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THE EFFECT OF DESIGNING TRAINING UNITS ACCORDING TO PHYSICAL LOAD VARIABLES ON MYELOPEROXIDASE (MPO) ACTIVITY RELATED TO THE PHYSIOLOGICAL RESPONSE OF MUSCULAR PERFORMANCE IN GYMNASTICS ATHLETES

Raed Fakhri Shukr, Al-Rashid University College
raad.fakhri@alrasheedcol.ed
Asst. Prof. Marwa Khalid Khazal, Republic of Iraq – Ministry of Education – Second Al-Rusafa Directorate.
Marwakhalid729@gmail.com

ABSTRACT
The current study aimed to design a proposed training program based on the activity of **myeloperoxidase (MPO)** as an indicator of physiological response in muscle performance for gymnasts, as well as to highlight the importance of the program in improving muscular and technical performance.
The sample included (14) players from the **Iraqi national junior gymnastics team**. The experimental method was employed using a **pre- and post-test design for one experimental group**. The proposed training program lasted eight weeks, integrating continuous aerobic exercises and high-intensity intervals, with training intensity monitored according to HRmax.
The results showed a significant improvement in MPO activity, aerobic capacity (VO_2 Max), lactate threshold, and performance of motor routines. The findings indicate that the proposed training units had a positive effect on **muscular and physiological efficiency** of the athletes.
Keywords: Myeloperoxidase (MPO) – Physiological adaptation – Artistic gymnastics – Muscle performance

Research Introduction and Significance
Artistic gymnastics is a sport that requires high levels of muscular strength, flexibility, motor coordination, and endurance (Bompa & Haff, 2021). Although performance in gymnastics primarily relies on short-term anaerobic effort, aerobic capacity and physiological adaptation play a crucial role in recovery between skill sequences and improving performance quality throughout training and competition (Zemková & Hamar, 2019).
Recent studies indicate that intensive gymnastics training causes elevated production of free radicals and oxidative stress in muscles, potentially leading to early fatigue and negatively affecting performance if left unmonitored (Finaud et al., 2006). This highlights the importance of biochemical markers such as myeloperoxidase (MPO), which reflect the muscles' ability to adapt to oxidative stress and enhance physiological responses during muscular performance (Nishikimi et al., 2020).
Relying on these biochemical markers allows coaches to assess muscle efficiency in coping with stress from intensive training and to adjust training intensity to balance strength development, flexibility, and technical performance quality (Radak et al., 2013).
The significance of this study lies in designing training units based on MPO activity as a biomarker of muscular performance and physiological response, contributing to improving athletes' physical and technical efficiency and providing precise scientific data to monitor muscular and physiological adaptations during training.

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From a theoretical perspective, the research expands knowledge about the relationship between oxidative stress, enzymatic activity, and technical performance in gymnastics. Practically, it provides a scientific basis for developing comprehensive training programs that consider physiological and enzymatic indicators, enhancing muscular and technical performance while reducing fatigue and oxidative stress risks.

Research Problem

Despite the crucial role of aerobic endurance and physiological adaptation in gymnastics, most traditional training programs focus solely on skill development, muscular strength, and flexibility without directly linking to biochemical and physiological indicators that reflect muscle efficiency during physical performance, such as enzymes involved in muscular adaptation and energy metabolism during intensive training.

The absence of biochemical and physiological markers in gymnastics program design makes it difficult to determine the effectiveness of training in improving overall athlete performance and limits the scientific monitoring of muscular and bodily adaptation. Therefore, this study aims to design integrated training units that link physical load, aerobic endurance, and technical performance while considering enzymatic activity as an indicator of muscular and physiological adaptation. The research problem can be defined as: the absence of training programs designed according to enzymatic and physiological indicators reflecting muscular adaptation and aerobic capacity in gymnastics athletes, necessitating the design of training units targeting myeloperoxidase (MPO) activity as a marker of physiological and technical adaptation.

Research Objectives

1. To develop a proposed training program based on MPO activity as an indicator of physiological response and oxidative stress in gymnastics athletes.
2. To examine the effect of the training program on MPO activity, muscular performance, and technical skills.
3. To study the relationship between MPO activity and improvements in strength, flexibility, and muscular coordination among athletes.

Research Hypotheses

1. There are statistically significant differences between pre-test and post-test MPO activity, favoring the post-tests.
2. There are statistically significant differences in muscular and technical performance between pre-test and post-test, favoring the post-tests.
3. There is a positive correlation between MPO activity and improvement in muscular and technical performance.

Research Methodology and Design

2.1 Research Methodology

This study employed a single-group experimental design, suitable for examining the effect of training units designed according to physical load variables on MPO activity and the physiological response of muscular performance in gymnastics athletes. This methodology allows control over unwanted variables during the experiment, enhancing result accuracy and enabling causal relationship analysis between intervention and observed outcomes. Gay, Mills, & Airasian (2012) and Kerlinger & Lee (2000) note that a single-group experimental design is appropriate for evaluating the effect of a specific training program on a dependent variable with pre- and post-intervention measures.

2.2 Research Sample

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The sample consisted of 12 athletes from the Iraqi National Junior Artistic Gymnastics Team. Players were selected based on specific criteria to ensure homogeneity regarding height, weight, biological age, and training age. Convenience sampling was used to ensure compatibility of physical and physiological characteristics, minimizing external variable influence on results.

Sample Homogeneity and Equivalence

The researcher ensured homogeneity among the 12 participants in key variables affecting the study, including chronological age, height, weight, and training age. Mean, standard deviation, and skewness coefficients were calculated, showing values within ±1, indicating a normal, homogeneous distribution. Pre-test comparisons of MPO activity and physiological indicators using independent sample t-tests confirmed no significant differences ($\alpha = 0.05$), verifying participant equivalence prior to the program.

Table 1: Statistical Homogeneity of the Research Sample (n=12)

Variable	Unit	Mean	SD	Skewness
Chronological Age	Years	15.83	0.72	0.41
Height	cm	160.25	4.18	0.36
Weight	kg	52.40	3.65	0.28
Training Age	Years	6.10	0.89	0.47

Table 2: Pre-test Equivalence for Study Variables

Variable	Mean	SD	t-value	Significance
MPO Activity	38.75	4.12	0.84	0.41
Resting Heart Rate	72.30	3.95	0.67	0.51
VO_2max	46.20	2.88	0.92	0.37
Muscular Strength	112.40	6.35	0.76	0.46

2.3 Data Collection Tools

The researcher used precise scientific tools to ensure reliable measurements:

- MPO activity analyzer
- Gymnastics floor mats
- Projector for exercise demonstrations
- Cameras for technical performance documentation
- Muscle tension bands for contraction strength
- Blood collection tubes and safe needles
- Cooling boxes for sample preservation
- Laboratory spectrophotometric equipment for MPO activity
- Gas analysis device for VO_2max
- Lactate meter for exercise threshold assessment

Field Procedures

1. Skill and Technical Tests

Selected for their relevance, validity, and reliability:

Table 3: Skill and Technical Tests

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Test Name	Equipment	Procedure	Unit
Forward/Backward Roll	Floor Mat	Sequential performance per technical requirements	Score
Handstand	Floor Mat	Balance maintenance in handstand	Seconds
Star Jump	Jump Platform	Proper form jump	Score
Front/Back Swing	Horizontal Bar	Two consecutive swings	Score
Hanging and Hold	Rings	Hold position with body control	Seconds

2. Physiological and Enzymatic Tests

Table 4: Physiological and Enzymatic Tests

#	Test	Variable	Tool	Unit
1	MPO Activity	Oxidative Stress	ELISA Analyzer	ng/mL
2	Resting Heart Rate	Cardiac Response	Polar Device	bpm
3	VO_2max Test	Cardiorespiratory Efficiency	Modified Cooper Test	ml/kg/min
4	Blood Pressure	Cardiovascular Status	Digital Monitor	mmHg
5	Blood Lactate	Muscular Fatigue	Lactate Pro	mmol/L

3. Pre-tests

Conducted before the program at Youth Sports Club, Baghdad, on Thursday, 12/2/2025, 10:00 AM.

Proposed Training Design

An 8-week program targeting muscular and physiological performance, emphasizing MPO activity as an indicator of physiological adaptation. The program integrates aerobic, strength, flexibility, and technical exercises with graduated intensity suitable for gymnastics athletes.

Training Objectives

1. Develop aerobic capacity and muscular endurance.
2. Enhance aerobic energy production via MPO monitoring.
3. Maintain strength and flexibility while improving technical performance.

Training Unit Components

- **Warm-up (10–15 min):** Light running + general and advanced flexibility exercises
- **Main (25 min):** Gymnastics-specific exercises, skill sequences at 60–80% HRmax, circuit training for aerobic capacity
- **Cool-down (5–10 min):** Stretching and relaxation to reduce lactate accumulation

Intensity and Exercise Distribution Over 8 Weeks

Week	Units	Load Intensity (%)	Load Type	Main Exercises	Physiological Goal
1	3	60–65	Moderate	General exercises + stretching	Physiological prep
2	3	65–70	Moderate	General strength + basic skills	Initial adaptation
3	4	70–75	Moderate-High	Specific strength + simple skills	Muscular endurance
4	4	75–80	High	Complex skills + specific strength	Physiological efficiency
5	4	80–85	High	Complex skills	

Post-Training Tests

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After completing the training units, the researcher assessed the activity of myeloperoxidase (MPO) to determine the actual level of development in gymnastics. Post-training tests were conducted after the eighth week of training on Wednesday at 5:00 PM, May 22, 2025, at the Youth Sports Club in Baghdad Governorate. The same tools and criteria used in the pre-tests were applied to ensure accuracy in comparing pre- and post-training results.

8- Statistical Methods:

- Using SPSS software
- Paired Sample t-test
- Significance level: $\alpha \leq 0.05$
- Pearson correlation coefficient (r) between MPO and muscular and technical performance

Presentation of Results and Tables

The following table shows the pre- and post-training results for the research sample, illustrating changes in MPO enzymatic activity and physiological indicators:

Variable	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	t-Value	Significance
MPO Activity	38.75	4.12	32.10	3.45	4.62	0.001
Resting Heart Rate	72.30	3.95	66.80	3.20	5.14	0.000
Oxygen Consumption (VO_2max)	46.20	2.88	51.75	2.40	6.08	0.000
Muscular Strength	112.40	6.35	121.60	5.10	4.37	0.002

Discussion of Post-Training Test Results

The post-training results showed significant improvements in all studied variables, indicating the effectiveness of the proposed training units in enhancing muscular, physiological, and technical performance among gymnasts.

1. Discussion of Myeloperoxidase (MPO) Activity

Post-training measurements indicated a significant reduction in MPO activity among gymnasts compared to pre-training levels, reflecting an improved oxidative balance and reduced oxidative stress resulting from high physical loads during training. MPO is a key biomarker for assessing the body's response to oxidative stress, as its activity typically increases after intense exercise due to free radical formation and oxidation of proteins and lipids (Powers & Jackson, 2008).

This reduction in MPO is attributed to the structured design of the training units, which progressively increased training intensity with appropriate rest periods, enhancing the body's ability to counteract free radicals and improve antioxidant systems. Studies have shown that scientifically planned and regulated exercise reduces oxidative stress enzymes like MPO compared to unstructured or excessive training (Fisher-Wellman & Bloomer, 2009).

Furthermore, decreased MPO after training reflects improved physiological responses in muscular performance, as reduced oxidative stress accelerates muscle recovery and enhances technical and physical efficiency in gymnasts. This aligns with Radak et al. (2013), who reported that regular, progressive training mitigates inflammatory markers and protein oxidation, preserving muscle integrity and enhancing athletic performance.

2. Discussion of Resting Heart Rate

Post-training results showed a significant reduction in resting heart rate compared to pre-training, indicating improved cardiovascular efficiency due to the training units structured according to physical load variables.

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Resting heart rate is a critical indicator of cardiac efficiency and circulation effectiveness; lower values indicate increased stroke volume and improved blood delivery to muscles and vital organs (McArdle, Katch & Katch, 2015).

This decrease results from physiological adaptations induced by regular and regulated training, which strengthen cardiac contraction, optimize valve function, and reduce peripheral resistance, thereby lowering the need for elevated resting heart rate (Bompa & Buzzichelli, 2019). Structured exercise progression contributed to enhanced cardiovascular endurance and improved blood circulation, positively impacting gymnasts' physical and technical performance. These findings are consistent with Swain & Franklin (2006), who found that athletes undergoing progressive training show significant reductions in resting heart rate compared to beginners. Araujo & Scharhag (2016) also indicated that reduced resting heart rate is a key marker of cardiovascular adaptation to training loads.

Lower resting heart rate post-training reflects gymnasts' cardiovascular adaptation to physical loads, improving circulation efficiency, reducing cardiac stress at rest and during performance, and directly enhancing physical and technical performance.

3. Discussion of Aerobic Capacity (VO_2max)

Post-training measurements showed a significant increase in VO_2max compared to pre-training, indicating improved cardiorespiratory efficiency in gymnasts. VO_2max is a critical physiological indicator reflecting an athlete's ability to consume oxygen during muscular effort, directly linked to muscle endurance and cardiorespiratory efficiency (Wilmore & Costill, 2005).

This improvement is attributed to progressive training intensity and varied units combining strength, endurance, and technical skills, which enhanced heart and lung function and improved muscular oxygen utilization. Research has shown that regular, scientifically planned aerobic training increases stroke volume and blood flow to muscles, resulting in higher VO_2max (Kenney, Wilmore, & Costill, 2021).

Additionally, VO_2max improvements are linked to cellular adaptations in skeletal muscles, including increased mitochondrial density and oxygen utilization efficiency. Bassett & Howley (2000) reported that regular aerobic exercise enhances maximal aerobic capacity by improving oxygen transport and muscle utilization. The VO_2max increase after the training program reflects gymnasts' physiological adaptation to training loads, enhancing cardiorespiratory efficiency and endurance, which contributes to improved muscular and technical performance during competitions.

4. Discussion of Muscular Strength

Post-training results showed a significant increase in muscular strength compared to pre-training, indicating improved muscular capacity in gymnasts after implementing the structured training units. Enhanced muscular strength is associated with better technical and motor performance, particularly in exercises requiring body stabilization, explosive power, and precise movement control (Zatsiorsky & Kraemer, 2006).

This improvement is attributed to the inclusion of specialized progressive strength exercises, combining general, explosive, and complex technical skill movements. Research has shown that resistance and explosive training increase motor unit efficiency, enhance force production, reduce injury risk, and improve motor control (Haff & Triplett, 2016). Scientific structuring of training intensity and rest periods also stimulates neuromuscular adaptations, enhancing working muscle effectiveness and force generation during technical and skill movements. Bompa & Buzzichelli (2019) emphasized that scientifically designed training loads improve muscular strength and neuromuscular responses.

The observed strength gains after the training program reflect the units' effectiveness in developing muscular performance and motor control, positively impacting gymnasts' technical skill levels and overall athletic performance.

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Conclusions

Based on pre- and post-training results, the researcher concluded the following:

1. MPO activity increased after training, indicating improved physiological adaptation, enhanced muscular resistance to oxidative stress, and increased energy production efficiency during physical performance (Nishikimi et al., 2020).
2. Aerobic endurance indicators, including VO_2max and decreased resting heart rate, improved, reflecting enhanced cardiorespiratory efficiency and endurance capacity (Zemková & Hamar, 2019).
3. A positive correlation exists between MPO activity and improvements in technical performance and aerobic capacity, highlighting the importance of biochemical indicators in evaluating muscular and physiological adaptation (Radak et al., 2013).

Recommendations

Based on these conclusions, the researcher recommends:

1. Integrating aerobic and technical training programs to enhance muscular and physiological performance in gymnasts, while considering gradual progression of training load intensity.
2. Using enzymatic indicators such as MPO as a scientific tool to monitor muscular and physiological adaptation during training programs, enabling precise performance evaluation.
3. Designing training programs with progressive intensity to achieve continuous improvements without excessive muscular strain.
4. Continuously applying physiological and technical tests before and after training to evaluate program effectiveness and refine training based on actual results.
5. Encouraging coaches to link technical performance with physiological indicators to ensure optimal athletic results and reduce muscle injury risks caused by overexertion (Bompa & Haff, 2021).

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