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Cardiorespiratory Fitness, Muscular Strength, and Body Composition Among Junior Secondary Students in Nigeria: Evidence from Urban and Semi-Urban Settings

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Abstract

This study looked at cardiorespiratory fitness, muscular strength, and body composition among junior secondary school students in Nigeria, comparing students in urban and semi-urban communities. With physical activity declining and adolescent overweight and obesity becoming more common, there is growing concern about cardiometabolic health in young people. However, local evidence that reflects Nigerian school settings is still limited. Using a cross-sectional design, 612 students aged 11–14 years were recruited from public secondary schools in one metropolitan city and two semi-urban local government areas. Cardiorespiratory fitness was measured with the 20-m shuttle run test. Muscular strength was assessed using handgrip dynamometry and the standing broad jump. Body composition was assessed using body mass index (BMI) and waist-to-height ratio (WHtR). Data were analyzed using descriptive statistics, independent t-tests, and multivariate regression models. Overall, students in semi-urban settings recorded significantly better cardiorespiratory fitness and performed better in the standing broad jump than students in urban schools. Handgrip strength did not show a clear or consistent difference between settings. In contrast, students in urban schools had higher average BMI and WHtR, and a larger proportion were classified as overweight or centrally obese. Across the full sample, better cardiorespiratory fitness was linked to lower BMI and WHtR. Muscular strength showed smaller but generally positive associations with healthier body composition. When results were examined by sex, boys demonstrated higher muscular strength, while girls showed slightly higher adiposity indicators, regardless of whether they lived in urban or semi-urban areas. These findings suggest meaningful urban–semi-urban differences in fitness and body composition among Nigerian adolescents. The pattern likely reflects differences in daily movement opportunities, including habitual physical activity, active transport, and environmental supports for being active. The study points to the need for context-sensitive school-based physical education and public health strategies that strengthen cardiorespiratory fitness and prevent obesity, especially in rapidly urbanizing areas. Routine fitness monitoring in schools, better access to safe spaces for physical activity, and stronger Human Kinetics-informed curricula could help support healthier adolescent development and reduce future risk of non-communicable diseases.

Keywords: Cardiorespiratory fitness; Muscular strength; Body composition; Adolescents; Physical education; Urban–semi-urban disparities; Nigeria

1. Introduction

Adolescent physical fitness and body composition are strong signals of how healthy young people are now and how healthy they are likely to be in the future. Early and middle adolescence is a period of fast change physically, emotionally, and socially and these changes shape how young people move, eat, rest, and engage with daily life. Within this stage, cardiorespiratory fitness, muscular strength, and body composition stand out as core parts of health-related fitness because they are closely connected to heart health, metabolic function, healthy bones and muscles, and even confidence and well-being (Boellstorff *et al*., 2012; Lukaszewicz, 2020). Research across different countries shows a consistent pattern: adolescents with low fitness levels and unhealthy body composition are more likely to carry elevated risks into adulthood, including overweight and obesity, type 2 diabetes, hypertension, and reduced physical functioning.

This is why tracking these fitness components during the secondary school years is important not to label students, but to identify risks early and guide interventions that can protect long-term health (Awe, 2021; Halliday, 2021; Isa, 2021; Jimoh & Owolabi, 2021). In recent decades, adolescent lifestyles have shifted in ways that make healthy movement harder to maintain. Urbanization, technology, and changes in school and leisure routines have reduced everyday physical activity for many young people. At the same time, sedentary behaviors especially screen-based entertainment and reliance on motorized transport have increased (Brogden & Kennedy, 2018; Zwangobani, 2016). These trends have been linked to falling cardiorespiratory fitness and muscular strength among youth populations worldwide, alongside rising rates of overweight and obesity. Because schools provide regular contact with large numbers of adolescents, they are increasingly seen as practical and strategic settings for assessing fitness and supporting healthier habits through structured physical education and health promotion activities (Adeshina, 2021; Isa, Johnbull, & Ovenseri, 2021; Wegner, Omine, & Vincent, 2021).

Nigeria offers a particularly important context for examining these issues, yet the evidence base remains comparatively thin. The country is experiencing rapid population growth, expanding cities, and wide social and economic transitions that influence young people's diets, movement patterns, and health outcomes. Urban and semi-urban environments differ in meaningful ways, including access to recreational spaces, walkability, transport systems, food environments, and opportunities for both organized sport and informal play. Adolescents in urban areas may be more exposed to sedentary routines, energy-dense diets, and limited safe spaces for physical activity. In semi-urban settings, young people may still experience more incidental physical activity through walking, household responsibilities, and community-based outdoor play (Jones, 2017; Kansanga, 2020). Even so, this contrast is no longer straightforward. Many semi-urban communities are also changing rapidly, with lifestyle transitions that can blur the traditional boundary between "urban" and "non-urban" living.

Despite the relevance of these contextual differences, research on Nigerian adolescents' cardiorespiratory fitness, muscular strength, and body composition remains limited. Where studies exist, they often focus on a single fitness indicator, a specific region, or older students, and fewer studies take a comprehensive, school-based approach that examines multiple fitness components at once among junior secondary students. Comparative work between urban and semi-urban settings is also relatively scarce, making it harder to understand how environment and socio-demographic context shape adolescent fitness patterns within the same national setting (Hill-Herndon *et al*., 2019; Kennedy & Lee, 2018). This gap matters because early secondary school is a key period when young people establish habits that may persist into adulthood.

The present study responds to this need by generating context-specific evidence that reflects the day-to-day realities of Nigerian adolescents. By assessing cardiorespiratory fitness, muscular strength, and body composition together, the study offers a more complete picture of health-related fitness rather than treating these outcomes as isolated issues. Concentrating on junior secondary school students also makes it possible to capture early adolescent profiles before later pubertal changes become more pronounced, providing useful baseline information for prevention-oriented planning. Importantly, comparing urban and semi-urban school settings allows the study to explore how environmental conditions may contribute to fitness differences and health disparities, supporting a more nuanced understanding of adolescent health within Nigeria (Despres-Bedward, 2019; Silk, Andrews, & Thorpe, 2017).

In line with this rationale, the study aims to assess levels of cardiorespiratory fitness, muscular strength, and body composition among junior secondary school students in Nigeria, and to examine whether these indicators differ between students in urban and semi-urban settings. By addressing these aims, the study seeks to provide evidence that can strengthen school health programmes, guide physical education policy, and inform community-based interventions that promote healthier growth and development. Ultimately, the goal is to support practical, evidence-based strategies that improve adolescent fitness and reduce long-term non-communicable disease risk across diverse Nigerian environments (Akpan *et al*., 2017; Oni *et al*., 2018; Isa, 2020).

2. Methodology

This study used a school-based cross-sectional design to assess cardiorespiratory fitness, muscular strength, and body composition among junior secondary school students in Nigeria, with a specific focus on comparing urban and semi-urban settings. The approach was guided by established work in human kinetics, physical education, and adolescent health, and it was chosen because it allows researchers to describe fitness and body composition patterns across a large group of students at a single point in time. It also makes it possible to identify differences that may be linked to context such as lifestyle routines, movement opportunities, and environmental influences without requiring long-term follow-up.

The participants were junior secondary school students, roughly 10 to 14 years old, attending public secondary schools in selected urban and semi-urban communities. A multistage sampling method was used to strengthen representativeness. First, schools were grouped by location (urban versus semi-urban) and selected from official education authority lists using random selection procedures. Next, within each selected school, eligible students were randomly chosen to participate. This process helped reduce selection bias while ensuring that students were drawn from different environments where physical activity exposure and daily routines may differ.

Ethical approval was obtained from the relevant institutional and education authorities before data collection began. Permission was also secured from school leadership. Parents or guardians provided written informed consent, and students gave assent before participating. Because the study involved minors and physical fitness testing, particular attention was given to ethical safeguards, including confidentiality, voluntary participation, the right to withdraw, and safety during all measurements and physical performance tasks.

Data collection took place during normal school hours and was carried out by trained research assistants with backgrounds in human kinetics and health education. Anthropometric assessments followed standardized procedures. Height and body mass were measured and used to calculate body mass index (BMI). Where feasible, additional indicators such as skinfold thickness were included

to provide more detail on body composition. Cardiorespiratory fitness was assessed using a validated field test appropriate for adolescents, such as the 20-metre shuttle run, which provides an indirect estimate of aerobic capacity and is widely used in school-based fitness surveillance. Muscular strength was evaluated through handgrip dynamometry and simple functional field tests that capture both upper- and lower-body strength, including tasks such as the standing broad jump. All assessments followed consistent protocols to improve reliability, and students were given clear instructions and short familiarization opportunities to reduce anxiety and minimize "first-time" performance effects.

After data collection, results were coded and analyzed using statistical software. Descriptive statistics were first produced to summarize fitness and body composition across the full sample. Comparative analyses were then conducted to examine differences between urban and semi-urban students, as well as between boys and girls. Age and sex were treated as key covariates to account for developmental differences during early adolescence. Statistical significance was assessed using standard criteria, but interpretation also considered the practical meaning of differences, especially where findings have implications for school health programmes and physical education planning. This combination of descriptive profiling and comparative testing provided a clear, context-aware picture of adolescent fitness and body composition patterns in Nigeria.

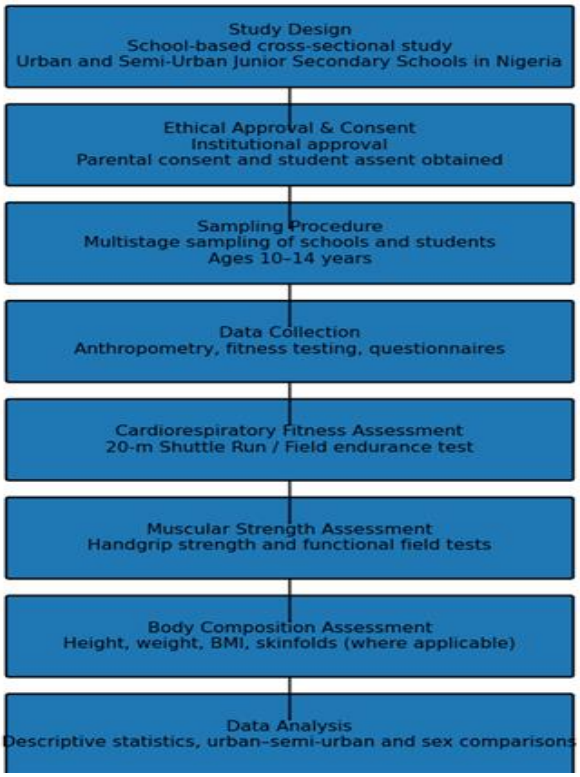

Fig 1: Flowchart of the study methodology

2.1. Conceptual and Theoretical Framework

The conceptual and theoretical foundation for assessing cardiorespiratory fitness, muscular strength, and body composition in junior secondary school students is rooted in the idea of health-related fitness. Health-related fitness is best understood as a set of physical qualities that reflect how well the body functions and how protected an individual is against disease and long-term health risks. Unlike performance-focused fitness, which is aimed at athletic achievement and competition, health-related fitness emphasizes everyday functioning, prevention of illness, and overall quality of life. Within this framework, cardiorespiratory fitness, muscular strength, and body composition are treated as core and connected components that shape adolescents' current well-being and their future risk of non-communicable diseases across the life course (Centeio *et al*., 2020; Ozer *et al*., 2020).

Cardiorespiratory fitness refers to how effectively the heart, lungs, and blood vessels deliver oxygen to working muscles during sustained physical activity. In exercise physiology, it is often used as a practical marker of aerobic capacity and metabolic efficiency. When cardiorespiratory fitness is higher, the body generally becomes better at transporting oxygen, producing energy efficiently, and recovering from physical effort. In adolescence, this fitness component is especially important because it reflects daily activity patterns and how the body is adapting during a period of rapid growth and developmental change. From a public health point of view, cardiorespiratory fitness is one of the most reliable indicators of cardiovascular and metabolic health. Studies consistently show that low cardiorespiratory fitness during adolescence is linked with higher likelihood of obesity, elevated blood pressure, reduced insulin sensitivity, and poorer mental health outcomes later in life (Poitras *et al*., 2016; Smedegaard *et al*., 2016). This makes it both a health marker and a useful target for early prevention efforts.

Muscular strength is another key pillar of health-related fitness and refers to the ability of muscles to produce force. In young people, muscular strength is shaped not only by physical activity but also by maturation and neuromuscular development. During early adolescence, strength gains often happen less through muscle enlargement and more through improved coordination and nervous system efficiency such as

better motor unit recruitment, improved movement control, and more effective muscle activation patterns (Greenspan *et al*., 2019; Vaquero-Solís *et al*., 2020). Adequate muscular strength supports posture, stability, functional movement, and injury prevention, and it can influence whether adolescents feel confident and capable enough to participate in physical activities. Beyond movement, muscular strength is also tied to metabolic health because skeletal muscle plays a major role in glucose uptake and energy regulation. For this reason, muscular strength is increasingly recognized as an independent predictor of health outcomes, complementing the protective effects of cardiorespiratory fitness and helping to build a fuller picture of adolescent health.

Body composition usually described as the balance between fat mass and fat-free mass provides the physical "base" within which cardiorespiratory fitness and muscular strength develop and express themselves. In simple terms, it helps explain what the body is made of and how that makeup can support or limit health and performance. Theories of energy balance and growth emphasize that body composition is shaped by the combined influence of physical activity, dietary intake, genetics, and the environment. During adolescence, these influences become even more noticeable because puberty triggers major changes in body size, shape, and composition. As young people grow, boys and girls often follow different developmental patterns, with differences in lean mass gains and fat distribution becoming more pronounced. A healthy body composition meaning a reasonable level of body fat alongside adequate lean mass is generally linked with better metabolic health, stronger physical functioning, and more positive psychological well-being. On the other hand, excess body fat during adolescence has been associated with reduced fitness levels, lower self-confidence, and increased risk of future non-communicable diseases (Rafferty *et al*., 2016; Rose & Soundy, 2020).

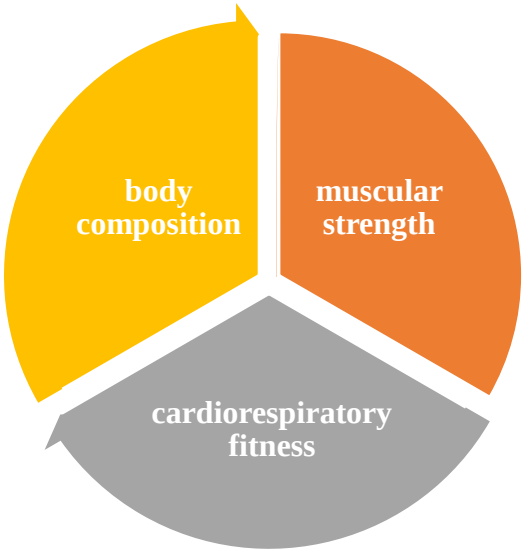

Fig 2: Core, interrelated components that collectively influence both immediate health outcomes.

A key idea in this conceptual framework is that cardiorespiratory fitness, muscular strength, and body composition should not be treated as separate or isolated qualities. Instead, they interact in ways that are often reinforcing. Regular participation in moderate-to-vigorous physical activity, for example, can improve both aerobic capacity and muscular strength. These improvements can then influence body composition by increasing total energy expenditure and supporting the development of lean mass. Higher cardiorespiratory fitness is frequently linked with lower levels of body fat because aerobic activity supports fat oxidation and improves metabolic efficiency (Amholt *et al*., 2020; Cilar *et al*., 2020). In the same way, higher muscular strength is often associated with greater lean mass, and lean mass is metabolically active meaning it can raise resting energy expenditure and help the body regulate weight more effectively. Taken together, these relationships suggest that progress in one component of health-related fitness can create momentum in the others. For adolescents, this is important because it means that improving fitness is not only about sporting ability; it can also support healthier growth patterns, reduce cardiometabolic risk, and strengthen overall well-being through a combined, "whole-body" effect.

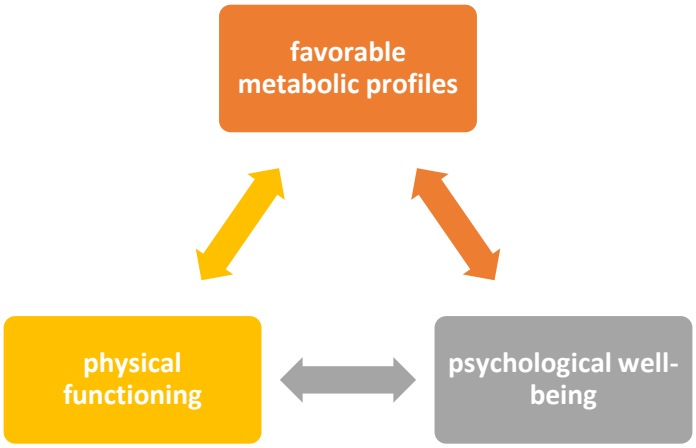

Fig 3: characteristics of a healthy body composition,

Adolescent growth and development provide an important backdrop for understanding how cardiorespiratory fitness, muscular strength, and body composition relate to one another. The junior secondary school years fall within early adolescence, a stage marked by rapid physical growth, major hormonal changes, and ongoing neurological development. During this period, young people often experience growth spurts that can temporarily affect coordination, endurance, and strength. At the same time, differences in pubertal timing can shape fitness levels and body composition in ways that are not solely explained by behavior. In other words, two students of the same age may show different fitness or body composition profiles simply because one is maturing earlier or later than the other (Akomea-Agyin & Asante, 2019; Awe, 2017; Osabuohien, 2019). Developmental perspectives emphasize that early adolescence is also a window of opportunity: the habits and physiological adaptations formed during this stage can have lasting effects, and physical activity patterns established at this age often continue into adulthood. This makes fitness and body composition assessment in junior secondary school highly valuable for long-term health planning and prevention (Safieh, 2019; Sommer & Mmari, 2015).

Socio-ecological thinking further strengthens this framework by showing that adolescent health is not shaped by biology alone. Fitness outcomes are influenced by layers of context home routines, school culture, peer influence, community safety, infrastructure, and wider social norms. Within Nigeria, urban and semi-urban settings create different daily realities that can support or restrict movement. Urban environments often involve more screen time, less walking, heavier reliance on motorized transport, and fewer safe open spaces for play and recreation. These conditions can reduce opportunities for routine physical activity, potentially lowering cardiorespiratory fitness and contributing to less favorable body composition. Semi-urban communities, although increasingly affected by similar lifestyle transitions, may still offer more incidental physical activity through active transport, outdoor play, and community-based movement, which can support better fitness profiles (Walker-Stevenson, 2017; Xu *et al*., 2020). Looking at fitness through this environmental lens helps explain why students living in different settings may show different health-related fitness patterns, even when they belong to the same national education system.

The connection among cardiorespiratory fitness, muscular strength, and body composition is also strongly supported by life course and preventive health perspectives. These approaches argue that health risks do not suddenly appear in adulthood; they develop over time, often beginning with early patterns of lifestyle behavior and physical development. Identifying low fitness or unhealthy body composition early gives schools, families, and public health systems a chance to intervene before chronic conditions become entrenched. This is particularly relevant in Nigeria, where non-communicable diseases are rising while infectious diseases remain a challenge, placing increasing pressure on the health system. Building adolescent fitness, therefore, is not only about youth well-being; it is also a forward-looking strategy that can reduce future health burdens. Schools are central in this preventive framework because they offer consistent access to adolescents and provide structured opportunities for assessment, physical education, and health promotion during a formative stage of life (Chung, Kim, & Lee, 2018; Keogh *et al*., 2018).

Within this conceptual structure, assessing cardiorespiratory fitness, muscular strength, and body composition together provides a more complete picture of adolescent health than measuring any one of these indicators in isolation. Cardiorespiratory fitness reflects aerobic capacity and functional endurance, muscular strength captures neuromuscular and musculoskeletal health, and body composition provides the structural and metabolic context within which the other two operate. Taken together, these components offer complementary insights into how healthy students are, how their bodies are developing, and how daily behaviors and environments may be shaping their growth (Pradhan, Wynter, & Fisher, 2015; Yakubu & Salisu, 2018).

In summary, the framework guiding this study draws from health-related fitness theory, adolescent developmental perspectives, and socio-ecological and life course approaches that link physical activity, physiological adaptation, and body composition. It treats cardiorespiratory fitness, muscular strength, and body composition as connected components that jointly influence present and future health. By grounding the framework in early adolescence and Nigeria's urban–semi-urban context, it offers a strong basis for interpreting empirical results and for guiding school-based strategies that promote healthier physical development and reduce long-term disease risk among Nigerian adolescents.

2.2. Measurement of Fitness and Body Composition

Accurate measurement of cardiorespiratory fitness, muscular strength, and body composition is essential for understanding the physical health of junior secondary school students and for producing evidence that can guide school health policies and practical interventions. In Nigerian school environments, measurement procedures must do more than meet scientific standards they also need to be realistic in terms of cost, time, safety, space, and cultural acceptability. For this reason, school-based studies often rely on standardized field methods that have been shown to provide reliable and reasonably valid results for children and adolescents, while still being feasible to implement in real-world school settings (Fantaye *et al*., 2020; Ivanova *et al*., 2020).

Cardiorespiratory fitness is typically assessed using practical field tests that estimate aerobic capacity through controlled exercise performed at submaximal or maximal effort. In school-based research, widely used options include the 20-metre shuttle run (commonly known as the beep test), the 6-minute walk test, and step tests. Among these, the 20-metre shuttle run is one of the most commonly used methods for adolescents because it is easy to organize, requires minimal equipment, and can be conducted with large groups. The test involves running back and forth between two lines set 20 metres apart, keeping pace with audio signals that gradually increase in speed. Students continue until they can no longer maintain the required pace or stop due to fatigue. Performance is then used to estimate aerobic capacity, often as an indirect indicator of maximal oxygen uptake. The shuttle run has been widely validated, with research showing moderate to strong relationships between shuttle run performance and laboratory-based measures of aerobic fitness. It also demonstrates strong test–retest reliability when instructions, pacing signals, and testing conditions are kept consistent (Forrester *et al*., 2018; Lall *et al*., 2019). In the Nigerian context, it is especially suitable because it does not require advanced devices, can be done on a school field or open court, and fits well within the time and space constraints typical of many public schools.

However, assessing cardiorespiratory fitness among junior secondary school students also requires sensitivity to adolescent development and school realities. Students within the same age bracket can differ substantially in maturation, body size, confidence, and exercise tolerance, all of which can influence performance. Motivation is another key factor: some students may stop early due to discomfort, fear of embarrassment, or unfamiliarity with the test, while others may push harder because of competitiveness or peer support. To improve reliability and fairness, testing procedures should include clear explanations of the task, a brief familiarization opportunity so students understand pacing and turning technique, and a consistent encouragement approach that avoids pressuring students beyond safe limits. Environmental conditions also matter. The running surface, available space, heat, humidity, and even the time of day can affect performance particularly when testing is conducted outdoors. Where possible, these conditions should be kept consistent across schools and testing days to reduce measurement bias.

Despite these practical challenges, field-based assessments of cardiorespiratory fitness remain highly valuable for school health research because they make it possible to generate population-level fitness profiles, compare groups such as urban and semi-urban students, and identify patterns that may signal future health risk. When carefully standardized and ethically conducted, these measurements provide a strong foundation for evidence-informed decisions in physical education planning, adolescent health promotion, and broader prevention strategies within Nigerian schools.

Muscular strength in adolescents is usually assessed with simple tests that capture either upper-body strength, lower-body strength, or a combination of both. In school-based research, handgrip strength is one of the most commonly used measures because it is straightforward to administer, safe for young people, and supported by strong evidence of reliability. The procedure involves the student squeezing a handgrip dynamometer as hard as possible, often with both hands, with either the best score or an average score recorded. Although it targets the forearm and hand muscles directly, handgrip strength tends to correlate reasonably well with overall muscular strength and functional capability, which is why it is often used as a practical proxy in larger studies. Research with adolescent samples has repeatedly shown good reliability for handgrip testing, especially when standardized instructions, consistent posture, and appropriate dynamometer sizing are maintained (Mugendawala & Muijs, 2020; Salifu *et al*., 2019).

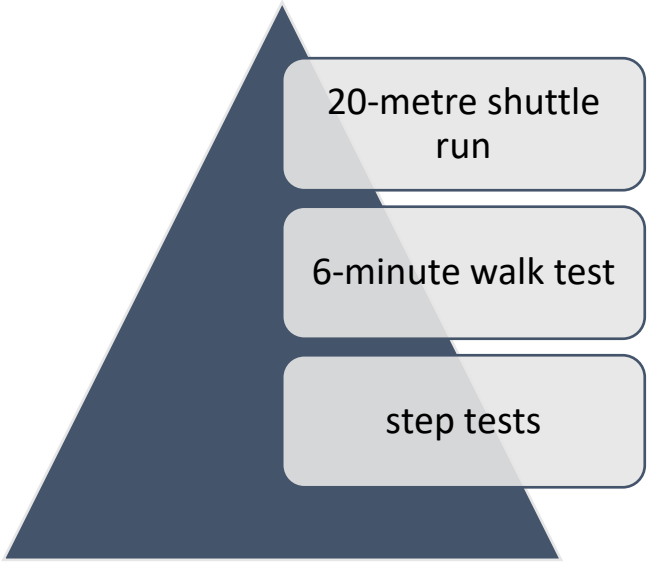

Fig 4: Field tests designed to estimate aerobic capacity through submaximal or maximal exertion.

To complement handgrip strength, many studies also include easy-to-administer field tests such as the standing long jump, sit-ups, or push-ups. These tests can capture aspects of explosive leg strength, trunk strength, or muscular endurance. The standing long jump is particularly popular in youth fitness assessments because it requires minimal equipment, is quick to conduct, and provides a useful indicator of lower-body power. It also shows good test–retest reliability in adolescents when the testing procedure is properly controlled. However, because field tests are influenced by technique and coordination, outcomes can be affected by how well students understand the movement and how confidently they perform it. This is especially important in early adolescence, when motor control is still developing. For that reason, clear demonstrations, a short practice trial, and consistent scoring rules are essential to improve fairness and reliability across participants and schools (Hayes & Bulat, 2017; Kiberu, Mars, & Scott, 2017).

Body composition assessment in junior secondary school students typically aims to estimate fatness and lean mass using methods that are non-invasive and suitable for field settings. The most widely used indicator is body mass index (BMI), calculated as weight (kg) divided by height squared (m^2). In school environments, height and weight can be measured with portable stadiometers and calibrated weighing scales, and good practice requires students to wear light clothing, remove shoes, and stand correctly for accurate readings. BMI is highly practical for population-level monitoring because it is quick, inexpensive, and reliable when measurement protocols are standardized. However, BMI does not directly measure body fat and can be less precise during adolescence, when changes in height, muscle development, and pubertal growth may influence BMI values even when body fat is not increasing (Akuma, 2017; Nketsia, Saloviita, & Gyimah, 2016).

Because of these limitations, some studies add skinfold thickness measurements to obtain a more direct estimate of body fat. Common measurement sites, such as the triceps and subscapular areas, are practical in adolescent populations and can be used to estimate body fat percentage when combined with appropriate prediction equations. When performed by well-trained assessors using calibrated calipers, skinfold measurements can produce reliable and useful data. In Nigerian school settings, however, skinfold assessment requires careful planning. Privacy and cultural sensitivity are important for participant comfort, especially for adolescents. In addition, inter-observer consistency is critical, because small differences in pinching technique or caliper placement can introduce measurement error. For this reason, assessor training, standardized procedures, and periodic reliability checks are necessary for high-quality data (Burgers, 2017; Harerimana & Mtshali, 2018).

Another method sometimes used is bioelectrical impedance analysis (BIA), which estimates body fat and lean mass based on how body tissues resist a small electrical current. Portable BIA devices are easy to transport and relatively simple to operate, but their accuracy can be affected by hydration status, recent exercise, and temperature. In school-based studies, it can be difficult to control these factors fully, which means BIA is often best used as a supportive measure rather than the main indicator of body composition, particularly in resource-limited contexts where strict pre-test conditions are harder to enforce.

Across all these measures, two issues are always central: validity and reliability. Validity concerns whether a test truly measures what it claims to measure, while reliability concerns whether results remain consistent across time or across different assessors. In adolescent populations, both can be influenced by motivation, fatigue, developmental stage, and testing conditions. That is why standardized protocols, calibrated equipment, trained assessors, and consistent testing environments are so important. Familiarization sessions help reduce "first-time" effects, and consistent procedures improve comparability especially when comparing students across urban and semi-urban settings (Gallicchio, Cooke, & Ring, 2017; Jing, 2016).

Ethical and practical realities also shape measurement choices when working with junior secondary school students. Parental consent and student assent must be obtained, and students should be clearly informed about what each test involves. Safety is especially important for tests that require maximal or near-maximal effort, such as endurance runs. Screening for known health conditions, providing close supervision, ensuring access to rest and hydration, and allowing participants to stop if they feel unwell are essential safeguards. These protections matter even more in school settings where medical support may be limited (Alexander, 2018; Husband, 2018).

In summary, assessing cardiorespiratory fitness, muscular strength, and body composition among junior secondary school students is most effective when it uses field-based methods that are valid, reliable, and practical for school environments. Cardiorespiratory fitness can be measured through standardized endurance tests, muscular strength through handgrip dynamometry and simple functional tests like the standing long jump, and body composition through anthropometric indicators such as BMI ideally supported by measures like skinfold thickness where feasible. When implemented with careful training, standardization, and cultural sensitivity, these assessments provide strong evidence for understanding adolescent health and for identifying meaningful differences between urban and semi-urban students in Nigeria.

2.3. Data Analysis Procedures

The data analysis plan for this study was developed to produce findings that are clear, credible, and easy to interpret, while still being rigorous enough to capture meaningful patterns in cardiorespiratory fitness, muscular strength, and body composition among junior secondary school students in Nigeria. Because health-related fitness is multidimensional and because adolescents differ widely in age, maturation, and environment the analysis procedures were designed to consider both biological factors (such as age and sex) and contextual influences (such as urban versus semi-urban school settings), using established statistical standards throughout.

The analysis begins with careful data screening and preparation. All results from the fitness tests and anthropometric measurements are entered into statistical software and checked for accuracy. This includes identifying entry errors, documenting missing values, and detecting outliers that may reflect measurement or recording problems rather than true performance. Descriptive statistics are then generated to summarize the sample and provide a baseline picture of the data. Means and standard deviations are used for continuous measures such as shuttle run performance, handgrip scores, and BMI, while frequencies and percentages

summarize categorical outcomes such as weight status categories or proportions classified as centrally obese (Baker, 2019; Predoiu *et al*., 2020). To determine whether the data meet assumptions required for parametric testing, normality is examined using both visual methods (such as histograms and Q–Q plots) and appropriate statistical checks. When variables show strong departures from normality, transformations may be considered, or non-parametric alternatives are used to ensure that inference remains valid.

A major part of the analysis focuses on comparing urban and semi-urban students. Independent group comparisons are used to examine differences in cardiorespiratory fitness, muscular strength, and body composition across settings. Where assumptions of normality and equal variances are met, parametric tests are applied because they provide strong statistical power. When assumptions are not met, non-parametric equivalents are used to provide more robust results. These initial comparisons help establish whether contextual differences exist at a basic level before adjusting for other factors (Hernández-Mendo *et al*., 2020; Maher, 2020).

Because adolescent fitness outcomes are strongly influenced by developmental stage and sex, the analysis explicitly accounts for covariates. Age is treated as a continuous covariate to reflect developmental variation even among students in the same grade. Sex is included as a categorical variable because boys and girls often differ in muscular strength, aerobic fitness patterns, and fat distribution during adolescence. To compare urban and semi-urban groups while controlling for these influences, analysis of covariance techniques are used where appropriate. This adjustment strengthens internal validity by reducing the risk that observed differences are simply due to age or sex composition differences between groups (Brinthaupt & Pennington, 2019; Vezzosi, 2017).

Beyond group comparisons, the study also examines relationships among key variables. Correlation analyses are conducted to explore how cardiorespiratory fitness and muscular strength relate to body composition indicators such as BMI and waist-related measures. Depending on how the data are distributed, Pearson correlations or Spearman correlations are used. These analyses help clarify whether fitter students tend to show healthier body composition profiles, which is important for interpreting fitness as a protective factor in adolescent health (Fasina, 2019; Mekonnen, Animaw, & Seyum, 2018).

To understand the combined influence of multiple factors at once, multivariate techniques are applied. Multiple regression models are used to identify independent predictors of key outcomes such as cardiorespiratory fitness, muscular strength, and body composition. Key predictors include school setting, age, and sex. This approach allows the study to estimate the unique contribution of each factor while holding the others constant. Where it adds explanatory value, interaction terms are introduced to test whether relationships differ by context for example, whether the effect of sex on fitness is stronger in one setting than the other, or whether age-related patterns vary between urban and semi-urban schools (Abayomi *et al*., 2020; Ibrahim *et al*., 2019).

Criteria for statistical decision-making are defined in advance. An alpha level of 0.05 is used as the threshold for statistical significance. When multiple tests are conducted, adjustments may be considered to reduce the chance of false-positive findings. Importantly, the analysis does not rely on p-values alone. Effect sizes are reported to show the magnitude and practical importance of observed differences and relationships. Depending on the test used, these may include standardized mean differences, partial eta squared, or correlation coefficients. This is crucial in adolescent health research because a statistically significant result may still reflect a small difference with limited real-world meaning (Adedoyin, 2017; Pathak *et al*., 2017). Confidence intervals are also presented for key estimates to show how precise the results are and to support interpretation beyond a simple "significant/not significant" conclusion.

Missing data are handled transparently because school-based studies often face challenges such as student absenteeism, incomplete testing, or equipment issues. The pattern and extent of missingness are examined first to determine whether missing values appear random or systematic. If missing data are minimal, listwise deletion may be used. If missingness is larger or could bias results, appropriate imputation strategies are considered to preserve statistical power while reducing bias. Whatever approach is adopted is clearly documented as part of methodological reporting (Munthali *et al*., 2018; Okolosi, 2020).

Throughout the analysis process, the assumptions behind each statistical technique are checked such as homogeneity of variance, linearity, and independence of observations. When assumptions are not met, alternative analyses or robust methods are used to maintain validity. This consistent attention to assumption testing improves the trustworthiness of the findings and strengthens the basis for conclusions.

In summary, the study uses a structured and comprehensive data analysis strategy that combines descriptive profiling, group comparisons, covariate-adjusted testing, correlational analysis, and multivariate modeling to examine fitness and body composition among junior secondary school students in Nigeria. By accounting for age and sex, and by comparing urban and semi-urban settings carefully, the analysis provides a detailed and context-sensitive understanding of adolescent health-related fitness. The inclusion of effect sizes and confidence intervals ensures that the results are not only statistically sound but also meaningful for decision-making in school health, physical education policy, and adolescent public health interventions (Jimoh, 2016; Suleiman *et al*., 2018).

2.4. Results: Fitness and Body Composition Profiles

The results of this study provide a detailed picture of cardiorespiratory fitness, muscular strength, and body composition among junior secondary school students in Nigeria, highlighting overall patterns as well as clear differences linked to settlement context and sex. Taken together, the findings suggest that adolescent health-related fitness in Nigeria is shaped by a combination of developmental processes, everyday activity opportunities, and environmental conditions that differ across urban and semi-urban settings.

Across the full sample, descriptive results showed moderate average levels of cardiorespiratory fitness, but with wide variation between students. While many participants demonstrated endurance levels that appeared broadly consistent with what would be expected for their age group, a sizable proportion displayed low aerobic capacity. This pattern points to a potentially limited engagement in sustained moderate-to-vigorous physical activity among a segment of junior secondary students. Muscular strength

outcomes followed a similar trend. Average strength scores indicated basic functional capacity, yet the spread of results suggested substantial differences in habitual activity exposure, coordination, and neuromuscular development across individuals. Body composition findings were mixed: most students fell within normal weight ranges, but the presence of both underweight and overweight students showed that Nigerian adolescents continue to experience a dual burden of malnutrition where undernutrition persists alongside the growing influence of lifestyle-related weight gain (Chukwurah, Nwadiani, & Ngwoke, 2018; Momoh, 2017).

When urban and semi-urban students were compared, settlement context emerged as a strong differentiating factor. Semi-urban students generally recorded higher cardiorespiratory fitness than their urban counterparts, with differences that were statistically significant and meaningful in practical terms. This trend is consistent with the idea that semi-urban living may still support more routine physical activity through active transportation, outdoor play, and higher levels of incidental movement. Urban students, by contrast, tended to show lower endurance performance, which may reflect greater exposure to sedentary behavior, heavier reliance on motorized transport, and limited access to safe, open spaces for recreation (Adebayo, 2018; Deemuai & Nwankwo, 2018).

Muscular strength also tended to favor semi-urban students, although the differences were generally smaller than those observed for cardiorespiratory fitness. Even so, the pattern suggests that semi-urban adolescents may experience more frequent daily physical loading through walking, household tasks, and informal sport, which can support strength development. In urban areas, physical activity may be more structured and time-limited restricted to school physical education classes or occasional sports participation while daily routines may involve less physical exertion overall, potentially weakening strength gains over time (Abdulraheem & Ibraheem, 2019; Okebukola, 2017).

Body composition results further separated urban from semi-urban students. Urban adolescents showed higher average BMI values and higher adiposity indicators, including a greater proportion classified as overweight or centrally obese. Semi-urban students were more likely to fall within normal weight categories. These differences align with broader patterns of urbanization in which dietary habits shift toward more energy-dense foods while physical activity declines. At the same time, underweight prevalence was still evident in both settings, underscoring that nutrition-related challenges remain complex and not limited to one environment (Abubakar, 2020; Ekuri & Akameze, 2016).

Sex-based analyses revealed differences that were broadly consistent with established developmental patterns. Boys demonstrated higher cardiorespiratory fitness than girls across both settlement contexts, and these differences remained evident after accounting for age. This may reflect a mixture of physiological factors and sociocultural expectations that often promote greater participation in vigorous physical activity among boys. Although girls generally showed functional endurance levels, the consistently lower aerobic capacity highlights the importance of supporting sustained activity opportunities for female students, especially in settings where social norms or limited school programming may discourage full participation (Abayomi *et al*., 2020; Esan & Adewunmi, 2018).

Similarly, boys outperformed girls on muscular strength assessments, particularly in measures related to explosive leg power and upper-body strength. These differences are in line with neuromuscular maturation patterns and early hormonal influences that begin to shape strength trajectories even in early adolescence. However, the spread of scores within each sex also mattered showing that individual differences in activity habits and exposure can amplify or reduce biological advantages (Emmers, Baeyens, & Petry, 2020; Reina *et al*., 2019).

Body composition outcomes showed higher adiposity indicators among girls compared with boys, particularly in measures sensitive to fat distribution. This pattern is consistent with typical pubertal development, where girls tend to accrue relatively more fat mass while boys gain relatively more lean mass. Importantly, the results suggested that the combination of sex and setting matters. Urban girls appeared to be particularly exposed to higher adiposity risk, reflecting how biological changes can interact with sedentary lifestyles, reduced movement opportunities, and dietary transitions common in urban environments (Addimando, 2019; Yada & Savolainen, 2017).

When urban–semi-urban comparisons were examined separately within sex groups, more nuanced patterns became visible. Semi-urban boys generally showed the strongest overall profiles, combining higher fitness levels with healthier body composition indicators. Urban girls, on average, displayed the least favorable combination, with lower fitness levels and higher adiposity markers. This "double disadvantage" pattern suggests that urbanization may not affect all adolescents equally. Instead, its influence may be more pronounced among female students if their opportunities for active transport, outdoor play, or sport participation are more constrained by safety concerns, cultural expectations, or school-level barriers.

Correlational findings reinforced the view that health-related fitness components are interconnected rather than independent. Higher cardiorespiratory fitness and stronger muscular performance were generally linked with healthier body composition indicators, including lower adiposity. These relationships appeared across settings and sexes, though they tended to be stronger among boys and among semi-urban students. This pattern suggests that maintaining or improving fitness in early adolescence may play a supportive role in healthier body composition development, especially where daily movement opportunities remain relatively high (Muwonge, Zavuga, & Kabenge, 2015; Wilhelmsen & Sørensen, 2017).

Overall, the results show that junior secondary school students in Nigeria display diverse fitness and body composition profiles that differ meaningfully by settlement context and sex. Semi-urban students tend to show better endurance, somewhat stronger muscular profiles, and healthier adiposity patterns than urban students, while boys tend to outperform girls in fitness measures but show lower adiposity indicators. These findings highlight early-emerging disparities and point to the importance of context-specific, sex-sensitive strategies to strengthen physical fitness and promote healthy body composition among Nigerian adolescents.

2.5. Discussion of Key Findings

The findings of this study offer a useful window into the cardiorespiratory fitness, muscular strength, and body

composition of junior secondary school students in Nigeria, showing patterns that are shaped by settlement context, biological development, and the broader lifestyle shifts associated with modernization. When interpreted alongside existing evidence, the results align with widely reported concerns about declining adolescent fitness and increasing adiposity, while also revealing local dynamics that reflect the realities of urban and semi-urban living in Nigeria. The clear differences observed between groups reinforce the idea that adolescent health-related fitness is not only a biological outcome but also a reflection of environment, opportunity, and everyday behavior during a sensitive period of growth (O'Brien *et al*., 2020; Vaz *et al*., 2015).

The moderate average levels of cardiorespiratory fitness, combined with large variability across students, mirror global patterns suggesting that many adolescents are not meeting recommended levels of physical activity. International studies have repeatedly linked falling aerobic fitness to increases in sedentary recreation, reduced active transport, and changing school routines that limit movement. In Nigeria, these drivers can be intensified by inconsistent delivery of physical education, limited sports infrastructure in many public schools, and unequal access to safe activity spaces. The wide dispersion in aerobic fitness therefore appears to reflect a "mixed reality": some students remain routinely active, while others may already be entering low-fitness trajectories that are associated with increased cardiometabolic risk later in life (Hutzler *et al*., 2019; Nketsia, 2017).

One of the most important results is the advantage observed among semi-urban students in cardiorespiratory fitness. This finding is consistent with evidence from many low- and middle-income settings where semi-urban or rural adolescents often accumulate more daily movement through walking, informal play, and household responsibilities. These activities may not be structured "exercise," but they contribute substantially to aerobic conditioning. Urban adolescents, in contrast, often experience environments that encourage inactivity motorized transport replaces walking, screen-based leisure becomes more dominant, and public spaces for play may be limited or perceived as unsafe. The present findings suggest that these urban constraints are not abstract; they are already detectable in measurable differences in adolescent endurance performance (Onukwugha *et al*., 2020; van Zijl Drive & Cape, 2017).

Muscular strength patterns support a similar interpretation, even though the urban–semi-urban differences were typically smaller than those seen for endurance. Semi-urban students' slightly higher strength levels likely reflect regular engagement in functional tasks and more frequent whole-body movement in daily routines. Strength in early adolescence is particularly responsive to consistent physical loading and neuromuscular practice rather than muscle size alone, so routine movement may provide important stimulation for strength development. Urban students may have greater exposure to organized sport in some cases, but the overall "movement volume" outside school can still be lower if daily life is more sedentary. This matters because adolescent muscular strength is increasingly recognized as an independent marker of health and future functional capacity, not simply an athletic performance variable (Adogu, 2015; Oluwaseyi, 2019).

The body composition findings higher adiposity indicators among urban students and a greater prevalence of overweight/obesity fit closely with established urbanization patterns. Urban living often brings dietary transitions toward energy-dense foods, sugar-sweetened beverages, and more frequent snacking, alongside reduced physical activity. Nigerian evidence has increasingly pointed to rising overweight and obesity in urban children and adolescents, occurring at the same time that undernutrition persists in other groups. The presence of underweight students across settings in this study highlights that the challenge is not one-dimensional. Instead, it reflects the "double burden" seen in many countries where socio-economic inequalities and rapid transitions create overlapping risks of both undernutrition and lifestyle-related weight gain (Adenrele, 2015; Kadijat, 2015).

Sex-based differences were also pronounced and broadly consistent with adolescent development research. Boys showed higher cardiorespiratory fitness and muscular strength, while girls showed higher adiposity indicators. Biologically, these patterns align with sex-related changes that emerge around puberty, including differences in lean mass development and fat distribution. Yet biology alone is not enough to explain the size and consistency of the gap. Sociocultural expectations often shape who is encouraged to play, train, compete, and engage in vigorous activity. In many Nigerian settings, boys are more likely to participate in sport and outdoor play with social approval, whereas girls may face subtle or explicit constraints related to safety, household expectations, dress norms, or perceptions about femininity and sport participation. These social patterns can translate directly into differences in fitness outcomes (Kunnuji, 2018; Shiffman *et al*., 2018).

A particularly important layer of interpretation emerges from the interaction between sex and settlement context. Urban girls appeared to represent the most vulnerable subgroup, combining relatively lower fitness with higher adiposity indicators. This is consistent with arguments in the literature that urbanization can affect girls more strongly because the barriers to outdoor movement fear of harassment, traffic exposure, limited female-friendly recreation spaces, and restrictive social norms tend to constrain girls more than boys. Semi-urban environments, while not free from gendered constraints, may still allow more incidental physical activity through walking, errands, and community movement, which could partially protect girls from the sharpest declines in fitness and the fastest increases in adiposity (Kunnuji *et al*., 2017; Mukoro, 2017).

The correlations observed between fitness components and body composition reinforce the broader conceptual view of health-related fitness as interconnected. Students with higher cardiorespiratory fitness and stronger muscular performance generally showed more favorable body composition profiles, which supports integrative models linking habitual physical activity to both metabolic health and body fat regulation. These relationships suggest that interventions aimed at improving fitness especially aerobic capacity may simultaneously support healthier body composition, making fitness promotion a practical "multi-benefit" strategy rather than a narrow performance goal (Awe, Akpan, & Adekoya, 2017; Osabuohien, 2017).

From a public health and education perspective, the implications are clear. Early adolescence is a crucial period when habits and physiological patterns begin to consolidate, and disparities observed at this stage can track into later adolescence and adulthood. The urban–semi-urban differences imply that interventions should not be uniform

across contexts. Urban schools, in particular, may require stronger and more creative strategies to build daily movement opportunities through improved PE implementation, active breaks, school-based fitness clubs, safe walking initiatives, and partnerships that expand access to secure recreation spaces. Girls should be a priority population in these efforts, not because they are less capable, but because their movement opportunities may be more constrained in ways that are structural rather than individual (Akpan, Awe, & Idowu, 2019; Ogundipe *et al*., 2019).

At the same time, the presence of both underweight and overweight students calls for balanced approaches that promote healthy growth rather than focusing solely on obesity. Nutrition education, school feeding quality, and supportive physical activity programming can be integrated to address both ends of the malnutrition spectrum. Schools remain one of the most practical platforms for such interventions because they reach adolescents consistently and can embed fitness promotion into routine learning and social life (Awe & Akpan, 2017; Isa, 2019).

Overall, the study's findings suggest that adolescent fitness and body composition in Nigeria are shaped by an interplay of environment, gendered opportunity, and lifestyle transition. While the results align with broader literature on declining youth fitness and rising obesity, they also highlight context-specific vulnerabilities particularly among urban students and urban girls that demand targeted, culturally responsive, and equity-driven strategies to strengthen physical fitness, support healthy body composition, and reduce the long-term risk of non-communicable disease (Ajayi & Akanji, 2021; Ejibenam *et al*., 2021; Osabuohien, Omotara, & Watti, 2021).

2.6. Conclusion and Policy Implications

This study offers a well-rounded picture of cardiorespiratory fitness, muscular strength, and body composition among junior secondary school students in Nigeria, and it shows clearly that early adolescent health-related fitness is shaped by where students live and by sex. Although many students demonstrated moderate aerobic fitness and basic functional strength, the wide spread in results suggests that adolescents are not developing uniformly. Some appear to be benefiting from regular movement and active routines, while others may already be drifting toward low-fitness and higher-risk profiles. The stronger fitness outcomes observed in semi-urban students higher aerobic capacity, slightly better strength performance, and lower adiposity indicators suggest that daily activity opportunities in these settings may still be relatively supportive of physical development. By contrast, the less favorable profile seen among urban students, including lower fitness and higher prevalence of overweight and obesity, reflects the growing influence of urbanization on movement patterns, dietary transitions, and sedentary lifestyles among Nigerian adolescents.

The sex-based differences observed add an important layer of interpretation. Boys generally performed better in cardiorespiratory fitness and muscular strength, while girls recorded higher adiposity indicators. These patterns are partly explained by normal biological changes in early adolescence, but they also reflect social realities that shape physical activity participation. In many contexts, boys are more socially encouraged to engage in vigorous play and sports, while girls may encounter barriers linked to safety, cultural expectations, or limited access to activity spaces that feel welcoming and appropriate. The implication is that fitness gaps are not only physiological; they are also influenced by opportunity, support, and the extent to which school and community environments enable all students especially girls to be active.

From a policy and practice standpoint, the findings point strongly to the need for school-based approaches that make physical activity regular, inclusive, and developmentally appropriate. Schools are one of the few settings that can reach adolescents consistently and equitably, regardless of household income or neighborhood resources. Strengthening physical education delivery should therefore be treated as a core health investment, not an optional extracurricular activity. Students need enough moderate-to-vigorous activity during the school week to build aerobic capacity and support muscular development, and this requires both time allocation and intentional programming. Because the urban setting appears to carry higher risk lower fitness and higher adiposity urban schools may need extra supports, including structured activity opportunities during breaks, well-organized PE sessions, and safe spaces that encourage daily movement rather than occasional participation.

The results also carry clear curriculum implications. At the junior secondary level, physical education curricula should emphasize health-related fitness outcomes rather than focusing primarily on sports performance or theoretical content. A stronger curriculum would intentionally balance aerobic activities, age-appropriate strength-building using body weight, flexibility and movement competence, and health literacy that links activity to long-term well-being. Including simple, non-stigmatizing self-monitoring skills such as understanding endurance, strength, and healthy body composition can help students build awareness and motivation without turning PE into a high-pressure testing environment. However, curriculum reform will only succeed if teachers are equipped to deliver it. Teacher training should therefore prioritize practical competence: how to run inclusive sessions, adapt activities for different ability levels, encourage participation among girls, and use basic fitness assessment tools responsibly and safely.

At a broader systems level, the findings support stronger coordination between education and health sectors. Preventing future non-communicable disease risk requires early intervention, and adolescent fitness is a practical entry point because it can shift both behavior and physiological risk factors. Investments in school infrastructure safe play areas, functional open spaces, and basic equipment are likely to have outsized benefits, particularly in urban schools where informal activity opportunities may be constrained. Community partnerships can also extend the reach of school efforts by supporting after-school programs, safe walking initiatives, and local recreation opportunities that make active living more feasible in daily life.

The study also highlights priorities for future research. Longitudinal work is needed to understand how early adolescent fitness patterns develop across secondary school years and how they connect to later health outcomes. More detailed evidence on mediating factors diet, physical activity behavior, socioeconomic conditions, school resources, neighborhood safety, and cultural norms would help explain why differences are emerging and which levers are most modifiable. Expanding research across more regions, including rural settings, would strengthen generalizability and support more equitable national planning. Finally,

intervention studies are essential to move from observation to action, testing what works in real Nigerian school environments and identifying scalable models that improve fitness and reduce unhealthy weight gain without excluding or stigmatizing any group.

In sum, this study reinforces that cardiorespiratory fitness, muscular strength, and body composition among Nigerian junior secondary students vary meaningfully by settlement context and sex, with urban students and especially girls in urban settings showing signals of higher vulnerability. Addressing these patterns through evidence-based, school-centered, and context-sensitive strategies offers a realistic pathway to strengthening adolescent health today and reducing preventable disease burden in the future.

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