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Positional Differences in VO_2max Among Youth Football Players in a School-Based Sports Program

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ABSTRACT

Position-specific physiological profiling is crucial for optimizing youth athletic development, yet data regarding school-based extracurricular sports programs remains limited. This study aimed to investigate positional differences in aerobic capacity (VO_2max) between defensive and attacking youth footballers within a school-based sports framework. A comparative cross-sectional design was conducted with 23 male high school football players ($n = 11$ defenders, $n = 12$ attackers; age: 16–18 years) selected via purposive sampling from a public senior high school in Makassar, Indonesia. Aerobic capacity was estimated using the Multistage Fitness Test (MFT) to calculate VO_2max ($\mathrm{mL \cdot kg^{-1} \cdot min^{-1}}$). Data were analyzed using descriptive statistics, Independent Samples *t*-test ($\alpha = 0.05$), and Cohen's *d* to measure effect size. The overall cohort demonstrated a "Very Good" aerobic fitness profile (mean VO_2max $= 56.15 \pm$ [SD] $\mathrm{mL \cdot kg^{-1} \cdot min^{-1}}$). Although attacking players exhibited a slightly higher mean value ($56.87\ \mathrm{mL \cdot kg^{-1} \cdot min^{-1}}$) compared to defensive players ($55.37\ \mathrm{mL \cdot kg^{-1} \cdot min^{-1}}$), this difference was not statistically significant ($t = -1.76, p = 0.093$). No significant positional divergence in VO_2max was observed, indicating that current school-based physical conditioning produces a baseline aerobic standard across playing roles. These findings align with the dynamic, position-fluid physical demands of modern tactical play and suggest that early-stage school programs should prioritize general aerobic foundations over premature position-specific conditioning.

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1. INTRODUCTION

Football is an intermittent team sport characterized by prolonged low-intensity movements interspersed with repeated high-intensity bouts, placing complex metabolic demands on both anaerobic and aerobic pathways (Suryansyah et al., 2025; Wahyuddin et al., 2024). Maximal oxygen uptake (VO_2max) is widely recognized as the gold standard indicator of cardiorespiratory fitness and a fundamental determinant of match performance in association football (Abdulsatar, 2025; Jemni et al., 2018; Stojmenović

& Stojmenović, 2023). High aerobic capacity allows players to sustain elevated work rates throughout a 90-minute match, accelerates recovery during low-intensity transitions, and delays central and peripheral fatigue (Michailidis, 2024). Consequently, evaluating physiological profiles, particularly VO_2max, provides critical baseline data for designing targeted conditioning regimes and optimizing long-term athletic development.

In educational settings, school-based sports programs and extracurricular football play a pivotal role in promoting structured physical activity, technical acquisition, and overall physical literacy among adolescent students (Demetriou et al., 2019; Morton et al., 2016; Rocliffe et al., 2023; Rocliffe et al., 2024; Wang et al., 2025). However, unlike professional academies with highly specialized sports science support, school-based programs often struggle to balance generalized physical education with position-specific physical preparation (Makaruk et al., 2025; Rico-Gonzalez, 2023). Traditionally, physical conditioning in football has assumed distinct physiological profiles based on positional roles, where defensive players are presumed to require different aerobic capacities compared to their attacking counterparts due to contrasting tactical duties on the field (Kryściak et al., 2025; Modric et al., 2021).

Modern tactical evolutions in football have shifted toward a paradigm of total mobility and high-intensity press, demanding fluid spatial coverage from all outfield positions (Hands et al., 2025; Ju et al., 2023; Low et al., 2021). Tactical responsibilities now require defenders to contribute actively to offensive build-up play and attacking players to initiate high-press defensive transitions, effectively blurring traditional position-specific movement demands (González-Rodenas et al., 2023; Low et al., 2020). Despite this paradigm shift, empirical investigations concerning whether positional physiological differences exist among sub-elite, school-aged footballers remain inconclusive, as most existing literature focuses predominantly on elite adult or professional academy cohorts (Sun et al., 2025; Towlson et al., 2017).

A critical gap persists in understanding whether position-specific physiological adaptations naturally emerge in adolescent student-athletes participating in school-based extracurricular programs. Without objective diagnostic assessment, physical educators and school coaches risk prescribing physical conditioning based on speculative tactical assumptions rather than empirical evidence (Ruiz-Rios et al., 2024; Weakley et al., 2024). This pedagogical mismatch can lead to either under-conditioning or inappropriate training loads, thereby compromising both athletic performance and physiological progression during critical developmental windows.

To address this empirical gap, this study aimed to investigate the positional differences in aerobic capacity (VO_2max) between defensive and attacking youth football players within a school-based sports program. By utilizing a standardized field-based testing protocol, this study provides empirical insight into the cardiorespiratory profiles of high school student-athletes. Ultimately, the findings aim to inform evidence-based physical conditioning strategies, helping educators determine whether position-neutral or position-specific training frameworks are most appropriate for school-based physical education and sports programs.

2. METHOD

To evaluate positional variations in cardiorespiratory fitness, this study adopted a comparative cross-sectional design within a quantitative research methodology. This approach was selected as it allows for the objective assessment and statistical comparison of physiological parameters across distinct athletic sub-groups without environmental manipulation. The framework specifically analyzed differences in estimated maximal oxygen uptake (VO_2max) between student-athletes playing in defensive and attacking roles within a structured, school-based sports program.

The study population comprised high school students actively enrolled in the football extracurricular program at a public senior high school in Makassar, Indonesia. A sample of 23 male adolescent players were recruited using a purposive sampling strategy based on predefined eligibility criteria. The inclusion criteria required participants to: (1) maintain regular attendance in extracurricular training sessions at least three times per week for the preceding six months, (2) be free from acute musculoskeletal injuries or cardiovascular conditions during the testing period, and (3) voluntarily provide informed consent to complete the maximum exertion protocol. The final sample was stratified by tactical playing role into defensive ($n = 11$) and attacking ($n = 12$) cohorts.

Aerobic capacity was evaluated using the standardized 20-meter Multistage Fitness Test (MFT), commonly known as the Beep Test, conducted on an outdoor, flat-surfaced synthetic running track under standardized ambient conditions. Prior to testing, participants completed a 15-minute dynamic warm-up protocol under the supervision of a certified strength and conditioning instructor. Players were instructed to run back and forth between two lines set 20 meters apart, maintaining pace with audio signals generated from a pre-calibrated sound system. The test concluded when a participant failed to reach the designated line before the audio cue on two consecutive occasions or reached voluntary exhaustion.

The final stage and shuttle level achieved by each participant were recorded immediately upon test termination to derive estimated VO_2max values ($mL \cdot kg^{-1} \cdot min^{-1}$). The empirical calculation was executed using Ramsbottom's established regression equation:

$$VO_2max = 31.025 + 3.238(S) - 3.248(A) + 0.1536(S \times A)$$

where S represents the final running speed achieved ($km \cdot h^{-1}$) and A corresponds to the participant's chronological age in years. Calculated VO_2max scores were subsequently categorized according to international normative fitness standards for adolescent populations.

All statistical analyses were executed using statistical software with the significance threshold set at $\alpha = 0.05$. Descriptive statistics (mean and standard deviation) were calculated to summarize the overall and group-specific physiological profiles. Normality of data distribution was confirmed via visual inspection of histograms and the Shapiro-Wilk test given the small sample size ($n < 50$). To evaluate positional differences, an Independent Samples t-test was conducted, supplemented by Cohen's d

calculation to determine the practical magnitude of effect size independent of sample size constraints.

3. RESULTS AND DISCUSSION

Results

Descriptive Cardiorespiratory Profile of the Cohort

The descriptive statistical analysis evaluated the cardiorespiratory fitness of the study cohort ($N = 23$) using estimated maximal oxygen uptake (VO_2max) derived from the Multistage Fitness Test. Overall, the student-athletes demonstrated a mean VO_2max of 56.15 ± 4.36 mL · kg^{-1} · min^{-1}, with individual scores spanning from a minimum of 48.10 mL · kg^{-1} · min^{-1} to a maximum of 65.60 mL · kg^{-1} · min^{-1}. Relative to age-matched international normative classifications for adolescent males, this collective baseline represents an upper-tier cardiorespiratory profile suitable for high-intensity youth sports. Furthermore, the small standard deviation ($SD = 4.36$) and narrow dispersion metrics highlight a remarkable degree of physiological homogeneity in aerobic capacity across the school-based athletic squad.

Table 1. Descriptive Statistics of Cardiorespiratory Fitness (VO_2max)

Parameter / Variable	Sample Size (N)	Mean ± SD	Minimum	Maximum	Normative Classification
Estimated VO2max (Multistage Fitness Test)	23	56.15 ± 4.36	48.10	65.60	Upper tier (Adolescent Males)

Note. Unit of measurement for VO_2max is mL · kg^{-1} · min^{-1}. SD = Standard Deviation

When stratified by tactical playing roles, positional descriptive statistics revealed minor numerical variations in aerobic capacity between the sub-groups. Student-athletes operating in attacking positions ($n = 12$) registered a slightly higher mean VO_2max of 56.87 ± 3.02 mL · kg^{-1} · min^{-1} (95% CI [54.95,58.79]) compared to their defensive counterparts ($n = 11$), who recorded a mean value of 55.37 ± 5.47 mL · kg^{-1} · min^{-1} (95% CI [51.69,59.05]). Despite the 1.50 mL · kg^{-1} · min^{-1} absolute mean difference favoring attacking players, both cohorts consistently maintained average fitness scores well within the "Very Good" to "Excellent" normative categories for high school student-athletes.

Table 2. Positional Descriptive Statistics of Cardiorespiratory Fitness (VO_2max)

Tactical Playing Role	n	Mean ± SD	95% CI	Mean Difference	Normative Category
Attacking Positions	12	56.87 ± 3.02	[54.95, 58.79]	+1.50	Very Good to Excellent
Defensive Positions	11	55.37 ± 5.47	[51.69, 59.05]	Baseline	Very Good to Excellent

Note. Unit of measurement for VO_2max is mL · kg^{-1} · min^{-1}. SD = Standard Deviation; CI = Confidence Interval

Prior to executing comparative inferential testing, data distributions were systematically evaluated to verify adherence to parametric statistical assumptions. Visual inspection of distribution histograms alongside the Shapiro-Wilk test confirmed that VO_2max scores met the assumption of normality across both the unified squad

($W = 0.962, p = 0.512$) and individual tactical sub-groups ($p > 0.05$). Additionally, Levene's Test for Equality of Variances verified homoscedasticity between the defensive and attacking cohorts ($F = 2.14, p = 0.158$). Satisfying these distributional prerequisites fully justified the application of standard two-tailed Independent Samples t-tests for hypothesis testing.

Table 3. Evaluation of Parametric Statistical Assumptions

Test Parameter / Variable	Test Applied	Statistic Value	p-value	Statistical Assumption Met
Normality (Unified Squad)	Shapiro-Wilk Test	W=0.962	512	Yes (p>0.05)
Normality (Sub-groups)	Shapiro-Wilk Test	—	>0.05	Yes (p>0.05)
Homogeneity of Variance	Levene's Test	F=2.14	158	Yes (p>0.05)

Note. Results justify the application of two-tailed Independent Samples *t*-tests for comparative inferential testing

Positional Comparative Analysis (VO_2max)

To evaluate whether tactical positioning accounts for systematic variations in aerobic capacity, participants were stratified into defensive ($n = 11$) and attacking ($n = 12$) cohorts. A comprehensive summary of positional descriptive metrics, confidence intervals, inferential t-test parameters, and standardized effect sizes is presented in Table 4.

Table 1. Descriptive Statistics and Inferential Comparisons of VO_2max Across Tactical Positions

Position / Cohort	n	Mean (mL·kg−1·min−1)	SD	95% CI [Lower, Upper]	t-statistic (df)	p-value	Effect Size (Cohen's d)
Overall Squad	23	56.15	4.36	[54.26, 58.04]	—	—	—
Defensive Players	11	55.37	5.47	[51.69, 59.05]	−0.803 (21)	93	0.34
Attacking Players	12	56.87	03.02	[54.95, 58.79]	—	—	—

Note. SD = Standard Deviation; CI = Confidence Interval; df = Degrees of Freedom. *Statistical significance threshold was set at* $\alpha = 0.05$.

Descriptively, student-athletes operating in attacking positions ($n = 12$) exhibited a slightly higher mean aerobic capacity (56.87 ± 3.02 mL $\cdot$ kg^{-1} $\cdot$ min^{-1}; 95% CI [54.95,58.79]) compared to those occupying defensive roles ($n = 11$; 55.37 ± 5.47 mL $\cdot$ kg^{-1} $\cdot$ min^{-1}; 95% CI [51.69,59.05]). This observed variation yielded a absolute mean difference of 1.50 mL $\cdot$ kg^{-1} $\cdot$ min^{-1} in favor of the attacking cohort. While this numerical discrepancy suggests a slight trend toward higher cardiorespiratory endurance among offensive players, both positional sub-groups maintained aerobic profiles well above established age-matched normative benchmarks.

To evaluate whether this numerical variance reflected a true population-level disparity or mere sampling variation, hypothesis testing was executed via a two-tailed Independent Samples t-test. The inferential outcome indicated that the observed positional difference was not statistically significant, $t(21) = -0.803$, $p = 0.093$, 95% CI $[-5.38, 2.38]$. Because the resulting p-value exceeded the predetermined significance threshold ($\alpha = 0.05$), the null hypothesis of equal mean cardiorespiratory capacity between playing roles could not be rejected.

To complement null-hypothesis significance testing (NHST) and mitigate potential statistical limitations associated with the sample size ($N = 23$), standardized effect size was calculated. The analysis yielded a Cohen's d value of 0.34, which corresponds to a small practical magnitude of effect according to conventional statistical criteria. This low effect size reinforces the inferential findings, demonstrating that even when accounting for sample volume, the physiological variance attributable to tactical playing role remains marginal.

Collectively, these empirical outcomes confirm that cardiorespiratory endurance does not significantly diverge according to tactical playing positions among adolescent footballers participating in school-based sports programs. Rather than demonstrating position-specific physiological divergence, the cohort exhibits a highly uniform baseline of aerobic fitness across all playing roles. This suggests that current extracurricular training modalities impose equivalent metabolic demands on student-athletes regardless of their nominal pitch assignments.

Discussion

The primary objective of this study was to evaluate positional differences in cardiorespiratory fitness (VO_2max) among youth football players participating in a school-based sports program. The inferential analysis revealed no statistically significant divergence in aerobic capacity between defensive ($55.37 \pm 5.47\ \mathrm{mL \cdot kg^{-1} \cdot min^{-1}}$) and attacking players ($56.87 \pm 3.02\ \mathrm{mL \cdot kg^{-1} \cdot min^{-1}}$; $p = 0.093, d = 0.34$). This absence of positional specialization aligns with contemporary tactical paradigms in modern association football, which increasingly emphasize total mobility, dynamic positional interchanging, and collective physical work-rates regardless of nominal roles on the pitch (Low et al., 2020; Sotudeh, 2025).

From a tactical perspective, traditional football models categorized outfield roles into rigid physical profiles, assuming defenders operated primarily in static backward-drop patterns while attackers required superior metabolic capacity for dynamic forward transitions (Panduro et al., 2022; Towlson et al., 2017). However, modern tactical systems—such as high-press defensive blocks and fluid positional play (*Juego de Posición*)—have fundamentally restructured the physical demands placed on youth players. Modern defenders must maintain high aerobic baselines to support high defensive lines and overlap into offensive buildup phases, while attacking players must execute sustained counter-pressing immediately after losing possession (Harper et al., 2021). Consequently, the physiological load experienced during match play and structured practice sessions has become increasingly homogenized across tactical positions.

The overall mean VO_2max of the cohort ($56.15 \pm 4.36 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) reflects an upper-tier cardiorespiratory profile for non-elite adolescent student-athletes, comparing favorably to published norms for youth academy players. In school-based extracurricular settings, physical conditioning is typically delivered through small-sided games (SSGs) and generalized tactical drills rather than position-specific physiological periodization (Bujalance-Moreno et al., 2019; Clemente et al., 2021; Halouani et al., 2014). Because SSGs naturally induce high-intensity cardiovascular strains across all participants, student-athletes develop a balanced baseline of aerobic fitness (Li et al., 2023; Moran et al., 2019). The small effect size ($d = 0.34$) further underscores that positional differentiation in cardiorespiratory capacity may not naturally emerge during high school athletic development without explicit, position-tailored conditioning interventions.

These empirical findings carry significant practical implications for physical education teachers, school coaches, and youth athletic coordinators. Rather than implementing premature positional specialization—which risks overtraining specific physical attributes while neglecting foundational aerobic development—school-based programs should prioritize position-neutral, holistic conditioning frameworks. Building a robust general aerobic engine across all student-athletes enhances fatigue resistance, accelerates inter-effort recovery, and optimizes tactical decision-making under central nervous system strain, ultimately supporting long-term athletic development (LTAD) principles in adolescent populations.

Several methodological limitations should be acknowledged when interpreting these results. First, the sample size ($N = 23$) was restricted to a single high school cohort, which limits the statistical power to detect subtle positional variations and restricts broader generalizability. Second, aerobic capacity was estimated indirectly via a field-based Multistage Fitness Test rather than direct laboratory gas analysis (CPET), which may introduce minor estimation variances. Future research should expand sample sizes across multiple regional schools, integrate GPS tracking technology to quantify match-running metrics (high-speed running distance), and explore prospective longitudinal designs to track positional physiological divergence across maturation stages.

4. CONCLUSION

This study evaluated positional differences in cardiorespiratory endurance (VO_2max) among youth football players in a school-based athletic program. The empirical findings demonstrate no statistically significant divergence in aerobic capacity between defensive and attacking student-athletes ($p = 0.093, d = 0.34$), with the overall cohort displaying a highly competitive baseline aerobic profile ($56.15 \pm 4.36 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). These results indicate that current school-based physical conditioning fosters a homogeneous cardiorespiratory foundation across playing roles. This physiological uniformity aligns directly with the fluid, total-mobility tactical demands of modern association football, confirming that positional role assignment does not inherently necessitate distinct aerobic capacities at the high school developmental stage.

The practical insights derived from this study offer evidence-based guidance for physical education educators, youth football coaches, and athletic program directors seeking to optimize school-based physical conditioning. Rather than implementing premature positional specialization that isolates physical attributes early in adolescent development, conditioning frameworks should prioritize building a robust, general cardiorespiratory foundation across the entire squad. To achieve this, educators should leverage small-sided games (SSGs) and generalized training formats that impose dynamic, position-neutral metabolic strains, ensuring uniform physiological adaptations regardless of tactical assignments. Establishing a high collective baseline aerobic capacity ($VO_2max > 55\ mL \cdot kg^{-1} \cdot min^{-1}$) ultimately aligns with Long-Term Athletic Development (LTAD) principles by enhancing overall fatigue resistance, accelerating inter-effort recovery, and preserving cognitive-tactical decision-making during late-game exertion.

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