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The Relationship between Physical Activity Level, Lactate Accumulation, and Heart Rate Variability among university students

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Abstract

Physical activity is linked with autonomic nervous system control and metabolic adjustments during physical activity. The goal of this research is to determine the connection between physical activity level, blood lactate production, and heart rate variability in college students.

The present cross-sectional study involved 80 healthy volunteers in the age range of 18 to 30 years old. Physical activity level was measured using the International Physical Activity Questionnaire. Heart rate variability indices were recorded at rest through a Polar H10 heart rate monitor, whereas the levels of blood lactate were determined prior to, immediately after, and during recovery from physical activity. Graded physical activity tests were conducted at 70 to 85 percent of maximal heart rate.

It was found that subjects in the high activity group have significantly reduced resting heart rate, significantly reduced post-exercise lactate concentration, and enhanced capacity of lactate clearance when compared to subjects in the low activity group ($p < 0.01$). Significant increase in HRV parameters associated with parasympathetic tone in high activity group was observed, while low frequency to high frequency ratio was lower ($p < 0.001$). There was significant negative correlation between post-exercise lactate concentration and HRV parameters and positive correlation with low to high frequency ratio.

It can be concluded that there is a positive relationship between physical activity and autonomic function as well as metabolism. HRV and lactate response can be used as effective markers of physical fitness and cardiovascular health.

Keywords: Physical Activity, Heart rate variability , Lactate, Autonomic Balance, Exercise Test

الملخص

النشاط البدني له دور مهم في تنظيم الجهاز العصبي الذاتي وتغيير العمليات الأيضية خلال ممارسة التمارين. حاولت هذه الدراسة تفهم كيف يرتبط مستوى النشاط البدني بتراكم اللاكتات في الدم، بالإضافة إلى تأثيره على تقلب معدل ضربات القلب عند طلاب الجامعة.

شارك في هذه الدراسة 80 شخصًا سليمًا تتراوح أعمارهم بين 18 و30 سنة. تم تقييم نشاطهم البدني من خلال استبيان عالمي للنشاط البدني. أما معدل ضربات القلب، فقد تم قياسه أثناء الراحة باستخدام جهاز **Polar H10.** كذلك، تم أخذ عينات من الدم لقياس مستوى اللاكتات قبل التمرين، فور الانتهاء منه، وخلال فترة الراحة بعد التمرين. وخضع المشاركون لاختبار تدريجي للجهد بنسبة تتراوح بين 70 و85% من أقصى معدل ضربات قلب متوقع لهم.

أظهرت النتائج أن المشاركين ذوي النشاط البدني المرتفع يمتلكون معدل ضربات قلب أقل أثناء الراحة، ومستويات أقل من اللاكتات بعد التمرين، وكفاءة أعلى في إزالة اللاكتات مقارنة بذوي النشاط البدني المنخفض **.(p < 0.01)** كما لوحظ ارتفاع معنوي في مؤشرات تقلب معدل ضربات القلب المرتبطة بالنشاط نظير الودي لدى مجموعة النشاط المرتفع، في حين انخفضت نسبة التردد المنخفض إلى التردد العالي **.(p < 0.001)** كذلك وُجد ارتباط سلبي معنوي بين مستويات اللاكتات بعد التمرين ومؤشرات تقلب معدل ضربات القلب، وارتباط إيجابي مع نسبة التردد المنخفض إلى التردد العالي.

تستنتج الدراسة وجود علاقة إيجابية بين النشاط البدني وتحسن وظائف الجهاز العصبي الذاتي والعمليات الأيضية. ويمكن اعتماد تقلب معدل ضربات القلب واستجابة اللاكتات كمؤشرين فعّالين للياقة البدنية وصحة الجهاز القلبي الوعائي.

الكلمات المفتاحية: النشاط البدني، تباين معدل ضربات القلب، حمض اللاكتيك، التوازن العصبي الذاتي، اختبار الجهد البدني.

1. Introduction

Physical activity is widely acknowledged as one of the key factors contributing to health due to its major impact on the cardiovascular system, metabolism, and functions of the autonomic nervous system. Recently, research interest has increased significantly due to attempts to understand the mechanisms underlying physical activity, which help maintain good health and prevent diseases [1]. One of such mechanisms involves exercise-induced changes in metabolic processes, in particular, lactate metabolism, and their relationship to heart rate variability and cardiovascular functions regulated by the autonomic nervous system [2].

Previously, lactate was known as one of the metabolic products formed in anaerobic conditions only. Currently, there is evidence that lactate performs multiple functions in energy metabolism and cell signalization [3]. Lactate increases in the blood during moderate- and high-intensity physical activity, owing to increased glycolysis rates. Lactate accumulation largely depends on the balance between lactate synthesis and clearance, which, in turn, depends on mitochondria density and oxidative capacity, as well as physical activity level of an individual [4].

Heart rate variability is one of the most acknowledged indices for monitoring the functional state of the autonomic nervous system, representing the ratio between sympathetic and parasympathetic nervous systems activities [5]. The high value of indices of heart rate variability, especially the root mean square of successive differences and the standard deviation of normal-to-normal intervals, indicates the predominance of parasympathetic tonus and good cardiovascular condition. On the contrary, low heart rate variability indicates the dominance of the sympathetic nervous system and poor physiological adaptability under stressful conditions [6]. Physical activity was found to positively affect the parameters of heart rate variability, contributing to the optimal functioning of the autonomic nervous system and cardiovascular system [7].

Metabolite production and its impact on heart rate variability constitute a crucial physiological connection between exercise-induced metabolic stress and autonomic regulation. Lactate production and metabolic by-products activate peripheral chemoreceptors and metaboreceptors, leading to a shift from parasympathetic to sympathetic nervous system tonus, and thus lowering heart rate variability [8]. This metabolic stress might be viewed as an indirect index of autonomic nervous system function under physical activity conditions.

Although there is a growing body of literature concerning the independent role of physical activity in the regulation of lactate metabolism and HRV, there is a paucity of research considering the correlation between physical activity levels, the effect of physical exercise on lactate levels, and autonomic regulation in apparently healthy young adults. Moreover, the interplay between metabolic recovery and autonomic system adaptation after exercise is not fully elucidated, especially for young people attending universities[9].

Thus, this paper is intended to analyze the interrelation between physical activity levels, blood lactate production, and HRV in university students. Based on these factors, it is expected that physically active subjects will display less lactate production, rapid lactate clearance, and better heart rate variability indicators, indicating their increased adaptation to physical activity.

2.Materials and Methods

2.1 Study Design

The chosen research design for the proposed investigation was an analytical cross-sectional study that aimed to evaluate the connection between physical activity levels, lactate production, and heart rate variability in healthy young adults. The use of this design seemed justified since it would enable the assessment of both physiological and biochemical indicators simultaneously within a specified population at one time point. Additionally, a cross-sectional design would facilitate the analysis of differences between various groups based on their physical activity levels and reveal possible associations between autonomic nervous system function, lactate production, and physical fitness.

2.2 Study Population

The population under study comprised university students and young adults drawn from the general public within an age bracket of 18-30 years. The subjects were recruited over the course of the study period using a convenient sampling technique. This involved the initial selection of volunteers through direct contact with potential participants on university premises and in other locations. Subsequently, the eligibility of each subject was determined by

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completing a health questionnaire and conducting a personal interview.

Ultimately, 80 subjects who qualified for inclusion in the study were identified. The age group chosen for the study was meant to limit variation in physiological factors resulting from differences in age, thus ensuring uniformity in cardiovascular and metabolic responses during exercise tests..

The criteria for selection entailed healthy males and females within the age bracket of 18 to 30 years without a past or present record of any diseases related to the cardiovascular, respiratory, metabolic, and neurological systems. It was also important that none of the participants be taking any medication that would affect their heart rate, sympathetic and parasympathetic nervous systems, or metabolism.

Participants who fell under the category of professional athletes, smokers, had chronic illnesses, had been ill recently, had injuries in the past few days, and consumed large amounts of caffeine before testing were excluded from the study. Any participants on medication that would alter their cardiovascular and metabolic response were also excluded.

Once selected, the participants were categorized based on their physical activity level using the International Physical Activity Questionnaire.

2.3 Group Classification

The participants were categorized into three different groups based on their level of physical activity using the International Physical Activity Questionnaire (IPAQ). The three categories of physical activity levels were low, moderate, and high. This categorization of physical activity levels was used to measure the effects of different levels of physical activity on physiological parameters.

2.4 Experimental Protocol

All participants were asked to refrain from strenuous physical activities for 24 hours prior to the test. Participants were also asked to refrain from consuming caffeine or heavy meals for at least 4 hours prior to the test. Participants were asked to rest quietly for 10 minutes upon arrival at the test site. After the resting period, the participants were asked to undergo a test of physiological responses.

2.5 Measurement of Heart Rate Variability (HRV)

HRV measurement was conducted under resting conditions with a validated Polar H10 heart rate monitor. The HRV parameters used for analysis were RMSSD (Root Mean Square of Successive Differences), SDNN (Standard Deviation of NN intervals), and LF/HF ratio (Low Frequency/High Frequency). The measurement was taken for 5 minutes in a supine position. HRV software was used for HRV analysis [10].

2.6 Measurement of Blood Lactate

The blood lactate concentration was measured using a Lactate Pro 2 analyzer. A capillary blood sample was taken from a finger tip at three time points: at rest, immediately after exercise, and 10 minutes after exercise. Lactate concentration was expressed in mmol/L. [11].

2.7 Exercise Protocol

Participants performed a graded exercise test with intensity gradually increased until reaching 70–85% of their estimated maximum heart rate (HRmax), calculated as:

$HRmax = 208 - (0.7 \times age)$

Heart rate was continuously monitored throughout the test[12].

2.8 Additional Measurements

The body mass index (BMI) was calculated by dividing weight (kg) by height squared (m^2). In addition, the resting heart rate was taken before the exercise test. This was done to measure cardiovascular status at rest[13].

2.9 Statistical Analysis

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The data was analyzed using SPSS software version 26. Quantitative data was expressed as mean ± SD. Normality of data was checked using the Shapiro-Wilk test. ANOVA was used for intergroup comparison, followed by Tukey's test for multiple comparisons. Pearson correlation was used for correlation analysis. Multiple regressions were used to identify significant predictor variables. Effect size was calculated using η^2 for ANOVA. $P < 0.05$ was considered statistically significant.

3. Results

3.1 Participant Characteristics

The experiment involved 80 participants (42 males, 38 females) ranging in age from 18 to 30 years old. Table 1 highlights the basic characteristics of the participants divided into three groups according to their activities

Table 1. Basic Characteristics of Participants

Variable	Low Activity (n=27)	Moderate Activity (n=26)	High Activity (n=27)	p-value
Age (years)	22.4 ± 2.1	23.0 ± 2.5	22.8 ± 2.3	0.52
BMI (kg/m²)	24.2 ± 2.5	23.5 ± 2.1	22.8 ± 2.0	0.08
Resting HR (bpm)	76 ± 8	72 ± 7	68 ± 6	<0.01

According to Table 1, there was no significant difference between the variables of age and BMI among all groups ($p>0.05$), while the resting heart rate was significantly reduced in response to increased physical activities ($p<0.01$).

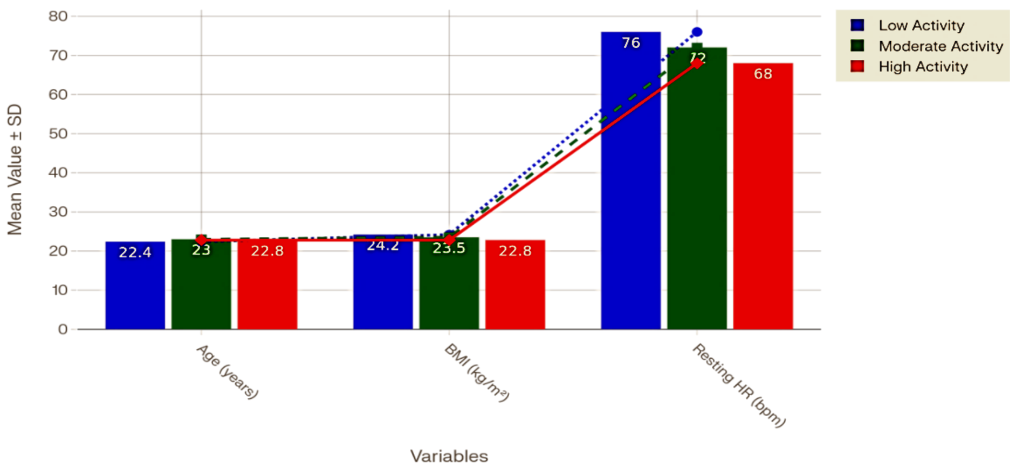

Figure 1. Comparison of Age, BMI, and Resting Heart Rate Across Physical Activity Levels

3.2 Blood Lactate Levels

Blood lactate concentrations were determined before exercise, right after exercise, and during the first 10 minutes of recovery. The findings for the three exercise categories are shown in Table 2.

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Table 2. Blood Lactate Concentrations (mmol/L) Among Different Exercise Categories

Time Point	Low Activity	Moderate Activity	High Activity	p-value
Baseline	1.3 ± 0.4	1.2 ± 0.3	1.1 ± 0.2	0.21
Immediately Post-Ex	5.5 ± 1.0	4.2 ± 0.8	3.5 ± 0.6	<0.001
10 min Recovery	4.2 ± 0.9	3.0 ± 0.7	2.2 ± 0.5	<0.001

From Table 2, it can be seen that lactate increase after exercise is greatest among the low activity subjects, while lactate decrease after exercise is smallest among the high activity subjects. . Furthermore, the rate of lactate decrease following exercise increases proportionately with increasing activity levels

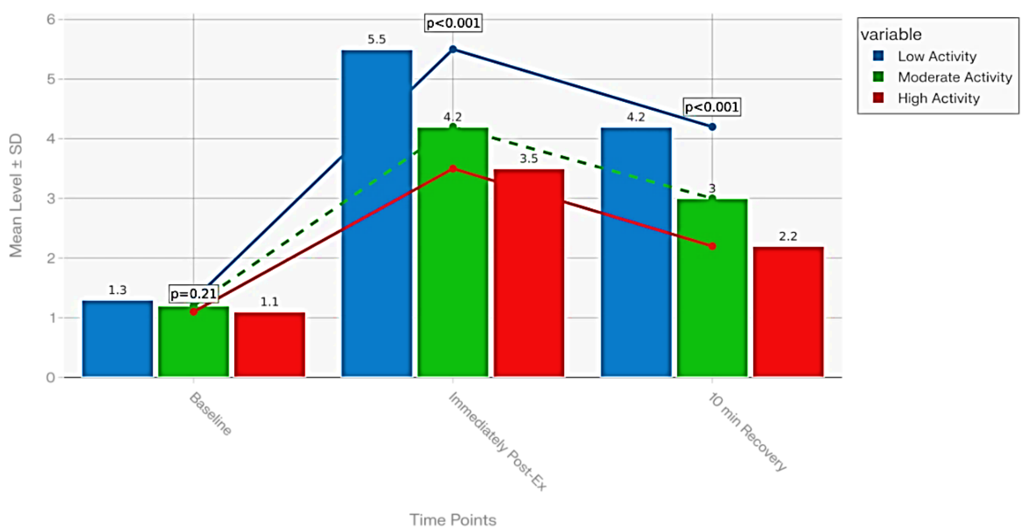

Figure 2. Blood Lactate Response to Exercise in Different Activity Groups

3.3 Heart Rate Variability (HRV) Indices

Resting HRV measurements were taken for the evaluation of autonomic regulation in the various groups of activity. RMSSD, SDNN, and LF/HF ratio results are shown in Table 3 below.

Table 3. Resting HRV Indices in Various Activity Groups

HRV Parameter	Low Activity	Moderate Activity	High Activity	p-value
RMSSD (ms)	**28 ± 6**	**36 ± 7**	**45 ± 8**	**<0.001**
SDNN (ms)	**40 ± 9**	**50 ± 10**	**60 ± 12**	**<0.001**
LF/HF Ratio	**2.5 ± 0.7**	**1.8 ± 0.5**	**1.2 ± 0.4**	**<0.001**

The results in Table 3 show that increased physical activity was correlated with increased RMSSD and SDNN values and decreased LF/HF ratio values, which suggests an increased parasympathetic influence on heart rate regulation

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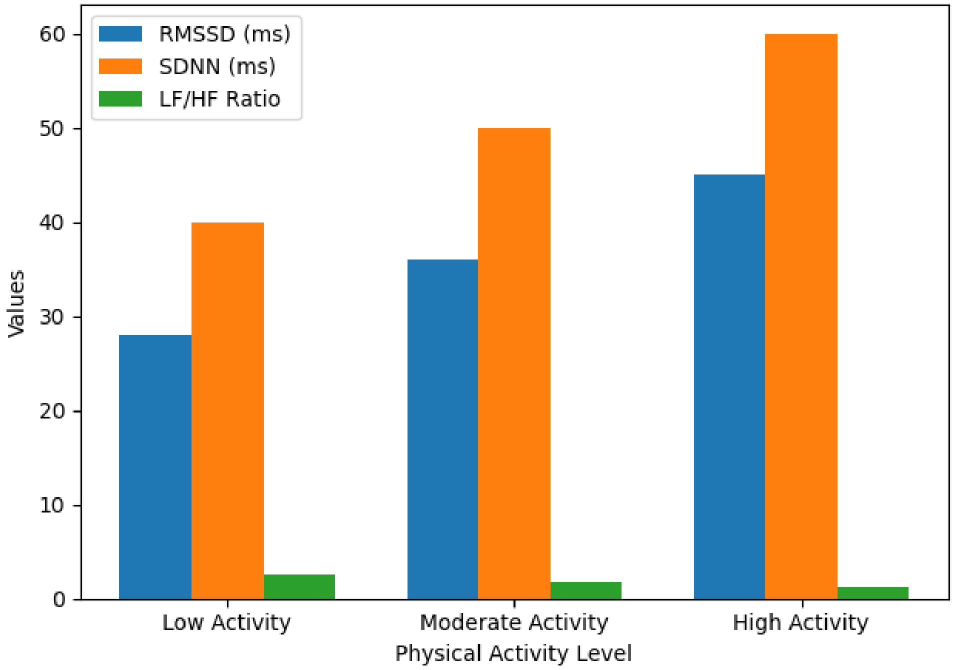

Figure 3. Resting RMSSD Values Across Activity Groups

3.4 Correlation Between Lactate and HRV

The Pearson correlation was carried out to find any relation between the lactate concentrations after exercise and HRV. The results are presented below in Table 4.

Table 4. Pearson Correlation for Post-Exercise Lactate and HRV

HRV Parameter	r-value	p-value
RMSSD	-0.62	<0.001
SDNN	-0.58	<0.001
LF/HF Ratio	0.55	<0.001

As can be seen from Table 4, elevated values of post-exercise lactate are positively correlated with increased sympathetic tone (elevated LF/HF ratio) and negatively correlated with decreased parasympathetic tone (decreased RMSSD and SDNN).

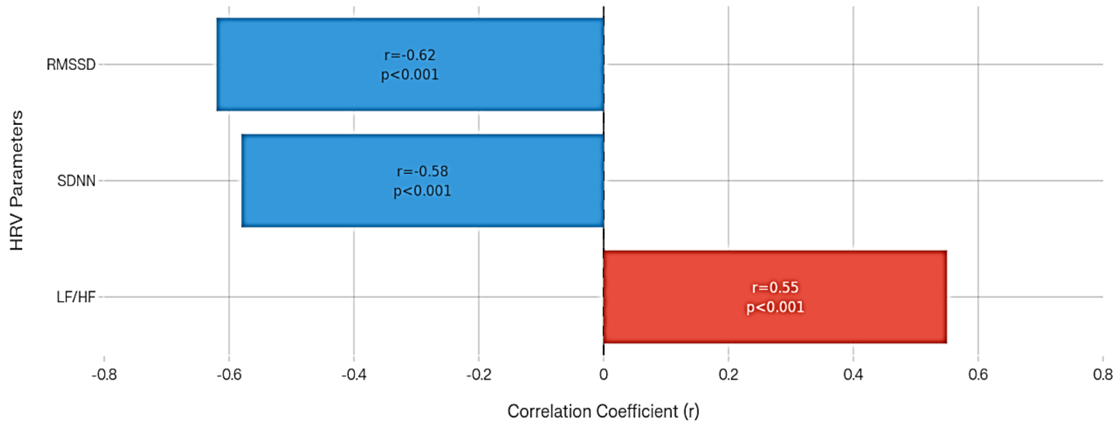

Figure 4. Correlation Between Post-Exercise Lactate and RMSSD

4. Discussion

Results from the current research offer substantial proof that higher amounts of regular physical activity among young individuals lead to numerous positive physiological responses[14] , such as decreased resting heart rate, quicker lactate clearance, and increased HRV[15]. The individuals in the high activity category showed significant increases in RMSSD and SDNN measures[16], coupled with decreases in LF/HF ratio measures, suggesting stronger parasympathetic tone and decreased sympathetic dominance when resting [17]. This is in agreement with other research that has shown the same benefits in autonomic balance through exercise [18]. This inverse correlation found between lactate levels following exercise and HRV demonstrates a clear connection between metabolism and autonomic control where higher lactate levels imply sympathetic activation, as opposed to parasympathetic influence[19] From a mechanistic point of view, this can be elucidated by the stimulation of chemoreceptors and metaboreceptors [20] as a result of an elevated level of lactate and hydrogen ions, which results in increased sympathetic activity and decreased parasympathetic activity[21]. Furthermore, the more rapid clearance of lactate among physically active individuals is indicative of greater oxidation, higher mitochondria density, better lactate transport, and buffering of metabolic acidosis[22]. It is therefore clear that these physiological changes highlight the necessity of regular physical activity not only in relation to efficient cardio function[23], but also in order to achieve optimal recovery from exercise and minimize physiological strain[24]. On a practical level, this means that HRV measurements and lactate readings can be used as effective, non-invasive indicators of physical fitness and autonomic-metabolic interaction[25]. Even though causation cannot be determined by the nature of the design used, there is ample indication of the relationships among physical activity, metabolism, and the autonomic system in a healthy and young group of individuals [26][27]. Moreover, the paper opens up a range of possibilities for further study, such as longitudinal studies on the effects of systematic training programs and the role of gender, as well as the inclusion of other indicators, such as VO_2 max and blood pH [28]. In summary, it can be seen that not only does exercise offer numerous physiological advantages, but it is also crucial in terms of providing recovery from stress and developing resilience, making it an essential component of lifestyle habits and contributing to good health in the future[29][30].

5.Conclusions

An increase in the amount of exercise corresponds to a more efficient metabolism, rapid clearance of lactate, and regulation of the autonomic nervous system in young adults. It is worth mentioning that a connection between the lactate level and heart rate variability indicates the tight interaction between metabolic and autonomic systems, and thus can be used to assess fitness and recovery capabilities of the body.

5.1 Limitations

This study is cross-sectional and does not allow for a conclusion regarding causation between variables. The sample size in the current investigation is rather small and collected based on convenience sampling; therefore, results cannot be generalized. Physical activity data was collected via self-reporting and may be affected by bias; some confounders, such as nutrition and sleep patterns, were not accounted for.

5.2 Implications

The above results indicate that aerobic exercises can promote metabolic and autonomic well-being. Lactate and heart rate variability levels can serve as good predictors of fitness and recovery in adolescents and adults.

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