Original Research Article

Estimation of Cardiovascular Fitness in School Going Children of Ropar District, Punjab, India

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Abstract

Cardiorespiratory fitness (CRF) is a key predictor of cardiometabolic health in children, yet region-specific data from many Indian districts are limited. This study estimated VO_2max among schoolchildren in Ropar, Punjab, and examined its associations with anthropometry, physical activity (PA), and socioeconomic status (SES).In this school-based cross-sectional study, 400 children (6–16 years; 198 boys, 202 girls) were selected using multistage stratified sampling. Anthropometry, physical activity**(**PA) (validated questionnaire), and socioeconomic status**(**SES) were recorded. VO_2max was estimated using four methods: 20-m shuttle run test (20mSRT), Queen's College Step Test (QCST), submaximal HR ratio, and a non-exercise equation. Analyses included t-tests/ANOVA, Pearson correlations, multivariable regression (adjusted for age, sex, BMI, school type), and agreement statistics (ICC, Bland–Altman).Mean (SD) age was 11.0 (±3.0) years. Mean VO_2max (20mSRT) was 40.2 (±7.5) $mL·kg^{-1}·min^{-1}$ (boys 42.5 vs girls 38.0; $p<0.001$). Low CRF (<35 $mL·kg^{-1}·min^{-1}$) was observed in 22%. VO_2max correlated negatively with BMI ($r=-0.45$), waist circumference ($r=-0.47$), and body fat% ($r=-0.49$), and positively with MVPA ($r=0.42$) and SES ($r=0.18$). Independent predictors ($R^2=0.48$) were age (+0.8/year), male sex (+3.0), BMI (−0.6 per $kg·m^{-2}$), and MVPA (+0.05 per min/day) (all $p<0.01$). Agreement was good between 20mSRT and QCST (mean diff +1.5; ICC=0.82) and moderate with the non-exercise method (mean diff +2.3; ICC=0.70).Nearly one in five children had low CRF. Adiposity and MVPA were key modifiable correlates. The 20mSRT is a practical field measure for this population, though systematic inter-method differences exist. School-based fitness surveillance and targeted PA interventions are warranted**.**

Keywords: Cardiorespiratory fitness, VO_2max, 20-m shuttle run, School going children, Physical activity, Body mass index.

Introduction

Cardiorespiratory fitness (CRF) most commonly operationalized as maximal oxygen uptake (VO_2max) or its validated field-based estimates reflects the integrated performance of the cardiovascular, pulmonary, hematologic, and muscular systems during sustained exercise [1,2]. Low CRF in childhood is associated with adverse cardiometabolic risk profiles, including elevated blood pressure, insulin resistance, unfavorable lipids and central adiposity [3,4]. Longitudinal and meta-analytic evidence suggests that higher CRF in youth predicts lower future cardiometabolic risk and that improvements in fitness reduce later risk [5,6]. Importantly, atherosclerotic changes related to cardiometabolic risk factors begin in childhood, underscoring the public-health importance of early CRF assessment [7].

Population surveillance indicates secular declines in youth fitness in many countries and rising childhood overweight and obesity trends that may amplify future noncommunicable disease burden [8,9]. In India, nutritional and lifestyle transitions have produced a growing double burden of under- and overnutrition along with reductions in habitual physical activity in many settings [10,11]. Punjab and its districts have reported notable increases in childhood adiposity, but standardized, region-specific CRF data for districts such as Ropar are limited.

For large school-based studies, field methods (20-m shuttle run, step tests, submaximal HR methods, and non-exercise equations) provide feasible and validated approaches to estimate VO_2max; however, prediction error and method agreement vary by age, adiposity and population, necessitating local validation and comparative assessment [12,13,14]. The present study therefore aimed to: (1) estimate VO_2max by multiple validated methods in schoolchildren aged 6–16 years in Ropar district, (2) describe the prevalence of low CRF, (3) examine associations between CRF and anthropometry, PA and SES, and (4) compare agreement and bias across VO_2max estimation methods.

Materials and Methods

Study design and setting

A cross-sectional, school-based study was conducted in Ropar district, Punjab between September, 2025 to January, 2026. Ethical approval was obtained from the Institutional Ethics Committee and written informed parental consent and child assent were secured.

Sampling and participants

Using multistage stratified random sampling, we selected government and private schools across urban and rural blocks. Within selected schools, children aged 6–16 years were invited; target sample size was n = 400 (based on precision for mean VO_2max and subgroup analyses). Exclusion criteria: chronic cardiorespiratory disease, musculoskeletal conditions restricting exercise, acute febrile illness, and lack of parental consent.

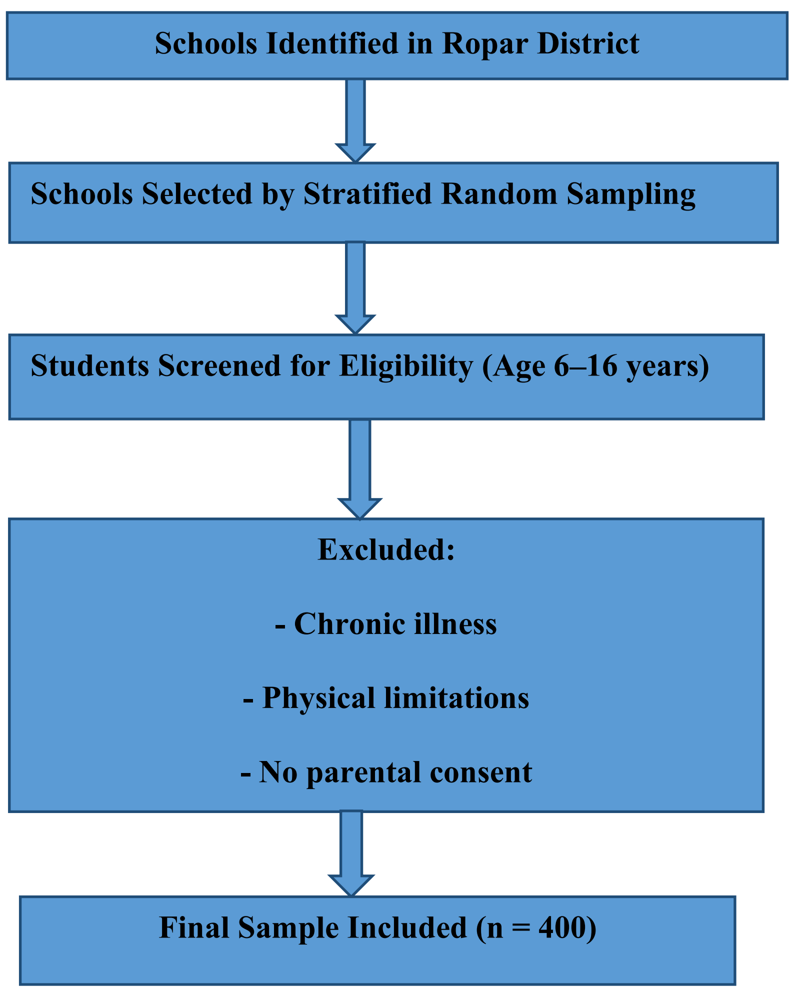

Figure 1: Flow diagram of participant recruitment and selection process

Measurements

Anthropometry: The researcher TAB measured height (stadiometer, to nearest 0.1 cm), weight (digital scale, 0.1 kg), waist circumference (midpoint between lowest rib and iliac crest, 0.1 cm), and body fat percentage (bioelectrical impedance, standardized protocol). BMI was calculated ($kg \cdot m^{-2}$) and categorized per age-sex standards where needed.

Physical activity (PA)**:** Habitual PA was assessed with a validated questionnaire adapted for Indian school children average minutes/day of moderate-to-vigorous physical activity (MVPA) were computed.

Socioeconomic status (SES): A structured SES index was derived from parental education, household assets and income proxies (higher score = higher SES).

VO_2max estimationfour approaches were used:

1. 20-m shuttle run test (20mSRT): Standard PACER/Léger protocol; maximal stage recorded and VO_2max estimated using the Léger equation.
2. Queen's College Step Test (QCST): 3-minute stepping at standardized cadence; VO_2max estimated from recovery HR using sex-specific equations.
3. Submaximal heart-rate (HR) ratio method: HR measured during standardized submaximal workload; extrapolated to age-predicted HRmax to estimate VO_2max (Uth method).
4. Non-exercise prediction equation: Demographic, anthropometric, resting HR and self-reported PA used to estimate VO_2max (validated regression model).

All tests were administered indoors on level surfaces, with standardized warm-ups and scripted encouragement. Safety screening and emergency preparedness were in place.

Statistical Analysis

Data were entered and analyzed in statistical software. Continuous variables are reported as mean (SD) and categorical variables as frequency (%). Group differences were assessed with independent t-tests or one-way ANOVA. Pearson correlation coefficients examined bivariate associations. Multivariable linear regression modeled VO_2max (20mSRT) with predictors: age, sex (male reference), BMI, MVPA and SES; model assumptions and collinearity were checked. Method agreement was assessed with intraclass correlation coefficients (ICC) and Bland–Altman statistics (mean bias ± 1.96 SD limits). Two-sided $p < 0.05$ was considered significant.

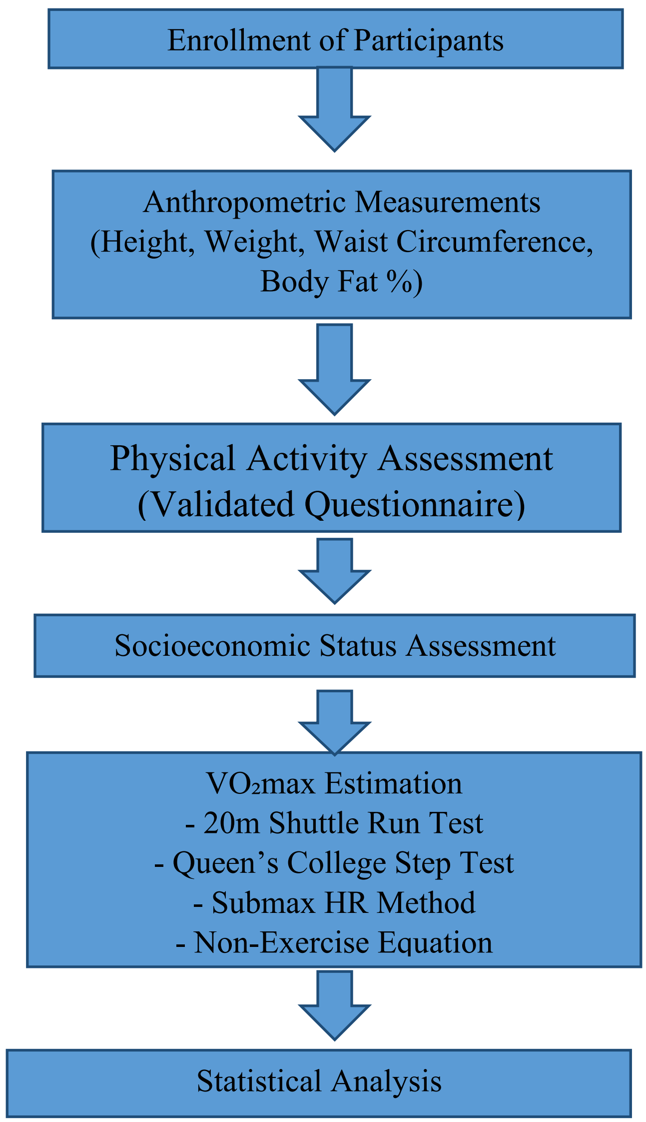

Figure 2: Overview of study procedures and data collection sequence

Results

Sample characteristics (Table 1):A total of 400 children participated (198 boys, 202 girls). Mean age was 11.0 (±3.0) years. Summary anthropometric and behavioral characteristics are shown in Table 1**.**

Table 1.Participant characteristics (n = 400)

Variable	Overall (n=400)	Boys (n=198)	Girls (n=202)
Age (years)	11.0 (3.0)	11.2 (3.1)	10.8 (2.9)
Height (cm)	144.0 (12.0)	146.5 (12.4)	141.7 (11.1)
Weight (kg)	40.5 (11.0)	41.8 (11.2)	39.2 (10.7)
BMI ($kg \cdot m^{-2}$)	19.4 (4.2)	19.4 (4.1)	19.3 (4.3)
Wais (cm)	68.0 (9.0)	69.0 (9.4)	67.0 (8.6)
Body fat (%)	24.2 (6.8)	22.0 (6.0)	26.5 (6.5)
MVPA(min/day)	45 (20)	52 (22)	38 (16)
SES index (0–100)	50 (12)	51 (12)	49 (12)

Values are mean (SD) unless indicated.

VO_2max estimatesand prevalence of low CRF (Table 2):Mean estimated VO_2max figures by method are shown in Table 2. Using the 20mSRT, overall mean VO_2max was 40.2 (7.5) $mL \cdot kg^{-1} \cdot min^{-1}$; boys 42.5 (7.0) vs girls 38.0 (7.2), $p < 0.001$. Using a cut-off of <35 $mL \cdot kg^{-1} \cdot min^{-1}$ to define low CRF, prevalence was 22.0% (88/400): boys 16% (32/198), girls 28% (56/202).

Table 2.VO_2max estimates by method ($mL \cdot kg^{-1} \cdot min^{-1}$)

Method	Overall	Boys	Girls
20mSRT	40.2 (7.5)	42.5 (7.0)	38.0 (7.2)
QCST	38.7 (8.0)	40.6 (7.5)	36.9 (8.2)
Submax HR	39.5 (7.8)	41.3 (7.3)	37.8 (7.8)
Non-exercise	37.9 (8.5)	39.2 (8.0)	36.5 (8.9)

Values are mean (SD)

Bivariate associations (Table 3):Pearson correlations between 20mSRT VO_2max and selected variables:

Table 3.Correlations with 20mSRT VO_2max (n=400)

Variable	r	p
BMI	−0.45	<0.001
Waist circumference	−0.47	<0.001
Body fat %	−0.49	<0.001

Variable	r	p
MVPA (min/day)	0.42	<0.001
SES index	0.18	0.01
Age	0.36	<0.001

Higher adiposity measures were moderately inversely associated with CRF; MVPA and age were positively associated.

Multivariable regression (Table 4): A linear regression model predicting 20mSRT VO_2max:

Table 4. **Multivariable linear regression predicting VO_2max (20mSRT)**

Predictor	β (unstandardized)	SE	p
Intercept	20.0	2.1	<0.001
Age (years)	+0.8	0.12	<0.001
Male sex (ref female)	+3.0	0.45	<0.001
BMI ($kg \cdot m^{-2}$)	−0.6	0.08	<0.001
MVPA (min/day)	+0.05	0.01	<0.001

Predictor	β (unstandardized)	SE	p
SES index	+0.03	0.01	0.02

Model $R^2 = 0.48$ (adjusted $R^2 = 0.46$). Interpretation: a 1-year increase in age associated with +0.8 $mL \cdot kg^{-1} \cdot min^{-1}$, each 1 $kg \cdot m^{-2}$ increase in BMI associated with −0.6 $mL \cdot kg^{-1} \cdot min^{-1}$, and each additional 60 min/day MVPA associated with +3.0 $mL \cdot kg^{-1} \cdot min^{-1}$.

Method agreement and reliability

ICC between 20mSRT and QCST = 0.82 (95% CI 0.78–0.85); mean difference (QCST − 20mSRT) = −1.5 (SD 3.2) $mL \cdot kg^{-1} \cdot min^{-1}$; Bland–Altman limits −4.8 to +7.8 $mL \cdot kg^{-1} \cdot min^{-1}$. ICC between 20mSRT and non-exercise estimator = 0.70 (95% CI 0.64–0.75); mean diff −2.3(SD 4.0) (limits −10.1 to +5.5). These indicate acceptable group-level agreement but notable individual-level variability (SEE ≈ 3–4 $mL \cdot kg^{-1} \cdot min^{-1}$).

Discussion

Key findings: In this district-level school sample from Ropar, mean estimated VO_2max by the 20mSRT was 40.2 $mL \cdot kg^{-1} \cdot min^{-1}$ and roughly 22% of children met the criterion for low CRF (<35 $mL \cdot kg^{-1} \cdot min^{-1}$). Boys exhibited higher aerobic capacity than girls. Adiposity measures (BMI, waist circumference, body fat %) were the strongest inverse correlates of VO_2max, while habitual MVPA showed a strong positive association. Multivariable modeling explained nearly half of VO_2max variance, with age, sex, BMI and MVPA as independent predictors. In method comparison, the 20mSRT and QCST showed good mutual agreement at the group level (ICC 0.82), but individual differences (limits of agreement) indicate that methods are not interchangeable for individual clinical classification.

Interpretation in context

The observed mean VO_2max and the 20% prevalence of low CRF align with reports from other settings showing substantial proportions of children with suboptimal fitness [5,8]. The stronger inverse relationship between adiposity and relative VO_2max is expected because excess fat mass contributes to increased body weight without proportional increases in oxygen-consuming tissue, lowering $mL \cdot kg^{-1} \cdot min^{-1}$ estimates [4]. The positive MVPA association suggests behavioral modification remains a primary target for improving CRF.

The comparative method analysis supports the practicality of the 20mSRT for school surveillance: it provided higher grouplevel estimates and stronger agreement with HR-based estimates than the non-exercise model, but individuallevel caution is warranted. These findings mirror prior validation work showing that prediction equations can be population-dependent and that local calibration improves accuracy [14,15].

Public health implications

Given the proportion of children with low estimated CRF and the clear modifiable associations with MVPA and adiposity, schools in Ropar district represent an effective platform for targeted interventions. Practical measures include enhancing PE curriculum time, integrating short high-intensity activity breaks, promoting active commuting where feasible, and creating after-school activity programs. Surveillance using the 20mSRT can monitor trends and help evaluate Programme impact.

Limitations

- **Cross-sectional design:** precludes causal inference regarding the directionality between CRF and adiposity.
- **VO_2max estimation:** gold standard laboratory measures were not feasible; therefore estimates rely on validated field methods with known SEE and possible systematic bias.
- **Self-reported PA:** although using a validated questionnaire, recall and social desirability bias may influence MVPA estimates. Objective accelerometer would strengthen future work.
- **Generalizability:** while sampling aimed for district representation, findings may not extrapolate to other states or provinces with different socioeconomic or ethnic profiles.
- **Maturation data:** direct measures of pubertal status (Tanner) were not collected and may explain some age/sex differences.

Recommendations and future directions

- Implement school-based physical activity interventions focusing on increasing MVPA (structured PE, active breaks, extracurricular sports), prioritizing girls and children with overweight.

- Establish routine CRF surveillance in district schools using standardized 20mSRT protocols, with periodic re-measurement to track trends and intervention effects.
- For future research, include objective PA measurement (accelerometers) and a laboratory-validated subsample (VO_2 gas analysis) to locally calibrate prediction equations and reduce SEE.
- Design longitudinal studies to investigate the directionality of associations and the long-term cardio metabolic impact of early CRF trajectories.
- Consider policy engagement with education authorities to mandate minimum PE time and infrastructure investments to promote active school environments.

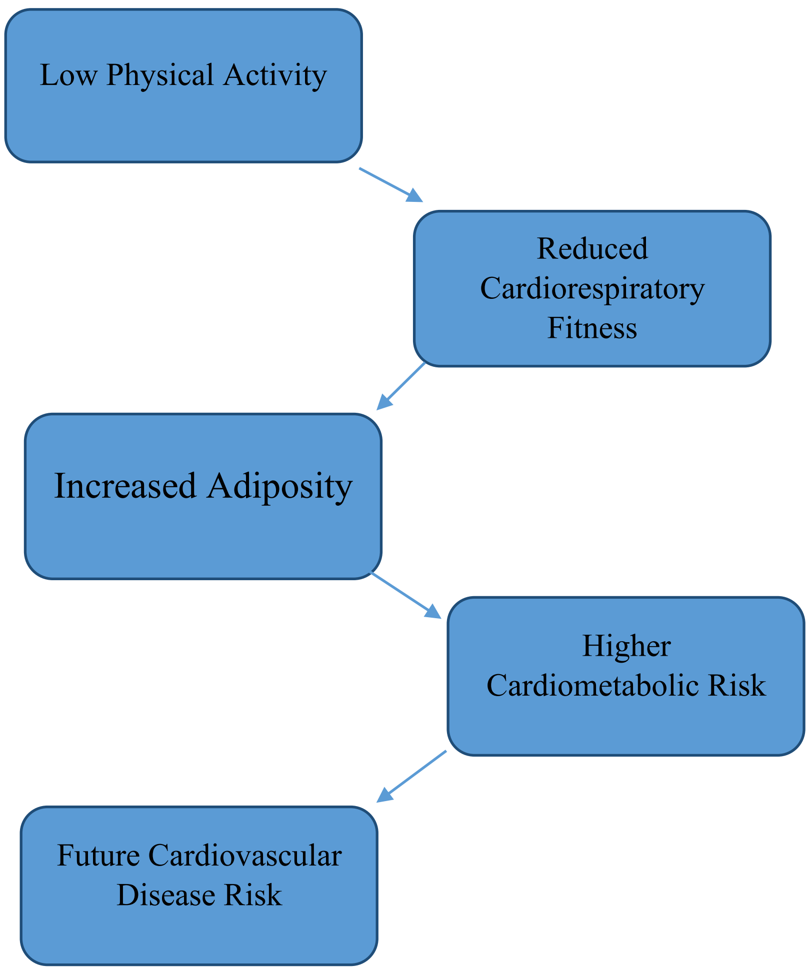

Figure 3: Conceptual pathway linking low cardiorespiratory fitness to long-term cardio metabolic risk

Conclusion

The present study provides district-level evidence on cardiorespiratory fitness (CRF) among schoolchildren in Ropar, Punjab, revealing that nearly one in five children had low estimated CRF. Girls and children with higher adiposity demonstrated lower VO_2max values. Anthropometric measures, particularly BMI and body fat percentage, were strong inverse predictors of CRF, whereas moderate-to-vigorous physical activity showed a positive association.

These findings reaffirm CRF as a clinically meaningful and modifiable indicator of pediatric health. Since childhood CRF tracks into adulthood and influences long-term cardiometabolic risk, early identification of low fitness offers a crucial opportunity for prevention. Field-based assessments such as the 20-meter shuttle run test proved feasible for large-scale school surveillance, though inter-method differences warrant cautious interpretation at the individual level.

From a public health standpoint, the results highlight the need to strengthen structured school-based physical activity programs, promote active lifestyles, and address modifiable determinants of adiposity. Integrating routine CRF monitoring into school health initiatives may provide a cost-effective approach for early risk detection and program evaluation.

Overall, this study establishes foundational data for the district and supports continued surveillance, longitudinal research, and policy engagement to improve youth health outcomes.

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Conflicts of Interest

No conflicts of interest.

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