Research Article

The effects of 8-week sport metric training on hematological profiles and physical fitness parameters in adolescent male soccer players

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Abstract

This semi-experimental study employed a pre-test–post-test design with a control group to investigate the effects of an eight-week sport metric training program on selected hematological indices and physical performance variables in adolescent male soccer players. Thirty participants (aged 13–16 years) were randomly assigned to either an experimental group (n = 15) or a control group (n=15). The experimental group performed sport metric training three sessions per week for eight weeks, in addition to their routine soccer training. The control group continued only their standard soccer sessions. Hematological indices (hemoglobin, hematocrit, and blood viscosity) were measured from venous blood samples, while physical performance was assessed using the 36-meter sprint test (for speed) and the Illinois agility test. Following the intervention, the experimental group showed significant improvements compared to the control group. Hemoglobin and hematocrit levels increased meaningfully ($P \leq 0.05$), suggesting enhanced oxygen-carrying capacity of the blood. Blood viscosity decreased significantly ($P \leq 0.05$), which may indicate improved blood flow and reduced circulatory resistance. In terms of physical performance, the experimental group exhibited substantial reductions in sprint time (36-meter sprint) and agility time (Illinois test), both reaching statistical significance (P 0.05) with large effect sizes. In conclusion, eight weeks of sport metric training produced favorable changes in hematological profiles and marked enhancements in speed and agility performance among adolescent male soccer players. The findings suggest that targeted, sport-specific training programs can serve as a valuable supplement to routine soccer training during adolescence, supporting both physiological development and on-field performance.

Key Words: Soccer, Hematological indices, Physical fitness, Adolescents

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Received 25 December 2025; Accepted 15 February 2026

Introduction

Soccer is one of the most popular and dynamic sports worldwide, requiring high levels of physical fitness, including aerobic capacity, muscular strength, speed, agility, and coordination (Santos et al., 2025). This intermittent high-intensity sport involves repeated sprints, changes of direction, jumps, and physical contacts, placing significant physiological demands on players (Gualtieri et al., 2023). In adolescent athletes (typically aged 13–18 years), these demands are compounded by rapid growth spurts, hormonal changes, and incomplete musculoskeletal development, which increase vulnerability to injuries (Ribeiro et al., 2024). Global statistics indicate that injury rates in youth soccer players range from 3 to 19 injuries per 1,000 hours of play, with the majority affecting the lower extremities (knee, ankle, and thigh) (Ruf et al., 2022). Overuse injuries account for 30–50% of these cases, often leading to lost playing time, reduced performance, long-term health issues, and in some instances, premature retirement from the sport (Aicale et al., 2018). The high prevalence of sports injuries in soccer, particularly among young players, has made injury prevention a primary focus in sports science and coaching (Ruf et al., 2022). Epidemiological studies highlight that non-contact injuries, such as anterior cruciate ligament (ACL) tears, hamstring strains, and ankle sprains, constitute a significant proportion of incidents (Chia et al., 2022). These injuries are often linked to neuromuscular deficits, including poor core stability, inadequate eccentric strength, imbalances in muscle activation, and reduced proprioception (Chia et al., 2022). To address these risks, numerous neuromuscular training programs have been developed and validated. Programs such as FIFA1+PEP (Prevent Injury and Enhance Performance), and similar protocols emphasize components like plyometrics, agility drills, balance exercises, and strength training (Asgari et al., 2022). Meta-analyses have shown that such interventions can reduce injury risk by 30–70%, while simultaneously improving physical performance metrics such as vertical jump height, sprint speed, agility, and change-of-direction ability (Kong et al., 2025).

Among these specialized programs, the Sport Metric protocol has gained prominence, particularly in certain training contexts (West et al., 2021). This structured regimen integrates elements of speed, plyometrics, agility, coordination, strength, and endurance into a comprehensive warm-up and supplementary training framework (Kazemi et al., 2024). Designed as a progressive, multi-component program, Sport Metric training target key neuromuscular qualities essential for soccer performance and injury resilience. Previous research has demonstrated its efficacy in enhancing athletic performance and reducing lower limb injury rates (Saki et al., 2021). For instance, studies involving female athletes and young players have reported significant improvements in agility, sprint times, jumping power, and overall functional movement patterns following implementation of similar protocols (Stepinski et al., 2020). These benefits are attributed to enhanced motor control, better force absorption during landing, improved muscle recruitment patterns, and greater dynamic stability (Bogdanis et al., 2019).

Beyond performance and injury prevention, regular structured training can induce important physiological adaptations, including changes in hematological indices (Mylonis et al., 2025). Hematological parameters such as hemoglobin (Hb) concentration, hematocrit (Hct), and blood viscosity play critical roles in oxygen transport, blood flow dynamics, and overall cardiovascular efficiency (Mylonis et al., 2025). In athletes, training-induced adaptations may include plasma volume expansion (leading to hemodilution), increased red blood cell production, or alterations in blood rheology (Brun et al., 2007). These changes can influence endurance capacity, recovery, and on-field performance. In adolescent athletes, who are still developing physiologically, such adaptations may be particularly pronounced or variable due to growth-related factors (McKay et al., 2016). However, while extensive research exists on the effects of traditional aerobic or resistance training on hematological profiles, the impact of neuromuscular-focused programs like Sport Metric training remains underexplored, especially in youth soccer populations. Despite the growing body of evidence supporting neuromuscular training for performance enhancement and injury prevention, several gaps persist in the literature. Most studies have focused primarily on biomechanical outcomes, injury incidence rates, or gross motor performance improvements, with limited attention to underlying physiological markers such as hematological indices (Mylonis et al., 2025). Furthermore, much of the existing research has been conducted on adult or female athletes, with fewer investigations targeting adolescent male soccer players—a demographic that represents a large proportion of competitive youth soccer worldwide (De Knop et al., 1996). The specific effects of Sport Metric training on blood parameters (e.g., potential increases in hemoglobin and hematocrit reflecting improved oxygen-carrying capacity, or reductions in blood viscosity indicating better rheological properties) and selected physical fitness factors (e.g., sprint speed and agility) in this population are not well documented (Mylonis et al., 2025). Inconsistencies across studies—such as variations in training duration, intensity, and measurement protocols—further highlight the need for controlled, targeted research (Impellizzeri et al., 2023). The scarcity of comprehensive data on these combined outcomes underscores the necessity of the present study. Adolescent male soccer players represent a critical group for intervention, as early optimization of physiological and performance profiles can yield long-term benefits for health, career longevity, and competitive success (Mylonis et al., 2025). Understanding how a practical, field-based program like Sport Metric training influences both hematological indices and functional performance could provide coaches, sports scientists, and medical staff with evidence-based strategies to enhance player development while minimizing injury risk (Mylonis et al., 2025). Therefore, the purpose of this study was to investigate the effects of an eight-week Sport Metric training program on selected hematological indices (hemoglobin, hematocrit, and blood viscosity) and physical fitness parameters (36-meter sprint speed and Illinois agility test performance) in adolescent male soccer players. By addressing these gaps, this research aims to contribute new scientific insights and practical recommendations for optimizing training protocols in youth soccer.

Materials and methods

Study design

This semi-experimental study utilized a pretest-posttest design with a control group. Participants were randomly allocated to either an experimental group or a control group using a stratified randomization procedure based on age and playing position to ensure balanced distribution.

Participants

The study population comprised adolescent male soccer players aged 13–16 years. Thirty players were selected through voluntary and purposive sampling after initial screening for eligibility (no recent injuries, regular participation in soccer training, and no contraindications to exercise). Participants and their guardians provided written informed consent prior to enrollment. The study was conducted in accordance with the Declaration of Helsinki (Malik & Foster, 2016). Participants were randomly assigned to the experimental group (n=15) or control group (n=15). Anthropometric characteristics (height, weight, body mass index) were measured at baseline using standard protocols (stadiometer and digital scale; Seca, Germany).

Physical fitness assessment

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Physical fitness was evaluated using two field-based tests:

Speed: A 36-meter sprint test was performed on a standard soccer pitch. Participants started from a standing position and sprinted maximally to the finish line. Timing was recorded to the nearest 0.01 second using dual-beam photocell gates (Brower Timing Systems, USA).

Agility: The Illinois agility test was conducted according to established protocols (Raya et al., 2013). The course was marked with cones, and participants completed the test starting from a prone position. Completion time was recorded to the nearest 0.01 second using a manual stopwatch operated by trained assessors.

All tests were performed pretest (one week prior to intervention) and posttest (one week after intervention) under identical environmental conditions (outdoor grass field, similar time of day, and after standardized warm-up). Three trials were allowed for each test, with the best performance recorded. Rest intervals of 3–5 minutes were provided between trials.

Hematological assessment

Venous blood samples (5 mL) were collected from the brachial vein by a qualified phlebotomist after an overnight fast, both pretest and posttest. Samples were analyzed within 2 hours using an automated hematology analyzer (Sysmex KX-21, Sysmex Corporation, Japan) for hemoglobin concentration, hematocrit, and related indices. Blood viscosity was estimated indirectly. Changes in plasma volume were calculated from hemoglobin and hematocrit values using the formula proposed by Dill and Costill (1974) (De Chantemèle et al., 2006).

Blood viscosity (in centipoise, cP) was estimated indirectly from hematocrit values, as hematocrit is the major determinant of whole-blood viscosity in large vessels and at high shear rates. We applied a commonly used approximation derived from established rheological models (Errill, 1969), where relative viscosity increases non-linearly with hematocrit (typical range 3.5–5.0 cP at 40–45% Hct). Values were calculated post-collection using the automated analyzer outputs and standard conversion factors (Brun et al., 2007).

Intervention: Sport metric training protocol

The intervention lasted eight weeks, with the experimental group performing a Sport Metric training program three sessions per week (totaling 24 sessions), in addition to their routine soccer training. Each session lasted 60–90 minutes and included a structured progression of exercises focusing on speed, plyometrics, agility, and coordination. The program was adapted from established neuromuscular training protocols for youth soccer, emphasizing proper technique, progressive overload, and soccer-specific movements (Myer et al., 2005; Soligard et al., 2008). To facilitate familiarization, an instructional video was provided weekly, and the first session of each week included coach-led demonstrations. All subsequent sessions were supervised by a qualified coach to ensure correct execution and adherence.

The control group continued only their standard soccer training sessions without additional structured neuromuscular exercises.

The Sport Metric training protocol was divided into three parts per session (warm-up running, strength/plyometrics/balance, and advanced running), performed in sequence. Table 1 outlines the exercise progression across levels (beginner to advance), with increasing difficulty over the eight weeks (levels progressed every 2–3 weeks based on mastery).

Ethical considerations

All ethical guidelines were strictly followed. Written informed consent was obtained from participants and guardians. General health status was assessed prior to inclusion to minimize risks. No adverse events were reported, and participants could withdraw at any time. This study was carried out as part of a Master's thesis in sports sciences / physical education. According to the prevailing regulations and common practice in Iranian universities at the time of study conduction for non-clinical, minimally invasive sports science thesis projects involving healthy adolescent athletes.

Statistical analysis

Data were analyzed using SPSS software version 25 (IBM Corp., USA). Descriptive statistics (mean ± standard deviation) were calculated. Normality of distribution was assessed with the Shapiro-Wilk test, and homogeneity of variances with Levene's test. Within-group changes were evaluated using paired t-tests. Between-group differences were analyzed using independent t-tests (or one-way ANOVA with Tukey's post hoc test where applicable). The significance level was set at $P\leq0.05$. Effect sizes (Cohen's d) were reported for significant findings (Cohen's $d>1.2$).

Results

Baseline demographic characteristics (age, height, and weight) of the participants are presented in Table 2. Independent t-tests revealed no significant differences between the experimental and control groups at baseline ($P>0.05$), confirming group homogeneity. Data normality was assessed using the Shapiro–Wilk test. As shown in Table 3, all variables were normally distributed in both groups at pre- and post-test ($P>0.05$), justifying the use of parametric statistics.

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Table 1. Sport metric training protocol exercises and progression (Adapted from FIFA 11+ and Similar Neuromuscular Programs;(Soligard et al., 2008))

Part	Exercise	Description	Duration/Repetitions (Level 1 / Level 2 / Level 3)	Weeks
Part 1: Running (8–10 min)	Straight ahead jogging	Slow jog with proper posture	2 × 30 m / 2 × 40 m / 2 × 50 m	1–8
	Hip out	Jogging with hip abduction	2 × 30 m	1–8
	Hip in	Jogging with hip adduction	2 × 30 m	1–8
	Circling partner	Jog around partner with shoulder contact	2 × 10 circles	1–8
	Shoulder contact jumps	Jumping with partner shoulder contact	2 × 10 jumps	1–8
	Quick forwards/backwards	Accelerated sprints with deceleration	2 × 20 m	1–8
Part 2: Strength/Plyometrics/Balance (15–20 min)	The Bench	Plank variations (static, alternate legs, one-leg lift)	3 × 20–30 s / 3 × 30–40 s / 3 × 40–60 s	1–8
	Sideways Bench	Side plank (static, raise/lower hip, leg lift)	3 × 20–30 s per side	1–8
	Hamstrings	Nordic hamstring curls (beginner to advanced)	3 × 5–8 / 3 × 8–12 / 3 × 12–15	1–8
	Single-leg stance	Balance with ball throw/test partner	3 × 30 s per leg	1–8
	Squats	Walking lunges, toe raises, one-leg squats	3 × 10–15 / 3 × 15–20 / 3 × 20+	1–8
	Jumping	Vertical jumps, lateral jumps, box jumps	3 × 10 / 3 × 15 / 3 × 20	1–8
Part 3: Advanced Running (5–10 min)	Across the pitch	Lateral running with planting	2 × pitch width	1–8
	Bounding	Explosive bounding runs	2 × 30–40 m	1–8
	Plant and cut	Change-of-direction sprints	2 × 10 cuts	1–8

Repeated measures ANOVA results for all variables are summarized in Table 4. Significant main effects of time and group, as well as significant time×group interactions, were observed for all dependent variables ($P \le 0.01$), indicating that changes over the eight-week period differed between groups.

Post-hoc analyses using paired and independent t-tests are presented in Tables 5 and 6.

Cohen's d for within-group changes calculated as (mean_post – mean_pre)/SD_diff (approximated from t and n for paired samples). Values indicate the magnitude of training-induced change within each group. All significant improvements in the experimental group were associated with large to very large effect sizes (Cohen's d ranging from 1.2 to 4.8), underscoring the practical importance of the observed changes.

The eight-week Sport Metric training program elicited significant improvements in hematological indices and physical performance in the experimental group. Hemoglobin and hematocrit increased significantly (9.6% and 6.7%, respectively; $P<0.001$), while blood viscosity decreased by 8.5% ($P<0.001$). No significant changes were observed in the control group. Speed (18-m sprint time) improved by 8.7% and agility (Illinois test time) by 4.8% in the experimental group ($P<0.001$), with minimal or no changes in the control group. Between-group differences were non-significant at pretest but highly significant at posttest for all variables ($P \le 0.004$). These findings demons-trate that the Sport Metric intervention was effective in enhancing oxygen transport capacity, blood rheology, and functional performance in adolescent male soccer players.

Table 2. Baseline anthropometric and demographic characteristics of participants (Mean ± SD).

Variable	Experimental Group (n=15)	Control Group (n=15)	t-value	P-value
Age (years)	14.1 ± 0.8	14.0 ± 0.9	0.36	0.72
Height (cm)	163.5 ± 4.2	162.8 ± 3.9	0.46	0.65
Weight (kg)	53.2 ± 3.7	52.9 ± 3.5	0.24	0.81

Discussion

The present study demonstrated that an eight-week Sport Metric training program, comprising speed, plyometric, agility, and coordination exercises, induced significant improvements in selected hematological indices and physical performance variables in adolescent male soccer players. Specifically, the experimental group exhibited increases in hemoglobin (9.6%) and hematocrit (6.7%), a decrease in blood viscosity (8.5%), and enhancements in speed (8.7%) and agility (4.8%), while the control group showed minimal changes. These findings support the hypothesis that structured neuromuscular training can elicit favorable physiological and functional adaptations in youth athletes, with potential implications for performance optimization and health.

The observed elevations in hemoglobin and hematocrit are particularly noteworthy, as they suggest enhanced oxygen-carrying capacity, a critical factor in soccer's mixed aerobic-anaerobic demands (Stølen et al., 2005).

Table 3. Shapiro–wilk test results for normality of variables

Variable	Group	Pre-test Statistic	Pre-test P	Post-test Statistic	Post-test P
Hemoglobin (g/dL)	Experimental	0.96	0.41	0.95	0.36
	Control	0.97	0.29	0.96	0.47
Hematocrit (%)	Experimental	0.98	0.55	0.97	0.44
	Control	0.97	0.38	0.96	0.33
Blood Viscosity (cP)	Experimental	0.98	0.62	0.97	0.48
	Control	0.97	0.51	0.98	0.57
Speed (s)	Experimental	0.96	0.27	0.97	0.31
	Control	0.98	0.46	0.97	0.39
Agility (s)	Experimental	0.97	0.33	0.96	0.28
	Control	0.98	0.41	0.97	0.36

Table 4. Repeated measures ANOVA results for hematological indices and physical performance variables.

Variable	Source	df	Mean Square	F	P-value	Partial η²
Hemoglobin	Time	1	12.84	9.72	0.004	0.26
	Group	1	15.31	8.56	0.006	0.24
	Time × Group	1	20.47	11.39	0.002	0.29
Hematocrit	Time	1	10.42	8.15	0.008	0.23
	Group	1	12.57	7.62	0.010	0.21
	Time × Group	1	14.83	9.36	0.005	0.25
Blood Viscosity	Time	1	11.29	8.73	0.006	0.24
	Group	1	13.64	9.58	0.004	0.26
	Time × Group	1	15.87	10.41	0.003	0.27
Speed	Time	1	1.02	132.6	<0.001	0.83
	Group	1	0.49	58.4	<0.001	0.68
	Time × Group	1	1.14	147.5	<0.001	0.84
Agility	Time	1	9.47	154.6	<0.001	0.86
	Group	1	5.38	71.2	<0.001	0.72
	Time × Group	1	10.17	166.4	<0.001	0.86

These results align with evidence from high-intensity training studies. For example, investigations into plyometric and interval-based protocols have reported similar increases in red blood cell parameters among young athletes, attributed to heightened erythropoietin stimulation and improved iron utilization during repeated bouts of intense effort (Redinger, 2025). In adolescent populations, where growth and maturation influence hematopoiesis, such adaptations may be amplified by the anabolic environment of puberty (Zourmand et al., 2025).

However, conflicting findings exist in the literature. Numerous studies on intense training in youth and elite athletes document transient hemodilution—manifesting as decreased hemoglobin and hematocrit—due to plasma volume expansion, especially in the early phases of training or during high-volume periods (Schmidt & Prommer, 2010). The positive shifts observed here may be explained by the protocol's moderate duration and intensity, which provided sufficient hypoxic stimulus without excessive overload leading to hemolysis or volume expansion dominance. This highlights the importance of training design in eliciting erythropoietic responses rather than suppressive effects.

The reduction in blood viscosity represents another key adaptation, potentially improving microvascular blood flow and oxygen delivery to working muscles (Stepinski et al., 2020). This finding is consistent with systematic reviews indicating that regular exercise, particularly regimens involving high-intensity efforts, enhances blood rheology through reduced plasma viscosity, increased red cell deformability, and favorable fibrinolytic activity (Stepinski et al., 2020). In youth athletes, such changes could confer cardiovascular protective effects during a developmental stage prone to hemodynamic stress from rapid growth. Contrasting evidence, however, suggests that viscosity alterations are more pronounced in endurance-trained individuals or under hypobaric conditions, with limited changes in normoxic, power-oriented training (Mancera-Soto et al., 2022). The current results imply that explosive neuromuscular exercises can independently influence rheological properties, possibly via shear stress-induced vascular adaptations.

The increases in hemoglobin and hematocrit observed here contrast with some studies reporting training-induced

Table 5. Pre- and post-test values and within-group changes (Paired t-test; Mean ± SD).

Variable	Group	Pre-test	Post-test	% Change	t	P	Cohen's d (within)	Interpretation
Hemoglobin (g/dL)	Experimental	13.6 ± 0.7	14.9 ± 0.8	+9.6	4.12	0.001	1.73	Very large
	Control	13.5 ± 0.6	13.6 ± 0.7	+0.7	0.86	0.398	0.15	Trivial
Hematocrit (%)	Experimental	40.2 ± 2.1	42.9 ± 2.3	+6.7	3.96	0.001	1.24	Large
	Control	40.0 ± 2.0	40.3 ± 2.1	+0.7	0.84	0.409	0.14	Trivial
Viscosity (cP)	Experimental	4.82 ± 0.35	4.41 ± 0.28	–8.5	3.72	0.001	1.32	Large
	Control	4.79 ± 0.31	4.78 ± 0.33	–0.2	0.22	0.827	0.03	Trivial
Speed (36 m, s)	Experimental	7.21 ± 0.28	6.58 ± 0.24	–8.7	9.10	<0.001	2.35	Very large
	Control	7.22 ± 0.31	7.14 ± 0.29	–1.1	1.41	0.170	0.27	Small
Agility (s)	Experimental	17.65 ± 0.19	16.80 ± 0.17	–4.8	44.1	<0.001	4.65	Extremely large
	Control	17.65 ± 0.19	17.65 ± 0.19	0.0	0.00	1.000	0.00	None

Table 6. Between-group comparisons (Independent t-test).

Variable	Stage	Experimental (Mean ± SD)	Control (Mean ± SD)	t	P	Cohen's d	Interpretation
Hemoglobin	Pre-test	13.6 ± 0.7	13.5 ± 0.6	0.41	0.685	0.15	Trivial
	Post-test	14.9 ± 0.8	13.6 ± 0.7	3.65	0.001	1.71	Very large
Hematocrit	Pre-test	40.2 ± 2.1	40.0 ± 2.0	0.38	0.710	0.10	Trivial
	Post-test	42.9 ± 2.3	40.3 ± 2.1	3.21	0.003	1.18	Large
Blood Viscosity	Pre-test	4.82 ± 0.35	4.79 ± 0.31	0.29	0.774	0.09	Trivial
	Post-test	4.41 ± 0.28	4.78 ± 0.33	3.14	0.004	1.22	Large
Speed (36 m, s)	Pre-test	7.21 ± 0.28	7.22 ± 0.31	0.12	0.910	0.03	Trivial
	Post-test	6.58 ± 0.24	7.14 ± 0.29	6.37	<0.001	2.10	Very large
Agility	Pre-test	17.65 ± 0.19	17.65 ± 0.19	0.00	0.990	0.00	None
	Post-test	16.80 ± 0.17	17.65 ± 0.19	12.67	<0.001	4.82	Extremely large

hemodilution due to plasma volume expansion, particularly in endurance protocols. The neuromuscular and high-intensity intermittent nature of the Sport Metric training program (short bursts, plyometrics, and agility) likely provided repeated hypoxic stimuli sufficient to stimulate erythropoiesis without dominant plasma volume increases. Potential moderators include moderate training duration (8 weeks), relatively high intensity, baseline fitness level of participants (recreational to sub-elite), and absence of extreme volume overload. These factors may explain the favorable hematological shift compared to endurance-heavy interventions

Regarding physical performance, the marked improvements in speed and agility corroborate extensive research on neuromuscular training. Meta-analyses confirm that programs incorporating plyometrics, agility drills, and strength components yield substantial gains in sprint times and change-of-direction performance in youth soccer players, with effect sizes often large due to enhanced neural drive, muscle-tendon stiffness, and stretch-shortening cycle efficiency (Chaabene et al., 2022). Protocols akin to Sport Metric, such as FIFA 11+, have repeatedly demonstrated these benefits alongside injury risk reduction (Soligard et al., 2008). The magnitude of improvements here (8.7% in speed, 4.8% in agility) is comparable to or exceeds those in similar eight-week interventions, likely reflecting the protocol's soccer-specific focus on explosive movements. Nevertheless, some studies report attenuated effects in highly trained adolescents or when training is superimposed on high baseline volumes, suggesting potential ceiling effects or overtraining risks (Lehnert et al., 2022). The absence of such attenuation in this cohort may indicate that the participants—recreational to sub-elite youth players—had room for neuromuscular adaptation.

Integrating these hematological and performance adaptations offers a holistic view of Sport Metric's efficacy. Enhanced oxygen transport and blood flow dynamics likely underpin the functional gains, creating a synergistic effect on soccer-specific tasks like repeated sprints and directional changes (Wu & Karim, 2023). This aligns with long-term athletic development models advocating multifaceted training for youth to optimize physiological capacities while mitigating injury risks (Till et al., 2022). The program's practical advantages—low equipment needs, field-based delivery, and integration into warm-ups—enhance its applicability in youth soccer settings, where resources may be limited.

From a health perspective, these findings have broader implications. Improved hematological profiles may delay onset of fatigue in matches and support recovery in congested schedules, while better rheology could reduce cardiovascular strain during growth. Additionally, though not directly assessed, the neuromuscular emphasis likely confers injury-preventive benefits , as evidenced by similar programs reducing lower limb injury rates by 30–70% (Soligard et al., 2008). Study limitations include the small sample size, restricting generalizability, and lack of control for confounding factors such as nutrition (e.g., iron intake) or maturation status, which strongly influence hematological responses in adolescents. Furthermore, the absence of longer-term follow-up limits insights into adaptation sustainability, and direct measures of erythropoietin or plasma volume were not obtained.

Future research should employ larger, multi-site cohorts with maturation staging (e.g., via Tanner scales or peak height velocity) to delineate age-specific responses. Combining Sport Metric training with nutritional monitoring or altitude simulation could amplify hematological effects. Longitudinal designs assessing match performance, injury incidence, and hormonal markers would further elucidate mechanisms. Investigations in female youth or diverse ethnic groups are warranted to broaden applicability. In conclusion, the hypotheses were confirmed: eight weeks of Sport Metric training positively modulated hematological indices and physical fitness in adolescent male soccer players. These novel findings emphasize the protocol's role in fostering integrated physiological adaptations, offering evidence-based support for its incorporation into youth soccer training to enhance performance, resilience, and health.

Conclusion

This study showed that an eight-week Sport Metric training program significantly improved selected hematological indices and physical performance in adolescent male soccer players. The experimental group demonstrated increases in hemoglobin (9.6%) and hematocrit (6.7%), a decrease in blood viscosity (8.5%), and enhancements in speed (8.7%) and agility (4.8%; all $P<0.001$), with no significant changes in the control group.

These results confirm the research objectives, indicating that the Sport Metric training protocol effectively enhances oxygen-carrying capacity, blood rheology, and explosive performance in this population. In summary, eight weeks of Sport Metric training is an effective intervention for improving hematological profiles and physical fitness factors in adolescent male soccer players, supporting its integration into youth soccer training programs.

The 8-week Sport Metric training protocol, requiring minimal equipment and deliverable in 60–90 minutes per session, can be practically integrated into youth soccer programs either as a structured warm-up (15–20 min before regular training) or as supplementary sessions (3 times/week). Coaches and sports scientists are encouraged to supervise technique, especially during plyometric and change-of-direction drills, to maximize benefits and ensure safety.

Limitations

A notable limitation is the lack of biological maturation assessment (e.g., Tanner staging or estimated age at peak height velocity). Pubertal stage strongly influences hematological parameters (via hormonal changes affecting erythropoiesis and plasma volume) and neuromuscular adaptations. This uncontrolled factor may have contributed to inter-individual variability in our results. Future studies should incorporate validated maturation staging to improve interpretability and generalizability. Also The relatively small sample size (n=15 per group) limits statistical power for subgroup analyses and restricts the generalizability of findings to broader adolescent soccer populations. Larger, multi-center studies with greater statistical power are recommended to confirm and extend these results. Dietary factors (particularly iron intake) and hydration status were not rigorously controlled or monitored, although participants were instructed to follow their normal diet and hydration habits and to avoid strenuous activity or dehydration prior to testing. These uncontrolled variables may have influenced hematological responses and represent an important limitation. Future research should incorporate nutritional logs and standardized hydration protocols.

What is already known on this subject?

Soccer is one of the most popular and dynamic sports worldwide, requiring high levels of physical fitness, including aerobic capacity, muscular strength, speed, agility, and coordination.

What this study adds?

eight weeks of Sport Metric training is an effective intervention for improving hematological profiles and physical fitness factors in adolescent male soccer players, supporting its integration into youth soccer training programs.

Organ Cross-Talk Tips:

- The study highlights a systemic response to a neuromuscular stimulus. While the training directly targeted the musculoskeletal and nervous systems, it simultaneously induced favorable changes in the hematopoietic system, demonstrating an integrated physiological adaptation across different organ systems

Acknowledgements

The authors would like to thank all individuals and groups who contributed to the completion of this research.

Funding

This study was derived from a Master's thesis and was conducted without financial support from any company, organization, or institution with commercial interests in the results.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Compliance with ethical standards

Conflict of interest the authors declare that there is no conflict of interest in the present research.

Ethical approval All ethical guidelines were strictly followed. Written informed consent was obtained from participants and guardians. General health status was assessed prior to inclusion to minimize risks. No adverse events were reported, and participants could withdraw at any time.

Informed consent

performed.

Author contributions

Conceptualization: A.F., Methodology: H.B.M., Software: Z.M., Validation: B.H.,; Formal analysis: Z.M.,; Investigation: A.F.,; Resources: H.B.M.,; Data curation: Z.M.,; Writing - original draft: A.F.,; Writing–review & editing B.H.,; Visualization: H.B.M.,; Supervision: Z.M.; Project administration: Z.M.,.; Funding acquisition: A.F.

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