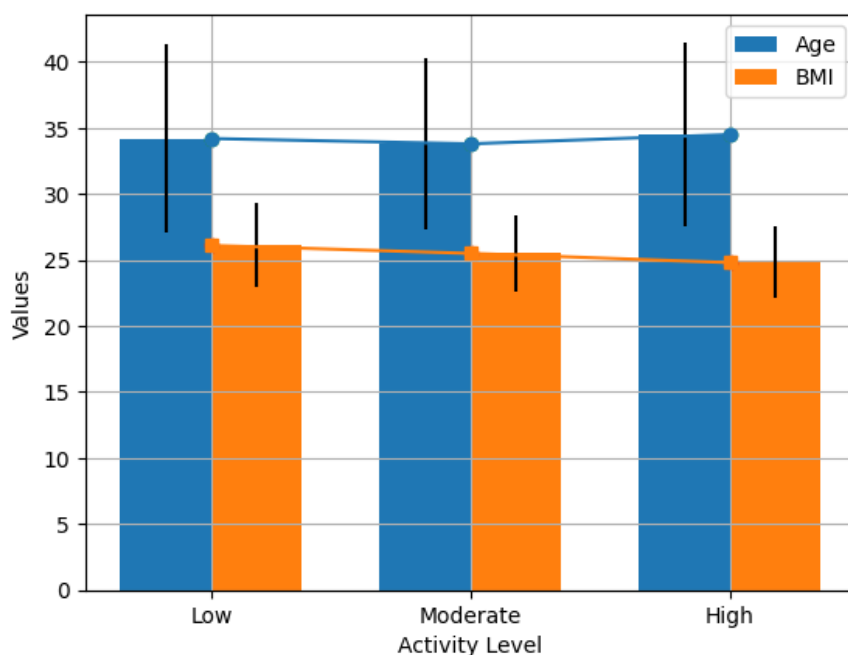


Figure 1 : Participant Characteristics (Age and BMI)

Also, males and females are distributed equally on each group of study and this minimizes any sex-based bias possible[19]. This is especially so because hormonal dissimilarity and muscle mass variation between the sexes can result in their enzyme excretion after the physical activity[20]. The study achieves a balance of gender and therefore, increases reliability and generalizability of the results[21].

In general, the similarity of the baseline traits of the study groups gives strong grounds to further analyses and the suggestion that the reasons of the observed biochemical differences are the differences in physical activity levels and not extrinsic confounding factors[22].

3.2 Creatine Kinase (CK) Levels

The baseline levels of CK were found to be similarly low in all the groups (Low: 112.5 ± 28.4 U/L, Moderate: 115.7 ± 30.1 U/L, High: 118.9 ± 31.2 U/L), indicating the absence of pre-existing muscle damage, as shown in Table 2. CK levels increased significantly in the moderate and high physical activity groups, as shown in Figure 2. The CK increase after exercise is an indication of exercise stress on muscle and temporary elevations of membrane permeability, but not structural damage[23]. The higher enzyme levels observed in the high activity group compared with the low activity group

, indicates the relationship between the intensity of exercise and the releasing of muscle enzymes[24].This suggests that CK is a sensitive indicator of acute muscular activity [25][26].

Table 2. CK levels (U/L) in study groups.

Group	Baseline CK (U/L)	Post-Exercise CK (U/L)
Low Activity	112.5 ± 28.4	–
Moderate Activity	115.7 ± 30.1	152.3 ± 35.6
High Activity	118.9 ± 31.2	198.6 ± 40.2

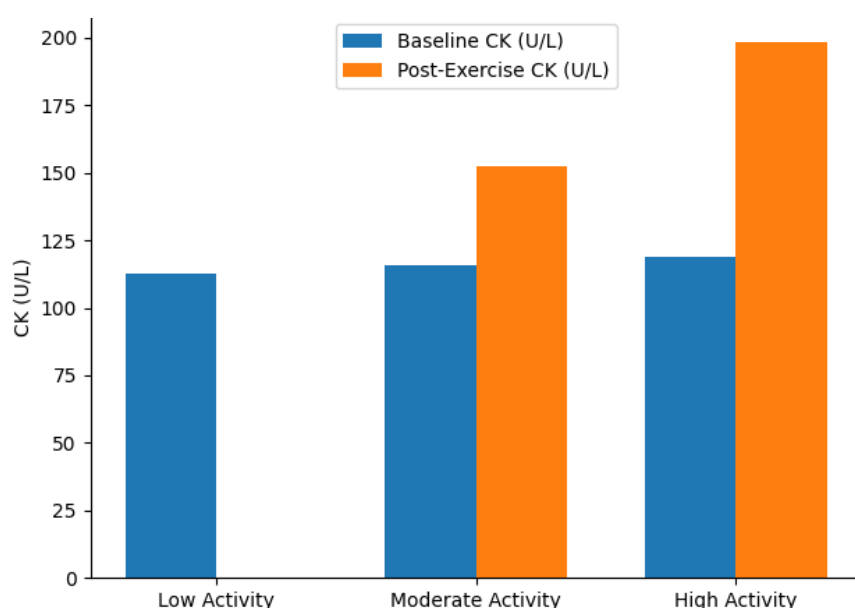


Figure 2 : Effect of Physical Activity on CK Levels

3.3 Lactate Dehydrogenase (LDH) Levels

LDH levels were significantly elevated. Baseline values were similar in low (210.3 ± 45.2 U/L), moderate (212.5 ± 46.1 U/L) and high activity groups (215.7 ± 47.0 U/L) which means that there were no pre-existing metabolic or muscular abnormalities. After exercises, the moderate (245.7 ± 50.4 U/L) and high activity group (290.8 ± 55.6 U/L) LDH levels were significantly elevated (Table 3, Figure 3).

The observed increase in LDH reflects increased metabolic demand and anaerobic energy turnover in the course of bodily exercises. The LDH is, however, to be taken as a non-specific signifier of tissue metabolic activity as it can be found in many tissues[27].

These results are in accordance with former studies. As an example, [28] have recorded high rises of LDH after high-intensity exercise with an increase reaching its highest point hours after an exercise with the extent of anaerobic metabolism. On the same note, [29] is also noting that repeated bouts of intense exercise by athletes portrayed significant post-exercise rises in LDH, showing that LDH activity is sensitive to the intensity of exercises plus the duration. These studies substantiate the idea that LDH can be considered an effective biomarker of the metabolic stress under the influence of physical exercise [30].

Compared to CK, which is mainly the evidence of membrane disruption of the muscle fibers, the increase of LDH might also indicate the presence of more lactate processing and turnover because of the increased usage of anaerobic pathways [31]. The simultaneous conditions of both markers indicate that extensive activity does not only question the muscle structural integrity, but also considerably raises the metabolic load [32].

Monitoring of LDH and CK is a more complete evaluation of muscular response to exercise, clinically. Unlike CK elevations, which can be used to determine muscle stress or microtrauma, LDH alterations could provide information about metabolic and energetic loads on tissues [33]. This complementary profiling may be especially applied in an athletic training and rehabilitation context, where the knowledge of the structural and metabolic responses to exercise can be used to develop personalized training intensity and recovery protocols [34].

Table 3. LDH levels (U/L) in study groups

Group	Baseline LDH (U/L)	Post-Exercise LDH (U/L)
Low Activity	210.3 ± 45.2	–
Moderate Activity	212.5 ± 46.1	245.7 ± 50.4
High Activity	215.7 ± 47.0	290.8 ± 55.6

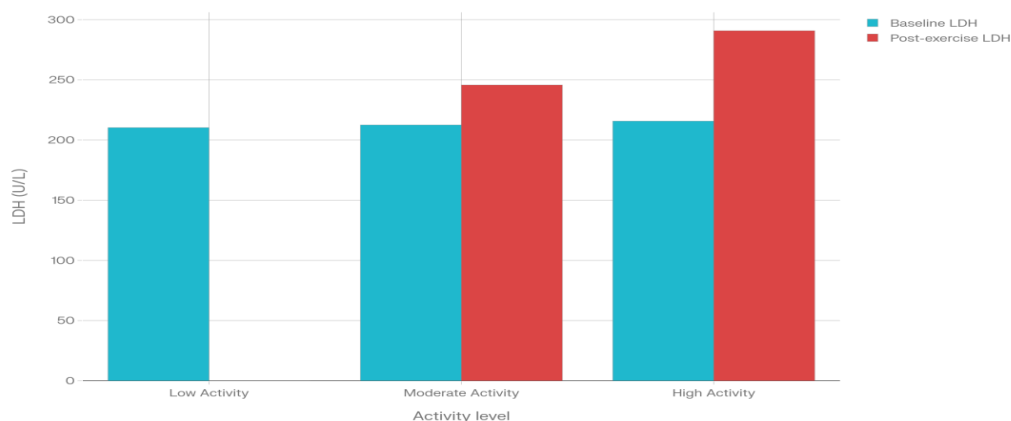


Figure 3 : Effect of Physical Activity on LDH Levels

3.4 Integrated Interpretation

One-way ANOVA showed that there were significant differences in post exercise CK and LDH levels between high and low activity groups ($p < 0.001$), and post hoc tukey tests showed the high activity participants had significantly higher levels of enzymes than low and moderate activity participants and moderate activity participants differed significantly with low activity participants ($p < 0.05$). This shows that the amount of physical exercise performed has a direct and quantitative effect on the enzymes in the muscle, with the intensity of the exercise being proportional to the increase in the levels of the enzymes, CK, and LDH[35]. The similarity in the baseline values shows that the conditions are the same in all the groups, and the differences are only because of the physical activity [36]. Note that the levels of CK and LDH are normally expected to peak 24-48 hours after the exercise, and the 30-minute test might not accurately show the peak levels of the enzymes. The increased levels are part of the normal physiological reaction, and the enzymes are important because they indicate the structural stress in the muscle (CK) and the metabolic activity and anaerobic energy expenditure (LDH)[37]. This finding agrees with previous studies, as the authors of [38] conducted a study found post-exercise CK release of 30-70 % and LDH release of 15-40 % in healthy individuals, which agrees with the idea that these enzymatic reactions are common after physical exercise[39]. Clinically, CK and LDH can give useful information regarding safe exercise prescriptions and prevent overtraining, and mild-to-moderate post exercise enzyme levels should be seen as normal adaptive responses[40]. Nevertheless, the present study has some limitations, one of them being the post-exercise measure at 30 minutes, which may fail to represent peak levels of enzymes, which normally will be at 24-48 hours and the use of self-reported physical activity questionnaires, which can create subjective bias [41]. The present study has several limitations.

First, serum CK and LDH levels were measured only 30 minutes after exercise, whereas peak enzyme concentrations are generally observed 24–48 hours post-exercise. Therefore, the current findings mainly reflect early physiological responses rather than peak enzymatic changes. Second, only total CK and LDH levels were measured without isoenzyme differentiation. Future studies involving CK-MM and LDH isoforms may provide greater specificity regarding tissue origin and muscle damage assessment. Additionally, physical activity classification was partially based on self-reported questionnaires, which may introduce subjective bias despite the use of supportive physiological measurements such as heart rate and blood lactate.

3.5 Heart Rate (HR) Response

The heart rate of the participants at rest was similar for all three groups: Low – 72.4 ± 6.8 bpm, Moderate – 71.9 ± 7.1 bpm, and High – 72.1 ± 6.5 bpm. However, the heart rates of the participants who performed moderate and high levels of activity were significantly higher at 98.6 ± 10.5 bpm and 115.3 ± 12.7 bpm, respectively, than those who performed low levels of physical activity (Table 4, Figure 4). This response is attributed to cardiovascular adaptation to increased exercise intensity, which increases with the workload and demands more oxygen supply to the muscles [42]. This significant increase in the high activity group can explain the increases in the levels of CK and LDH, which are directly proportional to the intensity of the workout [43].

The results are in line with the findings of other studies which suggest that heart rate is a valid measure of exercise intensity, which is highly correlated with the levels of muscle activity and metabolism in the body. Hence, the results obtained from the heart rate measurements provide a better understanding of the physiological adaptations to exercise [44].

Table 4. Heart Rate (bpm) in study groups

Group	Resting HR (bpm)	Post-Exercise HR (bpm)
Low Activity	72.4 ± 6.8	–
Moderate Activity	71.9 ± 7.1	98.6 ± 10.5
High Activity	72.1 ± 6.5	115.3 ± 12.7

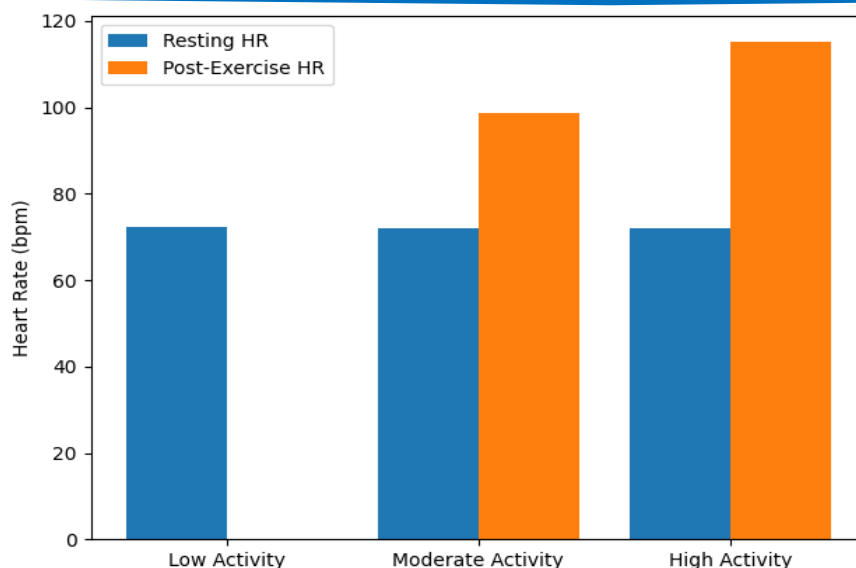


Figure 4 : Heart Rate Response Across Activity Groups

3.6 Blood Lactate Levels

Blood lactate levels at baseline were found to be similar among the three groups (Low: 1.2 ± 0.3 mmol/L, Moderate: 1.3 ± 0.4 mmol/L, High: 1.2 ± 0.3 mmol/L). After the exercise, the lactate levels increased significantly in the moderate (3.8 ± 0.7 mmol/L) and high activity groups (5.6 ± 0.9 mmol/L), with the highest levels being found in the high activity group (Table 5, Figure 5).

This increase can be attributed to an increased reliance on anaerobic glycolysis during more intense physical activity. The increased levels of lactate are directly related to the increased levels of LDH, as this enzyme is a major participant in the conversion of pyruvate and lactate [45].

The concomitant increase in lactate and LDH levels is consistent with the notion that increased levels of physical activity are associated with increased metabolic stress and energy demands[46].

Table 5. Blood Lactate Levels (mmol/L) in Study Groups

Group	Baseline Lactate (mmol/L)	Post-Exercise Lactate (mmol/L)
Low Activity	1.2 ± 0.3	—
Moderate Activity	1.3 ± 0.4	3.8 ± 0.7

High Activity	1.2 ± 0.3	5.6 ± 0.9
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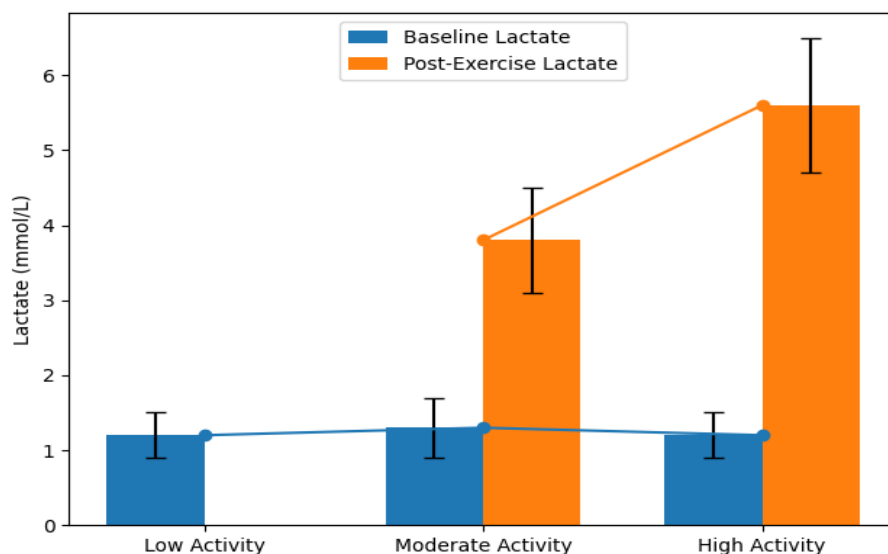


Figure 5: Blood Lactate Levels Across Activity Groups

3.7 Correlation Analysis

Pearson correlation analysis demonstrated significant positive correlations between post-exercise CK levels and blood lactate concentrations ($r = 0.68$, $p < 0.001$), as well as between LDH levels and post-exercise heart rate ($r = 0.72$, $p < 0.001$). These findings suggest that increasing exercise intensity is associated with greater muscular and metabolic stress.

4. Conclusion

These findings indicate that physical activity intensity plays an important role in modulating serum CK and LDH levels, reflecting both muscular stress and metabolic demand. Heart rate and blood lactate responses further support the physiological relationship between exercise intensity and muscular adaptation. Future longitudinal studies incorporating delayed post-exercise sampling and isoenzyme analysis are recommended to improve understanding of exercise-induced muscular adaptations and recovery mechanisms.

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