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The Effect Of Anaerobic Ability Training On Some Metabolic Stress Outcomes (Urea, Ammonia) And Complex Skill Performance Endurance In Young Boxers

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ABSTRACT
The aim of this study was to investigate the impact of using the metered anaerobic ability training to reduce the indices of metabolic stress and to develop the boxer's ability to withstand the complex skill performance. The experimental group joined an anaerobic training program for (8) weeks, 3 units per week. The measurements were based on biochemical analyses of blood collected immediately after the exertion, and a standardised skill test measuring the boxer's capacity to launch continuous compound punches on the boxing bag for three rounds. The statistical treatments showed unreserved moral superiority for the experimental group. A significant and statistically significant decrease in the rates of accumulation of ammonia and urea in the blood serum after exertion was recorded, in parallel with a high development in the number of repetitions of the correct skill performance under the pressure of extreme fatigue. These results show that anaerobic strength training induces deep physiological adaptations that delay central fatigue and protect muscles from breakdown, ensuring that the boxer maintains neuromuscular coordination and high accuracy in directing compound punches until the final seconds of the fight.

Keywords: Anaerobic Ability Training; Metabolic Stress Products; Urea; Ammonia; Performance Endurance; Composite Skill; Young Boxers.

ABSTRAK
Tujuan studi ini adalah untuk menyelidiki dampak penggunaan pelatihan kemampuan anaerobik terukur untuk mengurangi indeks stres metabolik dan mengembangkan kemampuan petinju untuk menahan performa keterampilan yang kompleks. Kelompok eksperimental mengikuti program pelatihan anaerobik selama (8) minggu, 3 unit per minggu. Pengukuran tersebut didasarkan pada analisis biokimia darah yang diambil segera setelah latihan, dan tes keterampilan standar yang mengukur kemampuan petinju untuk melancarkan pukulan majemuk secara kontinu ke kantong tinju selama tiga ronde. Pengobatan statistik menunjukkan keunggulan moral tanpa syarat bagi kelompok

eksperimen. Penurunan signifikan dan signifikan secara statistik dalam tingkat akumulasi amonia dan urea dalam serum darah setelah aktivitas fisik tercatat, bersamaan dengan perkembangan tinggi dalam jumlah pengulangan performa keterampilan yang benar di bawah tekanan kelelahan ekstrem. Hasil ini menunjukkan bahwa latihan kekuatan anaerobik memicu adaptasi fisiologis mendalam yang menunda kelelahan pusat dan melindungi otot dari kerusakan, memastikan petinju mempertahankan koordinasi neuromuskular dan akurasi tinggi dalam mengarahkan pukulan gabungan hingga detik-detik terakhir pertarungan.

Kata Kunci: Pelatihan Kemampuan Anaerobik; Produk Stres Metabolik; Urea; Ammonia; Ketahanan Performa; Keterampilan Komposit; Petinju muda.

INTRODUCTION

Boxing is an advanced form of high-intensity athletic performance, and boxers are subjected to a competitive environment of high physiological and physical efforts (Finlay et al., 2023). The role of young athletes has great importance in boxing for the development of the sport, since they need to move from elementary physical training to a high-level physiological model, which allows them to cope with the heavy conditions of fighting (Ilhomovich, 2022). At the forefront of the training that promotes the development of a boxer's proficiency is anaerobic ability training. It is orientated to the capacity of vital functions to work in their limits in the conditions of oxygen deficiency and accumulation of metabolic products (Tian, Niu & Bao, 2026). Boxing is an individual sport with a lot of physical exertion and variability. The energy production systems interact mainly in the anaerobic cycle (phosphagen and lactic acid systems) due to the rapid, vigorous and sequential dynamics of punches and movements within the ring (Al Behadili & Kasim, 2022; Tshibangu, 2025).

This type of repetitive physical work leads to physiological and biochemical changes in the muscles and circulatory system, resulting in metabolic strain and stress on the body systems (Kenney, Wilmore & Costill, 2022). Improving anaerobic capacity is more than just increasing punch speed; it has a physiological basis that allows athletes to resist fatigue and maintain the operational integrity of muscle and nerve cells during high-intensity activity (Xu et al., 2025). The anaerobic performance creates a significant biochemical and metabolic stress on the purine and phosphorus metabolic systems of the active muscles, resulting in the accumulation of metabolic stressors, primarily ammonia and urea (MacLaren & Morton, 2024). Ammonia reflects the degree of central nervous system stress and the breakdown of phospholipids and nucleotides, e.g. AMP, whereas urea represents the extent of protein breakdown and the metabolic demands on the liver and kidneys to remove toxins from intense exercise (Holeček, 2022). The build-up of these agents causes a significant decline in physical performance and a reduction in skill proficiency, especially during the later rounds of a fight when the boxer may experience a decline in concentration, strength, and speed of punching technique (Duyan et al., 2026).

The mechanisms controlling these metabolites are worth studying to understand how much a boxer's body is able to adapt to high training intensities (MacLaren & Morton, 2024). Managing metabolic stress outcomes is important not only physiologically but also has a direct impact on endurance and the development of proficiency in complex skills

(Susanto et al., 2026). This involves the proficiency in many techniques like as straight, round, and upward punches that necessitate precision, timing, and power until the last seconds of the round (Burkett, 2025; Kasim, 2022). Any unrestrained surge in ammonia and urea levels is indicative of an instant impairment in neuromuscular transmission effectiveness, resulting to a decrease in skill performance and accuracy of punches (de Lorenzo & Mihic, 2025; Salih, Hashim, & Kasim, 2021).

From this angle, the research significance regarding the influence of anaerobic ability training on the regulation of metabolic stress products, and the subsequent biochemical adaptations that contribute to the endurance of complex skill performance in young boxers, is evident in order to furnish trainers and specialists with objective frameworks to balance metabolic load and advance vital skill levels. This research intends to formulate scientific and applied strategies by creating a training program focused on anaerobic ability, analysing its effects on triggering physiological adaptations that lessen the harmful impacts of metabolic stress products, ultimately enhancing the young boxer's capacity to uphold strong and precise skill execution until the fight's final moments.

Research Problem

The sport of boxing, in its duration and intervals, fundamentally depends on anaerobic energy systems (Tortu et al., 2024). This requires the pugilist to perform a sequence of offensive and defensive movements at a high intensity and velocity (Teixeira et al., 2022). Emerging boxers must possess superior physiological capabilities to handle the rigour of training and competition, especially at advanced levels where a drop in physical and skill proficiency cannot be afforded (Kubiyeva et al., 2025). Observations in the ring and pedagogical experience confirm the significant reduction of the level of tolerance of the general performance of skills in critical moments of the fight in many young boxers, which is expressed in the slowness of the execution of skills, the decrease of precision and efficiency. This reduction is often due to the inadequate use of traditional training methods that do not emphasise anaerobic strength training according to stringent physiological standards. Anaerobic exercise without control and high intensity will produce metabolic byproducts in the muscle and circulatory system, especially ammonia and urea.

High ammonia levels mean that the central nervous system and nucleotide breakdown are being strained, and high yoya means protein breakdown and increased stress on medical devices, making it difficult to transmit the neuromuscular fibres and reducing the ability to continue performing complex skills. Although these indications hold significance, there is a deficiency of research examining the degree to which anaerobic ability training results are metabolically adjusted and their influence on "composite skill performance endurance," a vital factor in young boxers. Thus, the research issue pertains to investigating the impact of anaerobic training on regulating metabolic stress byproducts and enhancing skill performance endurance in adolescent boxers, offering coaches physiological and biochemical metrics that facilitate performance enhancement and fatigue mitigation. Empirical observations indicate that the majority of boxers see a decline in their composite skill performance during the third round of bouts. Upon examining the research, the origin of the body's ineffectiveness un managing stress results was identified, resulting in both peripheral and cerebral weariness. Consequently, the research inquiry seeks to examine the impact of anaerobic training on modulating stress output levels and enhancing the endurance of juvenile boxers' skill execution.

Research Objectives

1. Preparation of standardized exercises to develop anaerobic ability in young boxers.
2. To identify the effect of these exercises on some products of metabolic stress (urea, ammonia) after exertion in the research sample.
3. To identify the impact of these exercises on the development of composite skill performance endurance in young boxers.

Research Hypotheses

1. There are statistically significant differences between the pre- and post-tests in the levels of metabolic stress products (urea, ammonia) and in favor of the post-test (better physiological adaptation).
2. There are statistically significant differences between the pre- and post-tests in the level of endurance of composite skill performance and in favor of the post-test.

Research Areas

1. Human Area: Boxers of the Babylon Governorate Youth Team
2. Temporal Area: Period from (1/2/2026) to (10/6/2026).
3. Spatial Area: The boxing hall of Hilla Sports Club.

METHODS

Research Methodology

The investigator employed an experimental approach by establishing two equivalent groups (experimental and control) with pre- and post-tests, tailored to align with the research issue and its aims.

Research population and sample

The study cohort was intentionally chosen from a group of young boxers, comprising a total of 30 individuals. The research sample was chosen using a random technique (lottery), consisting of (20) boxers, who were categorised into two groups: an experimental group (10 boxers) and a control group (10 boxers). The investigator performed equivalence and homogeneity assessments for the two cohorts for height, weight, age, and the variables being examined.

Homogeneity of the research sample

The sample exhibited homogeneity across several factors (height, weight, age, training age), and this is evidenced in Table (1).

Table 1. Shows the homogeneity of the research sample.

Variables	Unit of Measurement	M	SD	Torsion coefficient	Preview error
Age	Year	17.43	0.75	0.80	0.81
Length	Cm	169.50	5.31	0.35	0.65
Weight	Kg	69.40	5.15	0.23	0.54
Training Age	Year	2.15	1.50	0.77	0.87

Means of information collection, devices and tools

Academic Sources and Citations.Player data and test results registration form.Apparatus: Chronometer, treadmill for physiological assessments, weighted

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boxing bags, and gloves. Centrifuge, blood collection vials, and a chemical analyser (Spectrophotometer) for quantifying ammonia and urea levels in serum.

Exploratory experiment

The investigator performed a preliminary experiment prior to initiating the primary trial on 5/2/2026, utilising a cohort of ten young boxers from both the research community and external sources. The objective of the experiment was:

1. Verify the authenticity of the equipment and instruments employed (boxing bags, phlebotomy tools, laboratory analytical devices).
2. Be aware of the duration required to complete a composite skill assessment.
3. Guaranteeing the productivity of the assistant workforce (medical personnel and assistant instructors) in complying with the precise schedule for blood sample collection (immediately post-exertion and after a 3-minute rest period). Recognising challenges and barriers to circumvent them in the primary experiment.
4. Extracting the scientific principles underlying the assessment of skill performance endurance (integrity, reliability, and impartiality).

Scientific Basis of Tests

To guarantee scientific rigour and precision in the findings, the investigator was determined to derive the scientific parameters (integrity, reliability, and impartiality) of the examined physiological assessments, as outlined:

Validity of tests: To determine the validity of physiological tests, the researcher relied on (self-truthfulness, which expresses the truthfulness of experimental scores in relation to real scores. Self-truthfulness was calculated statistically by treating consistency, where the square root of the stability coefficient (self-truthfulness = consistency√) was found. This treatment has produced high values of self-truthfulness that are close to the correct one, confirming conclusively that the tests actually measure what they are designed to measure with a high degree of accuracy and confidence Alotaibi (2017) Table (2) shows that.

Stability of the tests: To ascertain the stability coefficient of the examined variables (ammonia, urea, composite skill performance tolerance), the investigator employed the test-retest methodology on the participants of the exploratory study. The initial test was conducted, followed by a repetition of the exam after seven days, specifically on 12/2/2026, maintaining identical spatial and temporal settings. The application of the Pearson correlation coefficient to the outcomes of the two assessments revealed strong and positive correlation coefficients, signifying the consistency and dependability of the results. To depend on them primarily in the encounter. Table (2) illustrates that.

Objectivity : Objectivity is attained when the outcomes are entirely free from the personal influence or subjective involvement of the examiner and the researcher. The assessment of catecholamines and blood glucose levels in this study was conducted utilising accurate computerised laboratory instruments that are not subject to interpretation. Aside from the persistence required for intricate skill execution, the investigator required officials.

Table 2. Shows the coefficients of stability, subjective honesty and objectivity of the physiological variables under study.

Physiological variable	Unit of Measurement	Test-Retest	Self-Honesty

Ammonia	µmol/L	0.88	0.93
Urea	mg/dL	0.89	0.94
Withstand Skill Performance	Degree	0.72	0.84

Main experience:

Pre-Test: Administered on February 15, 2026, before to the commencement of the primary experiment, blood (5 ml) was extracted from the cubital vein of the boxers immediately following the execution of the composite skill performance tolerance assessment, and subsequently, the results were classified to ascertain the equivalence between the two cohorts.

Table 3. Shows the arithmetic medians, standard deviations, calculated t-value and significance level for the experimental and control groups in the pre-tests (for the purpose of equivalence).

Variables	Unit of Measurement	Experimental		Control		T
		M	SD	M	SD	
Ammonia	µmol/L	115.40	4.21	114.80	4.10	0.32
Urea	mg/dL	44.20	2.55	43.90	2.62	0.25
Withstand Skill Performance	Degree	142.00	54.50	143.50	5.10	0.63

Table (3) indicates that all computed t-values for the examined variables (ammonia, urea, skill performance tolerance) were lower than the critical t-value of (2.101) at a significance level of (0.05) with 18 degrees of freedom. This suggests that there are no statistically meaningful disparities between the experimental and control groups in the pre-tests, so affirming the equivalence of the two groups and their commencement from the same baseline prior to the main experiment.

Determinants of the training curriculum

1. Course duration: (8) weeks (two intermediate mesocycles).
2. Number of Weekly Units: (3) Training Units (Days: Sunday, Tuesday, Thursday).
3. Total Training Units: (24) Training Units.
4. Training unit time: approximately (90) minutes (divided between warm-up, main section, and cool-down).
5. Components of the training load used:.
   a. Training intensity: Intensity ranged from (85% - 95%) of maximum heart rate (HR max). Pulse was used as an indicator of intensity (170-190 beats/minute).
   b. Volume of work (repetitions and performance time): The work was divided into intervals of time that simulated boxing rounds and rhythmic changes in them (e.g., intense explosive action of 15 to 30 seconds).
   c. Rest periods (recovery): Incomplete rest (in which the pulse drops to 120-130 beats/min) was used to ensure a metered accumulation of fatigue products (urea, ammonia) within the muscle, forcing the functional organs to accelerate their clearance processes. The work-to-rest ratio was (1:1) or (1:2) depending on the exercise objective.

Post-Test: On April 17, 2026, subsequent to implementing the training technique, the investigator gathered and organised the data to facilitate analysis and discourse aimed at deriving precise results.

Statistical methods

The investigator employed the statistical software (SPSS) to determine the statistical measures: arithmetic mean, standard deviation, skewness, sampling error, T-test for paired samples, and T-test for independent samples.

RESEARCH RESULTS

Presentation and analysis of the results

Table 4. Shows the arithmetic medians, standard deviations, calculated t-value and the level of significance in the pre-post-test between the experimental and control groups

Variables	Unit of Measurement	Groups	Pre-tests		Post-tests		T	Sig
			M	SD	M	SD		
Ammonia	μmol/L	Experimental	115.40	4.21	88.50	3.12	5.82	0.000
		Control	114.80	4.10	112.30	4.55	1.14	0.000
Urea	mg/dL	Experimental	44.20	2.55	34.60	1.84	4.65	0.000
		Control	43.90	2.62	42.80	2.70	0.88	0.000
Composite skill performance tolerance	Repeated punches	Experimental	142.00	5.50	178.00	4.25	6.12	0.000
		Control	143.50	5.10	145.00	5.15	1.05	0.000

Table (4) demonstrates that the ammonia variable in the experimental group's post-test results revealed a substantial decline in ammonia levels (88.50 μmol/L) when compared to the pre-test (115.40 μmol/L), and the computed t-value was (5.82), indicating a significant difference in favour of the post-test. In contrast, the control group had no significant variation, with the computed (t) value being only (1.14).Concerning the urea variable: the experimental group's average urea concentration declined from (44.20 mg/dL) in the pre-test to (34.60 mg/dL) in the post-test, resulting in a t-value of (4.65), indicating significance. Regarding the control group, its levels were nearly unchanged (42.80 in the dimension compared to 43.90 in the pre-test) with a non-significant (t) statistic of (0.88). Concerning the skill variable (composite skill performance tolerance): the results demonstrated a significant and marked enhancement in the experimental group in terms of the number of repetitions (compound and precise punches) during the post-test, where the arithmetic mean escalated from (142.00) repetitions in the pre-test to (178.00) repetitions in the post-test. The derived value of (t) was (6.12), so affirming the existence of considerable relevance. In the control group, the observed development was minimal and statistically insignificant (from 143.50 to 145.00), yielding a t-value of (1.05).

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Table 5. Shows the arithmetic media, standard deviations, calculated t-value and the level of significance in the post-test between the experimental and control groups.

Variables	Unit of Measurement	Experimental		Control		T	Sig
		M	SD	M	SD		
Ammonia	μmol/L	88.50	3.12	112.30	4.55	5.34	0.000
Urea	mg/dL	34.60	1.84	42.80	2.70	4.88	0.000
Composite skill performance tolerance	Repeated punches	178.00	4.25	145.00	5.15	7.21	0.000

The table shows that the ammonia variable The data revealed a significant advantage of the experimental group where the average concentration of ammonia in the blood after exertion was (88.50) μmol/L with a standard deviation of (3.12), whereas the control group had a mean of (112.30) μmol/L with a standard deviation of (4.55). The calculated value of (t) was statistically analysed and found to be (5.34) indicating a significant and statistically significant reduction of ammonia levels to the favour of the experimental group.Urea variable: The results were consistent with the ammonia variable, where the experimental group had an average urea concentration of (34.60) mg/dL with a standard deviation of (1.84), while the control group recorded an arithmetic mean of (42.80) mg/dL with a standard deviation of (2.70).

The difference between the two groups was statistically significant (t = 4.88), supporting the experimental group and demonstrating a true reduction in the rate of protein catabolism.The skill variable (complex and correct punches under fatigue tolerance): The results of the post-test showed a clear superiority of the experimental group in the skill, as the arithmetic mean of the experimental group reached (178.00) complex and correct punches under fatigue with a standard deviation of (4.25). As opposed to this, the mean value for the control group was stabilised at (145.00) on many occasions with a standard deviation of (5.15). The value of (t) for the difference between the two averages, shown in (7.21), indicates a very high statistical value, which confirms the distinct and statistically significant superiority of the experimental group in maintaining the performance of the technique and skill, compared to the control group. The scholar shows that the critical t-value for 18 degrees of freedom and the significance level 0.05 is (2.101). Since all t-values in Table 3 are above this threshold, the study hypotheses are supported.

DISCUSSION

The statistical analysis results from the former tables clearly show significant evidence that the experimental group is effective in reducing the metabolic stress products (ammonia and urea) and improving (composite skill tolerance) in comparison to the control group. This considerable progression is owed to the efficiency of the suggested training syllabus with emphasis on anaerobic performance training, which has brought about significant functional adaptations. Regarding changes in ammonia concentration, the data indicated a significant decrease in blood ammonia levels in the experimental group after exercise. The scholar explains this progress by saying that anaerobic strength training has increased the efficiency of muscle cells in rapidly and constantly rebuilding the energy complex (ATP). Korzeniewski (2026) argues that systematic anaerobic training increases anaerobic enzyme activity, reducing the need for muscles to reach critical fatigue stages wherein adenosine monophosphate (AMP) is metabolised, leading to the main production of ammonia as an unintended consequence of vigorous muscle activity.

This agrees with Tshibangu (2023) who claims that training adaptation enhances the clearance rate of blood metabolites, which allows boxers' functional systems to clear ammonia faster and avoid high concentrations impacting the brain, thereby protecting the central nervous system (CNS) from fatigue. The results confirmed the experimental group's superiority, as evidenced by their decreased urea levels after the competition. According to the scholar, the training method has helped to the latest adaptation expressed by the concept of the "protein sparing effect. This approach is substantiated by Wang et al. (2023), who suggest that high-intensity metered sports training enhances the functional economy of the body and increases efficiency in the mobilisation and utilisation of carbohydrate as the main energy source. Further, PMuñoz-López et al. (2026) highlights that low serum urea levels measured after exercise in trained athletes are absolute evidence of reduced muscle cell stress and lower catabolism rates, which is completely in line with the findings of the experimental research sample. In relation to the noticeable progression of composite skill performance tolerance, this superiority arose as an unavoidable and inherent consequence of the previously discussed physiological adaptations.

According to Tornero-Aguilera et al. (2022), the endurance of skill performance is chiefly influenced by the resistance to central and peripheral fatigue, with the gradual accumulation of ammonia, an inhibitor of motor nerve signals, facilitating a stable neural environment for efficient nerve impulse transmission in boxers. Engaging in anaerobic training alongside skill practice cultivates a "motor memory" that is resistant to exhaustion. Subjecting young boxers to training stresses that mimic the demands of a fight via repetition fostered the development of fast muscle fibres' ability to sustain contractions (kinetic frequency) with strength and precision, enabling the experimental group to uphold the efficacy of compound punches without a decrease in technical skill even late in the evaluation.

CONCLUSIONS AND RECOMMENDATIONS

Considering the outcomes derived from the statistical analyses of the pre- and post-assessments, along with the scientific discourse surrounding the physiological and skill-related factors of the study, the researcher arrived at the subsequent conclusions:

1. The anaerobic training methodology has been proved to be quite effective in stimulating functional adaptations in the muscle cells of young boxers. This is evidenced by the acceleration of the removal of metabolic by-products, in particular, the decrease in the concentration of ammonia in the blood after exercise, which indicates the ability of organic systems to delay the onset of rapid central fatigue.
2. Standardised anaerobic training has improved the functional efficiency of boxers' physiques, by optimising energy production mechanisms to use carbohydrates and fats, while conserving muscle protein reserves (Protein Sparing), as evidenced by the marked decrease in serum urea levels after strenuous activity.
3. Physiological regulation of fatigue byproducts (urea and ammonia) had a direct and favourable impact on technical performance. The boxers demonstrated an enhanced capacity for neuromuscular coordination, enabling them to execute

compound punches with rapid and accurate kinetic frequency, over extended durations, achieving considerable advancement in the endurance of complex skill execution.

4. The proposed training curriculum (anaerobic ability training) is certainly more effective than the traditional training program, confirming the improvement of skill in combat sports is realised only with improving the efficiency of physiological systems that regulate energy production and fatigue endurance.

Recommendations

1. It is essential to incorporate the terminology of the suggested training curriculum (anaerobic ability training) during both the special preparation phase and the competitive phase for young boxers, to guarantee that their functional capabilities are equipped to endure the demands of actual bouts.
2. Coaches are instructed to create compound training that merges rigorous skill execution with anaerobic energy exercises (amidst accumulated exhaustion), to acclimatise the boxer's neural system to provide accurate motor commands even under severe metabolic strain.
3. Incorporate biochemical assessments (such as urea, ammonia, and lactic acid levels) as a crucial component of the regular assessment of boxers' training conditions, utilising them as empirical markers to modify training intensities and prevent overtraining.
4. Comparable research is examining several physiological and biochemical factors related to muscle injury and stress (e.g., creatine kinase CK, antioxidants).
5. Implement the training syllabus across various age and weight categories in boxing, or in other combat sports like wrestling and taekwondo, to evaluate its impact on skill performance enhancement.

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