RESEARCH PAPER

Serum Creatine Kinase and Lactate Dehydrogenase as Markers of Exercise-Induced Muscle Adaptation: A Comparative Study in Athletes and Sedentary Individuals

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ABSTRACT

Background & Objectives: Regular physical activity is associated with biochemical adaptations, particularly in muscle-derived enzymes such as creatine kinase (CK) and lactate dehydrogenase (LDH). This study aimed to compare CK and LDH levels between athletes and sedentary individuals and to assess their association with training characteristics.

Methods: A comparative cross-sectional study was conducted among 200 apparently healthy participants aged 18–30 years, divided into athletes (n=100) and sedentary individuals (n=100). Serum CK and LDH levels were estimated using standard enzymatic methods. Statistical analysis was performed using independent t-test, Pearson correlation.

Results: Athletes demonstrated significantly higher CK (414.66 ± 266.26 U/L) and LDH (230.39 ± 37.45 U/L) levels compared to sedentary individuals (137.22 ± 59.64 U/L and 198.17 ± 25.87 U/L, respectively), with strong statistical significance ($p < 0.001$). However, no significant correlation was observed between CK or LDH with training hours or frequency, nor between CK and LDH levels in either group ($p > 0.05$).

Conclusion: Athletes demonstrated significantly higher CK and LDH levels compared to sedentary individuals, reflecting physiological adaptation to regular exercise. These elevations were not influenced by training hours or frequency, indicating a stronger role of acute exercise intensity and individual variability. Overall, CK and LDH act as markers of transient muscle stress and metabolic activity rather than indicators of chronic training load.

Keywords: *Creatine kinase; Lactate dehydrogenase; Athletes; Sedentary lifestyle; Exercise physiology*

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INTRODUCTION

Regular physical activity is widely recognized for its beneficial effects on overall health, metabolic function, and disease prevention. However, exercise—particularly when performed at moderate to high intensity—can induce physiological stress on skeletal muscles, leading to transient structural and biochemical alterations [(1)]. Among the most commonly studied biomarkers of exercise-induced muscle stress are creatine kinase (CK) and lactate dehydrogenase (LDH), both of which are intracellular enzymes released into circulation following muscle

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membrane disruption [2]. Creatine kinase plays a crucial role in cellular energy metabolism by catalyzing the reversible conversion of creatine and adenosine triphosphate, thereby maintaining energy homeostasis during muscle contraction [3]. Elevated serum CK levels are widely considered a sensitive indicator of muscle damage and have been extensively used to monitor exercise-induced muscle injury[4]. Similarly, lactate dehydrogenase is involved in anaerobic glycolysis and reflects metabolic stress and tissue turnover [5]. Increased LDH levels following physical exertion are indicative of enhanced anaerobic metabolism and cellular stress [6]. Athletes, particularly those engaged in regular and intensive training, are frequently exposed to repeated cycles of muscle loading and recovery. This chronic exposure leads to physiological adaptations that may influence the baseline and post-exercise levels of muscle enzymes [7]. In contrast, sedentary individuals, who lack such adaptations, may exhibit different biochemical responses to physical stress. Understanding these differences is important for distinguishing between physiological adaptation and pathological muscle damage. Despite extensive research on exercise-induced changes in CK and LDH, variability in these biomarkers remains a challenge, as their levels are influenced by multiple factors including training intensity, duration, type of exercise, hydration status, and individual physiological characteristics [8]. Furthermore, the relationship between habitual physical activity and baseline enzyme levels in athletes compared to sedentary individuals is not yet fully understood. Therefore, the present study aims to evaluate and compare serum CK and LDH levels between athletes and sedentary individuals, and to explore the influence of exercise-related factors on these biomarkers. This investigation seeks to provide insights into the physiological implications of regular training and to contribute to the understanding of muscle enzyme dynamics in different activity profiles.

MATERIAL AND METHODS

The present study was designed as a comparative cross-sectional observational study to evaluate and compare biochemical parameters among athletes and sedentary individuals. The study was conducted in School of Health Sciences, Chhatrapati Shahu Ji Maharaj University, Kanpur, India in collaboration with the Department of Physical Education, Chhatrapati Shahu Ji Maharaj University, Kanpur, India. A total of 200 apparently healthy participants aged between 18 and 30 years were enrolled as per inclusion and exclusion criteria and equally divided into two groups: an athlete group (n = 100), comprising individuals engaged in regular, structured physical training for a minimum of 2 hours/day and actively participating in competitive or organized sports for 6 months, and a sedentary group (n = 100), consisting of individuals who had not engaged in regular physical exercise or structured training for at least the preceding six months. Ethical approval for the study was obtained from the Human Ethical Committee, C.S.J.M. University, Kanpur, (Approval No.: 2024-Jun-003), and written informed consent was obtained from all participants prior to enrollment in accordance with established ethical guidelines. Venous blood samples (5 mL) were collected from each participant under aseptic conditions following an overnight fast. The samples were allowed to clot and were then centrifuged at 3000 rpm for 10 minutes to separate the serum, which was analyzed using fully automated clinical chemistry analyzers, serum CK and serum LDH was estimated by the IFCC recommended UV kinetic method. Statistical analysis was performed using the SPSS version 26.0 software. Continuous variables were expressed as mean ± standard deviation, and comparisons between the two groups were conducted using the independent Student's t-test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Gender distribution among study participants

A total of 200 participants were included in the study, comprising 100 athletes and 100 sedentary individuals. The sex distribution was comparable between the two groups, with males constituting 60% and females 40% in both groups (Table 1).

Table 1. Distribution of participants according to sex

Group	Male n (%)	Female n (%)	Total n (%)
Athletes	60 (60%)	40 (40%)	100 (100%)
Sedentary	60 (60%)	40 (40%)	100 (100%)

Values are expressed as number (n) and percentage (%) of total study participants.

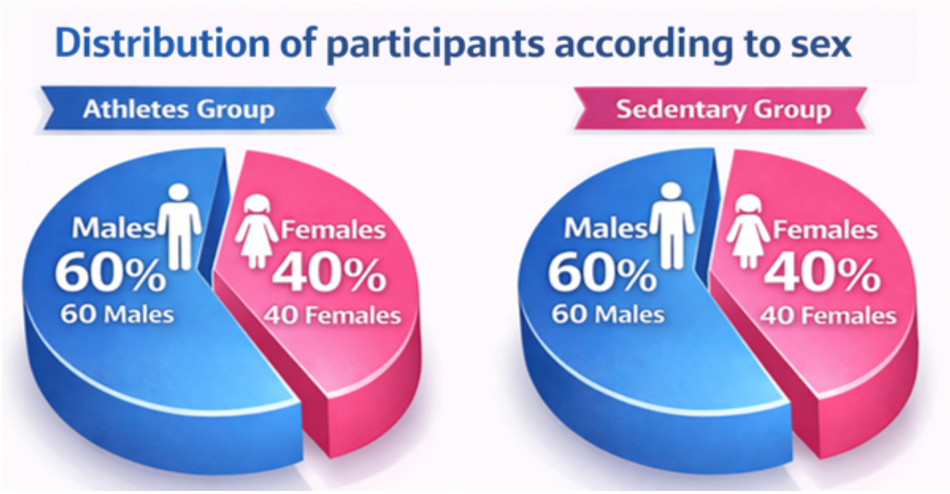

Figure 1: Distribution of participants according to sex in Athletes and Sedentary groups; Both groups showed similar gender distribution (60% males, 40% females)

Age distribution of Athletes and Sedentary Individuals

The mean age of the athlete group was **23.92 ± 3.10 years**, with males averaging **24.01 ± 3.05 years** and females **23.78 ± 3.18 years**, indicating a comparable age distribution between genders with slightly lower variability among males. In the sedentary group, the overall mean age was **23.86 ± 2.82 years**, with males at **23.95 ± 2.79 years** and females at **23.72 ± 2.87 years**, suggesting minimal gender-based differences in age. Overall, both groups exhibited similar age distributions; however, the athlete group demonstrated marginally higher variability compared to sedentary individuals, as illustrated in Figure 2. The comparison of age between athletes and sedentary individuals showed no statistically significant difference. The t-value of -0.14 with a p-value of 0.886 indicates that the difference is not statistically significant ($p > 0.05$), suggesting that both groups were age-matched and comparable for further analysis.

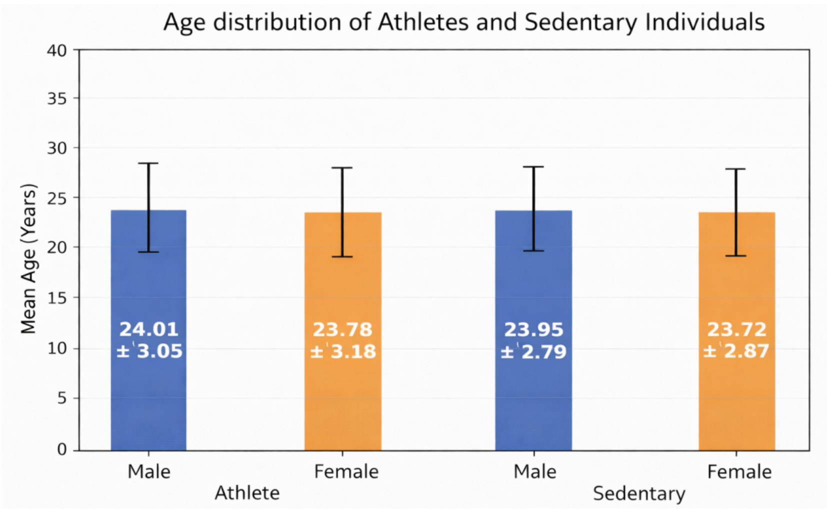

Figure 2: Age distribution of athletes and sedentary individuals

Lifestyle characteristics and Hydration status among study participants

A higher proportion of athletes reported adherence to a specific diet, with 64 (64%) participants compared to 23 (23%) in the sedentary group, while 36 (36%) athletes and 77 (77%) sedentary individuals did not follow a specific diet. Similarly, supplement use was more common among athletes, observed in 48 (48%) participants, whereas only 9 (9%) sedentary individuals reported supplement intake; the majority of sedentary individuals (91 (91%)) did not use supplements compared to 52 (52%) athletes. Regarding hydration status, adequate hydration was noted in 71 (71%) athletes and 84 (84%) sedentary individuals, while mild dehydration was observed in 29 (29%) athletes and 16 (16%) sedentary participants (Table 2). Other characteristics showed that there was no significant difference in height between athletes (**165.75 ± 8.89 cm**) and sedentary individuals (**164.82 ± 9.07 cm**) ($p = 0.468$). However, sedentary individuals had significantly higher weight (**68.69 ± 10.21 kg**) and BMI (**25.19 ± 2.33 kg/m²**) compared to athletes (**61.94 ± 8.89 kg** and **22.48 ± 2.09 kg/m²**, respectively) ($p < 0.001$)

Table 2. Lifestyle characteristics and Hydration status among study participants

Parameters	Category	Athletes no./(%)	Sedentary no./(%)
Specific diet	Yes	64 (64%)	23 (23%)
	No	36 (36%)	77 (77%)
Supplement	Yes	48 (48%)	9 (9%)
	No	52 (52%)	91 (91%)
Hydration	Adequate	71 (71%)	84 (84%)
	Mild dehydration	29 (29%)	16 (16%)

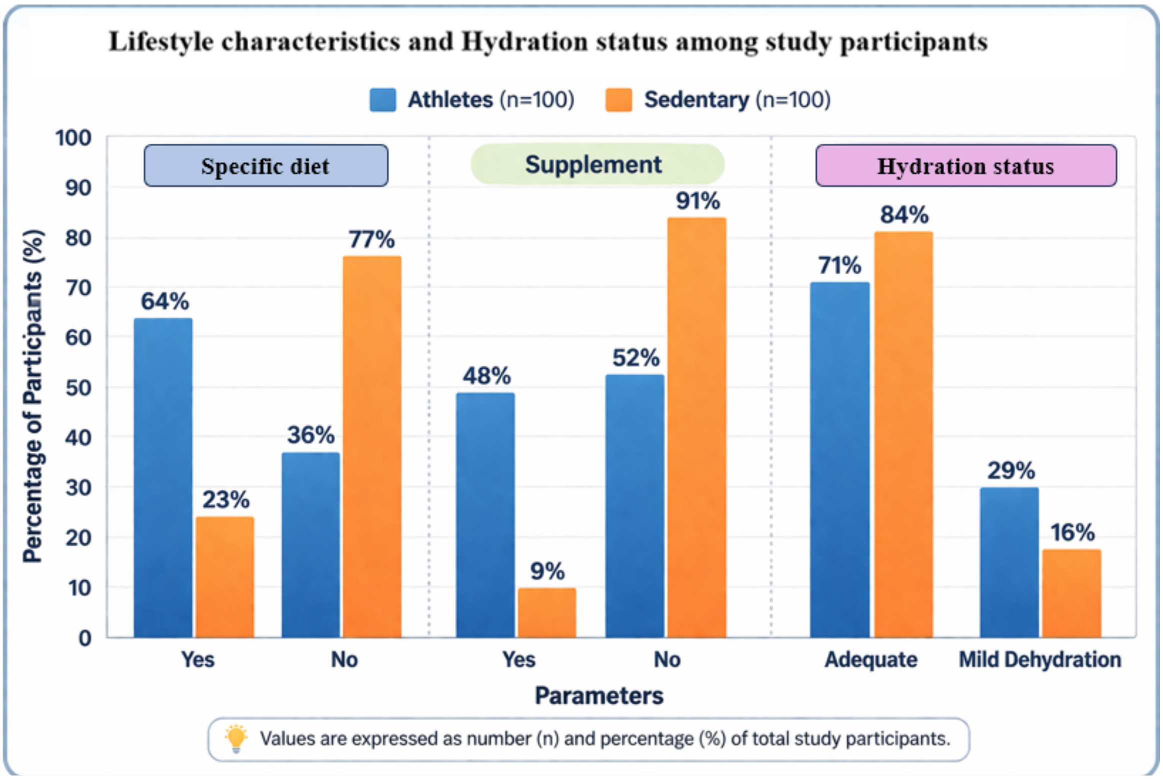

Figure 3: Lifestyle characteristics and Hydration status among Athletes and Sedentary individuals

Training characteristics among Athletes

Among athletes, an average training duration of 2.96 ± 0.63 hours per day and a training frequency of 5.87 ± 1 sessions per week (Table 3 , figure 4)

Table 3. Training characteristics among Athletes

Parameters	Mean ± Std.
Training Hours/day	2.96 ± 0.63
Training Frequency/week	5.87 ± 1

Values are expressed as mean ± standard deviation (SD).

Figure 4: Bar graph showing mean training hours per day and training frequency per week among Athletes, presented as mean ± standard deviation.

Comparison of CK and LDH between Athletes and Sedentary Individuals

Comparison of biochemical parameters revealed significantly higher levels of CK and LDH among athletes compared to sedentary individuals. The mean CK levels were 414.66 ± 266.26 U/L in athletes and 137.22 ± 59.64 U/L in sedentary individuals ($p < 0.001$). Similarly, LDH levels were significantly elevated in athletes (230.39 ± 37.45 U/L) compared to sedentary participants (198.17 ± 25.87 U/L) ($p < 0.001$) (Table 4).

Table 4. Comparison of CK and LDH between Athletes and Sedentary Individuals

Parameters	Athletes	Sedentary	t-value	p-value
CK (U/L)	414.66 ± 266.26	137.22 ± 59.64	-10.17	<0.001
LDH (U/L)	230.39 ± 37.45	198.17 ± 25.87	-7.08	<0.001

Values are expressed as mean ± standard deviation (SD). Independent sample t-test applied. $p < 0.05$ considered statistically significant.

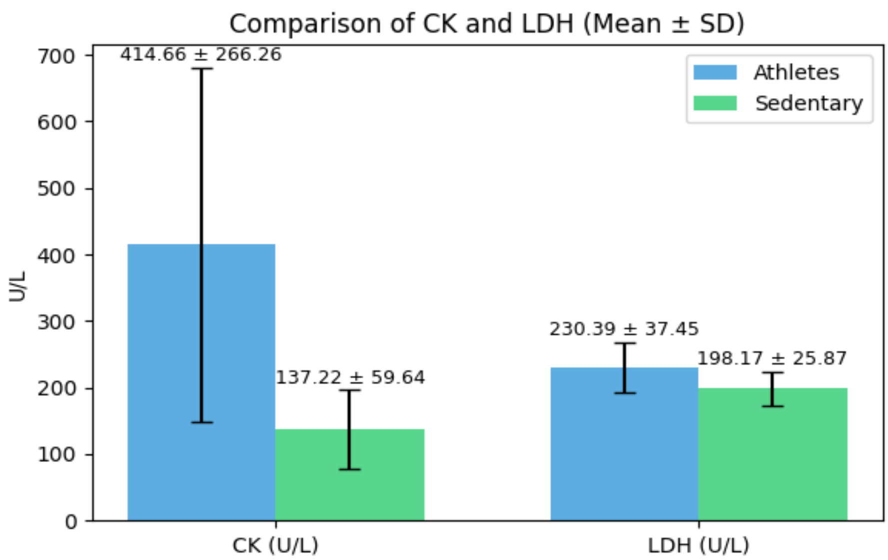

Figure5: Serum CK and LDH levels in Athletes and Sedentary Individuals;
Bar graph comparing CK and LDH levels between Athletes and Sedentary groups, presented as mean ± SD.

Association of CK and LDH with training hours, and frequency among Athletes

Correlation analysis among athletes showed no significant association between CK levels and training hours per day (r = 0.11, p = 0.298), or training frequency per week (r = -0.09, p = 0.358). Likewise, LDH levels did not show significant correlation with training hours (r = 0.01, p = 0.943), or training frequency (r = -0.08, p = 0.415) (Table 5).

Table 5. Correlation of association of CK and LDH with training hours, and frequency among Athletes

Parameters	Training Hours	Training Frequency (r, p)
CK (U/L)	0.11, (0.298)	-0.09, (0.358)
LDH (U/L)	0.01 (0.943)	-0.08 (0.415)

Values are expressed as correlation coefficient (r) and p-value. Pearson correlation analysis was applied. A p-value < 0.05 was considered statistically significant.

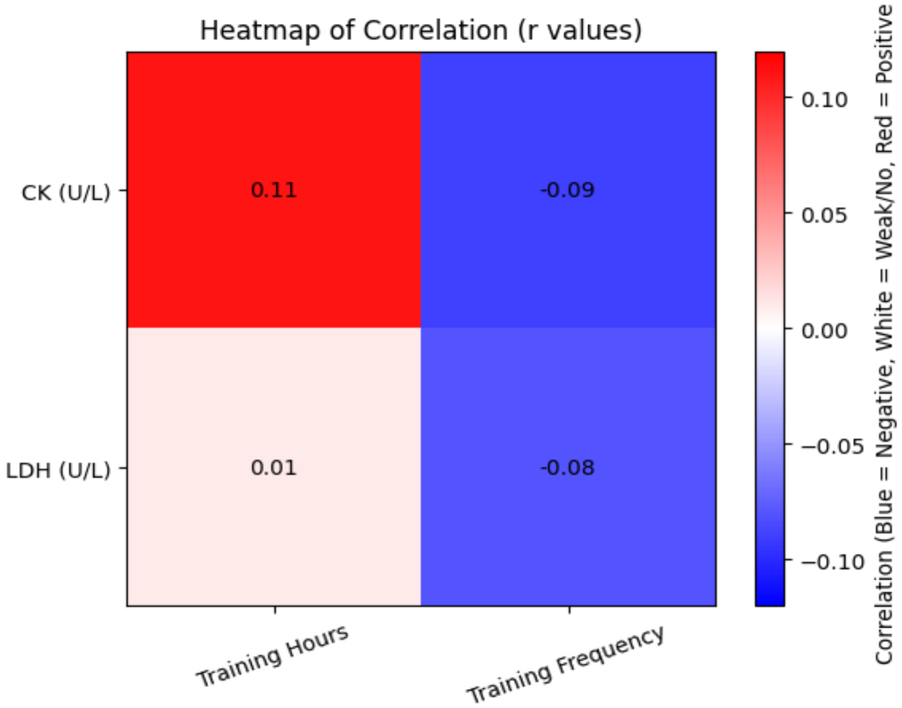

Figure 6: Heatmap showing correlation between muscle enzymes and training variables

Association of Creatine Kinase with LDH among Athletes and Sedentary Individuals

No significant correlation was observed between CK and LDH levels in either athletes (r = 0.10, p = 0.323) or sedentary individuals (r = 0.10, p = 0.334) (Table 6).

Table 6. Association of Creatine Kinase with LDH among Athletes and Sedentary Individuals

Parameters	Athletes (r, p)	Sedentary(r, p)
CK v/s LDH	0.10, (0.323)	0.10, (0.334)

Values are expressed as correlation coefficient (r) and p-value. Pearson correlation analysis was applied. A p-value < 0.05 was considered statistically significant.

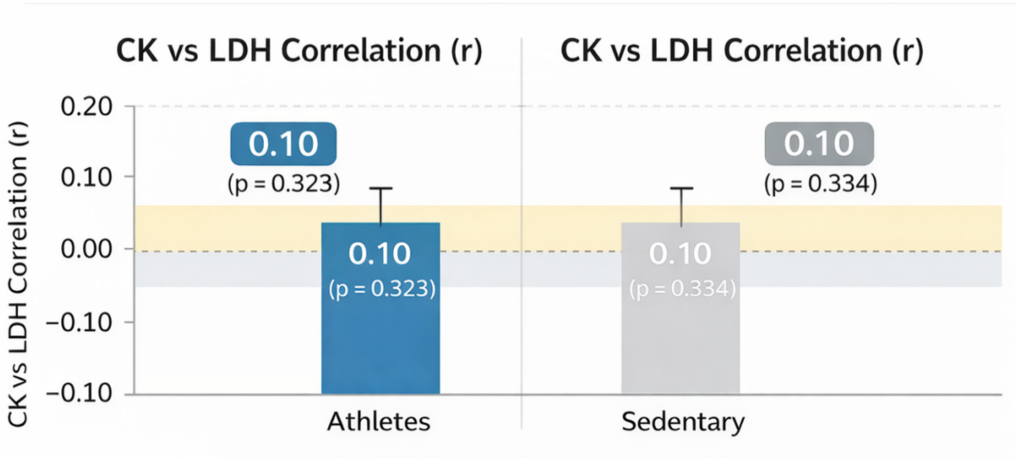

Figure 7: Correlation of serum Creatine Kinase with Lactate Dehydrogenase in Athletes and Sedentary Individuals

DISCUSSION

The present study evaluated exercise-associated alterations in CK and LDH among athletes and sedentary individuals. The findings demonstrated significantly higher CK and LDH levels in athletes compared to sedentary individuals, indicating a clear association between regular physical activity and increased muscle enzyme release. Both sedentary and athletic groups in the present study demonstrated a comparable sex distribution (60% males and 40% females), thereby minimizing potential sex-related bias in physiological and lifestyle outcomes. Athletes exhibited markedly better lifestyle practices, with a higher proportion adhering to a structured diet (64%) compared to sedentary individuals (23%), **Gough (2025)** supporting evidence that engagement in organized physical training is associated with improved nutritional behavior [9]. Similarly, supplement use was more prevalent among athletes (48%) than sedentary participants (9%), reflecting common strategies adopted to enhance recovery and performance in physically active populations **Gough (2025)** [9]. In contrast, adequate hydration was observed more frequently among sedentary individuals (84%) than athletes (71%), with a higher proportion of athletes showing mild dehydration (29%), likely attributable to increased fluid loss during prolonged training sessions. This finding is consistent with recent observations that athletes may underestimate hydration requirements despite awareness of its importance [2] . Furthermore, athletes demonstrated significantly lower body weight and body mass index compared to sedentary individuals, indicating favorable body composition associated with regular physical activity. Comparable findings have been reported by **Parmar et al. (2025),** who observed lower body fat percentage and higher lean body mass and metabolic rate among physically active individuals, despite no significant differences in BMI, highlighting the limitation of BMI as a sole indicator of body composition [10]. The elevated CK levels observed in athletes are consistent with the established role of CK as a sensitive marker of skeletal muscle membrane disruption following repeated mechanical stress. Similar findings have been reported by **Brancaccio et al. (2007)** [11] and **Radišić Biljak et al. (2025)** who demonstrated that trained individuals exhibit higher baseline CK levels due to chronic adaptation to exercise-induced microtrauma [12]. In the present study, the magnitude of CK elevation in athletes suggests ongoing muscle remodeling rather than pathological damage, which is in line with physiological adaptation mechanisms described in endurance and resistance training. LDH levels were also significantly higher among athletes, reflecting increased metabolic turnover and reliance on anaerobic glycolysis during physical activity [13]. Comparable observations have been reported by **Liang et al. (2016)** who highlighted that LDH elevation may indicate metabolic stress rather than structural muscle injury [6]. The relatively lower variability of LDH compared to CK in the present study further supports its role as a more stable marker of metabolic adaptation. No significant correlation was observed between CK or LDH levels and frequency, or daily training hours among athletes, suggesting that these biomarkers may reflect acute physiological responses rather than cumulative training exposure. This observation is consistent with **Brancaccio et al. (2007); Reichel et al. (2020)** reports indicating that variability in CK levels is influenced more by exercise intensity and individual susceptibility than by training duration alone [11,14]. The lack of association in the present study may also reflect adaptive mechanisms in trained individuals, leading to reduced enzyme leakage with repeated exposure to physical stress. Additionally, no significant relationship was found between CK and LDH levels in either sedentary or athletic groups, indicating that these biomarkers likely represent distinct physiological processes, with CK reflecting structural muscle damage and LDH representing metabolic stress. Thus, the data reinforce the interpretation that CK and LDH serve as markers of transient muscle stress rather than reliable indicators of chronic training load, and their elevations should be understood in the context of acute physiological responses rather than sport discipline.

LIMITATIONS

The intensity of exercise, timing of sample collection relative to physical activity, and recovery status were not standardized, which may have influenced enzyme levels. Additionally, the cross-sectional design limits the ability to establish causal relationships. Despite these limitations, the study provides useful insights into exercise-related biochemical adaptations in young adults.

CONCLUSION

The present study highlights the significant influence of physical activity on biochemical and physiological parameters. Athletes exhibited markedly higher levels of serum CK and LDH compared to sedentary individuals, reflecting exercise-induced muscle adaptation rather than pathological changes. Both groups were comparable in terms of age and gender, ensuring the validity of the observed differences. Sedentary individuals showed significantly higher body weight and BMI, indicating a less favourable metabolic profile, whereas athletes demonstrated healthier lifestyle patterns. Despite elevated enzyme levels in athletes, no significant correlation was found with training duration or frequency, suggesting that these responses are influenced by individual variability rather than training load alone. Additionally, the absence of correlation between CK and LDH indicates that these biomarkers act independently. Overall, the findings emphasize that elevated muscle enzymes in athletes should be interpreted as physiological adaptations, and clinical evaluation must consider an individual's physical activity status to avoid misinterpretation.

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