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Sapna Goswami
Ph.D. Scholar, Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India

Dr. Deepak Sharma
H.O.D Exercise physiology, Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India

Corresponding Author:
Sapna Goswami
Ph.D. Scholar, Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India

A review effect of training on metabolic hormonal and infllamatory parameters of boxers

Sapna Goswami and Dr. Deepak Sharma

Abstract
The research articles focus on the biochemical variables in boxing and combat sports, exploring the impact of training and competition on metabolic, hormonal, and inflammatory parameters in athletes. The studies involve elite male boxers and athletes from various combat sports evaluating metabolic hormones, inflammatory markers, tissue damage indicators, and oxidative stress markers before and after matches or training. The research findings indicate that boxing and combat sports lead to significant elevations in glucose, lactate metabolic hormones, inflammatory markers, and markers of muscle damage. Additionally, the studies reveal that combat exercise increases levels of metabolic hormones and enzymes associated with muscle damage, suggesting potential signs of traumatic injury. However, the impact of combat sports on anabolic hormones, lipid profiles, kidney function markers, and minerals is found to be non-significant. The articles emphasize the importance of understanding the metabolic alterations during combat sports to optimize athletes' performance enhancement while also underlining the need for further in-depth studies to comprehend the effects of combat sports on biochemical marker.

Keywords: Biochemical marker, training, metabolic hormonal, infllamatory parameters, boxers

Introduction
The body goes through a number of chemical changes as a result of every human activity (Vasudevan *et al*., 2013) [32]. It is therefore possible to conduct physical education and sports training in a more scientific manner as sports biochemistry shows the core of human life activities in sports. Though it is a relatively new field of study, exercise biochemistry is crucial to both theory and practice in human sports (Hausman *et al*., 2001) [10]. The use of biochemical technology in sports can significantly hasten the advancement of sports science, enhance physical well-being, and raise athletes' skill and competitiveness levels (Turgut *et al*., 2017) [31]. A key element of sports science is biochemistry, which aids in the explanation of the chemical and molecular mechanisms behind muscular physiology, exercise-induced stress, and athletic performance (Furrer *et al*., 2023) [8]. It is essential to comprehend these processes in order to maximize training regimens and enhance athletic performance. It gives a detailed explanation of the metabolic processes unique to many sports, offering a useful perspective on the relationship between metabolism and athletic performance (Furrer *et al*., 2023) [8]. The topic is arranged in a unique way according to athletic events to reflect the various demands of athletes. Biochemistry's foundational ideas are well described, removing the need for further biochemistry literature.
Every cell in an athlete's body has to be working at optimal capacity in order for them to perform at the peak of their abilities. The metabolic activity of each biochemical pathway is restricted by nutrient deficits, which may also affect any following responses (Murray & Rosenbloom, 2018) [24]. Performance will be determined by optimal biochemical control, regardless of whether an athlete is trying to break a record or recover from an injury. Even among athletes who compete in the same sport, food analysis cannot predict nutritional status since every athlete has a different biochemistry (Lee *et al*., 2017) [18]. Each sport has unique nutritional demands, and athletes within that sport will have unique requirements as well, depending on factors including age, medical history, nutrient absorption, metabolism, genetic predisposition, and medication use. Even athletes who seem fit and compete well may be vulnerable to injuries or have delayed recovery due to inadequacies.

Accurate supplementing is made possible by laboratory testing, which provides an athlete's health state without prejudice or judgement (Amawi *et al*., 2024) [1].

Boxing is a physically demanding sport that requires intense training and competition. The physical demands of boxing lead to muscle damage, inflammation, and oxidative stress, which can impact performance and long-term health. Understanding the biochemical responses to training in boxers is essential for optimizing performance and preventing injuries (Sumlu *et al*., 2018) [28].

Muscle injury is indicated by training-induced elevations in lactate dehydrogenase (LDH) and creatine kinase (CK). The sensitive indicators of muscle injury, CK and LDH, show disruption of muscle fibres when they are elevated. The study of the chemical reactions that boxers' bodies have to training, exercise, and competition is known as boxer biochemistry. Boxing is a physically demanding activity that causes substantial alterations in the body's biochemistry because to its fast-paced motions, powerful blows, and prolonged physical exertion. Boxers' biochemistry is a dynamic, intricate system that includes a number of physiological processes, such as:

1. Energy metabolism: To perform at their best, boxers need a lot of energy, which is produced by breaking down carbs, lipids, and protein.
2. Muscle physiology: Boxing causes quick contractions and relaxations of the muscles, which alters the makeup of the muscle fibers, the activity of enzymes, and the metabolism.
3. Hormonal responses: The release of several hormones, including as testosterone, cortisol, and adrenaline, is stimulated by boxing. These hormones are essential for controlling energy metabolism, muscular function, and recuperation.
4. Oxidative stress and inflammation: Boxing increases the release of inflammatory markers and reactive oxygen species (ROS), which can harm tissues and reduce performance.
5. Balance of nutrients and electrolytes: Boxers need a sufficient amount of nutrients and electrolytes, such as proteins, carbs, lipids, salt, potassium, and magnesium, to sustain optimal physiological function. It's critical to comprehend boxers' biochemistry in order to maximise performance, avoid injuries, and expedite recuperation. Through an examination of the biochemical reactions to boxing, trainers, coaches, and players may create plans to improve power, speed, endurance, and overall performance.

Among the important biological indicators that boxers should be aware: Fatigue and anaerobic metabolism are indicated by lactate. One indicator of inflammation and muscle injury is creatine kinase. One indicator of systemic inflammation is C-reactive protein. Cortisol: A sign of weariness and stress. Testosterone: An indicator of muscle repair and development. In order to maximise performance and succeed in the sport, players and coaches may create individualised training regimens, dietary plans, and recuperation techniques by keeping an eye on these indicators and comprehending the biochemical reactions to boxing.

Inflammatory response significant increases in C-reactive protein (CRP), a marker of chronic inflammation, are also brought on by training. CRP is an accurate indicator of Elevation of CRP, a sensitive indicator of inflammation, denotes continuous tissue injury and healing. Training raises oxidative stress indicators such as malondialdehyde (MDA) and F2-isoprostanes. These alterations point to cellular damage and lipsid peroxidation. Training has an impact on energy metabolism by raising anaerobic metabolism indicators like lactate and pyruvate and lowering aerobic metabolism markers like citrate and succinate. Hormonal reactions to training might also include cortisol rises and testosterone falls. These modifications could have an impact on performance and long-term health.

Methodology

Studies have used various methodologies to assess biochemical changes in boxers, including blood sampling, muscle biopsies, and urinary analysis. Training programs have varied in intensity, frequency, and duration. For studies to be considered for the review, they must meet the criteria as follows. The Studies included competitive bouts, sparring, or simulated amateur boxing activities which include investigations of competitive bouts, endocrine, biochemical, or performance responses; and the subjects were carded senior amateur boxers within their respective governing bodies. A peer-reviewed English-language periodical may publish research in full-text format. Twenty duplicate studies were eliminated from the total of 78 papers that met the search parameters and were deemed suitable for additional examination (Figure 1). After 58 papers' titles and abstracts were first evaluated for relevancy, 39 more relevant manuscripts were subjected to a full-text examination to determine their eligibility in light of the qualification requirement. Studies that included any of the following were not accepted. If people trained in mixed-combat disciplines, the use of incorrect simulation activity profiles (e.g., punch maximum per round), physical or argogenic intervention or case studies. One hundred and twenty-five studies from 1985 to 2021 were selected for the study (Figure 1). Twenty-one more of the twenty-five materials that were included were selected for meta-analysis. The article describes the physiological responses to boxing-specific exercises found in the literature, which are shown in Table 1.

Results

Six studies were analysed Blood Lactate values after pre–post boxing-specific activity by Davis, Wittekind, signifies there were significant ($P < 0.001$) rise in peak blood lactate post-boxing-specific activity after comparing to baseline. Substantial heterogeneity was shown at the level of $p<0.001$. Kaynar in 2019 [13], three reports were compared cortisol levels pre and post boxing specific activity and found significant (P=0.002) improvement in cortisol post boxing specific activity, when compared to the baseline and heterogeneity was observed at 64% and P=0.03. according to Graham (2011), Kaynar, (2019) [13], Muscle damage and inflammation levels of players was checked with pre and post boxing-specific activity which was quantified by CK, Mb, ALT and AST levels. It was found that there were optimal improvement in Creatine Kinase values (P=0.0006) and Mb ($p<0.0001$), and non-significant increases in both ALT (P=0.43) and AST (P=0.07) post boxing-specific activity, compared to baseline and no heterogeneity (P=0.91), low heterogeneity (I2=30%, P=0.24) and considerable heterogeneity ($p<0.0001$, P=0.006) were found for CK, Mb, ALT and AST, respectively. Two studies were analyses by Loturco in 2021, Nikolaidis in 2017 counter-movement jump (CMJ) performance pre–post boxing specific were found non-significant increases in CMJ height (P=0.21) post boxing specific activity after contrast to baseline. There was No heterogeneity in data.

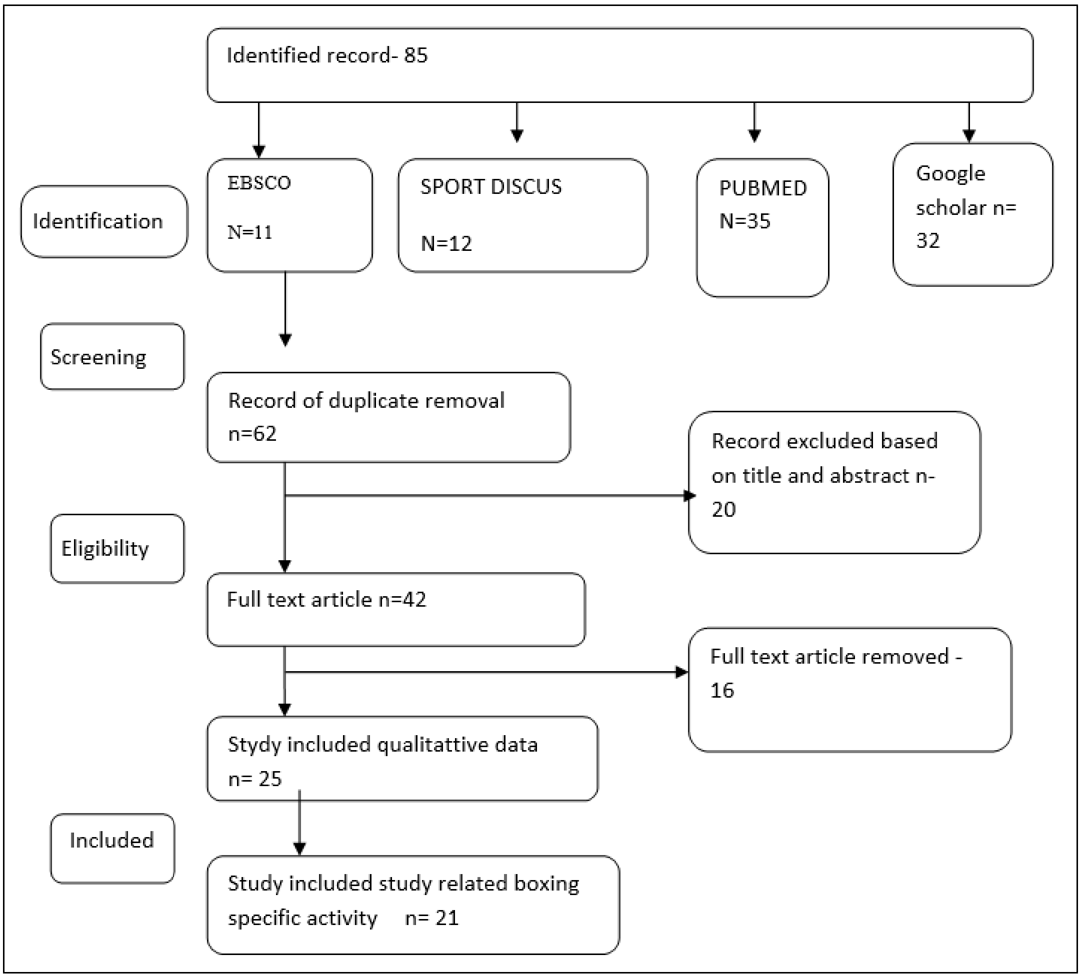

Fig 1: Flowchart of Study Selection Process

Discussion

A research on the hormonal, inflammatory, and metabolic states of male professional boxers was carried out by Yakup. In order to know the value of plasma parameters, venous blood samples were collected before and after the sparing from twenty fighters with more than five years of boxing experience. The results demonstrated that during a nine-minute boxing fight, markers of oxidative stress, markers of inflammation, markers of muscle injury, and levels of glucose and lactate were all considerably raised. The plasma levels of anabolic hormone (IGF-1), androgenic hormone (free and total testosterone), lipids, renal function indicators (creatinine and urea), and minerals did not substantially alter, however the total oxidant status (TOS) may decrease. Boxing athletes' pre- and post-training metabolic factors were studied by Nurcan Kilic Baygutalp (2016). Twenty professional boxers participated in the study, and measurements were taken of a number of biochemical markers prior to and six minutes following the fight. Combat activity was found to significantly reduce blood levels of IGF and elevate levels of ACTH, AST, GGT, ALT, and GH. The culprit, according to the researchers, is muscle injury, and training significantly increased GH levels, which is a normal response to exercise-induced stress looked at how a boxing bout training model affect enzymes of lever and muscular injuries of puglists in the short term. The research had 14 interested boxers and consisted of warm-up 30 minutes, major portion and cool-down of 15 minutes workouts. Venous blood samples were taken from the study group both before and after the sparring session. The CK and LDH levels, as well as enzyme activities including AST, ALT, and GGT, were spectrophotometrically analysed using the Beckman Coulter AU 5800 auto analyzer (Kaynar, 2019) [13]. Muhammad Fatih Bilici (2019) examined the effects of acute boxing bout training on biochemical markers in male boxers who compete at an elite level. There were twenty-two male top boxers in excellent health that made up the national squad. Before and throughout the sub-region sparring session, blood samples were taken. The best boxers' levels of direct bilirubin, total bilirubin, and high-density lipoprotein cholesterol (HDL) decreased statistically significantly following the sparring session assessed the physiological and biochemical responses of the top Egyptian fighters to boxing training. Seventeen elite male Egyptian boxers, aged 18 to 23, who were registered members of the Egyptian boxing organization participated in the study (El-Ashker & Nasr, n.d.). The body's processes and metabolism were measured prior to and during the boxing training regimen. The results demonstrated that boxing exercises were associated with significant reductions in blood lactate (BL) concentration, respiratory exchange ratio (RER) values, resting heart rate (HRrest), recovery heart rate after one minute (RHR1st), recovery heart rate after two minutes (RHR2nd), and recovery heart rate after three minutes (RHR3rd). However, they were linked to significant increases in peak heart rate (HRPeak), relative and absolute VO2Max, Creatine Kinase (CK), and Lactate Dehydrogenase (LDH) values (El-Ashker & Nasr, n.d.). In summary, comprehending the metabolic changes that take place during boxing fights can provide athletes important information on how to maximise their performance. To ascertain the possible impacts of boxing training on the physiological and biochemical elements of the body, more investigation is required. In a

2010 research, Ashok Kumar Gosho focused on lab-based evaluation to investigate amateur boxers' physiological responses to different activities in the ring. In 2X4 simulated rounds, the boxers' mean VO2 peaks were 56.3, 57.6, 57.8, and 59.3 ml/kg/min, whereas their mean VO2max on the treadmill was 59.7±4.9 ml/kg/min. The concentration of '/blood lactate (13.6 mMol/L) and average heart beat (192 bpm) were found to be higher than those in the majority of intermittent team activities (Ghosh, 2010) [9]. Coswig (2016) sought to examine how 25 male professional mixed martial artists' bodies responded to sparring and formal mixed martial arts competitions. In both cases, blood samples were obtained both before and after the matches. Two-way analysis of variance was used to compare the dependent parametric variables. The individuals had trained for 39.4±25 months, were 1.74±0.05 m, 80±10 kg, and 26.5±5 years old. The training groups practiced basketball for two hours, five days a week, for eight weeks. Looked at the effects of training on important physiological and biochemical characteristics in Indian football players of various ages. Of the 120 football players, thirty were divided into four groups: senior (SR), under-16 (U16), under-19 (U19), and under-23 (U23) where the training sessions were subdivided into two periods: the four-week Competitive Phase (CP) and the eight-week Preparatory Phase (PP). In football players under the age of 19, investigated the training effect on particular morphological, physiological, and biochemical character of players. For the study, a total of 30 male Indian soccer players between the ages of 16 and 18.99 were enlisted. There were five days a week with four hours of instruction each. Karaman *et al*. (2021) [12] investigated the ways in which lipid levels, physical conditions, individual characteristics, and duration and intensity of exercise might influence the way in which training and exercise impact biochemical indicators. The study examined the effects of a single competitive training session on liver enzyme levels and muscle injuries in male university students who practiced taekwondo and wrestling (Karaman *et al*., 2021) [12]. In order to find out how exercise influenced basketball players' levels of creatinine, urea, and electrolyte balance, Kocahan (2021) [17] performed a research (Kocahan *et al*., 2021) [17]. According to Manna *et al*. (2016) [23], the players' anaerobic power, back and grip strength, serum urea, serum uric acid, and HDLC level significantly improved after training, while their recovery heart rate, hemoglobin, total cholesterol, and triglyceride levels significantly decreased. The players' height, body mass and LBM, maximum heart rate (HRmax), VO2max, and LDLC level, however, did not differ much (Manna *et al*., 2016) [23]. During a 12-day altitude training camp, studied the morning biochemical blood parameters of female judo players. The initial few days of training were less difficult than regular retraining at sea level, according to a research on elite female judo players. The first night at altitude was spent with lower amounts of G, CK, and U than the subsequent days. On the first day of camp and during the whole seven-day observation period, G and CK displayed noteworthy correlations. On day one and throughout the whole period, there was a link between baseline plasma CK and body mass (Brancaccio *et al*., 2010) [3].

The long-term benefits of regular physical exercise on biochemical markers, body composition, and motor function were studied by Rodrigues Neto (2015) on women involved in the family health plan. Twenty-one women, age's 49±10 years, were divided into two groups for the research. For 24 weeks, the experimental group (EG=14) had a planned fitness programme that included walking, water aerobics, and gym visits three times a week. The control group (C=7) got no assistance. Biochemistry, body composition, and motor function were all studied. The findings revealed that for EG, there was a notable increase in HDL and a large decrease in triglycerides, but for GC, there was a considerable increase in triglycerides and VLDL. There was no variation in body composition across the groups (Neto *et al*., 2015) [25]. The study focuses on how different physiological and biochemical characteristics of athletes are affected by physical exercise. It contains research done on Olympic Greco-Roman wrestlers, who underwent three different assessments, both prior to and during their training sessions. The blood glucose levels were much lower after exercise, and the total leukocyte, lymphocyte, and neutrophil levels were significantly greater after training than they were before. Nevertheless, there was no appreciable change in the hematologic or biochemical indices over the six-month training period. myoglobin and CK. After shadow boxing, the blood levels of these two later compounds increased (Cardoso Saldaña *et al*., 1995) [4]. In strength sports, lipid levels were more in line with normal.

The study concludes by emphasising the value of physical training in enhancing metabolic markers, motor function, and general health. To fully comprehend how training affects an athlete's general health and performance, more study is required.

With an emphasis on the function of muscular lactate levels (BLa) and anaerobic glycolysis in actual competitive fights, the study looks at the physiological reactions of boxers during competitive fights. The findings demonstrate that sparring, with BLa values present in some situations, partially imitates the demands of competitiveness (Khanna & Manna, 2006) [14]. Comparing the pre-post change to competitive bouts, it was, however, less overall. Simulations particular to boxing elicit a robust physiological response that is weakened, perhaps as a result of the reduced stress response. Hormonal responses to amateur boxing are also investigated in this study. Cortisol, adrenaline, noradrenaline, and HGH (human growth hormone) were shown to rise moderately to extremely substantially in a previous investigation of the hormonal response to fighting, but not boxing (Finlay *et al*., 2022) [7]. Cortisol, a steroid hormone secreted by the adrenal cortex through the HPA, was the hormone that was tested the most frequently in this research. Large pre-post increases in salivary or blood cortisol were seen when accounting for all boxing-specific modes; post-sparring showed the largest rise (ES=2.09), followed by competition (ES=1.57). The new analysis supports previous research showing a correlation between stressful activities like competitive sports or high-intensity fighting and elevated cortisol concentrations. This would inevitably impact the body's response to competitive environments. Extended increases in cortisol levels might indicate inadequate recovery, overexertion, high levels of psychological or physical stress, or both. Future research on the health and potential overreaching or overtraining status of amateur boxers should assess other hormonal markers in addition to cortisol (Slimani *et al*., 2017) [27]. Compared to the body of knowledge about physiological responses to exercise, research on the endocrine response unique to boxing is still relatively recent. The little research suggests that boxers need a lot of hormones, though. This study also looked at muscular damage and inflammatory responses related to exercises unique to amateur boxing. Practitioners frequently employ CK and Mb as biomarkers to evaluate muscle or metabolic stress. This review found modest (ES=0.65) and substantial

(ES=1.43) pre-post elevations in CK and Mb following boxing-specific exercise. Significant pre-post alterations have also been noted in other commonly used markers of skeletal muscle damage, such as ALT (ES=0.97) and AST (ES=1.37), up to 10 minutes following boxing-specific activity. After semi-contact sparring as compared to full sparring, which involved head hits, boxers' CK levels were found to be lower (Finlay *et al*., 2022) [7]. This might suggest that exposure to more head impacts or blunt force trauma resulted in higher levels of muscle damage. Subsequent research might assess this in a boxing population and differentiate it from more general markers such as CK by utilizing reliable and sensitive head trauma biomarkers such serum neurofilament light chain (NFL). After participating in mixed martial arts (MMA), which has distinct physical and technical requirements akin to boxing, CK concentration may peak 24 hours later. Overall, the study offers insightful information on the physiological reactions of boxers during competitive matches and indicates that more investigation is necessary to fully comprehend these reactions (Donnelly *et al*., 2023) [5]. The study focuses on how muscle damage affects amateur boxers and emphasizes the need of healing methods and increasing attention to measuring biomarkers associated with muscle injury. Pre- and post-competition changes in inflammation and muscle injury may impact athletes' neuromuscular and task-specific performance, possibly resulting in fatigue; however, these studies' findings are based on a small body of research, suggesting that performance is not significantly affected (Mańka-Malara & Mierzwińska-Nastalska, 2022) [19]. Loturco *et al.* research (2021) found that CMJ height and upper-and lower-body power output were stable following a competitive fight found gains in CMJ relative to baseline levels in Greek amateur boxers following a 3×3 simulated boxing match; this suggests that punch force and lower-body strength and power are strongly correlated with punch force, and that the lower extremities significantly contribute to punch technique. Punch force increased 7.7% during the pre-competition phase from the baseline to the third sparring round and remained constant during the boxers' competition phase trials. Over the course of the tournament, there was a glaringly opposite pattern, with the fastest reaction times being recorded in the third round as compared to the first (Ispirlidis *et al*., 2008) [11]. This suggests that punch performance was unaffected by sparring load, even if it may have occasionally resulted in a little delay in response times. Due to the boxers' exposure to extreme strength and power training over the pre-competition period, the researchers hypothesised that the disparities between the two periods may be explained. It is possible, although speculative, that the previous workout's warming up or post-activation performance enhancement (PAPE) effect is the cause. In a 3-by-2-minute punching, professional amateur boxers showed slight increases in punch force using different attention-focused techniques to further support the absence of performance decline.

Studies conducted in 2017 by Thomson and Lamb and in 2018 and 2020 by Finlay *et al.* discovered that during simulated rounds unique to boxing, the outer load, as measured by a tri-axial accelerometer (PlayerLoadTM), tended to rise. The study's finding that there was no influence on performance might also mean that the amateur boxers it examined had received enough training to be competitive in their specific sport. (Thomson & Lamb, 2017) [29].

To sum up, these investigations offer insightful information about the physiological and biochemical impacts of different sports, such hockey, mixed martial arts, and boxing, on players. Coaches who comprehend these elements can produce more efficient courses of action for their sportsmen (Finlay *et al*., 2022; Thomson & Lamb, 2017) [7, 29].

Conclusion

Sports biochemistry reveals how physical activities, such as boxing, induce complex biochemical responses that impact performance and recovery. Understanding these changes, including shifts in muscle damage markers, energy metabolism, and hormonal levels, is crucial for optimizing training and preventing injuries. The biochemical analysis of sports-specific activities allows for personalized training and recovery strategies, ultimately enhancing athletic performance. Continued research is needed to deepen our understanding of these processes and refine approaches to improve athlete health and performance. Accurate biochemical assessment remains essential for tailored interventions in sports training and recovery.

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