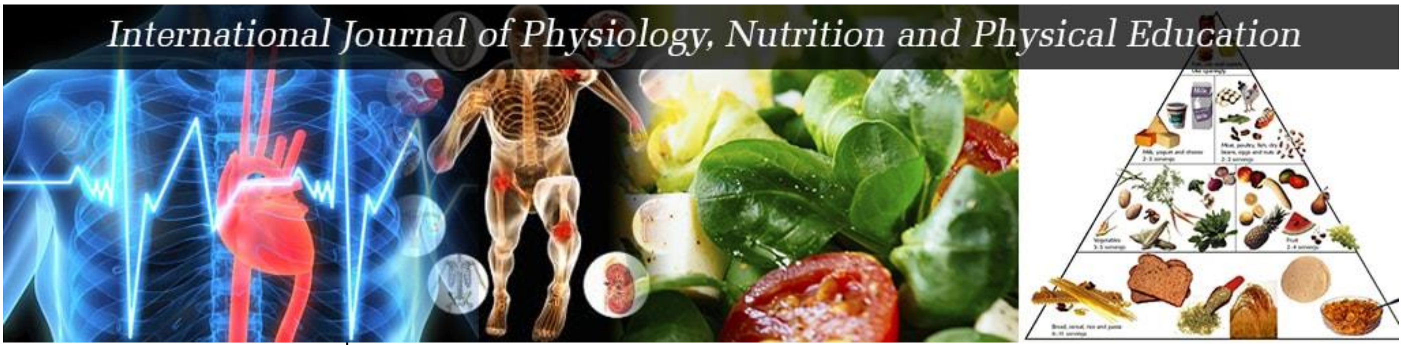

ISSN: 2456-0057
IJPNPE 2025; 10(2): 213-215
Impact Factor (RJIF): 5.91

www.journalofsports.com
Received: 11-07-2025
Accepted: 15-08-2025

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Resting Heart Rate and Aerobic Capacity relation in Early Adolescents: A School-Based Cross-Sectional Study

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DOI: https://doi.org/10.22271/journalofsport.2025.v10.i2d.3095

Abstract
Background: Resting heart rate (RHR) is a simple, low-cost physiological marker that may reflect cardiorespiratory fitness. Evidence in adults suggests an inverse association between RHR and aerobic capacity (VO_2max), but data in early adolescents are limited. The purpose of this study was to measure the resting heart rate and VO_2max of school students, analyse their correlation, and assess whether RHR can predict VO_2max.
Methods: In a school-based cross-sectional study, 84 students (mean age = 12.48 ± 1.05 years) completed standardized RHR assessment (radial pulse for 60 seconds) and the 20-m shuttle-run test (Léger protocol) to estimate VO_2max. Normality was checked using Shapiro-Wilk. Spearman's rank correlation (primary analysis) tested the association between RHR and VO_2max. Simple linear regression examined whether RHR predicted VO_2max.
Results: RHR and VO_2max were significantly and inversely correlated (Spearman's $\rho = -0.384$, $p < .001$). In linear regression, RHR was a significant predictor of VO_2max, explaining a modest proportion of variance (≈15%).
Conclusions: Among early adolescents, lower resting heart rate was associated with higher VO_2max, supporting the potential utility of RHR as a quick screening indicator of aerobic fitness in school settings. RHR should complement, not replace, field fitness tests. Longitudinal and intervention studies are warranted to establish predictive thresholds.

Keywords: Resting Heart Rate, VO_2max, adolescents, aerobic fitness, shuttle-run, school health

Introduction
Resting heart rate, as an easily obtainable physiological marker, has been shown to correlate with maximal oxygen uptake (aerobic capacity), suggesting its potential utility in estimating VO_2max in young adults (Grant *et al.*, 2013) [1]. Furthermore, recent investigations have highlighted a proportional relationship between heart-rate reserve and oxygen-uptake reserve, supporting the premise that resting heart rate can serve as a surrogate marker for aerobic capacity (Ferri Marini *et al.*, 2022) [2]. Indeed, recent regression-based approaches that integrate resting heart rate with exercise-induced heart rate data have demonstrated enhanced accuracy in VO_2max prediction (Matsuo *et al.*, 2022) [3]. Moreover, the link between lower resting heart rates and greater parasympathetic tone reinforces the utility of resting heart rate as a non-invasive indicator for VO_2max estimation (Garcia *et al.*, 2022) [4]. Resting heart rate measurement is routinely incorporated into protocols that assess maximal aerobic capacity, such as the step-test method employed in adolescent fitness research (Manna *et al.*, 2023) [5]. Integrating heart-rate variability metrics with resting pulse further refines VO_2max predictive models, enhancing their applicability to adolescent populations (Brockmann & Hunt, 2023) [6]. Nevertheless, empirical validation of these predictive relation within early adolescent groups is currently scarce, highlighting a critical gap for future research. Moreover, age-specific differences in heart-rate recovery and maximal heart-rate responses observed in pediatric exercise studies underscore the necessity of establishing adolescent-specific calibration curves for resting-HR-based VO_2max estimation

(Baraldi *et al*., 1991; Heinzmann-Filho *et al*., 2018) [7,8]. Preliminary evidence from youth interventions indicates that reductions in resting heart rate accompany concomitant gains in VO_2max, reinforcing the plausibility of HR-based predictive models for this age group (Manna *et al*., 2023) [5].

Method

Design and Setting

We conducted a cross-sectional observational study among pre-adolescent students (classes 6-8) from a coeducational school in India. Data collection occurred during regular school hours in the school's indoor/outdoor sport facility.

Participants

A total of 84 students participated, with a mean age of 12.48±1.05. Inclusion criteria were apparent good health and regular school attendance. Exclusion criteria were acute illness on test day, known cardiopulmonary or musculoskeletal conditions limiting exercise, or failure to complete testing. All subjects were informed about the purpose of the study, and informed consent was given before the start of the test by students and their parents.

Measures

Resting Heart Rate (RHR): The RHR was measured manually at the radial artery for a full 60 s with the participant seated quietly for ≥5 min; the lowest stable reading of two trials separated by 2 min was recorded (Wheatley, 2018) [9]. **Cardiorespiratory fitness (VO_2max):** The VO_2max was measured using the 20-m shuttle run test (Léger protocol) (Léger *et al*., 1988) [10], conducted on a marked court with standardized audio signals; testers provided scripted encouragement. VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) was computed from the final completed stage/speed using the published prediction equation.

Procedure

Following a standardized briefing and warm-up (5-7 min of light calisthenics and dynamic stretches), students performed the 20-m shuttle run in groups of 8-12 under the supervision of researcher. RHR was assessed in a quiet classroom prior to the fitness test. All assessors were trained physical education personnel.

Statistical Analysis

Descriptive statistics such as mean and standard deviation are used for analysis. Normality was evaluated using Shapiro-Wilk tests for RHR and VO_2max. Because the association between RHR and VO_2max can be monotonic but non-normal, we specified Spearman's rank correlation (ρ) for the primary analysis. The simple linear regression analyses were performed to determine whether VO_2max predicted by RHR. The threshold for statistical significance was established at $p < .05$. Analyses were conducted in IBM SPSS-26.

Results

The VO2max mean and SD are 80±13, and the RHR mean and SD are 37.12±2.31. Table 1 shows the Spearman's correlations between resting heart rate and VO_2max. A significant correlation was evident between RHR rate and VO_2max (Spearman's ρ = -0.384, p = 0.000). A simple linear regression analysis (VO_2max ~ RHR) yielded a significant negative slope of -0.099 (SE = 0.027, $p < 0.001$), indicating that individuals with lower resting heart rates tended to have higher VO_2max scores. The model was significant (F (1, 82) = 13.47) and accounted for approximately 14.9% of the variance in VO_2max Table 2. Figure 1 presents the scatter plot with the fitted regression line.

Table 1: Spearman correlation between RHR and VO_2max

Variables	Spearman's ρ	p-value
Resting HR (bpm) vs VO2max (ml·kg−1·min−1)	-0.384	0.000

Table 2: Result of simple linear regression predicting VO_2max from RHR

Parameter	Estimate (B)	SE (slope)	t (slope)	P (slope)	R^2 (model)	F(1, n−2)
Intercept	42.377				0.150	14.426
RHR slope	-0.065	0.017	-3.798	0.000		

Regression uses ordinary least squares; R^2 reflects the variance explained by RHR

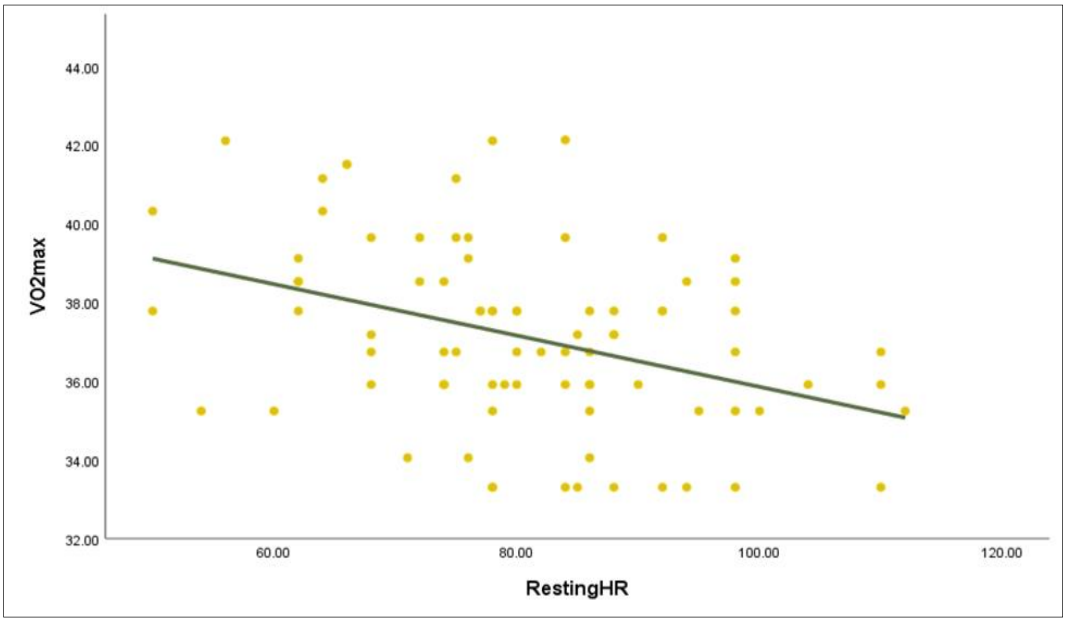

Fig 1: Scatter plot (with fitted regression line) between Resting Heart Rate and VO_2max.

Discussion

This investigation revealed a statistically significant inverse relationship between resting heart rate and VO_2max among early adolescents, indicating that lower RHR was associated with higher estimated aerobic capacity. The observed moderate correlation and the modest yet significant variance in VO_2max explained by RHR alone support the physiological principle that reduced resting heart rates often signify greater parasympathetic influence and enhanced cardiorespiratory efficiency, which are characteristic of superior aerobic fitness. Prior research supports this connection, with studies on children identifying heart rate as a key factor in estimating aerobic capacity (Jacks *et al*., 2008) [11]. Similarly, research in the UK focusing on men has established heart rate as a determinant for estimating aerobic capacity in relation to age (Faulkner *et al*., 2007) [12]. Moreover, the methodology employed by Vema *et al*. (2009) [13] utilized heart rate measurements during physical activity as an appropriate technique for estimating aerobic capacity. These findings are in agreement with the work of Gamberale (1972) [14] and Arts & Kuipers (1994) [15]. who also utilized heart rate for assessing aerobic capacity, the latter specifically in athletes. While doing physical activity Mojtaba *et al*. (2011) [16] reported positive but nonlinear (Esposito *et al*., 2004) [17] relationship between VO_2 and heart rate averaged across participants.

Conclusion

The moderate, inverse correlation suggests RHR can serve as a quick screening signal for aerobic fitness in schools where time, space, and equipment are constrained. The modest explained variance indicates that RHR should be integrated with other information such as age, sex, maturation status, habitual activity, and body composition while interpreting fitness. In program evaluation, RHR may be useful as a secondary outcome alongside shuttle-run performance to triangulate changes in aerobic capacity following physical activity. While RHR offers a pragmatic screening cue in resource-limited school settings, it should complement, not replace, validated field assessments when individual-level aerobic fitness estimates are required.

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