RESEARCH ARTICLE

Magnitude of Biochemical Differences in Muscle and Renal Markers Between Athletes and Sedentary Individuals: An Effect Size Approach

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ABSTRACT

Regular physical activity induces significant biochemical adaptations affecting both muscle metabolism and renal function. This study aimed to evaluate the magnitude of differences in muscle and renal biomarkers between athletes and sedentary individuals using effect size (Cohen's d) analysis. A total of 200 apparently healthy participants aged 18–30 years were included, comprising athletes (n=100) and sedentary individuals (n=100). Serum creatine kinase (CK), lactate dehydrogenase (LDH), creatinine, creatinine clearance, and uric acid were estimated using standard biochemical methods. Effect size analysis demonstrated a very large effect for CK (d = 1.39) and a large effect for LDH (d = 1.00), indicating substantial exercise-induced muscle stress. Creatinine clearance also showed a large effect (d = 0.86), while serum creatinine (d = 0.46) and uric acid (d = 0.39) exhibited moderate and small-to-moderate effects, respectively. These findings suggest that muscle-derived enzymes show the most pronounced differences between athletes and sedentary individuals, whereas renal parameters reflect physiological adaptations rather than pathological changes.

Keywords: Creatine kinase; Lactate dehydrogenase; Effect size; Cohen's d; Athletes; Renal biomarkers; Exercise physiology

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Introduction

Physical activity is a key determinant of metabolic and physiological homeostasis, exerting significant effects on multiple organ systems, particularly skeletal muscle and renal function. Regular exercise induces both acute and chronic biochemical adaptations that enhance functional capacity and maintain systemic balance [1,2].

Creatine kinase (CK) and lactate dehydrogenase (LDH) are well-established biomarkers of muscle integrity and metabolic activity. CK plays a central role in cellular energy metabolism by catalyzing the reversible transfer of phosphate between creatine and adenosine triphosphate (ATP), while LDH is involved in anaerobic glycolysis, facilitating the conversion of pyruvate to lactate [3,4]. Elevated levels of these enzymes are frequently observed following physical exertion and are indicative of muscle membrane disruption, increased permeability, and metabolic stress [5]. In trained athletes, persistently elevated baseline levels may reflect physiological adaptation to repeated training stimuli rather than pathological muscle injury [6]. In addition to muscle-derived enzymes, renal function markers such as serum creatinine, creatinine clearance, and uric acid are also influenced by physical activity. Serum creatinine is closely associated with muscle mass and turnover, and its levels may be elevated in physically active individuals due to increased muscle metabolism [7]. Creatinine clearance, an indirect measure of glomerular

filtration rate (GFR), may vary due to exercise-induced hemodynamic changes [8]. Similarly, uric acid levels can increase as a result of enhanced purine metabolism and oxidative stress during intense physical activity [9].

Although several studies have demonstrated statistically significant differences in these biochemical parameters between athletes and sedentary individuals, reliance solely on p-values may not adequately reflect the magnitude or clinical importance of these differences. Effect size analysis, particularly Cohen's d, provides a more robust measure by quantifying the extent of differences independent of sample size [10]. Therefore, the present study was designed to evaluate muscle and renal biochemical parameters in athletes and sedentary individuals and to determine the magnitude of these differences using effect size analysis. This approach aims to improve the interpretation of biochemical markers in physically active populations and to distinguish physiological adaptations from pathological alterations.

Material and Methods

The present study was designed as a comparative cross-sectional observational study to evaluate and compare muscle and renal biochemical parameters among athletes and sedentary individuals, with particular emphasis on quantifying the magnitude of differences using effect size analysis (Cohen's d). The study was conducted at the School of Health Sciences, Chhatrapati Shahu Ji Maharaj University (C.S.J.M.), Kanpur, India, in collaboration with the Department of Physical Education of the same institution. A total of 200 apparently healthy participants aged between 18 and 30 years were enrolled according to predefined 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 per day and actively participating in competitive or organized sports for at least 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 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. Venous blood samples (5 mL) were collected under aseptic conditions following an overnight fast of 8–10 hours, allowed to clot, and centrifuged at 3000 rpm for 10 minutes to separate serum, which was analyzed immediately or stored at 2–8°C until analysis. Serum creatine kinase (CK) and lactate dehydrogenase (LDH) were estimated using the IFCC-recommended UV kinetic method with ERBA diagnostic kits, while serum creatinine and uric acid were measured using the Jaffe's kinetic and uricase-peroxidase enzymatic methods, respectively; creatinine clearance was calculated using the Cockcroft–Gault formula. Statistical analysis was performed using SPSS version 26.0, with continuous variables expressed as mean ± standard deviation However, the primary analytical focus of the study was the estimation of effect size using Cohen's d, calculated as the difference between group means divided by the pooled standard deviation, to provide a standardized measure of the magnitude of differences independent of sample size; effect sizes were interpreted as small (0.2), moderate (0.5), and large (≥0.8), thereby allowing a more meaningful assessment of the physiological impact of exercise on biochemical parameters beyond conventional statistical significance.

Results

Sex distribution of participants

The study included a total of 200 participants, equally allocated to the athlete (n = 100) and sedentary (n = 100) groups. The gender composition was consistent across both groups, with males representing 60% (n = 60) and females 40% (n = 40). This uniform distribution indicates that both groups were comparable with respect to sex, minimizing potential gender-related bias in the analysis.

Table 1: Sex-wise distribution of participants

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

Data are presented as number (n) and percentage (%).

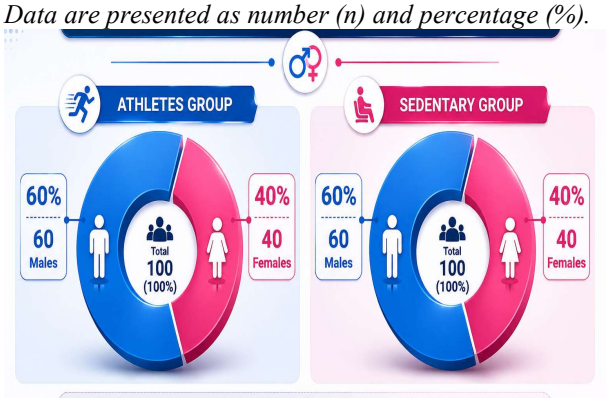

Figure 1: *Distribution of participants according to sex in Athletes and Sedentary groups; Both groups showed similar gender distribution (60% males, 40% females)*

Comparison of baseline and lifestyle characteristics among study participants

The baseline and lifestyle characteristics of the study population are summarized in Table 2. There was no significant difference in age (23.92 ± 3.10 vs. 23.86 ± 2.82 years; p = 0.886) or height (165.75 ± 8.89 vs. 164.82 ± 9.07 cm; p = 0.468) between athletes and sedentary individuals, indicating comparability between the groups. However, athletes had significantly lower body weight (61.94 ± 8.89 kg vs. 68.69 ± 10.21 kg; p < 0.001)

and body mass index (BMI) (22.48 ± 2.09 kg/m² vs. 25.19 ± 2.33 kg/m²; $p < 0.001$) compared to sedentary individuals. With respect to lifestyle characteristics, a higher proportion of athletes reported adherence to a specific diet (64% vs. 23%), whereas the majority of sedentary individuals did not follow any specific dietary pattern (77% vs. 36%). Similarly, supplement use was more prevalent among athletes (48%) compared to sedentary participants (9%), with most sedentary individuals (91%) reporting no supplement intake. In terms of hydration status, adequate hydration was observed in a greater proportion of sedentary individuals (84%) compared to athletes (71%), while mild dehydration was more common among athletes (29% vs. 16%). Overall, these findings indicate that although demographic characteristics were comparable between the groups, athletes demonstrated significantly healthier anthropometric profiles and distinct lifestyle patterns compared to sedentary individuals.

Table 2. Baseline, Lifestyle, and Hydration characteristics of study participants

Parameter	Category	Athletes (n = 100)	Sedentary (n = 100)	t-value	p-value
Age (years)	—	23.92 ± 3.10	23.86 ± 2.82	-0.14	0.886
Height (cm)	—	165.75 ± 8.89	164.82 ± 9.07	-0.73	0.468
Weight (kg)	—	61.94 ± 8.89	68.69 ± 10.21	4.99	<0.001 *
BMI (kg/m²)	—	22.48 ± 2.09	25.19 ± 2.33	8.67	<0.001 *
Specific Diet	Yes	64 (64%)	23 (23%)	—	—
	No	36 (36%)	77 (77%)	—	—
Supplement Use	Yes	48 (48%)	9 (9%)	—	—
	No	52 (52%)	91 (91%)	—	—
Hydration Status	Adequate	71 (71%)	84 (84%)	—	—
	Mild dehydration	29 (29%)	16 (16%)	—	—

Effect size (Cohen's d) analysis

Effect size analysis using Cohen's d was performed to quantify the magnitude of differences in biochemical parameters between athletes and sedentary individuals, independent of sample size. The analysis revealed considerable variability in effect sizes across the studied biomarkers. Creatine kinase (CK) demonstrated the largest effect size (d = 1.39), indicating a very large and clinically meaningful difference between the two groups. Lactate dehydrogenase (LDH) also exhibited a large effect size (d = 1.00), reflecting a substantial difference in metabolic enzyme activity. Creatinine clearance showed a large effect (d = 0.86), suggesting significant physiological variation in renal function between athletes and sedentary individuals. In contrast, serum creatinine demonstrated a moderate effect size (d = 0.46), indicating a less pronounced but still notable difference. Serum uric acid exhibited a small-to-moderate effect size (d = 0.39), suggesting relatively minor variation compared to other parameters. Overall, these findings indicate that muscle-derived enzymes, particularly CK and LDH, exhibit the most substantial differences between groups, whereas renal parameters demonstrate comparatively moderate changes.

Table 3: Effect size (Cohen's d) for comparison between Athletes and Sedentary individuals

Parameter	Athletes (Mean ± SD)	Sedentary (Mean ± SD)	Cohen's d	Interpretation
Creatine Kinase	414.66 ± 266.26	137.22 ± 59.64	1.39	Very Large
Lactate Dehydrogenase	230.39 ± 37.45	198.17 ± 25.87	1.00	Large
Serum Creatinine	0.89 ± 0.13	0.83 ± 0.13	0.46	Moderate
Creatinine Clearance	105.89 ± 18.95	122.74 ± 20.57	0.86	Large
Serum Uric Acid	5.28 ± 1.05	4.89 ± 0.95	0.39	Small–Moderate

Graphical interpretation

The bar chart clearly shows higher mean values of CK and LDH in athletes, while creatinine clearance is lower compared to sedentary individuals. The differences are visually most prominent for CK, supporting its very large effect size.

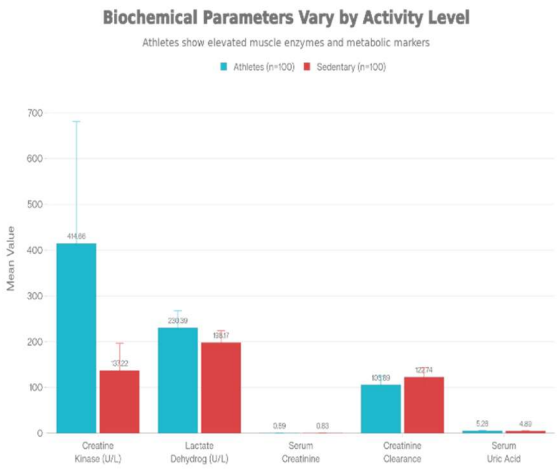

Figure 2: Mean ± SD values of biochemical parameters in Athletes and Sedentary groups

The forest plot illustrates the magnitude of effect sizes (Cohen's *d*) for biochemical parameters comparing Athletes and Sedentary individuals

The forest plot illustrates the magnitude of effect sizes (Cohen's *d*) for biochemical parameters comparing athletes and sedentary individuals. Creatine kinase demonstrated the largest effect size, clearly exceeding the threshold for a very large effect, indicating a pronounced difference in muscle damage between the two groups. Lactate dehydrogenase and creatinine clearance also showed large effect sizes, confirming substantial physiological differences related to muscle metabolism and renal handling. In contrast, serum creatinine and serum uric acid exhibited small-to-moderate effect sizes, reflecting comparatively lesser but still meaningful differences. Overall, the forest plot visually confirms that muscle-derived enzymes exhibit the strongest and most clinically relevant differences between athletes and sedentary individuals.

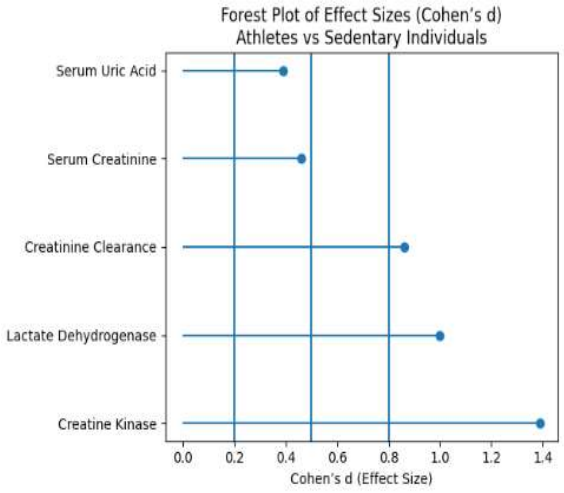

Figure 3: Forest plot of Effect Sizes (Cohen's d) for biochemical parameters

Discussion

The present analysis highlights that muscle-derived enzymes serve as the most sensitive indicators of exercise-induced physiological adaptation. The very large effect size observed for creatine kinase (CK) reflects substantial muscle membrane disruption and increased enzyme leakage associated with repeated physical exertion, a finding consistent with previous studies that identify CK as a reliable marker of exercise-induced muscle damage (Brancaccio et al., 2007; Baird et al., 2012) [5,6]. Similarly, lactate dehydrogenase (LDH) demonstrated a large effect size, indicating enhanced anaerobic metabolism and increased muscle turnover in athletes, which aligns with established evidence on metabolic adaptations to sustained physical activity (Powers and Howley, 2018) [1]. Creatinine clearance also exhibited a large effect; however, this finding is more appropriately attributed to physiological adaptations rather than impaired renal function, as exercise is known to influence renal hemodynamics, increase muscle mass, and elevate creatinine production (Banfi and Del Fabbro, 2006; Poortmans, 1984) [7,8]. In contrast, serum creatinine showed only a moderate effect size, supporting the notion that its elevation in athletes primarily reflects increased muscle metabolism rather than pathological changes. Serum uric acid demonstrated the smallest effect size, suggesting a relatively limited contribution of purine metabolism and oxidative stress in distinguishing athletes from sedentary individuals (Lippi et al., 2008) [9]. Overall, these findings emphasize that CK and LDH are dominant markers of exercise-induced stress, while renal parameters predominantly reflect physiological adaptation rather than dysfunction. Furthermore, the application of effect size analysis provides a more meaningful interpretation of these differences, offering deeper insight into their clinical and physiological relevance beyond conventional reliance on p-values alone (Cohen, 1988) [10].

Conclusion

Effect size analysis revealed that biochemical differences between athletes and sedentary individuals are most pronounced in muscle-derived enzymes, particularly CK and LDH. Renal parameters showed moderate to large effects but are best interpreted as physiological adaptations rather than indicators of disease. These findings underscore the importance of considering physical activity status when interpreting biochemical markers in clinical practice.

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