

ASSOCIATIONS OF BASAL HEMATOLOGICAL PARAMETERS AND SYSTEMIC INFLAMMATORY MARKERS WITH PERFORMANCE IN YOUNG FEMALE WEIGHTLIFTERS

Bekir Tokay¹

¹ Usak University, Faculty of Sport Sciences, Uşak, Türkiye

ORCID: B.T. 0000-0003-0059-0736

Corresponding author: Bekir Tokay, **E-mail:** bekir.tokay@usak.edu.tr

Received: 26.12.2025; **Accepted:** 23.03.2026; **Available Online Date:** 31.05.2026

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Cite this article as: Tokay B. Associations of Basal Hematological Parameters and Systemic Inflammatory Markers with Performance in Young Female Weightlifters. J Basic Clin Health Sci 2026; 10: 229-239.

ABSTRACT

Purpose: This study aimed to assess baseline hematological profiles and systemic inflammatory status of elite (EWL) and sub-elite (S-EWL) female weightlifters in relation to performance.

Material and Methods: Twenty-seven female athletes (Age: 18.48 ± 1.72 years) were categorized as EWL ($n = 14$) or S-EWL ($n = 13$). Age, height, body weight, BMI, training experience, and maximal snatch (MSn), clean & jerk (MC&J), and total lift (MTotal) performances were recorded. Performance values were adjusted for body weight using allometric scaling (ASn, AC&J, ATotal). Basal hematological parameters and systemic inflammatory markers were analyzed. Between-group comparisons were performed using Mann–Whitney U test, and correlations were assessed with Spearman's coefficient.

Results: No significant differences were found in demographics or training experience ($p > 0.05$). EWL showed significantly MSn ($p = 0.011$), MC&J ($p = 0.004$), and MTotal ($p = 0.005$) performances. Allometrically scaled relative strength was superior in EWL for AC&J and ATotal ($p < 0.05$). Hematological and inflammatory parameters were largely similar, although MONO% was higher in EWL ($p = 0.046$). In EWL, NEU% and NLR positively correlated with ASn performance ($r = 0.631$ and $r = 0.565$; $p < 0.05$); no significant correlations were observed in S-EWL.

Conclusion: Elite female weightlifters exhibited superior absolute and allometrically scaled performance compared to sub-elites. Hematological and inflammatory markers were similar between groups, except for MONO%, which was elevated in elite athletes, potentially reflecting adaptive immune responses. These findings underscore the importance of individualized training and recovery strategies and regular blood monitoring to optimize performance and prevent overtraining.

Keywords: Hematological parameters, inflammatory markers, performance, young female athletes, weightlifting

INTRODUCTION

Weightlifting is an Olympic sport that demands high levels of strength, power, speed, and advanced training status. Success in weightlifting is achieved through the athlete's well-coordinated anthropometric, hematological, physiological, and

metabolic characteristics, combined with regular training and technically precise execution of snatch and clean & jerk movements (1-3). Achieving elite performance in Olympic-style weightlifting requires both maximal technical proficiency and the strength capacity of the entire musculature (4, 5).

As with other individual and physically demanding sports, athletes in weightlifting are subjected to high loads and maximal weights, which inherently carries a risk of injury that can cause varying degrees of tissue and organ damage (2, 5, 6). Moreover, it is well established that isometric contractions, along with the repeated exposure to heavy loads and exercise-induced physiological stress, play a critical role in eliciting metabolic, structural, strength, hormonal, hemodynamic, and inflammatory responses in bodies of athletes (5, 7-10). In particular, the duration, type, and intensity of exercise have been shown to significantly influence inflammatory regulation and leukocyte balance during adaptive responses (7, 8, 11).

Recent studies in both athletes and other populations have utilized inflammatory markers derived from routine hematological tests (12, 13). These markers include key blood cell ratios such as red cell distribution width (RDW), neutrophil-to-lymphocyte ratio (NLR), monocyte-to-lymphocyte ratio (MLR), and platelet-to-lymphocyte ratio (PLR). While there is research examining exercise type-specific inflammatory responses in sports involving high-load resistance training, including weightlifting, the relationship between baseline inflammatory status and sport type remains incompletely understood (14, 15). Considering the complexity of exercise-induced inflammation in athletes, composite inflammatory indices such as the Systemic Immune-Inflammation Index (SII) and Aggregate Systemic Inflammation Index (AISI) have been developed to provide a more comprehensive evaluation beyond individual inflammatory cells (16-19).

As far as could be determined, although studies in various sports have examined the relationships between hematological parameters such as hemoglobin, hematocrit, and erythrocytes, systemic inflammatory indices, and baseline values of neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and monocyte-to-lymphocyte ratio (MLR) with performance (12, 13, 20), research specifically addressing the basal status of these immuno-inflammatory parameters and their association with performance in female weightlifters is lacking. Furthermore, the functional role of hematological parameters and baseline inflammatory status in technical disciplines such as the snatch and clean & jerk has not yet been comprehensively elucidated. Therefore, investigations focusing on this topic are needed.

The literature indicates that these parameters have been extensively studied in endurance athletes, however, research evaluating both hematological and inflammatory profiles in strength and power sports, particularly among female weightlifters, remains extremely limited (21). In Türkiye, studies in the field of weightlifting have predominantly focused on performance, technical analysis, or biomechanics, and there are virtually no studies comparing the hematological and inflammatory responses of elite and sub-elite female athletes. This gap represents a significant limitation in understanding the immunological effects of high-intensity training in female athletes.

In this context, examining hematological and inflammatory markers simultaneously in female weightlifters offers a valuable contribution to the literature by highlighting physiological adaptations associated with elite status, enhancing performance monitoring, and identifying sport-specific biological markers. The study will address the current lack of data on female weightlifters in Turkey and will contribute to the development of evidence-based recommendations for athlete health and training management. The study hypotheses are as follows: H1: Elite female weightlifters exhibit higher hematological and baseline inflammatory parameters compared to sub-elite athletes. H2: Hematological and inflammatory parameters are significantly associated with weightlifting performance and total allometrically scaled relative strength. H3: There are differences in the direction and magnitude of relationships between demographic characteristics and hematological and inflammatory markers between elite and sub-elite groups.

MATERIAL AND METHODS

Participants

This study was designed as a cross-sectional and observational investigation examining the relationships between baseline hematological parameters, systemic inflammatory markers, and performance in young female weightlifters. The study cohort consisted of 27 active young female athletes (Age: 18.48 ± 1.72 years) categorized according to the age classifications of the International Weightlifting Federation (22) and the Turkish Weightlifting Federation (23): Youth (16–17 years), Junior (18–20 years), and Under-23 (21–23 years). Due to the limited population of elite young female weightlifters and the cross-sectional nature of the

study, the sample size was not determined a priori based on power analysis. Instead, the sample included all athletes available during the study period who met the inclusion criteria.

Participants were divided into two groups based on competition and performance level: the Elite Weightlifter Group (EWL; $n = 14$; Age: 18.86 ± 1.83 years) and the Sub-Elite Weightlifter Group (S-EWL; $n = 13$; Age: 18.08 ± 1.55 years). EWL athletes were selected from competitors with experience at international championships, such as the European Championships, World Championships, and the Olympic Games, whereas S-EWL athletes had experience at national or regional competitions. Group allocation was based on the highest competition level in which athletes had previously participated; medal achievements were not considered in the classification. To provide an objective performance context for this classification, the IWF ranking list was also reviewed (24). The presence of EWL athletes in the IWF ranking database supports the competitive distinction between the groups.

The study was approved by the Non-Interventional Clinical Research Ethics Committee of Uşak University (Date: 17.12.2025, Decision No: 1004-1004-23). Prior to participation, all athletes provided written informed consent, and the research was conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion criteria for the study were: active, licensed female athletes with at least three years of experience in Olympic-style weightlifting who regularly participated in training and had competed at the reported competition levels. Exclusion criteria included a history of musculoskeletal injury within the last three months, previous surgeries or fractures involving the musculoskeletal system, deformities of the extremities, hematological, metabolic, neurological, or immunological disorders, and ongoing infections. Demographic information, anthropometric measurements (age, height, body weight, body mass index), sport history, and competition experience were collected using a standardized record form. Athletes' maximal snatch and clean & jerk performance data were obtained from the official websites of national and international federations.

Anthropometric Assessments

The primary physical evaluations in this study included body weight, height measurements, and blood sampling. Anthropometric assessments were conducted in the athletes' familiar training environment, with participants wearing light clothing, prior to breakfast in the morning. Before data collection, all measurement procedures were pre-tested to identify potential issues, and necessary health precautions were implemented to ensure participant safety.

Height was measured with participants standing barefoot in an upright posture using a stadiometer (Seca 714, Hamburg, Germany) with a precision of ± 0.1 cm. Body weight was recorded using a digital scale (TANITA-MC 580, Tokyo, Japan) with ± 0.1 kg accuracy. Body mass index (BMI) was calculated as body weight (kg) divided by the square of height (m^2). Additional demographic and training-related data, including age, training experience, height, body weight, and BMI, were collected using a standardized evaluation form.

Performance Data

Maximal snatch (MSn) and clean and jerk (MC&J) performance values were obtained from the official records of THF and IWF and pertain to the 2025 competition season.

Allometric Relative Strength Calculation

To account for the influence of body weight on performance and to provide a more accurate representation of the athletes' true strength capacity, allometrically scaled relative strength values were calculated in this study. This approach enables meaningful comparisons among athletes from different weight categories by normalizing strength performance relative to body mass. Accordingly, body mass index (BMI), a commonly used indicator of anthropometric characteristics (25), and allometric relative strength values were calculated separately for the snatch (ASn), clean and jerk (AC&J), and total lift (ATotal). In this method, strength performance is adjusted using an allometric exponent of 0.67 (2/3). This exponent is based on the principle of geometric similarity, which suggests that muscle cross-sectional area (a two-dimensional construct associated with force production) scales with body mass (a three-

dimensional construct) raised to the power of 2/3. Therefore, this scaling approach allows lifting performance to be evaluated independently of body mass and provides a more objective assessment of the relationship between strength performance and physiological variables such as hematological parameters and systemic inflammatory markers (26-30). Allometric relative strength was calculated using the following formula:

$$\text{Allometric Relative Strength (kg/kg}^{0.67}\text{)} = \frac{\text{Total Lift (kg)}}{\text{Body Mass (kg)}^{0.67}}$$

Hematological Sample Collection and Analysis

Blood samples were collected in the athletes' familiar training environment after a 24-hour rest period, in the afternoon (15:00–17:00) prior to regular training sessions. Participants were instructed to avoid alcohol and caffeine-containing foods and beverages at least one day before testing and to refrain from intense physical activity and training for at least 24 hours prior. Blood sampling was scheduled considering the follicular phase of the menstrual cycle for all participating female athletes.

For each participant, basal blood samples were collected at rest by experienced healthcare personnel following aseptic-antiseptic protocols. Venous blood was drawn from the antecubital vein using a catheter into 4 mL K3-EDTA tubes (4 mL vacutainer; BD Vacutainer, Franklin Lakes, NJ, USA). Samples were stored at room temperature under appropriate conditions without centrifugation and delivered to the laboratory within two hours. Hematological parameters were analyzed using an automated hematology analyzer (Cell-Dyn 1800, Abbott Diagnostics, Abbott Park, IL, USA) according to the manufacturer's instructions. Leukocyte subpopulations were determined as follows: total white blood cells (WBC, $10^3/\mu\text{L}$), neutrophils (NEU, $10^3/\mu\text{L}$), lymphocytes (LYM, $10^3/\mu\text{L}$), monocytes (MONO, $10^3/\mu\text{L}$), eosinophils (EOS, $10^3/\mu\text{L}$), basophils (BASO, $10^3/\mu\text{L}$), as well as percentages of lymphocytes (LYM%) and monocytes (MONO%). Erythrocyte parameters included red blood cell count (RBC, $10^6/\mu\text{L}$) and hemoglobin concentration (Hb, g/dL). Platelet parameters included platelet count (PLT, $10^3/\mu\text{L}$) and mean platelet volume (MPV, fL).

Calculation of Inflammatory Biomarkers

To assess basal combined inflammatory indices, complete blood count parameters were evaluated, including WBC, NEU, MONO, LYM, PLT, Hb,

hematocrit (HCT), red cell distribution width (RDW), MPV, and platelet distribution width (PDW). The systemic immune-inflammation index (SII) was calculated using the formula: $\text{PLT} \times \text{NEU} / \text{LYM}$ ($10^3/\mu\text{L}$). The aggregate systemic inflammation index (ASII) was calculated as: $\text{NEU} \times \text{PLT} \times \text{MONO} / \text{LYM}$ ($10^3/\mu\text{L}$). In addition, four conventional inflammatory markers were calculated: neutrophil-to-lymphocyte ratio ($\text{NLR} = \text{NEU}/\text{LYM}$), platelet-to-lymphocyte ratio ($\text{PLR} = \text{PLT}/\text{LYM}$), monocyte-to-lymphocyte ratio ($\text{MLR} = \text{MONO}/\text{LYM}$), and MPV/PLT ratio (12, 31). Systemic inflammation scores and indices were compared between the EWL and S-EWL groups.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY, USA). Data distribution was assessed using the Shapiro–Wilk test. For demographic and anthropometric variables, as well as maximal and allometrically scaled performance measures (MSn, MC&J, MTotal, ASn, AC&J, ATotal), which met normality assumptions, descriptive statistics are presented as mean $\pm$ standard deviation (SD). Group differences were assessed using independent t-tests, and the magnitude of differences was quantified using Cohen's d. Hematological and inflammatory parameters, which did not meet normality assumptions, are presented as median (interquartile range, IQR). Group comparisons were performed using the Mann–Whitney U test, and effect sizes (r) were reported. Associations between these parameters and allometrically scaled performance variables (ASn, AC&J, ATotal) were examined using Spearman's rank correlation coefficient (ρ). Statistical significance was set at $p < 0.05$. Given that weightlifting performance is inherently influenced by body mass, all performance values were normalized using allometric scaling to account for body weight effects. The strength of correlations was interpreted according to Evans (1996), and all analyses were conducted in accordance with recommended statistical standards for biomedical research (32, 33).

RESULTS

The demographic, anthropometric, and performance characteristics of EWL and S-EWL young female weightlifters are summarized in Table 1. No significant differences were observed between groups in most demographic and anthropometric variables, including age, height, body weight, and

training experience ($p > 0.05$, Cohen's d ranging from 0.20–0.53), except for BMI, which was significantly higher in EWL compared to S-EWL ($p = 0.047$, Cohen's $d = 0.80$). In contrast, all performance-related variables differed significantly between groups ($p < 0.05$), with the EWL group demonstrating higher values than the S-EWL group in MSn (Cohen's $d = 1.38$), MC&J (Cohen's $d = 1.45$), MTot (Cohen's $d = 1.43$), ASn (Cohen's $d = 0.86$), AC&J (Cohen's $d = 0.96$), and ATot (Cohen's $d = 0.93$), indicating medium to large effect sizes for all comparisons. Consistent with these findings, the allometrically scaled performance values were also higher in the EWL group, particularly for the AC&J and ATot lifts ($p < 0.05$). The difference in ASn did not reach statistical significance ($p = 0.035$). The corresponding effect sizes indicated moderate effects (Cohen's $d = 0.85$ – 0.96). Although ASn values were higher in the EWL group, this difference did not attain statistical significance ($p = 0.035$, Cohen's $d = 0.85$). According to Table 2, there were no statistically significant differences between the EWL and S-EWL groups in most hematological and inflammatory parameters ($p > 0.05$). However, MONO% values were significantly higher in the EWL group compared to the S-EWL group ($p = 0.046$), with a moderate effect size ($r = 0.38$).

Although not statistically significant, NEU% values tended to be higher in the S-EWL group ($p = 0.094$, $r = 0.32$), indicating a moderate effect. Similarly, inflammatory markers such as SII and NLR were descriptively higher in the S-EWL group, but these differences did not reach statistical significance ($p > 0.05$), with small-to-moderate effect sizes ($r = 0.21$ – 0.28).

The relationships between hematological and inflammatory parameters and allometrically scaled relative performance variables in the EWL and S-EWL groups are presented in Table 3. In the EWL group, a strong positive correlation was observed between NEU% and ASn ($r = 0.631$, $p = 0.016$). In addition, a moderate-to-high positive correlation was identified between the NLR and ASn performance ($r = 0.565$, $p = 0.035$). In the EWL group, no statistically significant correlations were found between the remaining hematological and inflammatory parameters and ASn, AC&J, or ATot performance variables (all $p > 0.05$). In the S-EWL group, no statistically significant relationships were detected between any hematological or inflammatory parameters and ASn, AC&J, or ATot performance variables (all $p > 0.05$).

Table 1. Demographic, anthropometric, and performance characteristics of EWL and S-EWL young female weightlifters

Variables	EWL (n=14)		S-EWL (n=13)		p	Cohen's d
	Mean	SD	Mean	SD		
Age (years)	18,86	1,83	18,08	1,55	0,246	0,45
Height (cm)	161,14	7,93	159,77	5,15	0,601	0,20
BW (kg)	67,29	16,31	57,92	8,01	0,071	0,71
BMI (kg/m ²)	25,67	4,88	22,61	2,21	0,047*	0,79
TE (years)	6,00	2,07	5,00	1,68	0,183	0,52
MSn (kg)	83,21	12,92	69,46	5,12	0,002*	1,37
MC&J (kg)	101,07	14,78	84,46	5,95	0,001*	1,45
MTot (kg)	184,29	27,51	153,92	10,82	0,001*	1,43
ASn (kg/bw(kg) ^{0.67})	5,01	0,46	4,61	0,46	0,035*	0,85
AC&J (kg/bw(kg) ^{0.67})	6,09	0,50	5,60	0,50	0,019*	0,96
ATot (kg/bw(kg) ^{0.67})	11,11	0,95	10,22	0,95	0,023*	0,93

BW: Body weight, BMI: Body mass index, TE: Training experiment, MSn: Maximal snatch, MC&J: Maximal clean and jerk, MTot: Maximal total (snatch + clean and jerk), ASn: Allometric relative snatch, AC&J: Allometric relative clean and jerk, ATot: Allometric relative total (snatch + clean and jerk). EWL: Elite weightlifter group, S-EWL: Sub-elite weightlifter group. * All variables were analyzed using independent t-tests. $p < 0.05$ indicates a statistically significant difference. Effect sizes are reported as Cohen's d .

Table 2. Comparison of hematological and inflammatory markers between EWL and S-EWL female weightlifters

		EWL (n=14)	S-EWL (n=13)			
		Median (IQR)	Median (IQR)	U	p	r
Hematological Parameters	RBC (10 ⁶ /μL)	4.42 (4.33-4.66)	4.39 (4.15-4.63)	75.5	0.452	0.14
	Hb (g/dL-1)	14 (12.52-14.7)	12.8 (12.25-13.5)	62.5	0.166	0.26
	PLT (10 ³ /μL)	252 (238.25-316.5)	248 (238.5-336.0)	87.5	0.865	0.03
	WBC (10 ³ /μL)	6.42 (5.83-9.21)	7.57 (7.16-9.17)	82.0	0.662	0.08
	NEU (10 ³ /μL)	4.18 (3.41-5.39)	4.89 (4.44-6.09)	64.0	0.190	0.25
	NEU %	59.75 (56.02-64.65)	65.5 (59.65-74.4)	56.5	0.094	0.32
	LYM (10 ³ /μL)	1.79 (1.55-2.20)	1.86 (1.42-2.25)	89.0	0.923	0.01
	LYM %	26.75 (21.95-29.85)	22.9 (19.7-29.0)	72.0	0.356	0.17
	MONO (10 ³ /μL)	0.62 (0.44-0.85)	0.49 (0.37-0.73)	66.5	0.234	0.22
	MONO %	8.65 (7.6-10.55)	7.6 (5.6-9.05)	50.0	0.046*	0.38
	EOS (10 ³ /μL)	0.15 (0.08-0.24)	0.15 (0.07-0.26)	90.0	0.961	0.00
	EOS %	2.21 (1.17-3.79)	1.88 (1.03-3.10)	83.0	0.698	0.07
	BASO (10 ³ /μL)	0.12 (0.09-0.15)	0.12 (0.09-0.15)	89.0	0.922	0.01
	MPV (fL)	10.25 (8.3-10.6)	9.7 (8.3-10.0)	77.5	0.512	0.12
Inflammatory Markers	NLR	2.26 (2.05-2.74)	2.72 (2.15-3.80)	68.0	0.264	0.21
	PLR	150.89 (129.77-158.97)	146.15 (133.33-184.25)	84.0	0.734	0.06
	MLR	0.31 (0.26-0.45)	0.31 (0.19-0.37)	73.0	0.382	0.16
	SII	615.71 (473.42-780.07)	856.51 (670.84-1037.38)	61.0	0.145	0.28
	AISI	446.33 (249.79-566.71)	360.23 (202.98-727.20)	87.0	0.846	0.03
	MPV/PLT	0.03 (0.02-0.04)	0.03 (0.02-0.04)	84.0	0.734	0.06

RBC: Red blood cell, Hb: Hemoglobin, PLT: Platelet, WBC: White blood cell; NEU: Neutrophil, NEU%: Neutrophil percentage, LYM: Lymphocyte, LYM%: Lymphocyte percentage, MONO: Monocyte, MONO%: Monocyte percentage, EOS: Eosinophil, EOS%: Eosinophil percentage, BASO: Basophil, MPV: Mean platelet volume, NLR: Neutrophil-to-lymphocyte ratio, PLR: Platelet-to-lymphocyte ratio, MLR: Monocyte-to-lymphocyte ratio, SII: Systemic immune-inflammation index, AISI: Aggregate index of systemic inflammation, MPV/PLT: Mean platelet volume-to-platelet ratio. Data are presented as median (IQR). EWL: Elite weightlifter group, S-EWL: Sub-elite weightlifter group. Group comparisons were performed using the Mann-Whitney U test. U = Mann-Whitney U statistic; r = effect size

DISCUSSION

This study aimed to examine the relationships between basal hematological profiles, systemic inflammatory markers, and performance in young female weightlifters by comparing elite (EWL) and sub-elite (S-EWL) weightlifters. The findings demonstrated that the two groups were comparable in terms of demographic and anthropometric characteristics (age, height, body weight, BMI, and training experience; $p > 0.05$), with small to moderate effect sizes (Cohen's d ranging from 0.20 to 0.79). In contrast, both absolute (MSn, MC&J, and MTotal) and allometrically normalized (ASn, AC&J, and ATotal) performance outcomes were significantly higher in the EWL compared with the S-EWL ($p < 0.05$), with moderate to large effect sizes (Cohen's d ranging from 0.85 to 1.45) (Table 1). These results suggest that the superior performance observed in elite athletes may not be solely attributable to body mass but may instead reflect long-term exposure to

high-intensity training, enhanced strength capacity, and advanced neuromuscular adaptations.

With respect to hematological and inflammatory parameters, the groups exhibited largely similar baseline profiles; however, the monocyte percentage (MONO%) was significantly higher in the elite group compared with the S-EWL ($p = 0.046$; $r = 0.38$) (Table 2). At the same time, the relative preservation of leukocyte and platelet parameters in elite female weightlifters may be interpreted as an indicator of adaptive physiological responses associated with high training status (2). This finding suggests that, despite sustained exposure to intense training stress, hematological homeostasis can be effectively maintained in elite athletes.

In the elite group, the elevated monocyte percentage could reflect chronic physiological and immune adaptations associated with long-term high-intensity anaerobic training rather than acute inflammation.

Table 3. Spearman correlations between hematological and inflammatory parameters and allometrically scaled performance variables in elite and sub-elite female weightlifters.

Variable	Groups	ASn		AC&J		ATotal	
		r	p	r	p	r	p
RBC (10 ⁶ /μL)	EWL	0.178	0.543	0.152	0.605	0.196	0.503
	S-EWL	0.305	0.310	0.413	0.160	0.377	0.204
HGB (g/dL)	EWL	-0.143	0.625	-0.121	0.680	-0.081	0.782
	S-EWL	0.052	0.865	0.214	0.482	0.143	0.640
PLT (10 ³ /μL)	EWL	-0.160	0.584	-0.160	0.584	-0.156	0.594
	S-EWL	0.390	0.188	0.237	0.436	0.313	0.297
WBC (10 ³ /μL)	EWL	0.020	0.946	0.011	0.970	0.015	0.958
	S-EWL	0.011	0.972	0.003	0.993	-0.055	0.858
NEU (10 ³ /μL)	EWL	0.160	0.584	0.108	0.714	0.143	0.626
	S-EWL	0.220	0.471	0.171	0.577	0.121	0.694
NEU %	EWL	0.631*	0.016	0.437	0.118	0.525	0.054
	S-EWL	0.514	0.072	0.413	0.160	0.421	0.152
LYM (10 ³ /μL)	EWL	-0.451	0.106	-0.266	0.358	-0.332	0.246
	S-EWL	-0.413	0.161	-0.380	0.200	-0.413	0.161
LYM %	EWL	-0.462	0.096	-0.299	0.299	-0.389	0.169
	S-EWL	-0.445	0.128	-0.349	0.242	-0.363	0.223
Mono	EWL	-0.264	0.362	-0.262	0.366	-0.273	0.345
	S-EWL	-0.137	0.655	-0.085	0.782	-0.071	0.817
Mono %	EWL	-0.460	0.098	-0.405	0.151	-0.434	0.121
	S-EWL	0.099	0.748	0.187	0.541	0.198	0.517
Eos	EWL	-0.218	0.454	-0.172	0.557	-0.167	0.568
	S-EWL	-0.448	0.124	-0.315	0.294	-0.369	0.215
Eos %	EWL	-0.134	0.648	-0.103	0.725	-0.090	0.759
	S-EWL	-0.0440	0.133	-0.281	0.353	-0.335	0.263
Baso	EWL	-0.400	0.156	-0.391	0.167	-0.435	0.120
	S-EWL	-0.036	0.907	0.106	0.729	0.047	0.879
MPV	EWL	-0.143	0.626	-0.191	0.513	-0.218	0.455
	S-EWL	0.044	0.886	0.080	0.795	0.030	0.922
NLR	EWL	0.565*	0.035	0.415	0.140	0.499	0.069
	S-EWL	0.445	0.128	0.349	0.242	0.363	0.223
PLR	EWL	0.468	0.091	0.231	0.427	0.327	0.253
	S-EWL	0.456	0.117	0.297	0.324	0.407	0.168
MLR	EWL	-0.077	0.794	-0.134	0.648	-0.103	0.725
	S-EWL	0.055	0.859	0.107	0.727	0.126	0.681
SII	EWL	0.341	0.233	0.169	0.563	0.248	0.392
	S-EWL	0.418	0.156	0.270	0.373	0.319	0.289
AISII	EWL	0.130	0.659	0.073	0.805	0.112	0.703
	S-EWL	0.115	0.707	0.022	0.943	0.077	0.803
MPV/PLT	EWL	0.081	0.782	0.134	0.648	0.099	0.737
	S-EWL	-0.071	0.817	0.083	0.789	-0.022	0.943

RBC: Red blood cell, Hb: Hemoglobin, PLT: Platelet, WBC: White blood cell; NEU: Neutrophil, NEU%: Neutrophil percentage, LYM: Lymphocyte, LYM%: Lymphocyte percentage, MONO: Monocyte, MONO%: Monocyte percentage, EOS: Eosinophil, EOS%: Eosinophil percentage, BASO: Basophil, MPV: Mean platelet volume, NLR: Neutrophil-to-lymphocyte ratio, PLR: Platelet-to-lymphocyte ratio, MLR: Monocyte-to-lymphocyte ratio, SII: Systemic immune-inflammation index, AISII: Aggregate index of systemic inflammation, MPV/PLT: Mean platelet volume-to-platelet ratio. EWL: Elite weightlifter group, S-EWL: Sub-Elite weightlifter group. Associations between hematological and inflammatory parameters and allometrically scaled weightlifting performance variables were examined using Spearman's rank correlation coefficient (ρ), considering the non-normal distribution of the data and the limited sample size. Statistical significance was set at $p < 0.05$. Statistically significant correlations are indicated by an asterisk (*).

Short-term (≈ 60 s) anaerobic has been shown to transiently increase monocytes and natural killer cells in the early post-exercise period, with this response being acute, temporary, and largely reversible, while other immune cell populations return to baseline within 24 hours (34, 35). These adaptations are further reflected in the reprogramming of monocyte metabolism during inflammatory responses, contributing to tightly regulated immune activity (36). Taken together, these findings indicate that anaerobic loading primarily modulates monocyte responses through exercise-specific neuroendocrine and immune mobilization mechanisms rather than via pathological inflammation. In individuals undergoing repeated high-intensity anaerobic training, this response may reflect physiological adaptations that facilitate immune regulation and tissue remodeling, potentially mediated by enhanced anti-inflammatory cytokine production (37-39).

When examining performance–inflammation relationships, significant positive correlations were observed in the EWL between allometrically scaled snatch performance (ASn) and both NEU% ($r = 0.631$; $p = 0.016$) and NLR ($r = 0.565$; $p = 0.035$) (Table 3). These findings suggest that a neutrophil-dominant immune profile may reflect exercise-induced increases in neutrophil counts (40), as well as neutrophil elevation and lymphocyte reduction during early post-exercise recovery (41) and may represent sport-specific adaptations to intensive training in elite athletes (42, 43). In contrast, no significant associations between inflammatory markers and performance were observed in the sub-elite group. However, the relatively elevated basal inflammatory indices (NLR and SII) in this group are consistent with previously reported acute immune responses following intensive resistance exercise (42, 44), suggesting that S-EWL may experience higher exercise-induced inflammatory loads that could influence recovery and performance sustainability.

The existing literature indicates that resistance-based and anaerobic exercise modalities can induce transient alterations in hematological and inflammatory biomarkers. High-intensity resistance exercise has been shown to provoke short-term increases in muscle damage and inflammatory markers, typically emerging in the early post-exercise period and returning toward baseline within 24 hours (45, 46). In the study by Ibis et al. (2010), changes in erythrocyte parameters were observed following

anaerobic exercise and during a 24-hour recovery period; however, these alterations did not reach statistical significance. Acute exercise-induced increases in erythrocyte-related indices are largely attributed to reductions in plasma volume, with subsequent fluid and electrolyte replacement and rest facilitating the restoration of vascular volume homeostasis and normalization of erythrocyte levels. Previous studies further indicate that hematological and inflammatory responses to resistance exercise may vary depending on exercise intensity, duration, and individual training status (47, 48). Such exercise modalities impose substantial mechanical loading on muscle and connective tissues, leading to transient fluctuations in neutrophil and lymphocyte counts during the acute phase (49-51). Conversely, long-term and regular training adaptations have been shown to improve erythrocyte parameters and oxygen transport capacity (52, 53). Moreover, Forti et al. (2017) demonstrated that nine weeks of resistance training favorably modulated basal inflammatory profiles in healthy individuals. These responses are thought to be partially mediated by exercise-induced hormonal alterations, such as elevations in cortisol, which influence leukocyte mobilization and neutrophil–lymphocyte balance (55). In elite athletes, repeated exposure to such physiological stressors may facilitate the development of a more controlled and regulated inflammatory profile, reflecting enhanced recovery capacity and physiological resilience. Notably, neutrophil counts vary according to the duration and intensity of exercise, which may account for fluctuations in NLR and other inflammatory markers (56). In this context, the relatively elevated basal inflammatory indices observed in the sub-elite group, particularly NLR and SII, are consistent with previously reported immune alterations associated with intensive but less-adapted training loads (14, 44). These findings could indicate that adaptive mechanisms related to immune regulation and recovery might operate more efficiently in elite athletes (57), whereas the comparatively higher inflammatory load in sub-elite athletes may potentially affect recovery processes and the sustainability of performance.

Overall, the findings of this study indicate that basal hematological and inflammatory markers were largely similar between elite and sub-elite female weightlifters. While minor variations were observed, these differences were not pronounced, suggesting that both groups share comparable hematological

and inflammatory profiles. These results highlight the importance of considering individual hematological and inflammatory characteristics when designing training loads and recovery strategies, particularly in developing athletes, to optimize performance while minimizing excessive physiological strain.

Limitations

The strengths of this study include the simultaneous examination of performance, hematological, and inflammatory parameters in young female weightlifters across elite and sub-elite levels, allowing a holistic evaluation of adaptive responses. Limitations include the relatively small sample size, inclusion of only female athletes, and the lack of monitoring acute post-training changes. Additionally, potential confounding factors such as nutrition, sleep, and hormonal status were not controlled. The cross-sectional design limits causal interpretation of observed differences. Future studies should consider larger sample sizes, include both male and female athletes, employ longitudinal designs, and control for additional influencing factors.

CONCLUSION

Elite female weightlifters demonstrated superior absolute and allometrically scaled performance compared to their sub-elite counterparts. Although these performance differences were observed, no significant differences were found in hematological and inflammatory parameters between the groups, suggesting that basal systemic inflammatory profiles in young female weightlifters do not appear to be strongly influenced by training status. However, MONO% was significantly higher in the elite group, potentially reflecting adaptive immune responses associated with long-term high-level training exposure. These findings underscore the importance of individualized training and recovery strategies according to athlete level. Furthermore, regular monitoring of blood parameters may contribute to optimizing performance and managing training load.

Acknowledgement: The author expresses sincere gratitude to the Olympic-style weightlifting athletes and their coaches for their valuable participation, as well as to the Turkish Weightlifting Federation for their support and cooperation throughout the study.

Author contribution: Conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, funding acquisition: B.T.

Conflict of interests: The authors declare no conflicts of interest.

Ethical approval: This study was conducted in accordance with the principles of the 2013 Declaration of Helsinki and was approved by the Non-Interventional Clinical Research Ethics Committee of Uşak University (Approval Date: 17.12.2025; Approval Number: 1004-1004-23). All participants were fully informed about the purpose, scope, and procedures of the study, and written informed consent was obtained prior to data collection. For participants whose personal or clinical details or any identifying images were included, written informed consent for collection and publication was obtained from both the participants and their parent/legal guardian.

Funding: This project was self-funded.

Peer-review: Externally peer-reviewed.

REFERENCES

- Garhammer J. A review of power output studies of Olympic and powerlifting: Methodology, performance prediction, and evaluation tests. *J Strength Cond Res* 1993;7(2):76-89.
- Erdağı K. Olimpik halter eğitimi ve ağırlık antrenmanlarında çalışan kas grupları. Ankara: Türk Eğitim Yayınları; 2022.
- Kilincarslan Z, Erdağı K. A review study on Olympic weightlifting. *J Sport Sci Innov* 2025;1(1):54-73.
- Kır R, Uzun ME, García-Vázquez JF, et al. Comparison of pinch strength and its relationship with performance and demographic variables in elite female weightlifters. *J Sport Sci Innov* 2025;1(1):16-29.
- Storey A, Smith HK. Unique aspects of competitive weightlifting: Performance, training and physiology. *Sports Med* 2012;42(9):769-790.
- Hammami N, Hattabi S, Salhi A, et al. Combat sport injuries profile: A review. *Sci Sports* 2018;33:73-79.
- Chazaud B. Inflammation during skeletal muscle regeneration and tissue remodeling: Application to exercise-induced muscle damage management. *Immunol Cell Biol* 2016;94:140-145.
- Erdoğan M, Yüksel MF, Işık B, et al. The effects of acute moderate intensity training on hematological parameters in elite para-badminton athletes. *J Mens Health* 2021;18(2):1-8.
- Aktar B, Özyürek S, Koca U, et al. Acute effects of proprioceptive neuromuscular facilitation compared to active range of motion exercises on respiratory and hemodynamic responses in critically ill patients: A pilot study. *J Basic Clin Health Sci* 2025;9(2):327-334.
- Kır R, Civan AH, Coşkun F, et al. Handgrip strength in female Olympic-style weightlifters: An

- investigation of its associations with competitive level, performance, and anthropometric characteristics. *J Sport Sci Innov* 2025;1(1):1-15.
11. Ihalainen JK, Schumann M, Eklund D, et al. Combined aerobic and resistance training decreases inflammation markers in healthy men. *Scand J Med Sci Sports* 2018;28(1):40-47.
 12. Işık B, Küçüktürk S, Yüksel MF, et al. The effects of acute high-intensity interval training on hematological parameters and neutrophils-to-lymphocytes ratio in elite taekwondo athletes according to gender. *Eur J Clin Exp Med* 2022;3:306-315.
 13. Forget P, Khalifa C, Defour JP, et al. What is the normal value of the neutrophil-to-lymphocyte ratio? *BMC Res Notes* 2017;10:12.
 14. Kaniganti US, Majumdar P. Effect of a weight lifting training session on leukocyte count and myokine (interleukin-6) levels. *J Phys Educ Sport* 2019;19(4):2435-2440.
 15. King DE, Carek P, Mainous AG, et al. Inflammatory markers and exercise: Differences related to exercise type. *Med Sci Sports Exerc* 2003;35(4):575-581.
 16. Rose GL, Mielke GI, Durr M, et al. Effect of resistance training on chronic inflammation: A systematic review and meta-analysis. *Transl Sports Med* 2021;4(6):900-913.
 17. Zacher J, Wesemann F, Joisten N, et al. Cellular integrative immune markers in elite athletes. *Int J Sports Med* 2023;44(4):298-308.
 18. Bayrak AF, Doğan MM, Çetin B. A study on the systemic inflammatory index (SII) and related factors in patients with malignant otitis externa. *J Basic Clin Health Sci* 2024;8(3):759-764.
 19. Wang C, Ning Z, Lu Q, et al. Reference interval establishment for neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio, and systemic immune-inflammation index in athletes: Analysis of sex and sport type impact. *J Clin Lab Anal* 2025;39(5):e70005.
 20. Akca HS, Dulger O, Ozkan A, et al. Analyzing the variation in hematological inflammatory indicators throughout gestation. *Adv Health Sports Technol Sci* 2025;2(1):9-15.
 21. Nikolaidis PT, Veniamakis E, Rosemann T, et al. Nutrition in ultra-endurance: State of the art. *Nutrients* 2018;10(12):1995.
 22. International Weightlifting Federation (IWF). Technical and competition rules & regulations 2025. [Accessed: 01 Feb 2026]. Available from: <https://iwf.sport/wp-content/uploads/downloads/2025/11/IWF-TCRR-2025-as-of-05-November-2025.pdf>
 23. Türkiye Halter Federasyonu (THF). Müsabaka talimatı. Gençlik ve Spor Genel Müdürlüğü. [Accessed: 01 Feb 2026]. Available from: <https://halter.gov.tr/>
 24. International Weightlifting Federation (IWF). 2025 Annual World Ranking list IWF. [Accessed: 17 Jan 2026]. Available from: https://iwf.sport/results/ranking-list/ranking-list-2018-2025/?ranking_year=2025&ranking_agegroup=Senior&ranking_gender=W
 25. Timurtaş E, Selçuk H, Canöz EU, et al. The effect of different body mass index levels on static and dynamic postural balance performance in adults. *J Basic Clin Health Sci* 2023;7(1):131-138.
 26. Dooman CS, Vanderburgh PM. Allometric modeling of the bench press and squat: Who is the strongest regardless of body mass? *J Strength Cond Res* 2000;14(1):32-36.
 27. Marković G, Sekulić D. Modeling the influence of body size on weightlifting and powerlifting performance. *Coll Antropol* 2006;30(3):607-613.
 28. Folland JP, Mc Cauley TM, Williams AG. Allometric scaling of strength measurements to body size. *Eur J Appl Physiol* 2008;102(6):739-745.
 29. Crewther BT, McGuigan MR, Gill ND. The ratio and allometric scaling of speed, power, and strength in elite male rugby union players. *J Strength Cond Res* 2011;25(7):1968-1975.
 30. Freemyer B, Andrews S, Stickley C. Allometric scaling hip joint moments optimally reduces anthropometric differences in males and females. *Sports Biomech* 2024;23(12):3213-3223.
 31. Yildirim SB, Yilmaz KA, Altuntaş NB, et al. Relationship between combined systemic inflammatory indices with presence and severity of hyperemesis gravidarum. *Eur Rev Med Pharmacol Sci* 2023;27(18).
 32. Evans JD. Straightforward statistics for the behavioral sciences. Pacific Grove: Brooks/Cole; 1996.
 33. Mukaka MM. A guide to appropriate use of correlation coefficient in medical research. *Malawi Med J* 2012;24(3):69.
 34. Gabriel H, Urhausen A, Kindermann W. Mobilization of circulating leucocyte and lymphocyte subpopulations during and after

- short, anaerobic exercise. *Eur J Appl Physiol Occup Physiol* 1992;65(2):164-170.
35. Meyer-Lindemann U, Moggio A, Dutsch A, et al. The impact of exercise on immunity, metabolism, and atherosclerosis. *Int J Mol Sci* 2023;24(4):3394.
 36. Zhu X, Meyers A, Long D, et al. Frontline science: Monocytes sequentially rewire metabolism and bioenergetics during an acute inflammatory response. *J Leukoc Biol* 2019;105(2):215-228.
 37. Gleeson M, Bishop NC, Stensel DJ, et al. The anti-inflammatory effects of exercise: Mechanisms and implications for the prevention and treatment of disease. *Nat Rev Immunol* 2011;11(9):607-615.
 38. Handzlik MK, Shaw AJ, Dungey M, et al. The influence of exercise training status on antigen-stimulated IL-10 production in whole blood culture and numbers of circulating regulatory T cells. *Eur J Appl Physiol* 2013;113(7):1839-1848.
 39. Aw NH, Canetti E, Suzuki K, et al. Monocyte subsets in atherosclerosis and modification with exercise in humans. *Antioxidants* 2018;7(12):196.
 40. Yamada M, Suzuki K, Kudo S, et al. Effect of exhaustive exercise on human neutrophils in athletes. *Luminescence* 2000;15:15-20.
 41. Walzik D, Joisten N, Zacher J, et al. Transferring clinically established immune inflammation markers into exercise physiology: Focus on neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio and systemic immune-inflammation index. *Eur J Appl Physiol* 2021;121(7):1803-1814.
 42. Kaniganti US, Karigar CS, Chatterjee P. NLR: An incipient marker to monitor inflammation, overtraining, and recovery in athletes. *Int J Phys Educ Sports Health* 2022;9(4):138-141.
 43. Hansson E, Gilworth RE, Glaser J, et al. Neutrophil: Lymphocyte ratio and cell-free DNA dynamics during excessive heat stress in occupational and experimental settings. *J Therm Biol* 2026;104424.
 44. Liu JF, Chang WY, Chan KH, et al. Blood lipid peroxides and muscle damage increased following intensive resistance training of female weightlifters. *Ann N Y Acad Sci* 2005;1042(1):255-261.
 45. Ammar A, Turki M, Chtourou H, et al. Pomegranate supplementation accelerates recovery of muscle damage and soreness and inflammatory markers after a weightlifting training session. *PLoS One* 2016;11(10):e0160305.
 46. Ibis S, Hazar S, Gökdemir K. Aerobik ve anaerobik egzersizlerin humoral bağışıklığa akut etkisi. *Sport Sciences* 2010;5(2):135-142.
 47. Fortunato AK, Pontes WM, De Souza DMS, et al. Strength training session induces important changes on physiological, immunological, and inflammatory biomarkers. *J Immunol Res* 2018;2018:9675216.
 48. Wang YH, Jiang HC, Luo DL, et al. Effect of resistance exercise on peripheral inflammatory biomarkers in healthy adults: A meta-analysis of randomized controlled trials. *Eur Rev Med Pharmacol Sci* 2022;26(21).
 49. Toumi H, Best TM. The inflammatory response: Friend or enemy for muscle injury? *Br J Sports Med* 2003;37(4):284-286.
 50. Dohi K, Mastro AM, Miles MP, et al. Lymphocyte proliferation in response to acute heavy resistance exercise in women: Influence of muscle strength and total work. *Eur J Appl Physiol* 2001;85:367-373.
 51. Bizjak DA, Jacko D, Zimmer P, et al. Acute alterations in the hematological and hemorheological profile induced by resistance training and possible implication for microvascular functionality. *Microvasc Res* 2018;118:137-143.
 52. Mairbäurl H. Red blood cells in sports: Effects of exercise and training on oxygen supply by red blood cells. *Front Physiol* 2013;4:332.
 53. Craig SK, Byrnes WC, Fleck SJ. Plasma volume during weightlifting. *Int J Sports Med* 2008;29(2):89-95.
 54. Forti LN, Van Roie E, Njemini R, et al. Effects of resistance training at different loads on inflammatory markers in young adults. *Eur J Appl Physiol* 2017;117(3):511-519.
 55. Patlar S. Effects of acute and 4-week submaximal exercise on leukocyte and leukocyte subgroups. *Isokinet Exerc Sci* 2010;18(3):145-148.
 56. Peake J, Suzuki K. Neutrophil activation, antioxidant supplements and exercise-induced oxidative stress. *Exerc Immunol Rev* 2004;10(1):129-141.
 57. Erdağı K, Yüksel MF, Sevindi T. Elit kadın haltercilerde maksimal kuvvet antrenmanının hematolojik parametreler üzerine etkisi. *Türk Spor Bilimleri Dergisi* 2018;1(1):41-48.