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Short Communication

The Influence of Repeated Gymnastic Conditioning on Bodily Function and Athletic Performance Characteristics

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Abstract

Background: Regular participation in artistic gymnastics involves repeated physical exertion that produces measurable responses in the hematological and endocrine systems. The present study examined alterations in circulating leukocytes, leukocyte distribution, and adrenal-related hormonal activity among adult gymnasts during their training period. The investigation included 20 athletes, comprising 10 males and 10 females, participating in different gymnasstics disciplines. Blood samples were examined to determine leukocyte counts and changes in the leukocyte formula, while urinary measurements were used to assess epinephrine, norepinephrine, and 17-ketosteroid concentrations. Initial and post-training measurements were compared to identify variations associated with physical exertion. Leukocyte concentrations increased across all four baseline groups, with values rising from 6,400–7,500 cells/mm^3 to 9,500–11,800 cells/mm^3 following training. A moderate increase in lymphocyte proportion was also reported, followed by a return toward the normal range during recovery. Urinary epinephrine, norepinephrine, and 17-ketosteroid concentrations increased after exercise. These observations demonstrate an acute hematological and hormonal response associated with gymnastics activity and provide information about physiological adjustments during athletic conditioning.

Keywords: Artistic Gymnastics; Hematological Response; Leukocyte Mobilization; Adrenal Hormones; Epinephrine; Norepinephrine; Physical Conditioning; Endocrine Adaptation; Exercise Physiology; Athletic Performance.

INTRODUCTION

Artistic gymnastics is a physically demanding sporting discipline that requires a combination of muscular strength, explosive power, flexibility, balance, coordination, and movement precision. Repeated practice of technically complex movements places considerable demands on several physiological systems. The human body responds to these demands through biochemical, structural, hormonal, and functional adjustments that contribute to the maintenance of physical performance. Repeated strength and power exercises also influence endocrine activity, the hormonal pathways involved in metabolic regulation and muscular adaptation [1]. Physical exertion produces temporary alterations in circulating immune cells, including changes in total leukocyte concentration and the relative distribution of different leukocyte populations. These responses are associated with exercise intensity, duration, sympathetic nervous system activation, and the redistribution of immune cells between blood and tissues [2]. The interaction between physical activity and immune regulation is an important component of the body's response to repeated exercise exposure [3].

Leukocytosis is frequently observed during and immediately following physical exertion. The magnitude and duration of this response depend on the characteristics of the exercise performed. Catecholamine release contributes to the rapid mobilization of circulating leukocytes, whereas subsequent hormonal responses influence the distribution of neutrophils during recovery [4]. Changes in circulating leukocytes may therefore provide useful information about the physiological response to training loads. The relationship between exercise and immune-cell redistribution is also influenced by the duration of physical activity and the time elapsed after exercise completion. Previous physiological observations have demonstrated

that immediate and delayed leukocyte responses may follow different temporal patterns, with catecholamines and cortisol contributing to these changes [5]. Recovery-related immune responses are therefore relevant when interpreting blood measurements collected at different intervals following exercise [6].

Exercise also influences immune regulation through interactions between the nervous, endocrine, and immune systems. These mechanisms contribute to the mobilization and redistribution of immune cells during physical activity [7]. The relationship between exercise intensity, recovery, and immune function is especially important for athletes participating in repeated training sessions [8]. The adrenal glands contribute to physiological regulation during exercise through the secretion of catecholamines and corticosteroid hormones. Epinephrine and norepinephrine participate in cardiovascular regulation, energy mobilization, and the physiological response to muscular activity. Cortisol secretion is also influenced by exercise intensity, with more demanding physical activity generally producing a stronger endocrine response [9].

The hypothalamic-pituitary-adrenal axis contributes to the regulation of physiological responses during physical stress. Exercise-related hormonal changes reflect interactions between central nervous system activity, metabolic requirements, and endocrine regulation [10]. Repeated physical loading can influence these responses, although the magnitude of hormonal adaptation depends on training characteristics and recovery conditions [11]. Gymnastics provides a useful sporting context for investigating these physiological responses because different apparatus-based exercises involve distinct combinations of muscular activity, movement duration, and physical intensity. The physiological demands of gymnastics are therefore not uniform across training activities [12].

The present investigation examined changes in leukocyte concentration, leukocyte distribution, and adrenal-related hormonal measurements among adult male and female gymnasts. The study aimed to describe the hematological and endocrine responses associated with training and to assess the extent to which these measurements changed following physical exertion.

MATERIALS AND METHODS

Study Participants

The investigation included 20 adult artistic gymnasts, consisting of 10 male and 10 female participants. All participants were involved in regular gymnastics training and performed discipline-specific exercises. The male participants completed training activities involving the horizontal bar, rings, and floor exercises. Female participants performed floor exercises, balance beam routines, and uneven-bar activities. The original study did not provide detailed information regarding participant age distribution, body composition, training experience, health screening, or competitive level. These characteristics should be included in a final journal submission if the corresponding records are available.

Study Design and Sample Collection

Hematological and hormonal measurements were collected to examine physiological variations associated with gymnastics training. Blood samples were obtained before and following the training activity. An additional assessment was reported after a 14-hour interval to examine changes during the subsequent recovery period. Blood specimens were analysed to determine total leukocyte concentrations and the relative distribution of leukocyte populations. Hormonal investigations were conducted using 24-hour urine samples submitted to a certified biochemical laboratory.

The hormonal measurements included:

- Epinephrine concentration.
- Norepinephrine concentration.
- 17-ketosteroid concentration.

Hematological Assessment

Total leukocyte concentrations were examined before and after training. Participants were classified into four groups according to their initial leukocyte measurements. The leukocyte formula was also evaluated to identify changes in the relative proportions of circulating immune cells. Subsequent observations were used to describe the return of these measurements toward their normal range during recovery.

Hormonal Assessment

Urinary concentrations of epinephrine and norepinephrine were measured before and following training. The concentration of 17-ketosteroids was also evaluated as an indicator of adrenal-related steroid metabolism. All hormonal measurements were expressed in milligrams per 24 hours, following the units reported in the original investigation.

Statistical Analysis

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The collected observations were subjected to statistical evaluation using analysis of variance (ANOVA), as reported in the original manuscript. The original statistical notation was recorded as $p \leq 00.5$. Because this notation is ambiguous, the intended significance threshold and the actual statistical outputs require confirmation before journal submission. Individual observations, standard deviations, confidence intervals, and exact ANOVA results were not available in the supplied manuscript.

RESULTS

Changes in Total Leukocyte Concentration

The hematological measurements demonstrated an increase in total leukocyte concentration following gymnastics training. Based on the initial measurements, participants were categorized into four groups according to their baseline leukocyte counts. The first group consisted of four gymnasts with an initial leukocyte concentration of 6,400 cells/mm^3. Following training, the concentration increased to 9,500 cells/mm^3. The second group included five participants whose initial value was 6,800 cells/mm^3, increasing to 10,200 cells/mm^3 after exercise. The third group comprised three gymnasts with an initial concentration of 7,200 cells/mm^3, which increased to 10,800 cells/mm^3. The fourth group contained eight participants with an initial value of 7,500 cells/mm^3, rising to 11,800 cells/mm^3 following training (Table 1).

Table 1: Comparative Changes in Circulating Leukocyte Concentrations Following Gymnastics Training.

Participant group	Number of gymnasts	Before training (cells/mm^3)	After training (cells/mm^3)
Group A	4	6,400	9,500
Group B	5	6,800	10,200
Group C	3	7,200	10,800
Group D	8	7,500	11,800

The recorded measurements demonstrate an increase in leukocyte concentration across all four groups. The greatest absolute increase occurred in Group D, where the concentration increased by 4,300 cells/mm^3.

Variations in Leukocyte Distribution

Examination of the leukocyte formula revealed a moderate increase in the proportion of lymphocytes, reported at approximately 40%. Other leukocyte components were described as remaining within normal limits. The observed alterations were associated with the initial phase of exercise-related leukocyte mobilization. Subsequent assessment after approximately 14 hours indicated that the leukocyte measurements had returned toward their normal range. These observations suggest that the hematological response was temporary rather than a sustained elevation throughout the recovery period (Figure 1).

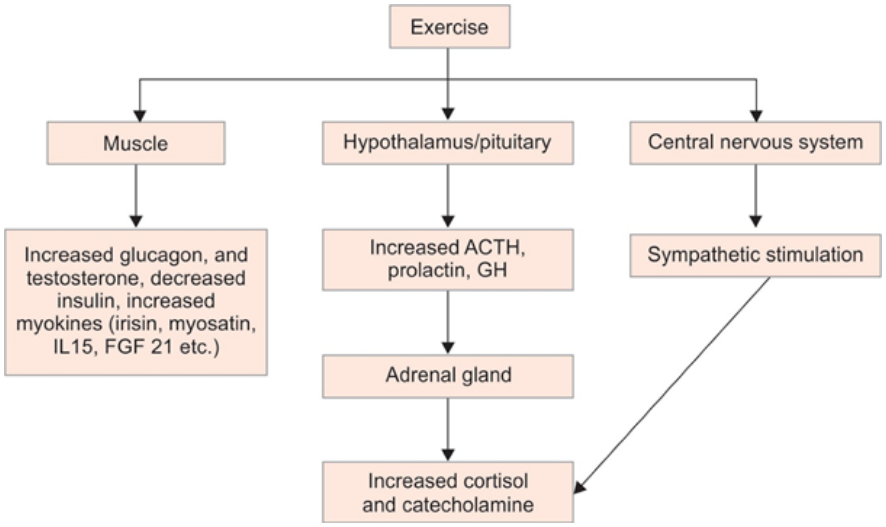


Figure 1: Schematic Representation of Hematological and Endocrine Responses to Gymnastics Training.

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Changes in Adrenal-Related Hormonal Measurements

The urinary hormonal measurements demonstrated increases in all three investigated parameters following physical activity. Epinephrine concentration increased from 4.6 mg/24 hours before training to 7.11 mg/24 hours after training. Norepinephrine concentration increased from 8.2 to 12.7 mg/24 hours. Similarly, 17-ketosteroid concentration increased from 10.5 to 12 mg/24 hours (Table 2).

Table 2: Changes in Urinary Hormonal Measurements Before and After Physical Activity.

Hormonal parameter	Before training (mg/24 hours)	After training (mg/24 hours)
Epinephrine	4.60	7.11
Norepinephrine	8.20	12.70
17-Ketosteroids	10.50	12.00

The greatest absolute increase was observed in norepinephrine concentration, which increased by 4.5 mg/24 hours. Epinephrine showed an increase of 2.51 mg/24 hours, whereas the 17-ketosteroid measurement increased by 1.5 mg/24 hours. The comparative findings indicate that gymnastics-related physical exertion was accompanied by increases in both catecholamine and steroid-related urinary measurements.

DISCUSSION

Hematological Responses to Gymnastics Training

The findings demonstrate an increase in circulating leukocyte concentrations following physical activity among the investigated gymnasts. This response is consistent with the established relationship between muscular exertion and temporary changes in circulating immune-cell populations.

Gymnastics involves repeated muscular contractions, rapid changes in body position, and technically demanding movements. These activities stimulate physiological mechanisms associated with cardiovascular regulation and immune-cell redistribution. The magnitude of the response may differ according to the intensity and duration of individual exercises. Research examining competitive gymnastics has demonstrated that different apparatus-based routines produce distinct physiological demands. Variations in heart rate, oxygen consumption, and blood lactate concentrations indicate that the physical workload differs across gymnastics activities [13]. Similar apparatus-dependent physiological patterns have also been documented during simulated competitions involving elite female gymnasts [14].

The physiological demands of male gymnastics routines are also influenced by the specific apparatus and the duration of individual performances. Measurements obtained during still-ring exercises demonstrate substantial cardiovascular and metabolic requirements despite the relatively short duration of the routines [15]. These observations provide a physiological context for interpreting the hematological changes identified in the present investigation.

Interpretation of Leukocyte Mobilization

The increase in leukocyte concentration observed across all four groups indicates a temporary hematological response to physical exertion. Exercise-induced leukocytosis is influenced by the redistribution of circulating immune cells and changes in hormonal activity. Catecholamines contribute to the rapid movement of leukocytes into the circulating blood compartment. Cortisol-related mechanisms may also influence subsequent changes in neutrophil distribution. These responses occur over different time intervals and are influenced by the timing of blood collection [16]. Exercise-related immune responses should not automatically be interpreted as evidence of impaired immune function. Physical activity produces complex changes in immune-cell circulation, with responses varying according to exercise intensity, duration, and recovery status [17].

The reported increase in lymphocyte proportion and subsequent movement toward normal values during recovery are consistent with the temporary nature of exercise-associated immune-cell redistribution. Regular physical conditioning may influence the magnitude of these responses, although the present investigation does not establish a direct relationship between training experience and the observed changes [18]. Recovery is an important component of exercise-related immune regulation. Changes in circulating immune cells following physical exertion may continue after the completion of training, making the timing of blood collection important when comparing hematological measurements [19].

Endocrine Responses to Physical Exertion

The hormonal measurements showed increases in urinary epinephrine, norepinephrine, and 17-ketosteroids

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following training. These findings indicate that physical activity was accompanied by changes in adrenal-related endocrine activity. Epinephrine and norepinephrine are involved in the regulation of cardiovascular activity, energy availability, and metabolic responses during muscular work. Their secretion increases the availability of physiological resources required to support physical activity.

The hypothalamic-pituitary-adrenal axis also participates in the regulation of the endocrine response to exercise. Hormonal changes are influenced by exercise intensity, duration, individual training status, and recovery conditions [20]. The increase in urinary catecholamine concentrations observed in this investigation is consistent with the involvement of sympathetic endocrine mechanisms during physical exertion. However, urinary measurements collected over 24 hours represent cumulative excretion and cannot establish the precise timing of hormonal secretion during individual gymnastics routines.

Relationship Between Hematological and Hormonal Responses

Hematological and endocrine responses are closely interconnected during physical activity. Increased sympathetic activity and adrenal hormone secretion influence the movement and distribution of leukocytes within the circulation. The simultaneous increases in leukocyte concentrations and urinary catecholamine measurements suggest that both systems responded to the training activity. However, the available observations do not establish a direct statistical association between individual hormonal changes and leukocyte concentrations.

Exercise-related changes in immune-cell activity are also influenced by the recovery period. Research involving physically active participants has demonstrated that the magnitude and duration of immune responses vary according to exercise exposure and subsequent recovery [21]. The relationship between neuroendocrine activity and immune regulation provides an explanation for the temporary changes observed after exercise. Interactions between hormonal pathways and immune-cell distribution are recognized components of the physiological response to physical stress [22].

Implications for Gymnastics Conditioning

The findings provide information about the hematological and endocrine responses associated with gymnastics training. Monitoring these physiological parameters may help researchers understand how athletes respond to repeated physical demands.

Exercise-related immune responses are influenced by several interacting factors, including training intensity, nutritional status, recovery time, and individual physiological characteristics. Consequently, leukocyte measurements should be interpreted alongside other indicators of physical condition rather than used independently to evaluate athletic adaptation [23]. Several limitations should be considered when interpreting the present findings. The sample included only 20 participants, and the available manuscript does not provide separate male and female results. Detailed information about training intensity, session duration, participant characteristics, and hormonal sampling procedures is also limited.

Furthermore, the available data do not include individual measurements, variability estimates, or complete statistical comparisons. The findings therefore describe observed changes rather than establishing definitive causal relationships between training exposure and long-term physiological adaptation. Future investigations incorporating repeated sampling, sex-specific comparisons, standardized exercise protocols, and clearly defined recovery intervals would provide a more comprehensive understanding of these responses.

CONCLUSION

The investigation identified measurable hematological and endocrine changes among adult artistic gymnasts following physical training. Increased leukocyte concentrations were recorded across all four participant groups, indicating a temporary alteration in circulating immune-cell levels associated with exercise. The observed changes in lymphocyte distribution and their subsequent movement toward normal values suggest that recovery processes contribute to the regulation of hematological responses. Increased urinary concentrations of epinephrine, norepinephrine, and 17-ketosteroids further demonstrate the involvement of adrenal-related hormonal activity during physical exertion. These findings illustrate the interaction between immune regulation and endocrine responses under the demands of gymnastics conditioning. The observed variations provide useful information about physiological reactions to repeated muscular activity. However, the limited sample size, absence of individual-level measurements, and incomplete statistical information restrict the interpretation of long-term training adaptations. Further investigations incorporating standardized exercise protocols and repeated hormonal and hematological assessments are needed to clarify these

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relationships.

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