Alqalam Journal of Medical and Applied Sciences. 2025;8(4):2244-2249
https://doi.org/10.54361/ajmas.258422

Original article

Impact of Exercise Physiology on Hematological Parameters: Insights into Sports Hematology from a Libyan Cohort

Khairia Laflof

Department of Physiology, University of Sabratha, Faculty of Medical Technology, Sabu, Sabratha, Libya.
Email: khayriyah.laflouf@sabu.edu.ly

Abstract
Acute exercise induces rapid hematological alterations, including hemoconcentration, leukocyte mobilization, and platelet activation. While such responses are well documented globally, data from North Africa are lacking. To investigate acute changes in complete blood count (CBC) parameters, hemoglobin (Hb), hematocrit (Hct), red blood cell count (RBC), white blood cell count (WBC), and platelet count (Plt) in a Libyan cohort, and to assess the influence of gender and training status. A total of 150 healthy adults (92 males, 58 females; aged 18-35 years) underwent maximal treadmill exercise. Participants were classified as trained (n=80) or untrained (n=70). Venous blood samples were collected 30 minutes pre- and 30 minutes post-exercise. CBC indices were measured using an automated hematology analyzer. Statistical analyses included paired t-tests and two-way ANOVA (gender - training). Hb, Hct, RBC, WBC, and Plt significantly increased post-exercise. Hb rose from 14.0 ± 1.3 to 14.8 ± 1.2 g/dL ($p<0.001$), Hct from 42.5 ± 3.8% to 44.1 ± 3.7% ($p<0.01$), RBC from 4.8 ± 0.5 to 5.0 ± 0.5 $\times10^6/\mu L$ ($p=0.03$), WBC from 6.1 ± 1.2 to 6.8 ± 1.3 $\times10^3/\mu L$ ($p=0.01$), and Plt from 238 ± 46 to 263 ± 49 $\times10^3/\mu L$ ($p<0.001$). Males exhibited larger platelet increases, while untrained participants showed greater Hb and Hct rises. Acute maximal exercise in Libyan adults induces hemoconcentration, leukocytosis, and thrombocytosis, with gender and training status modulating specific responses. These results provide the first sports hematology dataset from Libya, aligning with international literature and informing athlete monitoring in the region.
Keywords: Exercise Physiology; Hematology; Complete Blood Count; Sports.

Introduction

Sports hematology, the discipline concerned with the interaction between physical activity and hematological function, has grown into a key field within exercise physiology and sports medicine. Blood serves as the central medium for transporting oxygen, nutrients, hormones, and immune cells during physical exertion. Understanding hematological responses to exercise is therefore essential for not only optimizing athletic performance, but also for ensuring athlete health, guiding training programs, and differentiating physiological changes from pathology.

Acute exercise induces immediate alterations in blood composition, which may last from minutes to hours depending on intensity, duration, and recovery. One of the most prominent responses is hemoconcentration, driven by a rapid reduction in plasma volume due to fluid shifts into the interstitial and intracellular spaces [1]. This results in transient increases in hemoglobin concentration (Hb) and hematocrit (Hct), even in the absence of actual changes in red blood cell mass. Exercise also mobilizes red blood cells (RBCs), with splenic contraction playing a major role. In mammals, the spleen acts as a reservoir of erythrocytes that can be released into circulation during sympathetic activation, thereby enhancing oxygen delivery [2]. This phenomenon, although less dramatic in humans compared to some animals, contributes to exercise-induced increases in hematocrit and Hb.

White blood cells (WBCs) undergo redistribution during exercise. Acute leukocytosis is typically observed, reflecting demargination of neutrophils and lymphocytes, increased bone marrow release, and stress hormone stimulation [3]. These changes are interpreted as part of the transient immunoenhancement induced by physical exertion.

Platelet count (Plt) also rises acutely during exercise, a process linked to splenic release, hemoconcentration, and catecholamine-mediated mobilization [4]. While this transient thrombocytosis may support vascular integrity and tissue repair, it also raises questions regarding cardiovascular risk in susceptible individuals.

Training status influences hematological responses to exercise. Endurance-trained athletes typically exhibit expanded plasma volume, higher total red blood cell mass, and attenuated hemoconcentration compared to untrained individuals [5]. As a result, untrained subjects often display greater relative increases in Hb and Hct during acute exertion. Conversely, trained athletes may show a more pronounced mobilization of leukocytes and platelets, reflecting their enhanced stress adaptation and immune system responsiveness.

Gender also modulates hematological responses. Males generally present higher baseline Hb and Hct due to androgen effects on erythropoiesis, while females exhibit lower values, influenced by menstrual blood loss and hormonal differences [6]. These baseline disparities shape post-exercise dynamics. For instance, males may demonstrate larger absolute platelet increases, while females may exhibit more modest shifts due to lower initial reserves.

Received: *10-08-2025* - ***Accepted***: *08-10-2025* - ***Published***: *14-10-2025*

Internationally, numerous studies have documented hematological adaptations to exercise [7] reported significant increases in Hb, Hct, WBC, and platelets following maximal treadmill exercise in a U.S. cohort, with distinct gender and training status effects [4] highlighted platelet activation and altered hemostasis during exercise, emphasizing clinical implications. More recent investigations have expanded this field, exploring not only CBC indices but also cytokines, growth factors, and progenitor cells [8,9,10].
Despite this extensive literature, data from African populations remain limited. Most sports hematology studies have been conducted in Europe, North America, or Asia. Regional variations, including climate, hydration patterns, nutritional iron intake, and genetic factors, may influence hematological responses to exercise. For instance, populations living in arid climates, such as Libya, often experience higher baseline hematocrit due to chronic low-grade dehydration and environmental stressors [11]. Nutritional challenges, including iron deficiency, may also shape hematological profiles in young adults.
Libya presents a unique context for sports hematology research. The country has a young and growing population with increasing participation in recreational and competitive sports. Yet, research in exercise physiology remains sparse. Clinical hematology services exist, but systematic investigations into sports-related blood responses have not been conducted. Establishing normative data for acute hematological responses in Libyan adults is therefore critical. Such data can aid sports federations, medical practitioners, and anti-doping authorities in interpreting blood test results.
Furthermore, Libya's climate (hot, arid, with significant seasonal variation) and dietary habits (traditional Mediterranean with increasing Western influences) may impact baseline hematology and exercise responses. By documenting hematological shifts in Libyan athletes and non-athletes, this study provides a foundation for sports medicine in North Africa while contributing to global comparative literature.
The primary aim of this study was to investigate the acute effects of maximal treadmill exercise on key hematological parameters, including hemoglobin (Hb), hematocrit (Hct), red blood cell count (RBC), white blood cell count (WBC), and platelet count in a cohort of 150 healthy Libyan adults. Specifically, the study sought to:
Quantify pre- to post-exercise changes in complete blood count (CBC) indices.
Examine the influence of gender differences on hematological responses to acute exercise.
Evaluate the impact of training status (trained vs. untrained participants) on these responses.
Provide region-specific baseline data for North Africa, contributing to global sports hematology literature and offering practical insights for athlete monitoring, clinical evaluation, and anti-doping practices.

Methods

Study design and population

This was a prospective observational study conducted between January 2024 and June 2025 in two Libyan cities, Surman and Sabratha. The study followed the principles of the Declaration of Helsinki and received approval from the Libyan Hospital Committee. All participants provided written informed consent prior to enrollment. A total of 150 healthy adults (92 males, 58 females; age range 18–35 years) were recruited via advertisements, university sports clubs, and fitness centers. Eligibility criteria were established to ensure that participants represented a healthy, non-clinical population while accounting for differences in physical activity.

Eligibility criteria

Participants eligible for inclusion in the study were required to be between 18 and 35 years of age, non-smokers, and free from any history of chronic diseases such as diabetes, cardiovascular conditions, anemia, or autoimmune disorders. Additionally, individuals must not have experienced any acute illness or infection within the preceding four weeks and should not be undergoing treatment with medications known to influence hematological parameters, including corticosteroids, iron supplements, or anticoagulants. Conversely, individuals were excluded from participation if they had a documented history of hematological disorders or suffered from chronic respiratory or cardiovascular conditions. Those who had donated blood within the past three months, as well as individuals who were pregnant or breastfeeding at the time of recruitment, were also excluded from the study.

Data collection and procedure

Participants were stratified into two distinct groups according to self-reported physical activity levels, which were verified through structured interviews and validated questionnaires. The trained group (n = 80) comprised individuals who had engaged in structured aerobic or mixed training for at least 250 minutes per week over a minimum of 12 consecutive weeks prior to enrollment. Their activities included running, football, cycling, and swimming. In contrast, the untrained group (n = 70) consisted of individuals who had participated in less than 60 minutes of physical activity per week during the preceding three months. This classification was consistent with the World Health Organization (WHO) guidelines on physical activity and aligned with established research protocols in exercise physiology.

Received*: 10-08-2025 -* ***Accepted****: 08-10-2025 -* ***Published****: 14-10-2025*

https://doi.org/10.54361/ajmas.258422

Anthropometric measurements, including height and body mass, were obtained using standardized procedures. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). On average, trained participants exhibited significantly lower BMI values compared to their untrained counterparts ($p < 0.05$).
All participants underwent a maximal treadmill exercise test following the standardized Bruce protocol, which involves progressive increases in speed and incline every three minutes until volitional fatigue or inability to maintain the treadmill pace. This protocol was selected due to its widespread validation, reproducibility, and relevance to aerobic capacity assessment. Exercise duration was recorded, and maximal oxygen consumption (VO_2max) was estimated using regression equations specific to the Bruce protocol. Trained individuals demonstrated significantly longer exercise durations and higher estimated VO_2max values compared to the untrained group ($p < 0.001$).
Venous blood samples were collected at two time points: 30 minutes prior to the treadmill test following 10 minutes of seated rest (pre-exercise), and within 30 minutes after the cessation of exercise (post-exercise). Blood was drawn via antecubital venipuncture using EDTA-coated vacutainer tubes, gently inverted, and analyzed within two hours of collection. Complete blood count (CBC) indices were assessed for all samples, including hemoglobin concentration (Hb, g/dL), hematocrit percentage (Hct, %), red blood cell count (RBC, $\times 10^6/\mu L$), white blood cell count (WBC, $\times 10^3/\mu L$), and platelet count (Plt, $\times 10^3/\mu L$). Internal and external quality control procedures were conducted daily to ensure the accuracy and precision of the hematological analyzer.

Statistical analysis
Data were analyzed using SPSS version 28.0 (IBM). Results are expressed as mean ± standard deviation (SD)**.** Paired t-tests were applied to compare pre- and post-exercise values within the total cohort. Two-way ANOVA was used to examine the effects of gender (male vs female) and training status (trained vs untrained) on hematological responses. Post-hoc Bonferroni correction was applied for multiple comparisons. A p-value <0.05 was considered statistically significant. Sample size justification was based on previous studies [7,4], with an estimated effect size (Cohen's d = 0.45 for Hb increase) and power analysis indicating that a minimum of 120 participants would provide >90% power to detect differences. Our cohort of 150 participants exceeded this requirement.

Results
As shown in (Table 1), acute maximal exercise significantly elevated all hematological indices. Hemoglobin rose by +0.8 g/dL, hematocrit by +1.6%, RBC by +0.2 $\times 10^6/\mu L$, WBC by +0.7 $\times 10^3/\mu L$, and platelets by +25 $\times 10^3/\mu L$. These findings are consistent with acute hemoconcentration, leukocytosis, and thrombocytosis induced by strenuous exercise.

Table 1. Hematological parameters in all participants (n = 150)

Parameter	Pre-exercise (Mean ± SD)	Post-exercise (Mean ± SD)	p-value
Hemoglobin (g/dL)	14.0 ± 1.3	14.8 ± 1.2	<0.001
Hematocrit (%)	42.5 ± 3.8	44.1 ± 3.7	0.002
RBC ($\times 10^6/\mu L$)	4.8 ± 0.5	5.0 ± 0.5	0.030
WBC ($\times 10^3/\mu L$)	6.1 ± 1.2	6.8 ± 1.3	0.010
Platelets ($\times 10^3/\mu L$)	238 ± 46	263 ± 49	<0.001

(Table 2) shows Males exhibited higher baseline Hb and Hct values compared to females (p<0.01). Both sexes showed post-exercise increases, but the platelet rise was more pronounced in males (+29 $\times 10^3/\mu L$) than in females (+15 $\times 10^3/\mu L$). WBC increases were comparable between genders.

Table 2. Gender-specific hematological responses

Parameter	Male Pre (Mean ± SD)	Male Post (Mean ± SD)	Female Pre (Mean ± SD)	Female Post (Mean ± SD)
Hemoglobin (g/dL)	14.5 ± 1.1	15.2 ± 1.0	13.2 ± 1.0	13.8 ± 0.9
Hematocrit (%)	44.1 ± 3.5	45.6 ± 3.3	40.3 ± 3.2	41.5 ± 3.0
RBC ($\times 10^6/\mu L$)	5.0 ± 0.4	5.2 ± 0.4	4.6 ± 0.4	4.8 ± 0.3
WBC ($\times 10^3/\mu L$)	6.2 ± 1.1	6.9 ± 1.2	6.0 ± 1.2	6.7 ± 1.3
Platelets ($\times 10^3/\mu L$)	240 ± 44	269 ± 47	236 ± 46	251 ± 48

Received*: 10-08-2025 -* ***Accepted****: 08-10-2025 -* ***Published****: 14-10-2025*

https://doi.org/10.54361/ajmas.258422

(Table 3) shows untrained participants displayed greater hemoconcentration, with Hb increasing by +1.1 g/dL and Hct by +1.6%. In contrast, trained participants showed a stronger leukocytic response (+0.8 $\times 10^3/\mu L$ vs +0.5 $\times 10^3/\mu L$). Platelet rises were significant in both groups but not statistically different.

Table 3. Training-specific hematological responses

Parameter	Trained Pre (Mean ± SD)	Trained Post (Mean ± SD)	Untrained Pre (Mean ± SD)	Untrained Post (Mean ± SD)
Hemoglobin (g/dL)	14.1 ± 1.2	14.6 ± 1.1	13.9 ± 1.3	15.0 ± 1.1
Hematocrit (%)	42.7 ± 3.7	43.6 ± 3.5	42.3 ± 3.9	44.3 ± 3.8
RBC ($\times 10^6/\mu L$)	4.9 ± 0.5	5.0 ± 0.5	4.8 ± 0.5	5.0 ± 0.5
WBC ($\times 10^3/\mu L$)	6.2 ± 1.2	7.0 ± 1.3	6.0 ± 1.1	6.5 ± 1.2
Platelets ($\times 10^3/\mu L$)	239 ± 45	264 ± 48	237 ± 47	262 ± 49

Discussion

The present study examined acute hematological responses to maximal treadmill exercise in a large cohort of healthy Libyan adults, providing novel data from a North African context. Our findings demonstrated significant increases in hemoglobin (Hb), hematocrit (Hct), red blood cells (RBC), white blood cells (WBC), and platelets following exercise. These responses confirm the well-established physiological phenomena of hemoconcentration, leukocytosis, and thrombocytosis during intense physical exertion. Importantly, gender and training status were found to modulate the magnitude of these responses, underlining the role of both biological and lifestyle factors in sports hematology.

The increases in Hb (+0.8 g/dL) and Hct (+1.6%) observed in this study align with previous reports [1,7]. Acute hemoconcentration results primarily from plasma volume reduction due to fluid shifts into interstitial and intracellular spaces during exercise. This mechanism enhances oxygen transport by increasing the concentration of circulating erythrocytes, albeit without a true rise in red cell mass. In addition, splenic contraction triggered by sympathetic activation likely contributes to the modest RBC increase seen in our data (+0.2 $\times 10^6/\mu L$). Although less pronounced in humans than in other mammals, splenic erythrocyte release during exertion has been consistently demonstrated [2].

Interestingly, untrained participants exhibited greater increases in Hb and Hct than trained individuals. This supports the concept that endurance training expands plasma volume, attenuating exercise-induced hemoconcentration [5]. By contrast, untrained individuals with smaller baseline plasma volumes experience proportionally larger shifts under stress. Exercise-induced leukocytosis was evident, with WBC increasing by +0.7 $\times 10^3/\mu L$. Such responses are attributed to multiple mechanisms, including catecholamine-mediated demargination of leukocytes, cortisol-stimulated bone marrow release, and enhanced hemodynamic shear stress mobilizing cells into circulation [3]. These changes are typically transient but may play a role in augmenting immune surveillance and tissue repair after exertion. Trained participants demonstrated a greater leukocytic response than untrained peers, consistent with evidence that chronic training conditions the immune system for rapid mobilization [10]. This enhanced responsiveness may partly explain the protective effects of habitual exercise against infection and inflammation. Platelet counts rose by +25 $\times 10^3/\mu L$, representing one of the largest relative changes.

Acute thrombocytosis during exercise has been described previously [4] and is linked to splenic platelet release, hemoconcentration, and adrenergic stimulation. While transient, this phenomenon enhances hemostatic readiness but also raises theoretical concerns regarding prothrombotic risk in predisposed individuals. The gender-specific analysis showed that males exhibited a greater absolute platelet rise compared to females. This observation may reflect differences in baseline platelet reserves, hormonal regulation, or sympathetic vascular reactivity [6]. Such findings highlight the need for sex-specific interpretation of hematological markers in sports medicine.

Our results confirmed expected baseline differences, with males presenting higher Hb and Hct than females. This is well established and attributed to androgen-driven erythropoiesis and the absence of menstrual blood loss in males [12]. Post-exercise, both sexes exhibited increases in all parameters, but platelet mobilization was more pronounced in males. These findings mirror global literature suggesting that sex hormones modulate hematological responses to physical stress. The contrasting responses between trained and untrained participants underscore the role of chronic exercise in shaping hematological adaptations. While trained individuals demonstrated attenuated hemoconcentration, they exhibited more robust leukocytic responses. These findings suggest that endurance training promotes plasma volume expansion while simultaneously conditioning immune mobilization. Such adaptations are beneficial for sustaining exercise performance and maintaining health under repeated physical stress [9].

***Received**: 10-08-2025 - **Accepted**: 08-10-2025 - **Published**: 14-10-2025*

This study provides the first systematic characterization of exercise hematology in a Libyan population. Regional environmental and cultural factors may influence baseline hematology and exercise responses. Libya's hot, arid climate predisposes to mild dehydration, potentially elevating baseline Hct levels. Nutritional factors, including iron availability and Mediterranean dietary habits, may also shape erythropoietic status. Furthermore, sports participation in Libya is growing, but structured endurance training remains limited compared to Western contexts. These factors may partly explain the greater hemoconcentration observed in untrained participants, who lacked adaptations associated with plasma volume expansion.
Our findings are consistent with those reported in Western cohorts [7]. Observed significant post-exercise increases in Hb, Hct, WBC, and platelets in U.S. adults, while [4]. demonstrated platelet activation during exercise. More recent studies emphasize the interplay between exercise, immunity, and hemostasis [8,10]. However, by focusing on a North African population, our study adds valuable context-specific data that can inform athlete monitoring and anti-doping protocols in the region. A key strength of this study lies in its large cohort (n=150) and stratification by gender and training status, enhancing generalizability. The use of a standardized exercise protocol (Bruce treadmill test) and an automated hematology analyzer ensured methodological consistency.
Nevertheless, limitations should be acknowledged. Plasma volume was not directly measured; hemoconcentration was inferred from Hb and Hct. Functional immune markers and platelet activation assays were not included, which would provide a deeper understanding of the observed changes. Finally, the study population was limited to young adults, restricting extrapolation to older or pediatric populations.

Conclusion

This study is the first to systematically examine acute hematological responses to maximal treadmill exercise in a Libyan cohort. It found significant post-exercise increases in hemoglobin, hematocrit, red and white blood cells, and platelets—reflecting hemoconcentration, leukocytosis, and thrombocytosis. Gender and training status influenced these responses: males showed higher baseline values and platelet mobilization, while trained individuals exhibited enhanced leukocyte mobilization. These findings align with global data but offer region-specific insights relevant to North Africa. The study underscores the need for population-specific reference ranges and cautions clinicians against misinterpreting transient post-exercise CBC changes. It contributes to athlete monitoring, clinical evaluation, and anti-doping efforts, and recommends future research incorporating plasma volume markers and longitudinal designs.

Acknowledgements

The authors would like to thank everyone for their help and support during the research study. They appreciate their cooperation, which was invaluable in enabling the authors to conduct the research, and they are grateful to those who participated in the study.

Disclosure statement

No potential conflict of interest was reported by the authors.

Authors' contributions

Khairia Bashere conducted the study, interpreted the data, and drafted the manuscript. The author has approved the paper for publication.

References

1. Sawka MN, Convertino VA, Eichner ER, Schnieder SM, Young AJ. Blood volume: importance and adaptations to exercise training, environmental stresses, and trauma/sickness. Med Sci Sports Exerc. 2000 Feb;32(2):332-48.
2. Stewart IB, McKenzie DC. The human spleen during physiological stress. Sports Med. 2002;32(6):361-9.
3. Pedersen BK, Hoffman-Goetz L. Exercise and the immune system: regulation, integration, and adaptation. Physiol Rev. 2000 Jul;80(3):1055-81.
4. El-Sayed MS, Sale C, Jones PG, Chester M. Blood hemostasis in exercise and training. Med Sci Sports Exerc. 2000 May;32(5):918-25.
5. Convertino VA. Blood volume: its adaptation to endurance training. Med Sci Sports Exerc. 1991 Dec;23(12):1338-48.
6. DellaValle DM, Haas JD. Impact of iron depletion without anemia on performance in trained endurance athletes at the beginning of a training season: a study of female collegiate rowers. Int J Sport Nutr Exerc Metab. 2011 Dec;21(6):501-6.
7. Wardyn GG, Rennard SI, Brusnahan SK, McGuire TR, Carlson ML, Smith LM, et al. Effects of exercise on hematological parameters, circulating side population cells, and cytokines. Exp Hematol. 2008 Feb;36(2):216-23.
8. Banfi G, Lundby C. Blood volume and hemoglobin mass in athletes: an update. Sports Med. 2018;48(Suppl 1):115-26.

***Received**: 10-08-2025 - **Accepted**: 08-10-2025 - **Published**: 14-10-2025*

9. Smith JA, Telford RD, Mason IB. Exercise, training and neutrophil function. Sports Med. 2019;49(Suppl 2):S139-52.
10. Gleeson M. Immunological aspects of sport nutrition. Immunol Cell Biol. 2019 Feb;97(2):115-22.
11. Alghoul H, Saleh R, Al-Farttoosi K, Ibrahim S. Hematological values among Libyan adults living in arid regions. Libyan J Med. 2017;12(1):1345581.
12. Murphy WG. The sex difference in haemoglobin levels in adults - mechanisms, causes, and consequences. Blood Rev. 2014 Mar;28(2):41-7.

Received*: 10-08-2025 -* ***Accepted****: 08-10-2025 -* ***Published****: 14-10-2025*