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Yogic Practices for Modulating Hematological Indices and Inflammatory Markers: A Non-Pharmacological Approach

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ABSTRACT

Background: Hematological parameters are essential for physiological homeostasis. While yogic practice benefits mental and physical health, its direct impact on blood composition remains underexplored, especially in young adults. **Purpose:** This study examined the effects of a twelve-week structured yogic intervention on hematological parameters, including haemoglobin, red blood cell (RBC) count, total white blood cell (WBC) count, neutrophils, eosinophils, lymphocytes, monocytes, and platelets, in college students. **Methods:** Twenty-four male students (ages 17–22) from Shyampahari Government Primary Teacher Training Institute, India, were randomly assigned to an experimental group ($n = 12$) practicing yoga (1 hour/day, 6 days/week) or a control group ($n = 12$) maintaining regular activities. Blood samples were analyzed pre- and post-intervention using the fully automatic Tulip Coralzer Smart 200 hematology analyzer. Statistical analyses were performed using IBM SPSS (Version 25) at $\alpha = 0.05$. Descriptive statistics, paired and independent t-tests were analyzed within- and between-group differences. **Results:** The experimental group showed significant increases in haemoglobin ($p = .038$), monocyte count ($p = .014$), and platelet count ($p = .049$), suggesting improved oxygen transport, immune function, and hemostatic regulation. Significant reductions in WBC count ($p = .005$) and lymphocyte count ($p = .047$) indicate a potential decrease in systemic inflammation. RBC count, neutrophils, and eosinophils showed no significant changes ($p > 0.05$). The control group exhibited no significant changes in any hematological parameters. **Conclusion:** A structured yogic intervention positively influenced hematological parameters, supporting its role as a non-pharmacological strategy for enhancing immune function and reducing inflammation in college students.

Key words: Yoga, Hematologic Tests, Hemoglobins, Leukocytes, Blood Platelets, Students

INTRODUCTION

Yoga, an ancient practice rooted in Indian tradition, integrates physical postures (asanas), breath control (pranayama), and relaxation to promote physical, mental, and emotional well-being (Yatham et al., 2023). It is widely recognized for its ability to enhance physiological functions, particularly cardiovascular, respiratory, and immune responses (Woodyard, 2011; Yeun & Kim, 2021). However, despite growing interest in its health benefits, yogic practice's impact on hematological variables remains an emerging area of research. Hematological parameters such as haemoglobin levels, red blood cells (RBCs), total white blood cell (WBC) count, neutrophils, eosinophils, monocytes, lymphocytes, and platelets play a crucial role in oxygen transport, immune defense, and hemostasis (Dean, 2005). Any imbalance in these parameters can lead to severe health complications, including anemia, immune suppression, and inflammatory disorders (Kuhn et al., 2017; Morrell et al., 2014). Given the rising prevalence of stress-induced (Madan et al., 2022), and lifestyle-related health disorders (Gupta, 2024), it is imperative to explore holistic, non-invasive, and preventive strategies to maintain optimal hematological health. Haemoglobin is a crucial component of red blood cells, responsible for transporting oxygen from the lungs to the rest of the body (Mairbäurl & Weber, 2012). Adequate haemoglobin levels ensure optimal oxygenation of tissues and organs (Billett, 1990), essential for energy production and overall vitality (Pittman, 2011). Low haemoglobin levels, often associated with anemia (Rhodes et al., 2022), can lead to fatigue (Sobrero et al., 2001), weakness (Turner et al., 2023), and reduced cognitive function (Gattas et al., 2020). Yogic practice's emphasis on controlled breathing may help enhance oxygen utilization and improve haemoglobin levels by optimizing erythropoiesis and circulation. Red blood cells (RBCs) play a vital role in maintaining oxygen transport and overall physiological homeostasis (Kuhn et al., 2017). A well-balanced RBC count

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is necessary for efficient oxygen delivery to muscles and tissues (Mairbäurl, 2013). Practices like pranayama and asanas enhance oxygen intake and utilization (Sharma et al., 2012), potentially stimulating erythropoiesis and improving RBC production (Elliott, 2008). Improved RBC function through yogic practice may lead to better endurance, physical performance, and reduced fatigue. Total white blood cell (WBC) count is a primary indicator of immune system function (Tigner et al., 2022). WBCs are the body's first line of defense against infections and diseases (Saidani et al., 2024). An imbalance in WBC levels can indicate immune suppression or hyperactivity, leading to increased susceptibility to infections or autoimmune disorders (Ferencova et al., 2023; Naoual et al.,2022). Studies suggest that yogic practices enhance immune modulation by reducing stress-induced immunosuppression (Arora & Bhattacharjee, 2008), and promoting leukocyte balance (Mishra et al., 2024), thereby strengthening the body's natural defense mechanisms. Neutrophils, a subtype of WBCs, are essential for fighting bacterial infections and responding to inflammation (Malech et al., 2014). They act as the body's first responders to microbial invasion (Rosales, 2020). Stress and lifestyle factors can compromise neutrophil function (Tsukamoto & Machida, 2012), leading to a weakened immune response (Dinauer, 2016). Yogic practice's ability to reduce stress and promote systemic balance may help optimize neutrophil production and function (Kedlaya et al., 2023), ensuring a more robust immune response against infections (Malech et al., 2014). Eosinophils are another critical component of the immune system, primarily involved in allergic reactions and parasitic infections (Shamri et al., 2011). Elevated eosinophil levels may indicate hypersensitivity or chronic inflammatory conditions such as asthma (Hirano & Matsunaga, 2023). Yogic practice's role in reducing systemic inflammation and modulating immune function (Chauhan & Rajesh, 2020), may help maintain eosinophil balance, potentially benefiting individuals with allergies or respiratory conditions. Monocytes play a significant role in the immune system by differentiating into macrophages and dendritic cells, which are essential for pathogen recognition and removal (León et al., 2005). They also contribute to tissue repair and immune regulation (Ogle et al., 2016). Yogic practices potentially enhance autonomic balance (Sathyaprabha et al., 2008), reduce inflammatory responses (Vijayaraghava et al., 2015), and may support monocyte activity, promoting better immune surveillance and recovery from infections or injuries. Lymphocytes, including T cells and B cells, are responsible for adaptive immunity, which provides long-term protection against infections (Alberts et al., 2002). A well-regulated lymphocyte count is crucial for immune memory and defense against pathogens (Janeway et al., 2001). Chronic stress has been shown to reduce lymphocyte activity, leading to impaired immune function (Lei et al., 2023; Golovatscka et al., 2012). Yogic practices stress-reducing and immune-boosting properties may help maintain lymphocyte levels (Kandhan et al., 2022), thereby enhancing immune resilience and reducing susceptibility to infections. Platelets are essential for blood clotting and wound healing (Ali & Mohamed, 2023). An imbalance in platelet count can lead to either excessive bleeding or an increased risk of thrombosis (Iyengar et al., 2023; Giannakeas et al., 2022). Regular yogic practice has been linked to improved cardiovascular health, which may indirectly support optimal platelet function by enhancing circulation (Heber & Volf, 2015), reducing oxidative stress (Signorello et al., 2024), and maintaining vascular integrity (Boulaftali et al., 2013).

Scientific studies have demonstrated that yogic practices positively affect autonomic regulation (Sathyaprabha et al., 2008), stress reduction (Signorello et al., 2024), and overall systemic function. The transition to adulthood presents various physiological and psychological challenges, increasing vulnerability to stress-induced changes in blood composition (Dhabhar et al., 2012), Hematological imbalances may predispose individuals to long-term health risks, such as anemia (Rhodes et al., 2022), chronic fatigue (Sobrero et al., 2001), and immune dysfunction (Henrie et al., 2022), it becomes essential to explore ways to mitigate these negative effects. Yogic practices have been shown to reduce stress (Signorello et al., 2024) and promote relaxation through the modulation of the hypothalamic-pituitary-adrenal (HPA) axis (Arora & Bhattacharjee, 2008), which may help restore hematological balance. Furthermore, pranayama enhances oxygenation and improves respiratory efficiency, potentially influencing RBC count and haemoglobin levels. Asanas increase blood circulation (Kochhar, 2017), improve lymphatic drainage (Singh, 2019), and facilitate detoxification (Sarkar & Varshney, 2017), which may contribute to optimal platelet function. Relaxation techniques further promote homeostasis by balancing immune responses (Kang et al., 2011), thereby enhancing the body's ability to combat infections and inflammation. These practices may contribute to improvements in blood circulation, oxygenation, and immune system functioning. The need for effective, non-pharmacological interventions to support hematological health in this population underscores the significance of investigating yogic practice's impact on blood parameters.

Hematological parameters play a critical role in assessing overall health and physiological balance, yet limited research has explored the influence of non-pharmacological interventions like yoga on these markers, particularly in young adult populations. While yogic practices are well-documented for their benefits on mental well-being and physical fitness, their potential effects on blood composition—key indicators of immune competence, oxygen transport, and inflammatory status—remain under-investigated. This study addresses this gap by examining the impact of a structured twelve-week yogic intervention on selected hematological variables in college students, thereby contributing to the growing body of evidence supporting yoga as a complementary approach to promoting physiological homeostasis.

METHODS

Study Design

This study employed an experimental design with a two-group pre-test and post-test framework to assess the impact of a twelve-week yogic intervention on selected hematological parameters. Participants were selected using probability sampling from the student population. The study was approved by the Department of Physical Education and Sports Sciences, University of Delhi, after obtaining clearance from the Department Research Committee and the Board of Research Studies. Students who were willing to participate signed a written informed consent form after receiving an oral explanation of the study's objectives. The participants were randomly assigned to one of two groups: the experimental group, which received yogic practices, and the control group, which did not receive any intervention. Group allocation was done by an independent researcher who was not involved in the assessments.

Participants

An a priori power analysis was performed using GPower software (version 3.1.9.7; University of Kiel, Kiel, Germany) to determine the minimum required sample size for the study. This analysis was conducted with parameters set at an anticipated large effect size (Cohen's d = 0.80), a significance level (α) of 0.05, and a desired statistical power ($1-\beta$) of 0.95, in alignment with the guidelines proposed by Kang (2021). The calculation indicated that a minimum of 23 participants would be necessary to achieve adequate statistical power. To mitigate the potential impact of participant attrition, an initial cohort of 35 individuals was recruited (Figure 1). Following exclusions and dropouts, the final sample comprised 24 participants who completed the study protocol. The study was conducted at Shyampahari Government Primary Teacher Training Institute, located in Birbhum, West Bengal, India, and involved male participants aged between 17 and 22 years. All participants had normal vision and were randomly assigned to either the control or experimental group, with 12 individuals in each group. The inclusion criteria ensured that none of the participants had a history of smoking, alcohol consumption, or any acute or chronic medical conditions, nor were they on any medications. A detailed overview of the participants' demographic and health characteristics is presented in Table 1. Prior to inclusion in the study, each participant underwent a comprehensive medical evaluation conducted by a qualified physician, who confirmed their eligibility and fitness for participation. Informed consent was obtained in writing from all participants, ensuring they voluntarily agreed to participate and fully understood the study's objectives, procedures, and potential risks. The research adhered rigorously to ethical guidelines, prioritizing participant protection and safety throughout the course of the study.

Study Organization

This study employed an experimental design with a two-group pre-test and post-test framework to assess the impact of a twelve-week yogic intervention on selected hematological parameters. Participants were selected through probability sampling from the student population. The primary objective was to generate empirical data on the potential effects of yogic practices on hematological variables, contributing to the growing body of evidence regarding its therapeutic efficacy.

Table 1. Baseline characteristics of the participants (Mean±SD)

Parameters	Overall Group (n=24)	Experimental Group (n=12)	Control Group (n=12)
Age (years)	20.17±1.05	19.92±0.90	20.42±1.17
Height (cm)	169.21±6.52	169.08±5.32	169.33±7.79
Weight (kg)	64.50±11.11	58.17±5.51	70.83±11.85
BMI (kg/m^2)	22.54±3.68	20.40±2.31	24.68±3.61
Waist (cm)	76.42±9.01	72.25±5.76	80.58±9.94
Hip (cm)	89.83±9.55	85.75±9.75	93.92±7.70
WHR	0.86±0.10	0.85±0.13	0.86±0.07
Pulse Rate (beats/min)	74.92±3.73	74.33±3.77	75.50±3.75
Respiratory Rate (breath/min)	24.42±4.08	23.67±4.34	25.17±3.83

Academic status – UG level; Primary language - Bengali; Occupation – Student; Marital Status – Unmarried; Diet (self-declared) – Veg and non-veg both; Socio-economic status – Lower middle class

Experimental Protocol

The experimental group performed a structured yogic intervention comprising Suryanamaskar, selected asanas, pranayama techniques, and relaxation practices, six days a week for twelve weeks. Each session lasted sixty minutes and was conducted from 8:00 to 9:00 AM, Monday through Saturday, at the Shyampahari Government Primary Teacher Training Institute ground in Birbhum, West Bengal. Intensity was progressively increased every three weeks following a load progression strategy. The intervention was rigorously supervised by the investigator to ensure adherence to the protocol. In contrast, the control group maintained their habitual daily activities without any external interventions or modifications to their routine. To assess the effects of the intervention, pre- and post-assessment measurements were administered to all participants. These evaluations, conducted at the commencement and conclusion of the twelve-week period, were designed to capture changes in the relevant variables. A detailed schematic representation of the intervention protocol is provided in Figure 2, which illustrates the specific sequence, duration, and nature of the practices incorporated into the yogic intervention.

Outcome Measures

This study aimed to evaluate the effects of a 12-week yogic intervention on various hematological parameters, including haemoglobin, red blood cell (RBC) count, total white blood cell (WBC) count, neutrophils, eosinophils, lymphocytes, monocytes, and platelets. A pre-test and post-test design

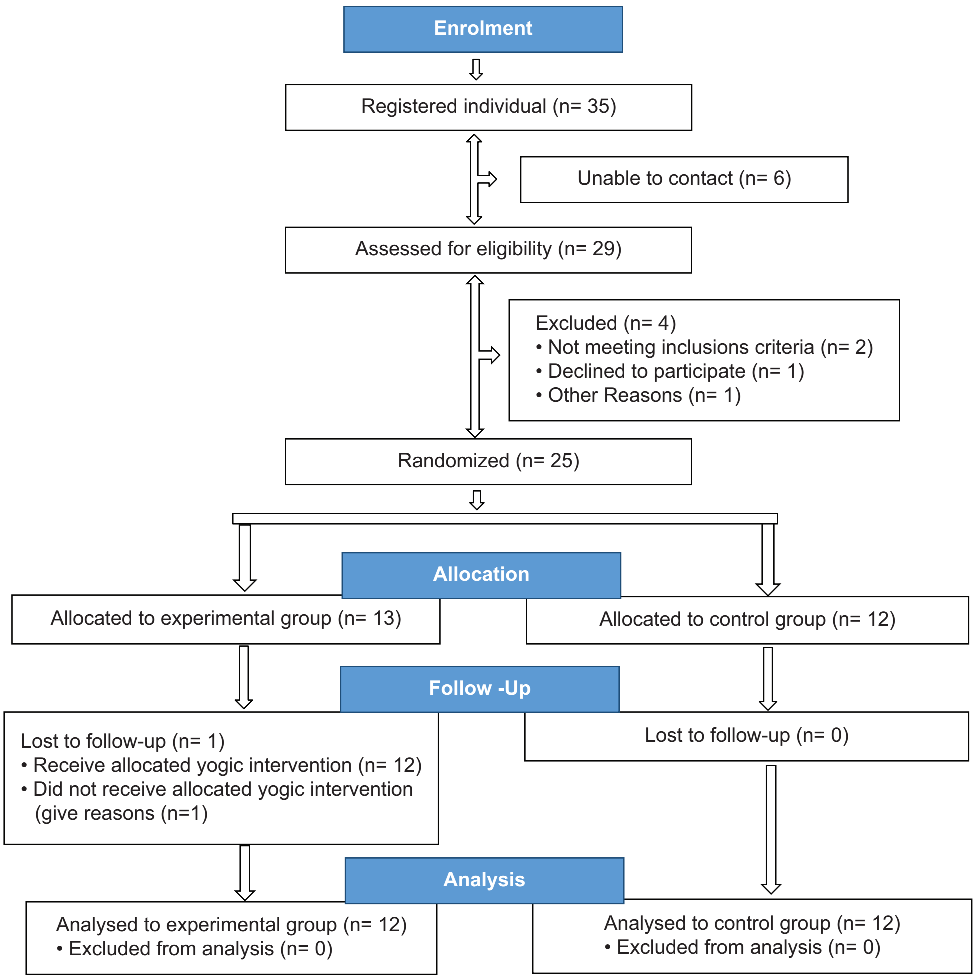

Figure 1. Participation selection consort flow chart

was employed to assess changes in these variables. Blood samples were collected from the antecubital vein under sterile conditions, ensuring aseptic technique, and promptly transported to a certified pathology laboratory for analysis. Hematological profiling was performed using the TULIP CORALYZER SMART 200, an automated system that provides high-precision measurements. To ensure the reliability of results, the study followed strict laboratory protocols and implemented comprehensive quality control procedures throughout the analysis process. Regular calibration of the equipment, adherence to established guidelines, and the application of both internal and external quality assurance measures were crucial in reducing measurement errors. Additionally, all tests were conducted under continuous supervision, ensuring compliance with the established protocols and prioritizing participant safety, thereby enhancing the accuracy, consistency, and validity of the findings. Table 2 displays the test-retest reliability coefficients for each of the measured variables, indicating the consistency of the assessments over time.

Statistical Analysis

Data distribution normality was examined using the Shapiro-Wilk test (Shapiro & Wilk, 1965), and the homogeneity of variances was assessed through Levene's test. Descriptive statistics were computed to provide a summary of the data, while inferential analyses involved paired t-tests to evaluate within-group differences and independent samples t-tests to compare groups. All statistical analyses were performed using IBM SPSS software (version 25), with a significance level of 0.05.

Table 2. The Intra-Class correlation coefficient for selected criterion variables

SL No.	Variables	Coefficient of Correlation
1	Haemoglobin	0.997
2	Red Blood Cells	0.998
3	Total WBC Count	0.911
4	Neutrophils	0.972
5	Eosinophils	0.891
6	Lymphocytes	0.947
7	Monocytes	1
8	Platelet	0.995

The significance level was set at 0.05

RESULTS

Table 3 provides a comprehensive summary of the descriptive statistics for the experimental (EG) and control (CG)

Weeks	Surya Namaskar (Dynamic Warm-up)	Asanas Practiced (In Sequential Order)	Asana Parameters (Holding Time×Repetitions×Rest)	Total Asana Duration	Pranayama (Anulom Vilom and Bhastrika)		Relaxation (Integrative Recovery)
1–3	1 Round (5 min)	Ardha-Halasana, Sarvangasana, Matsyasana, Halasana, Chakrasana, Naukasana, Bhujangasana, Shalabhasana, Naukasana, Dhanurasana, Ardha Matsyendrasana, Paschimottanasana, Vajrasana, Yogamudra, Ushtrasana, Padmasana, Utkatasana, Trikonasana, Vrikshasana, Tadasana, Shavasana	15 sec×2 × 5 sec (60 sec rest between sets)	30(min)	Breathing Ratio(1:1) I E 5 (Sec) 5 (Sec)	Cycle×Repetition×Rest between Repetitions 2×2 × 60 Sec	Shavasana (5 min)
4–6	2 Rounds (5 min)	Same as above	20 sec×2 × 5 sec (50 sec rest between sets)	30 (min)	Breathing Ratio (1:1:1) I H E 5 (Sec) 5 (Sec) 5 (Sec)	Cycle×Repetition×Rest between Repetitions 2×2 × 50 Sec	Shavasana (5 min)
7–9	3 Rounds (5 min)	Same as above	25 sec×2 × 3 sec (40 sec rest between sets)	30 (min)	Breathing Ratio (1:2:2) I H E 5 (Sec) 10 (Sec) 10 (Sec)	Cycle×Repetition×Rest between Repetitions 2×2 × 40 Sec	Shavasana (5 min)
10–12	4 Rounds (5 min)	Same as above	30 sec×2 × 3 sec (30 sec rest between sets)	30 (min)	Breathing Ratio (1:4:2) I H E 5 (Sec) 20 (Sec) 10 (Sec)	Cycle×Repetition×Rest between Repetitions 2×2 × 30 Sec	Shavasana (5 min)
Inhale (I), Hold (H), and Exhale (E)							

Figure 2. Yogic intervention module
Note. Inhale (I), Hold (H), and Exhale (E)

Table 3. Descriptive statistics

Variables	Group	Test	N	Mean	Std. Deviation	% Change
Haemoglobin (gm/dl)	EG	Pre-test	12	15.10	0.98	3.31
		Post-test	12	15.60	0.95	
	CG	Pre-test	12	15.14	0.75	-1.72
		Post-test	12	14.88	0.87	
Total Red Blood Cells Count (millions/cumm)	EG	Pre-test	12	5.50	0.54	2
		Post-test	12	5.61	0.33	
	CG	Pre-test	12	5.17	0.50	-0.97
		Post-test	12	5.12	0.40	
Total White Blood Cells Count (/cu.mm.)	EG	Pre-test	12	8158.33	2756.63	-23.08
		Post-test	12	6275.00	1887.34	
	CG	Pre-test	12	7433.33	2266.49	-10.99
		Post-test	12	6616.67	1722.49	
Neutrophils (%)	EG	Pre-test	12	47.42	8.01	11.07
		Post-test	12	52.67	7.34	
	CG	Pre-test	12	47.50	6.04	8.59
		Post-test	12	51.58	6.24	
Eosinophils (%)	EG	Pre-test	12	4.00	1.13	-4.25
		Post-test	12	3.83	0.94	
	CG	Pre-test	12	3.33	1.23	7.51
		Post-test	12	3.58	0.67	
Lymphocytes (%)	EG	Pre-test	12	46.25	8.75	-12.97
		Post-test	12	40.25	7.25	
	CG	Pre-test	12	46.92	6.87	-10.12
		Post-test	12	42.17	5.36	
Monocytes (%)	EG	Pre-test	12	2.33	0.49	39.48
		Post-test	12	3.25	1.14	
	CG	Pre-test	12	2.25	0.45	18.67
		Post-test	12	2.67	0.89	
Platelets Count (Lakh/cu.mm)	EG	Pre-test	12	2.01	0.41	14.43
		Post-test	12	2.30	0.45	
	CG	Pre-test	12	2.34	0.75	-4.27
		Post-test	12	2.24	0.67	

groups, detailing changes in key hematological parameters, including haemoglobin levels, red blood cell (RBC) count, total white blood cell (WBC) count, and the distribution of neutrophils, eosinophils, lymphocytes, monocytes, and platelets from pre-test to post-test. These findings offer empirical evidence supporting the efficacy of the intervention in modulating hematological profiles, thereby underscoring its potential role in physiological adaptation and overall health enhancement.

Table 4 presents the paired t-test results, revealing significant changes in various hematological parameters among participants in the experimental group (EG) following the intervention. The EG showed a statistically significant increase in haemoglobin levels $t(11) = 2.36$, $p = .038$; monocyte count $t(11) = 2.93$, $p = .014$; and platelet count $t(11) = 2.21$, $p = .049$. These improvements suggest that the intervention may have positively influenced oxygen transport capacity, immune function, and hemostatic regulation. Additionally, the EG exhibited a significant decrease in white blood cell (WBC) count $t(11) = 3.52$, $p = .005$ and lymphocyte count $t(11) = 2.24$, $p = .047$; which may indicate a potential reduction in systemic inflammation or stress-induced leukocytosis, contributing to better immune homeostasis.

While there was an increase in red blood cell (RBC) count and neutrophil count, these changes were not statistically significant $t(11) = 0.70$, $p = .496$ for RBC; $t(11) = 1.90$, $p = .084$ for neutrophils. Similarly, the eosinophil count showed a slight decrease, but this change was also not statistically significant $t(11) = 0.41$, $p = .689$.

In contrast, the control group (CG) did not show significant changes in any of the hematological variables, including haemoglobin levels $t(11) = 1.14$, $p = .279$; RBC count $t(11) = 0.33$, $p = .747$; WBC count $t(11) = 1.99$, $p = .072$; neutrophils $t(11) = 1.55$, $p = .148$; eosinophils $t(11) = 0.67$,

Table 4. Paired t-test between the pre-test and post-test of the experimental and control groups

Variables	Group	Test	Mean Difference	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Haemoglobin	EG	Pre-test	0.50	0.74	0.21	2.36	11	0.038*
		Post-test						
	CG	Pre-test	0.26	0.79	0.23	1.14	11	0.279
		Post-test						
Red Blood Cells	EG	Pre-test	0.11	0.52	0.15	0.70	11	0.496
		Post-test						
	CG	Pre-test	0.05	0.47	0.14	0.33	11	0.747
		Post-test						
White Blood Cells	EG	Pre-test	1883.33	1852.19	534.68	3.52	11	0.005*
		Post-test						
	CG	Pre-test	816.67	1421.80	410.44	1.99	11	0.072
		Post-test						
Neutrophils	EG	Pre-test	5.25	9.58	2.77	1.90	11	0.084
		Post-test						
	CG	Pre-test	4.08	9.10	2.63	1.55	11	0.148
		Post-test						
Eosinophils	EG	Pre-test	0.17	1.40	0.41	0.41	11	0.689
		Post-test						
	CG	Pre-test	0.25	1.29	0.37	0.67	11	0.515
		Post-test						
Lymphocytes	EG	Pre-test	6.00	9.29	2.68	2.24	11	0.047*
		Post-test						
	CG	Pre-test	4.75	8.96	2.59	1.84	11	0.093
		Post-test						
Monocytes	EG	Pre-test	0.92	1.08	0.31	2.93	11	0.014*
		Post-test						
	CG	Pre-test	0.42	1.00	0.29	1.45	11	0.175
		Post-test						
Platelets	EG	Pre-test	0.29	0.46	0.13	2.21	11	0.049*
		Post-test						
	CG	Pre-test	0.10	0.27	0.08	1.29	11	0.225
		Post-test						
		Post-test						

*Significant at 0.05 level

p =.515; lymphocytes t(11) = 1.84, p =.093; monocytes t(11) = 1.45, p =.175; or platelet count t(11) = 1.29, p =.225.

These findings suggest that the intervention had a significant impact on specific hematological markers in the EG, particularly enhancing haemoglobin, monocytes, and platelets while reducing WBC and lymphocyte counts. Although there were increases in RBC count, neutrophils, and a decrease in eosinophils, these changes were not statistically significant. The absence of significant changes in the CG further supports the specificity and efficacy of the intervention. Overall, these results provide compelling evidence of the intervention's role in improving key physiological markers, with potential implications for health optimization and immune function.

The independent t-test results presented in Table 5 show comparisons between the experimental group (EG) and control group (CG) for pre-test and post-test scores on various hematological variables, including haemoglobin, red blood cells, white blood cells, neutrophils, eosinophils, lymphocytes, monocytes, and platelets. In the pre-test, no significant differences were observed between the EG and CG across most variables. Specifically, haemoglobin t(22) = 0.11, p =.917; red blood cells t(22) = 1.58, p =.129; white blood cells t(22) = 0.70, p =.489; neutrophils t(22) = 0.03, p =.977; eosinophils t(22) = 1.38, p =.181; lymphocytes t(22) = 0.21, p =.837;monocytes t(22) = 0.43, p =.670; and platelets t(22) = 1.32, p =.201, all showed no statistically significant differences between the groups. However, in the

Table 5. Independent t-test of pre-test and post-test between experimental and control groups

Variables	Tests	Experimental		Control		t	P-value
		Mean	SD	Mean	SD		
Haemoglobin	Pre-test	15.10	.98	15.14	.75	.11	.917
	Post-test	15.60	.95	14.88	.87	1.95	.065
Red Blood Cells	Pre-test	5.50	.54	5.17	.50	1.58	.129
	Post-test	5.61	.33	5.12	.40	3.23	.004*
White Blood Cells	Pre-test	8158.33	2756.63	7433.33	2266.49	.70	.489
	Post-test	6275.00	1887.34	6616.67	1722.49	.46	.648
Neutrophils	Pre-test	47.42	8.01	47.50	6.04	.03	.977
	Post-test	52.67	7.34	51.58	6.24	.39	.701
Eosinophils	Pre-test	4.00	1.13	3.33	1.23	1.38	.181
	Post-test	3.83	.94	3.58	.67	.75	.460
Lymphocytes	Pre-test	46.25	8.75	46.92	6.87	.21	.837
	Post-test	40.25	7.25	42.17	5.36	.74	.469
Monocytes	Pre-test	2.33	.49	2.25	.45	.43	.670
	Post-test	3.25	1.14	2.67	.89	1.40	.175
Platelet	Pre-test	2.01	.41	2.34	.75	1.32	.201
	Post-test	2.30	.45	2.24	.67	.28	.782

*Significant at 0.05 level

post-test, a significant difference was found in the red blood cells, where the EG showed a higher mean value than the CG $t(22) = 3.23$, $p = .004$. No other post-test differences were significant for haemoglobin $t(22) = 1.95$, $p = .065$; white blood cells $t(22) = 0.46$, $p = .648$; neutrophils $t(22) = 0.39$, $p = .701$; eosinophils $t(22) = 0.75$, $p = .460$; lymphocytes $t(22) = 0.74$, $p = .469$; monocytes $t(22) = 1.40$, $p = .175$; or platelets $t(22) = 0.28$, $p = .782$. These results suggest that, following the intervention, the experimental group showed a significant improvement in red blood cell count compared to the control group, while no other significant changes were observed in the hematological variables tested.

DISCUSSIONS

The present study examined the effects of a 12-week yogic practice intervention on hematological variables in the experimental group (EG) and control group (CG) using a pre-test and post-test design. The findings, as presented in Table 3, indicate a statistically significant improvement in haemoglobin levels in the experimental group, whereas the control group did not exhibit a significant change. The results suggest that the improvement in haemoglobin levels following the yogic intervention is meaningful. This implies that the 12-week yogic practices employed in the study had a substantial effect on haemoglobin concentration, potentially due to enhanced physiological adaptations, improved oxygen-carrying capacity, and better erythropoietic responses associated with the applied intervention. The significant improvement in the experimental group aligns with previous research indicating that structured yogic interventions, particularly those involving asanas, pranayama, and relaxation, can enhance haemoglobin levels. One investigation reported a rise in mean haemoglobin levels from 11.3 gm/dL before yogic practices to 12.583 gm/dL after its implementation (Sharma et al., 2014). In a separate study involving college students, the group that engaged in yogic practices demonstrated a significant enhancement in haemoglobin levels, whereas no notable change was observed in the control group (Saradha et al, 2019). Mechanistically, regular engagement in yogic practices has been shown to stimulate erythropoiesis (Bara et al., 2024), and improve iron metabolism (Bara et al., 2024), all of which may contribute to elevated haemoglobin levels. Yogic breathing techniques such as pranayama enhance lung capacity (Singh, 2021), and oxygenation (Ramanathan & Bhavanani, 2023), thereby influencing haemoglobin synthesis. Additionally, the stress-reducing effects of yogic practices could contribute to better homeostasis (Pratiti, 2022), and optimal functioning of hematopoietic pathways (Shree & Bhonde, 2016).

Several studies have investigated the effects of yogic practices on RBC count. In this study, the experimental group exhibited an increase in mean RBC count from 5.504 to 5.610 million/cumm while remaining within the normal range. This aligns with prior research indicating a modest increase in RBC levels (Chandrashekhar et al., 2012; Purohit et al., 2013). However, statistical analysis at the 0.05 significance level did not confirm a significant increase, possibly due to the healthy baseline RBC count of participants. Variability in study outcomes may be influenced by initial health status, with more pronounced effects observed in individuals with lower baseline RBC levels. The present study's participants, having RBC counts within the normal range (4.7-6.1 million/µL for adult males), had limited scope for significant enhancement. Additionally, the standard deviation decreased from 0.541 to 0.333, suggesting a more uniform response but insufficient statistical significance. Physiological mechanisms underlying RBC enhancement through yogic practices include improved circulation, oxygen utilization, and endocrine stimulation. Practices like pranayama may induce mild hypoxia, stimulating erythropoietin (EPO) release and erythropoiesis (Ramanath et al., 2013). Improved blood flow and iron mobilization from reticuloendothelial cells may also contribute (Gowtham et al., 2018); Ramanath et al., 2013). These adaptations may be more evident in individuals with initially lower hematological parameters.

The present study demonstrates a statistically significant reduction in WBC count following a 12-week yogic intervention. Similar trends have been observed in prior research, indicating a decline in WBC levels after consistent yogic practice (Sharma & Gupta, 2016; Goyal & Agarwal, 2019; Sharma et al., 2014). This reduction, while within the physiological range, may be attributed to improved lymphatic circulation, stress reduction, and immune regulation (Kandhan et al., 2022). Additionally, yogic practice has been linked to enhanced natural killer (NK) cell activity and lower cortisol levels, suggesting a positive impact on immune function (Gopal et al., 2011; Tadi, 2024). Mechanisms such as hypoxia-induced erythropoiesis and cytokine modulation may further contribute to WBC regulation (Rayat & Paul, 2018). The findings reinforce yogic practice's potential role in supporting immune homeostasis through autonomic and respiratory system balance (Kandhan et al., 2022).

In the present study, neutrophil percentage increased from 47.417% to 52.667% following yogic practices while remaining within the normal range. This aligns with prior research suggesting yogic practice enhances immune function. Joshi (2017) observed elevated neutrophils after months of yogic practice, while Chandrashekhar (2012) reported an increase from 57.3% to 60.2% post-yogasana training. Similarly, Udayakumara (2016) found neutrophils rose from 56.9% to 63.05% following yogic therapy, indicating improved bacterial defense. Despite this trend, statistical analysis at the 0.05 level did not confirm a significant increase in the present study. Variability in findings across studies may result from individual differences in immunity, including health status, age, sex, and genetic predisposition. Additionally, uncontrolled lifestyle factors such as diet, sleep, stress, and physical activity may have influenced outcomes. The immunomodulatory effects of yogic practices likely involve stress reduction, autonomic regulation, and anti-inflammatory pathways, though individual responses may vary.

Eosinophils play a vital role in allergic responses and inflammation, and their reduction following yogic practices suggests a potential anti-inflammatory effect. In this study, eosinophil percentages declined from a pre-test mean of 4.0% to a post-test mean of 3.83%, though the change remained within the normal range. This finding aligns with previous research, such as Purohit et al. (2013), who reported a decline from 3.7% to 2.4%, and Udayakumara (2016), who observed a reduction from 4.4% to 3.3%. Other studies, including Sharma et al. (2013), Chandrashekhar (2012), and Dey (2015), also reported decreases, with varying magnitudes. Although these findings collectively suggest a role for yogic practices in modulating immune function, statistical analysis at the 0.05 significance level in this study did not indicate a significant reduction. Variability across studies highlights the complexity of immune responses to yogic interventions, influenced by factors such as participant demographics, yogic techniques, and intervention duration. This underscores the need for further research to clarify the mechanisms underlying these effects. Overall, this study adds to the growing evidence of the health benefits of yogic practices, emphasizing the need for continued investigation into their immunomodulatory potential across diverse populations.

The present study observed a significant reduction in lymphocyte percentage following the yogic intervention, with mean values decreasing from 46.250% pre-test to 40.250% post-test ($p < 0.05$). This aligns with previous research indicating the immune-modulating effects of yogic practices. Agnihotri et al. (2014) reported a decline in lymphocyte percentage from 32.36% to 31.48%, while Udayakumara (2016) found a reduction from 37.95% to 32.95%, highlighting improved immune regulation. These findings support the role of yogic interventions in promoting immune balance, potentially by alleviating systemic stress and inflammation.

In the present study, the yogic practices group exhibited a pre-test mean monocyte percentage of 2.333%. Following the intervention, the post-test mean monocyte percentage increased to 3.250%, a change that was statistically significant based on a paired t-test at the 0.05 level. Despite this increase, the values remained within the normal physiological range. These findings are consistent with those reported by Chatterjee and Mondal (2012), who observed a similar trend. In their study, the mean pre-test monocyte percentage among males was 0.80%, which increased to 0.87% after six weeks and further rose to 1.73% after 12 weeks, demonstrating significant change. Among females, the baseline monocyte percentage was 0.60%, which increased to 1.20% after six weeks and subsequently to 1.40% after 12 weeks of yogic practices. The findings from both studies suggest that yogic interventions can lead to a statistically significant enhancement in monocyte levels, though the extent of change varies and remains within normal physiological limits.

Regular yogic practices have been shown to positively influence platelet count and overall hematological health. Research indicates that individuals engaging in consistent yogic exercises experience significant increases in platelet count (Chohan et al., 1984; Goyal & Agarwal, 2019; Banerjee et al., 2019). A 12-week study on college students further supports this, demonstrating notable improvements in hematological parameters following yogic practice interventions (Rayat & Paul, 2018). The underlying mechanisms through which yogic practice affects platelet function involve multiple physiological processes. Stress reduction through hormonal regulation may help normalize platelet activity and lower thrombosis risk (Koudouovoh-Tripp et al., 2021; Kumar et al., 2018). Additionally, yogic practice is associated with reduced inflammatory markers, which may contribute to balanced platelet production (Sonmez &

Sonmez, 2017; Kiecolt-Glaser et al., 2014). Enhanced endothelial function through nitric oxide release also plays a role in inhibiting platelet aggregation (Patil et al., 2024; Wang et al., 1998). Furthermore, yoga's antioxidant effects may counteract oxidative stress, a known factor in platelet activation (El Haouari, 2019; Patil et al., 2014). The activation of the parasympathetic nervous system through yogic practices further supports cardiovascular health by mitigating excessive platelet aggregation (Shobana et al., 2022; Ozdemir et al., 2004). These findings suggest that regular yogic practice may serve as a valuable non-pharmacological approach to maintaining hematological balance and cardiovascular well-being.

LIMITATIONS AND FUTURE OF THE STUDY

While the findings of this study highlight the positive effects of yogic practices on selected hematological parameters, certain limitations should be acknowledged. First, the relatively small sample size (n = 24) may limit the broader applicability of the results. Additionally, the study was restricted to male college students from a single institution, which may reduce the generalizability across genders, age groups, and educational backgrounds. Dietary habits, sleep patterns, and stress levels—factors known to influence hematological profiles—were not controlled or monitored. Moreover, the study did not examine the persistence of hematological changes beyond the intervention period. Further investigations are warranted with larger, more diverse populations and longer follow-up durations to validate and expand upon these findings.

STRENGTHS AND IMPLICATIONS

The primary strength of this study lies in the methodological rigor of the twelve-week structured yogic intervention, which was specifically designed to assess its effects on hematological parameters in a cohort of college students. The randomized controlled design, coupled with pre- and post-intervention blood analysis using a fully automated hematology analyzer, ensures high internal validity and reliable measurement of the outcomes. Additionally, the careful statistical analysis using paired and independent t-tests strengthens the robustness of the findings by allowing for clear identification of significant within- and between-group differences.

From a practical perspective, the findings provide substantial evidence for the incorporation of yogic practices as an effective, non-pharmacological strategy for enhancing hematological health. The significant improvements in haemoglobin, monocytes, and platelets, alongside reductions in WBC and lymphocyte counts, highlight yogic practice's potential in modulating immune function and inflammatory responses. These outcomes suggest that yogic practices can be integrated into public health strategies aimed at promoting well-being and reducing systemic inflammation in young adults. Given the cost-effectiveness and accessibility of yogic practices, these findings support their inclusion in wellness programs within academic institutions, contributing to students' physical and mental health. Such interventions offer a sustainable and holistic approach to health promotion, particularly in the context of reducing reliance on pharmacological treatments.

CONCLUSIONS

Based on this study indicates that a twelve-week yogic practices intervention resulted in significant improvements in key hematological variables, including haemoglobin levels, white blood cell count, lymphocytes, monocytes, and platelet count, among participants in the experimental group. While red blood cells, neutrophils, and eosinophils also showed improvements, these changes did not reach statistical significance, indicating that a longer intervention period may be required for more pronounced effects. In contrast, the control group did not exhibit meaningful changes in any of the measured variables, reinforcing the specificity of yogic practices' impact. The findings suggest that yogic practices can enhance immune function, improve circulatory efficiency, and contribute to overall hematological health. Given its accessibility and cost-effectiveness, yogic practices present a promising complementary approach for preventive healthcare and wellness programs. Future research should explore the long-term effects of yogic practices on hematological parameters, investigate optimal practice durations, and examine their applicability across diverse populations.

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Author Contributions

AR contributed to the conception, design, data collection, and data analysis. He also prepared the tables and figures, drafted the manuscript, and revised and finalized it for publication. TNP contributed to the conception, design, planning, and supervision of the research. He set the goals, provided substantive supervision, and finalized the manuscript for publication.

Approval and Consent to Participate

This study was approved by the Department of Physical Education and Sports Sciences, University of Delhi, following clearance from the Department Research Committee and the Board of Research Studies (Ref. no. SF-1/Ph. D/2023/1481) Informed consent was obtained from all participants after a detailed briefing on the study's objectives, procedures, and their rights, including voluntary participation and the option to withdraw at any stage.

Data Availability Statement

The authors can provide data upon reasonable request.

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