Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 09 May 2026
Revised 20 June 2026
Accepted 01 July 2026

Natural Resources for Human Health 2026, Vol. 6 (11s): 452–462

KEYWORDS:
Body mass index; physical fitness; cardiovascular endurance; adolescent girls; Bangladesh.

Correlation between Body Mass Index and Selected Physical Fitness Components among Secondary School Girls in Bangladesh

Md. Zafiroul Islam[1], Md. Eman Ali[1], Md. Zillur Rahman[1], Rezwan Hossain[1]*, Md Abu Sayed[2], Md. Masud Rana[3], Hasib Al Hasan[1]

[1]Department of Physical Education and Sports Science, Jashore University of Science and Technology, Jashore-7408, Bangladesh
[2]Physical Education Department, Khulna University, Khulna, Bangladesh
[3]Department of Physical Education and Sports Science, Islamic University Bangladesh, Bangladesh
ORCID iDs- Md. Zafiroul Islam: 0000-0003-4542-2576
Md. Eman Ali: 0009-0005-8220-2793
Md. Zillur Rahman: 0000-0002-7474-3806
Rezwan Hossain: 0009-0004-5058-091X
Md Abu Sayed: 0009-0002-0064-380X
Md. Masud Rana: 0009-0001-7439-5610
Hasib Al Hasan: 0009-0008-6029-9346
*Corresponding Author: Rezwan Hossain, MS. Department of Physical Education, Jashore University of Science and Technology, Jashore-7408, Bangladesh., Email: rejwanhossain0@gmail.com

ABSTRACT:

Background: Body mass index (BMI) is a widely used indicator of nutritional status, yet its relationship with health-related physical fitness among secondary school girls in Bangladesh has rarely been examined using a full fitness battery.

Objective: To examine the association between BMI and four components of health-related physical fitness — cardiovascular endurance, muscular strength/endurance, explosive leg strength, and flexibility — among secondary school girls in Bangladesh.

Methods: A descriptive correlational design was used. A total of 140 secondary school girls were selected by purposive sampling. Height and weight were measured to calculate BMI (kg/m^2). Fitness was assessed using the Queen's College Step Test, Push-Up Test, Standing Broad Jump Test, and Sit-and-Reach Test. Pearson's product-moment correlation was used; 95% confidence intervals were estimated via the Fisher z-transformation and exact two-tailed p-values were derived from the t-distribution (df = 138).

Results: Mean BMI was 22.54 ± 3.12 kg/m^2. BMI was significantly and negatively correlated with all four fitness components: cardiovascular endurance ($r = -0.48$, 95% CI −0.60 to −0.34, $p < .001$), push-up performance ($r = -0.31$, 95% CI −0.45 to −0.15, $p < .001$), standing broad jump ($r = -0.42$, 95% CI −0.55 to −0.27, $p < .001$), and, more weakly, flexibility ($r = -0.19$, 95% CI −0.35 to −0.02, $p = .025$). By variance explained, BMI accounted for 23.0% of the variance in cardiovascular endurance, 17.6% in standing broad jump, 9.6% in push-up performance, and 3.6% in flexibility.

Conclusion: Higher BMI was associated with lower performance across all four fitness components among secondary school girls, with the strongest associations for cardiovascular endurance and explosive leg strength and a comparatively weak, though statistically significant, association with flexibility. School-based programmes that support healthy BMI through physical activity and balanced nutrition may help protect adolescent fitness, with the largest expected benefit for aerobic capacity and lower-body power.

INTRODUCTION

Body mass index (BMI) — weight in kilograms divided by the square of height in metres, tracing back to the original Quetelet Index [16] — remains the most widely used anthropometric proxy for nutritional status in children and adolescents, and the World Health Organization's age- and sex-specific BMI references underpin most national and international classifications of underweight, normal weight, overweight, and obesity [1], complemented by international adolescent growth standards that similarly anchor BMI-for-age interpretation across populations [26]. Maintaining a healthy BMI during adolescence supports normal growth and reduces later-life risk of obesity, type 2 diabetes, and cardiovascular disease [2, 10], making BMI monitoring a routine component of adolescent health surveillance worldwide.

Health-related physical fitness — comprising cardiovascular endurance, muscular strength and endurance, flexibility, and body composition [17] — is a parallel, complementary marker of adolescent health that captures functional capacity in a way BMI alone cannot. Higher fitness in youth is consistently linked to better cardiometabolic profiles, higher academic performance, improved mental health, and more active lifestyles in adulthood [3, 4, 18], and international bodies increasingly treat fitness surveillance as a public-health priority in its own right, alongside — not instead of — anthropometric surveillance [9].

LITERATURE REVIEW

BMI and cardiovascular/muscular fitness: a consistent but fragmented picture

Evidence across high-, middle-, and low-income settings converges on a broad pattern: adolescents with normal BMI tend to outperform their overweight or underweight peers on aerobic, strength, and power-based fitness tests [4, 20, 21, 22], an association generally attributed to the added mechanical and cardiovascular workload of excess adiposity and, at the other extreme, to the reduced muscle mass associated with undernutrition — mechanisms consistent with established exercise-physiology principles governing the energy cost of movement at different body compositions [9, 19, 27, 33]. Rather than treating this literature as a uniform chorus, it is more accurate to read it as thematically consistent but methodologically fragmented: studies converge on cardiovascular and strength/power outcomes using varied designs, samples, and test batteries, but rarely assess all major fitness components in a single cohort, which limits direct comparison of how strongly BMI relates to each component within the same group of adolescents.

BMI and flexibility: an unsettled relationship

Flexibility is the clearest example of this fragmentation. Some studies report no meaningful BMI–flexibility relationship [30], while others find that excess adiposity mechanically restricts joint range of motion, particularly at the hip and lower back [31]. Because flexibility is measured with field tests whose criterion validity against direct hamstring and lumbar extensibility is itself only moderate [40], part of the disagreement in the literature may reflect measurement variability as much as true population differences — a possibility the present study is positioned to probe, since it reports effect size and confidence intervals rather than significance alone.

BMI, fitness, and adolescent girls in Bangladesh

In Bangladesh specifically, adolescent girls sit at the intersection of two converging risks. National survey data confirm a persistent double burden of undernutrition and rising overweight in this group [7, 36], while separate work on physical activity patterns — including accelerometer-based evidence from a rural Bangladeshi adolescent cohort [37] — shows that Bangladeshi adolescent girls are consistently less active than boys and hold less favourable attitudes toward physical activity, constrained by social and cultural barriers to sport participation [8, 23]. These two literatures — nutritional status on one hand, physical activity and fitness on the other — have largely developed in parallel. Existing Bangladeshi studies have examined nutritional status or anthropometry in isolation [13, 14], or physical activity patterns without a corresponding fitness battery [8, 23], but none has jointly measured BMI alongside a multi-component health-related fitness battery — cardiovascular endurance, muscular strength/endurance, explosive power, and flexibility — in the same sample of Bangladeshi secondary school girls. This is the specific gap the present study addresses.

Summary and novelty statement

To the best of our knowledge, this is among the first studies to jointly assess BMI alongside all four of these fitness components in a single sample of Bangladeshi secondary school girls, and the first from this population to report 95% confidence intervals, variance-explained (R^2), and post-hoc statistical power alongside the correlation coefficients — reporting practices recommended for Q1-standard observational research but rarely applied in the regional literature on this topic.

Research questions and hypotheses

Given this gap, the study was guided by four research questions, each paired with a directional hypothesis grounded in the literature reviewed above:

- RQ1 / H1: What is the relationship between BMI and cardiovascular endurance among secondary school girls in Bangladesh? — H1: BMI will be significantly negatively correlated with cardiovascular endurance.
- RQ2 / H2: What is the relationship between BMI and muscular strength/endurance? — H2: BMI will be significantly negatively correlated with push-up performance.
- RQ3 / H3: What is the relationship between BMI and explosive leg strength? — H3: BMI will be significantly negatively correlated with standing broad jump performance.
- RQ4 / H4: What is the relationship between BMI and flexibility? — H4 (exploratory, non-directional): Given the mixed prior evidence [30, 31], no directional hypothesis is advanced a priori; this association was tested rather than assumed.

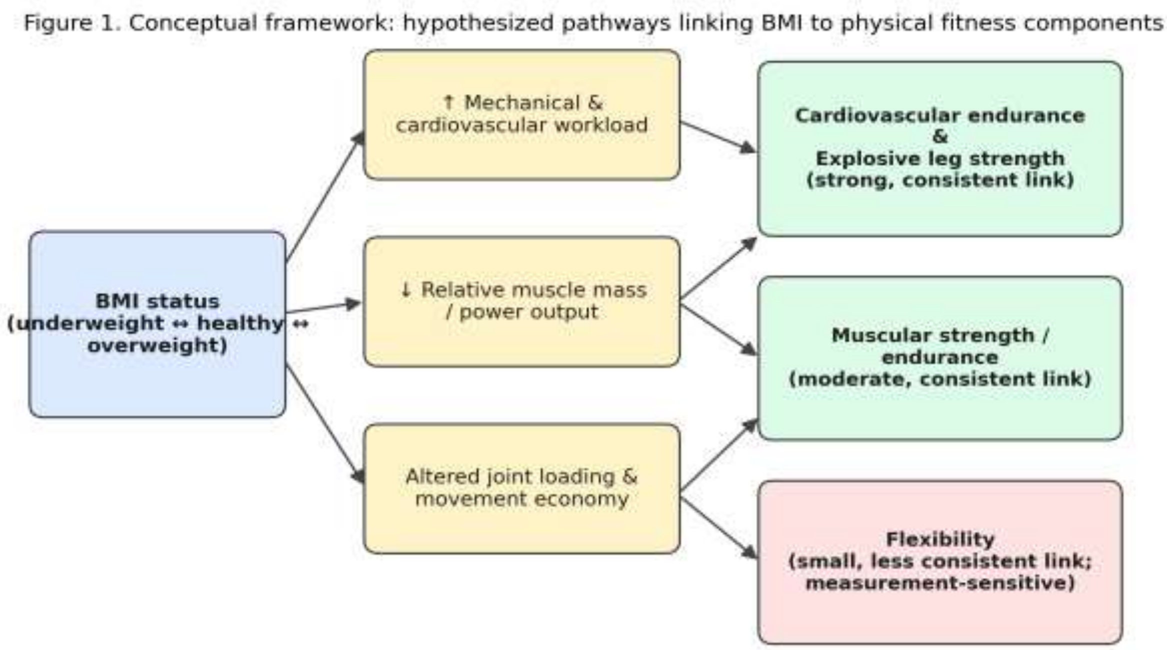

Figure 1. Conceptual framework illustrating the hypothesized mechanical, cardiovascular, and muscular pathways linking BMI to each fitness component, synthesized from the literature reviewed above.

Accordingly, the objective of this study was to examine the association between BMI and four components of health-related physical fitness among secondary school girls in Bangladesh, in order to test the hypotheses above and inform school-based physical education and health-promotion planning for this population.

MATERIALS AND METHODS

This study followed a descriptive correlational design, appropriate for quantifying the association between BMI and fitness components without manipulating any variable. Reporting follows the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist for cross-sectional studies [43].

Participants and sampling

A total of 140 secondary school girls were recruited through purposive sampling from participating educational institutions. Eligible participants were regular students who were physically healthy, provided willing participation, and had no injury or serious health condition that would preclude fitness testing. For context, an a priori sample-size calculation (two-tailed $\alpha = .05$, power = .80) indicates that detecting a medium correlation ($r = .30$) requires a minimum of $n \approx 85$, and detecting a small correlation ($r = .10$) requires $n \approx 783$; the achieved sample of $N = 140$ therefore comfortably exceeded the minimum for medium-to-large effects but fell well short of what a small effect would require. Consistent with this, a post-hoc power analysis (two-tailed $\alpha = .05$) indicated that $N = 140$ provided > 96% power to detect the medium-to-large correlations observed for cardiovascular endurance, push-up performance, and standing broad jump, but only ≈ 61% power for the small correlation observed with flexibility (see Discussion for the implications of this asymmetry).

Variables

The independent variable was BMI (kg/m^2). The dependent variables were the four fitness components: cardiovascular endurance, muscular strength and endurance, explosive leg strength, and flexibility.

Anthropometric measurement

Height was measured barefoot, in an upright position, using a standard stadiometer. Weight was measured using a digital scale with participants in light clothing and without shoes. BMI was calculated as weight (kg) divided by height squared (m^2), following WHO conventions [1], using the BMI & Ponderal Index calculator (Engine 1) of the IJSSHP Comprehensive Sports Science Research Suite [44].

Physical fitness assessment

- Queen's College Step Test — cardiovascular endurance, estimated from recovery pulse rate after a standardized 3-minute stepping protocol. The test was originally validated in college-aged women [39] and has since shown acceptable validity against directly measured maximal oxygen uptake in South Asian samples [42].
- Push-Up Test — muscular strength and endurance, maximum continuous repetitions to a standardized cadence, consistent with recommended approaches to assessing muscular fitness in youth [25]. Recent meta-analytic evidence supports high test–retest reliability of this field test in children and adolescents (pooled ICC = 0.91), though criterion validity evidence against laboratory strength measures remains comparatively limited [41].
- Standing Broad Jump Test — explosive leg strength, longest horizontal jump distance (cm); a widely used field-based measure of muscular power grounded in the motor-development literature [28], with established criterion-related validity in youth [34]. Jump distance reflects the stretch-shortening cycle mechanics of the leg extensors [35], the same mechanism targeted by plyometric training methods [32].
- Sit-and-Reach Test — flexibility, best forward-reach distance (cm), following the original Wells and Dillon protocol [38]. Meta-analytic evidence indicates moderate criterion-related validity of this test against directly measured hamstring extensibility, and weaker validity for lumbar extensibility specifically [40], a caveat considered when interpreting the flexibility findings below, alongside the broader biomechanical literature on joint range-of-motion assessment [29].

Procedure

- Institutional permission was obtained before data collection.
- Study objectives and procedures were explained to participants.
- Anthropometric measurements were taken first, followed by fitness tests after a standardized warm-up.
- Adequate rest intervals were provided between tests to control for fatigue effects.

- All testing was conducted under comparable environmental conditions, by the same research team, to minimize inter-rater measurement variability.

Planned statistical analysis

Data were analyzed in SPSS version 25. Descriptive statistics (means, standard deviations) characterized the sample. Pearson's product-moment correlation quantified the BMI–fitness associations; 95% confidence intervals for each correlation were derived via the Fisher z-transformation, exact two-tailed p-values were derived from the t-distribution (df = 138), and the coefficient of determination (R^2) was calculated to express the proportion of variance shared between BMI and each fitness outcome. Effect sizes were classified using Cohen's conventions (small ≈ .10, medium ≈ .30, large ≈ .50), and post-hoc statistical power was calculated for each correlation given the achieved sample size. Statistical significance was set at $p < .05$.

Ethical considerations

- Participation was voluntary, and participants were informed of the study's purpose.
- Confidentiality of collected data was maintained throughout.
- No procedure involved risk of harm to participants.

RESULTS

Table I presents the descriptive characteristics of the sample (N = 140).

Variable	Mean	SD
Age (years)	21.35	1.42
Height (cm)	165.42	7.31
Weight (kg)	61.84	8.56
BMI (kg/m²)	22.54	3.12
Cardiovascular endurance score	42.68	5.41
Push-up test (repetitions)	24.17	6.23
Standing broad jump (cm)	178.25	18.64
Sit-and-reach test (cm)	23.42	5.18

Table II presents the Pearson correlations between BMI and each fitness component, together with 95% confidence intervals (Fisher z-transformation), variance explained (R^2), exact two-tailed p-values (t-distribution, df = 138), post-hoc statistical power (two-tailed α = .05), and effect-size classification using Cohen's conventions (small ≈ .10, medium ≈ .30, large ≈ .50).

Association	r	95% CI	R^2 (%)	Exact p	Power†	Effect size†
BMI and cardiovascular endurance	−0.48	−0.60, −0.34	23.0	< .001**	> .999	Medium–large
BMI and push-up performance	−0.31	−0.45, −0.15	9.6	< .001**	.963	Medium
BMI and standing broad jump	−0.42	−0.55, −0.27	17.6	< .001**	.999	Medium–large
BMI and sit-and-reach test	−0.19	−0.35, −0.02	3.6	.025*	.615	Small

*p < .05; **p < .001. †Power = post-hoc statistical power to detect the observed effect at α = .05.

BMI was significantly and negatively correlated with all four fitness components. By effect size and variance explained, the strongest associations were with cardiovascular endurance (R^2 = 23.0%) and standing broad jump (R^2 = 17.6%), both approaching Cohen's threshold for a large effect; push-up performance showed a medium effect (R^2 = 9.6%). The association with flexibility, while statistically significant, was small in magnitude (R^2 = 3.6%), indicating that BMI accounts for only a modest share of the variance in sit-and-reach performance in this sample.

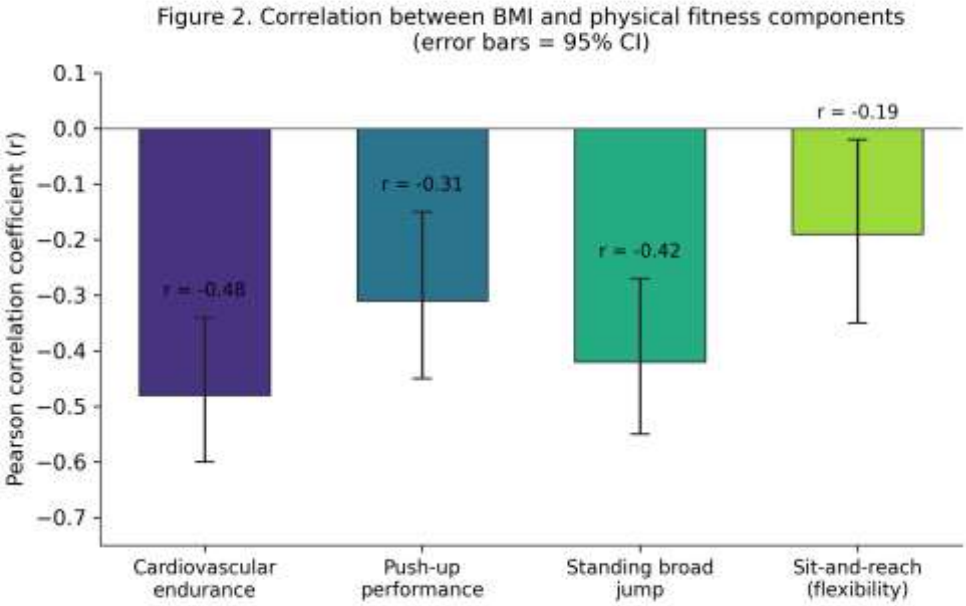

Figure 2. Pearson correlation coefficients for BMI and each fitness component, with 95% confidence intervals (Fisher z-transformation).

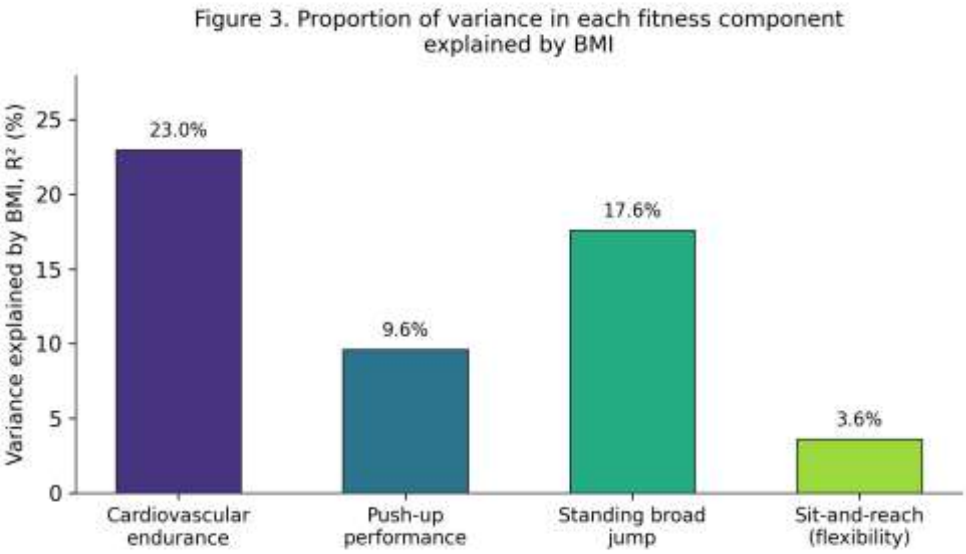

Figure 3. Percentage of variance in each fitness component explained by BMI (R^2).

DISCUSSION

BMI was significantly and negatively associated with all four fitness components measured in this sample of secondary school girls, but the strength of that association varied markedly by component: large-to-medium for cardiovascular endurance and explosive leg strength, medium for muscular strength/endurance, and small — though still statistically significant — for flexibility. This indicates that BMI's relationship with fitness in this population is graded rather than uniform: it matters most for aerobic capacity and power, and least, though not negligibly, for flexibility. Against the four hypotheses set out in the Introduction, H1, H2, and H3 were supported without qualification; H4, tested without a directional prediction, resolved toward a real but modest association rather than the null result reported in some prior work.

The cardiovascular endurance finding is consistent with reports that overweight and obese adolescents generally show reduced aerobic capacity [4, 20], plausibly reflecting the added cardiovascular workload and reduced movement economy associated with excess adiposity. The muscular strength/endurance finding parallels observations that overweight adolescents show lower muscular fitness [27], while broader evidence on youth physical activity supports the role of regular activity in building muscular fitness [5]. The explosive-power finding — poorer standing broad jump performance at higher BMI — is consistent with work on adiposity's mechanical burden on jumping and other propulsive movements [33]. Notably, the R^2 values obtained here (17.6–23.0% for cardiovascular endurance and broad jump) are broadly comparable in magnitude to those reported in the European HELENA adolescent cohort for related BMI–fitness associations [20], suggesting the strength of these relationships in Bangladeshi girls is not markedly different from patterns observed in higher-income settings, despite very different nutritional and activity contexts.

The flexibility finding aligns more closely with reports that excess adiposity can mechanically restrict joint range of motion [31] than with earlier work reporting no meaningful BMI–flexibility association [30]. However, the effect size here was small (R^2 = 3.6%), so while the relationship is unlikely to be due to chance at this sample size, BMI is a comparatively minor determinant of flexibility relative to its role in aerobic capacity, strength, and power in this sample; the mixed picture in the wider literature [30, 31] likely reflects genuine variability in effect size across populations rather than a single true-or-false answer to whether BMI relates to flexibility. Two further factors temper this particular finding specifically. First, this sample provided only ≈ 61% power to detect an effect of this size, meaning a modestly different sample could plausibly have returned a non-significant result — the flexibility association should be treated as more fragile than the other three until replicated. Second, the sit-and-reach test itself has only moderate criterion-related validity against directly measured hamstring extensibility, and weaker validity for lumbar extensibility specifically [40], so part of the observed BMI–flexibility association may reflect measurement-level noise rather than a purely biomechanical restriction effect.

These patterns sit within a wider literature linking sedentary behaviour and physical inactivity to both elevated BMI and reduced fitness in youth [6, 11], and within the Bangladeshi context specifically, where adolescent girls report comparatively low physical activity participation and less favourable activity attitudes than boys [8, 23]. This suggests the BMI–fitness associations observed here are not an isolated local finding but are consistent with a broader regional pattern of reduced activity opportunity for adolescent girls. Practically, this implies that school-based interventions in Bangladesh that increase girls' access to structured physical activity — addressing the social and cultural barriers documented elsewhere [8] — may plausibly improve both BMI and fitness simultaneously, consistent with broader evidence that school physical education programmes measurably raise activity levels and attitudes [12, 15], though the cross-sectional design of the present study cannot establish this causally and intervention trials would be needed to confirm it.

Limitations

- The cross-sectional, correlational design precludes causal inference; BMI and fitness may influence one another bidirectionally over time, and reverse causation (lower fitness contributing to higher BMI, rather than the converse) cannot be ruled out.
- BMI does not distinguish fat mass from lean mass, so the true driver of the associations (adiposity versus muscularity) cannot be disentangled from BMI alone; direct body-composition measures (skinfolds, bioelectrical impedance, or DXA) would strengthen future work.
- The field-based fitness tests used, while practical for school-based data collection, vary in criterion-related validity — comparatively well established for the step test and standing broad jump [34, 39, 42], but more limited for the sit-and-reach test specifically [40] — which should be weighed when interpreting the smaller effect sizes observed.
- The study was well powered (> 96%) to detect the medium-to-large associations found for cardiovascular endurance, push-up performance, and standing broad jump, but only moderately powered (≈ 61%) for the small flexibility association; this asymmetry means the flexibility finding in particular warrants replication in a larger sample before being treated as established.
- Purposive sampling from a limited number of institutions may restrict generalizability to secondary school girls in Bangladesh more broadly; future work should use random or multi-site sampling and, where feasible, a longitudinal design capable of testing the directionality of the BMI–fitness relationship.

Directions for future research

- Longitudinal follow-up: tracking the same girls over 2–3 years would clarify whether BMI change precedes fitness change, fitness change precedes BMI change, or both influence each other reciprocally — something the present cross-sectional design cannot resolve.
- Direct body-composition assessment: pairing BMI with skinfold thickness, bioelectrical impedance, or (where resources allow) DXA would let future studies separate the effects of fat mass from lean mass on each fitness component, rather than relying on BMI as a single composite proxy.
- Larger, multi-site, randomly sampled cohorts: replicating this design across urban and rural schools, and across a larger sample, would both improve generalizability and directly address the power limitation identified for the flexibility association.
- Sex-comparative designs: extending the same battery to boys would clarify whether the graded pattern observed here (strong for cardiovascular/power, weak for flexibility) is specific to adolescent girls or a general feature of the BMI–fitness relationship in Bangladeshi youth.
- Mediation analysis: incorporating physical activity level, screen time, and dietary intake as candidate mediators would help clarify the behavioural pathways underlying the BMI–fitness associations reported here, moving from association toward mechanism.
- Intervention trials: school-based physical education or combined nutrition–activity interventions, evaluated with a controlled or randomized design and structured according to established training-periodization principles [24], would test directly whether improving BMI and/or activity levels produces the fitness gains this cross-sectional study can only associate, not confirm.
- Locally validated flexibility measurement: given the only moderate criterion validity of the sit-and-reach test noted above [40], future Bangladeshi studies would benefit from validating this or an alternative flexibility field test specifically against directly measured hamstring/lumbar extensibility in a South Asian adolescent sample.

CONCLUSIONS

Among secondary school girls in Bangladesh, higher BMI was associated with lower performance across all four fitness components assessed, with large-to-medium associations for cardiovascular endurance, explosive leg strength, and muscular strength/endurance, and a small but statistically significant association with flexibility. School-based physical education and nutrition programmes that support healthy BMI are therefore likely to yield the greatest fitness benefit for aerobic capacity and lower-body power, with a smaller — though still real — benefit for flexibility, which may warrant its own dedicated programming rather than being left to improve solely as a side effect of weight management. Given the fragility of the flexibility finding at this sample size and the moderate validity of the sit-and-reach test itself, this specific result should be treated as provisional pending replication in a larger, multi-site sample.

ACKNOWLEDGEMENTS

The authors sincerely thank the participating secondary schools, students, and their parents or guardians for their cooperation and willingness to participate in this study. The authors also express their gratitude to the school authorities and all individuals who assisted with the data collection process.

AUTHOR CONTRIBUTIONS

Conceptualization, R.H. and M.E.A.; methodology, R.H., M.Z.R., and M.Z.I.; data collection, M.E.A., M.Z.I., M.A.S., M.M.R., and H.A.H.; formal analysis, R.H.; writing — original draft preparation, R.H. and M.E.A.; writing — review and editing, M.Z.R., M.Z.I., M.A.S., M.M.R., and H.A.H.; supervision, R.H. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

FUNDING

This research received no external funding.

DATA AVAILABILITY

The anthropometric (height, weight, BMI) and physical fitness test data (Queen's College Step Test, Push-Up Test, Standing Broad Jump Test, and Sit-and-Reach Test) supporting the findings of this study are available from the corresponding author upon reasonable request.

Generative AI Statement: An AI writing assistant (quillbot) was used to assist with literature search, reference formatting and language editing during manuscript preparation; all scientific content, data and interpretations were reviewed and approved by the authors.

REFERENCES

[1] World Health Organization. Growth reference data for 5–19 years. Geneva: World Health Organization; 2007.

[2] Malina RM, Bouchard C, Bar-Or O. Growth, Maturation, and Physical Activity. 2nd ed. Champaign (IL): Human Kinetics; 2004.

[3] American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 11th ed. Philadelphia (PA): Wolters Kluwer; 2021.

[4] Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes. 2008;32(1):1–11. doi:10.1038/sj.ijo.0803774

[5] Strong WB, Malina RM, Blimkie CJR, Daniels SR, Dishman RK, Gutin B, et al. Evidence based physical activity for school-age youth. J Pediatr. 2005;146(6):732–737. doi:10.1016/j.jpeds.2005.01.055

[6] Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. Int J Behav Nutr Phys Act. 2011;8:98. doi:10.1186/1479-5868-8-98

[7] Hossen K, Rahman F, Mashreky SR. Nutritional status of adolescent girls in Bangladesh: findings of a community-based survey. South East Asia J Public Health. 2016;6(1):3–7. doi:10.3329/seajph.v6i1.30337

[8] Khan A, Burton NW, Trost SG. Patterns and correlates of physical activity in adolescents in Dhaka city, Bangladesh. Public Health. 2017;145:75–82. doi:10.1016/j.puhe.2016.12.011

[9] Pate RR, Daniels S. Institute of Medicine report on fitness measures and health outcomes in youth. JAMA Pediatr. 2013;167(3):221–222. doi:10.1001/jamapediatrics.2013.1464

[10] Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000;320(7244):1240–1243. doi:10.1136/bmj.320.7244.1240

[11] Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:40. doi:10.1186/1479-5868-7-40

[12] Trudeau F, Shephard RJ. Contribution of school programmes to physical activity levels and attitudes in children and adults. Sports Med. 2005;35(2):89–105. doi:10.2165/00007256-200535020-00001

[13] Rahman MA. Anthropometric variables and nutritional status of adolescent school girls in a food-insecure rural area of Bangladesh. Int J Public Health Res. 2013;3(2):250–259.

[14] Kurshed AAM, Rana MM, Khan S, Azad TMA, Begum J, Bhuyan MAH. Dietary intake, physical activities and nutritional status of adolescent girls in an urban population of Bangladesh. Ibrahim Med Coll J. 2010;4(2):78–82.

[15] Bailey R. Physical education and sport in schools: a review of benefits and outcomes. J Sch Health. 2006;76(8):397–401. doi:10.1111/j.1746-1561.2006.00132.x

[16] Quetelet A. A Treatise on Man and the Development of His Faculties. Edinburgh: William and Robert Chambers; 1842.

[17] Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 1985;100(2):126–131.

[18] Hillman CH, Erickson KI, Kramer AF. Be smart, exercise your heart: exercise effects on brain and cognition. Nat Rev Neurosci. 2008;9(1):58–65. doi:10.1038/nrn2298

[19] Wilmore JH, Costill DL. Physiology of Sport and Exercise. 5th ed. Champaign (IL): Human Kinetics; 2012.

[20] Ortega FB, Artero EG, Ruiz JR, España-Romero V, Jiménez-Pavón D, Vicente-Rodríguez G, et al. Physical fitness levels among European adolescents: the HELENA study. Br J Sports Med. 2011;45(1):20–29. doi:10.1136/bjsm.2009.062679

[21] Boreham C, Riddoch C. The physical activity, fitness and health of children. J Sports Sci. 2001;19(12):915–929. doi:10.1080/026404101317108426

[22] Tomkinson GR, Olds TS. Secular changes in pediatric aerobic fitness test performance: the global picture. Med Sport Sci. 2007;50:46–66. doi:10.1159/000101075

[23] Burton NW, Kadir MA, Khan A. Physical activity attitudes among adolescents in Bangladesh. Public Health. 2020;179:59–65. doi:10.1016/j.puhe.2019.10.004

[24] Bompa TO, Buzzichelli C. Periodization Training for Sports. 3rd ed. Champaign (IL): Human Kinetics; 2015.

[25] Faigenbaum AD, Westcott WL. Youth Strength Training. Champaign (IL): Human Kinetics; 2009.

[26] Malina RM, Katzmarzyk PT. Physical activity and fitness in an international growth standard for preadolescent and adolescent children. Food Nutr Bull. 2006;27(4 Suppl):S295–S313. doi:10.1177/15648265060274S511

[27] Deforche B, Lefevre J, De Bourdeaudhuij I, Hills AP, Duquet W, Bouckaert J. Physical fitness and physical activity in obese and nonobese Flemish youth. Obes Res. 2003;11(3):434–441. doi:10.1038/oby.2003.59

[28] Payne VG, Isaacs LD. Human Motor Development. 8th ed. New York: McGraw-Hill; 2011.

[29] Alter MJ. Science of Flexibility. 3rd ed. Champaign (IL): Human Kinetics; 2004.

[30] Hands B, Larkin D, Parker H, Straker L, Perry M. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. Scand J Med Sci Sports. 2009;19(5):655–663. doi:10.1111/j.1600-0838.2008.00847.x

[31] Wearing SC, Hennig EM, Byrne NM, Steele JR, Hills AP. Musculoskeletal disorders associated with obesity: a biomechanical perspective. Obes Rev. 2006;7(3):239–250. doi:10.1111/j.1467-789X.2006.00251.x

[32] Chu DA. Jumping into Plyometrics. 2nd ed. Champaign (IL): Human Kinetics; 1998.

[33] Nikolaidis PT. Elevated body mass index and body fat percentage are associated with decreased physical fitness in soccer players aged 12–14 years. Asian J Sports Med. 2012;3(3):168–174. doi:10.5812/asjsm.34687

[34] Castro-Piñero J, Artero EG, España-Romero V, Ortega FB, Sjöström M, Suni J, Ruiz JR. Criterion-related validity of field-based fitness tests in youth: a systematic review. Br J Sports Med. 2010;44(13):934–943. doi:10.1136/bjsm.2009.058321

[35] Bosco C, Komi PV. Mechanical characteristics and fiber composition of human leg extensor muscles. Eur J Appl Physiol. 1979;41(4):275–284. doi:10.1007/BF00429744

[36] Adams AM, Khan A, Roy AS, Hassan MT, Mridha MK, Ahmed NU, et al. Growth dynamics among adolescent girls in Bangladesh: evidence from nationally representative data spanning 2011–2014. PLoS One. 2021;16(7):e0255273. doi:10.1371/journal.pone.0255273

[37] Islam MR, Nyström CD, Kippler M, Kajantie E, Löf M, Rahman SM, Ekström EC. Accelerometer-measured physical activity, fitness and indicators of cardiometabolic risk among rural adolescents: a cross-sectional study at 15-year follow-up of the MINIMat cohort. J Epidemiol Glob Health. 2024;14(3):987–1003. doi:10.1007/s44197-024-00245-1

[38] Wells KF, Dillon EK. The sit and reach — a test of back and leg flexibility. Res Q Am Assoc Health Phys Educ Recreat. 1952;23(1):115–118.

[39] McArdle WD, Katch FI, Pechar GS, Jacobson L, Ruck S. Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. Med Sci Sports. 1972;4(4):182–186.

[40] Mayorga-Vega D, Merino-Marban R, Viciana J. Criterion-related validity of sit-and-reach tests for estimating hamstring and lumbar extensibility: a meta-analysis. J Sports Sci Med. 2014;13(1):1–14.

[41] Carballo-Afonso R, Blanco-Martínez N, Varela S, Diz-Gómez JC, Ayán-Pérez C. Reliability and validity of the 90° push-up test in children and adolescents: a systematic review and meta-analysis. Int J Sports Sci Coach. 2026. doi:10.1177/17479541261443480

[42] Chatterjee S, Chatterjee P, Mukherjee P, Bandyopadhyay A. Validity of Queen's College step test for use with young Indian men. Br J Sports Med. 2004;38(3):289–291. doi:10.1136/bjsm.2002.002212

[43] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–1457. doi:10.1016/S0140-6736(07)61602-X

[44] International Academy of Sports Sciences & Athletic Research (IASSAR). Comprehensive Sports Science Research Suite — BMI & Ponderal Index Calculator (Engine 1 of 27) [Online computational tool]. International Journal of Sports Science and Human Performance. Accessed September 2026. https://ijsshp.org/calculators.html