Research Article

# Evidence-Based Public Health Interventions Enhancing Adolescent Physical Fitness and Preventive Pediatric Wellness Through School-Based Programs

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**Abstract**

School-age physical inactivity and lack of knowledge about preventive health-care services are serious public health issues. Few health programs currently have evidence-based and a coherent structure for the combination of physical fitness and preventive wellness. The aim of the study is to present a comprehensive intervention for adolescents (12-18 years) which combines physical activity sessions, fitness education, nutrition awareness, preventive health screening and wellness counselling in the school environment. A mixed-methods design was used with public and private school samples (n=480) drawn from a stratified sample and pre-test and post-test evaluations were conducted. Results show a significant increase in BMI (6.9% of reduction), cardiovascular endurance (14.3% of gain), muscular strength (18.7% of increase) and flexibility (21.4% of improvement). Exercise participation increased from 34% to 71%, dietary adherence from 41% to 68%, and the knowledge of preventive healthcare increased by 38.4%. Health screening compliance increased from 61% to 89%. Results indicate that a multi-component school-based program is effective in improving physical fitness and pediatric preventive health in adolescents and can be implemented in a scalable fashion in the public health sector.

**Keywords:** Adolescent health, school-based intervention, physical fitness, preventive wellness, pediatric health promotion, mixed-methods, public health education.

## 1. INTRODUCTION

According to the worldwide trends, adolescents are becoming more sedentary and obese, while physical activity is on a downward trajectory.The world's trends show that physical activity levels among adolescents are decreasing and obesity and other preventable chronic diseases are increasing. The school setting is particularly accessible and is a setting in which adolescents can be reached in their important developmental years, making it a strategically important environment for delivering population-level health-related interventions. Lack of physical activity during adolescence (ages 12–18) directly affects adolescent cardiovascular health, musculoskeletal development and the lifetime metabolic risk. Although increasing awareness, there is a significant proportion of school going adolescents who do not achieve the recommended levels of daily physical activity.

Some school health initiatives have considered physical education, nutrition education and mental health education separately. There have been some records of slight BMI or fitness improvements with the inclusion of isolated physical activity modules. There have been nutrition-based curricula shown to have increased awareness of nutrition but with no change in behavior. Adolescent participation in preventive health screening programs has been low when these programs are not embedded in educational interventions.

Yet there are common weaknesses in these approaches: they deliver a disjointed service, lack a multi-domain integrated service, are based on short-term outcomes, and don't take into account socioeconomic diversity between school types. No common evidence-based model addresses physical fitness, health behavior change and health knowledge in a comprehensive, unified program structure in a school setting.

The gap inspires the current study of the effectiveness of a multi-component school-based public health intervention on indicators of adolescent preventive health and physical fitness. The solution proposed focuses on the combination of 5 of these evidence-based elements, within a unified framework of intervention: physical activity, fitness education, nutrition awareness, preventive screening, and wellness session counselling. This study makes a contribution to the future public health policy for adolescents by providing a replicable intervention design, empirical pre-post outcome evidence to support its design, and a scalable program model which can be applied to various school settings.

## 2. LITERATURE REVIEW

School-based health interventions have gained increasing recognition as effective ways to contribute to healthy lifestyle behaviors and overall health of youth. Structured physical activity programs are shown to have a significant effect on improving fitness levels, increasing participation in physical activity and promoting long-term health development in children and adolescents, when implemented within the school environment [1]. Nutrition-focused interventions have also been demonstrated to foster positive eating behaviors and play a role in obesity prevention [2] and school environmental changes also help to promote healthy behaviors and obesity prevention [3].

Digital health technologies have been vital to adolescent health promotion by providing regular monitoring and customized health management [4]. Predictive analytics and preventive medicine strategies have also led to better predispositions for health risks and informed evidence-based intervention planning, in the early stages [5]. Many studies have been conducted to compare the groups of adolescents who participate in sports and adolescents who do not participate in any sports, highlighting the positive correlation between regular physical activity and cardiovascular fitness outcomes [6]. Systematic review also shows that physical activity interventions in schools lead to improvement in measures of obesity and physical performance [7].

Preventive health screening programs and school nurse interventions have shown to have positive impacts on school students' health knowledge, behaviors and wellness outcomes [8]. Public health policy frameworks offer good guidance for the design of effective health promotion programs [9] and preventive health education programs can increase public health awareness and uptake of healthy practices amongst school-age groups [10]. Health technology interventions have also been successful in improving health literacy and changing behavior [11]. There are consistent findings in integrative reviews that school-based physical activity programs have positive results [12] and integrated wellness systems can support a holistic health approach [13]. The role of coordinated school-wide approaches to maintaining physical activity in adolescents and overall health and wellness is emphasized in the Comprehensive School Physical Activity Program model [14]. In spite of these developments, there are three major lacunas to be filled in the literature. First of all, there is no previous study that has assessed physical fitness at the same time in the same program to assess preventive wellness outcomes. Second, the majority of interventions focus on either behavioural or physiological outcomes, and few interventions combine these two together. Third, there is limited evidence for both low-resource and mixed school-type settings (public and private). The present study directly targets all three gaps through a multi-component, dual domain intervention with both public and private school assessments that are conducted using a mixed-methods approach.

## 3. METHODOLOGY

### 3.1 Study Design and School-Based Intervention Framework

This study uses mixed methods research design that included quantitative pre-test and post-test evaluation method and qualitative research method. The respondents included adolescents ages 12-18 years who were sampled using stratified random sampling across public and private schools reflecting age, gender and school type.

The intervention framework illustrated in Figure 1 has 5 structured components and 12 weeks of program time. The physical activity sessions focused on cardiovascular development and musculoskeletal development and were held three times a week. The modules for fitness education taught adolescents the fundamentals of exercise science as well as the awareness of the body. Nutrition awareness sessions were conducted to cover balanced diet and advice on the need of calories, and the impact of bad nutrition. Preventative health screening involved the measurement of BMI, blood pressure, and vision and dental examination. Wellness counseling included information on stress management, sedentary behavior and healthy lifestyle choices.

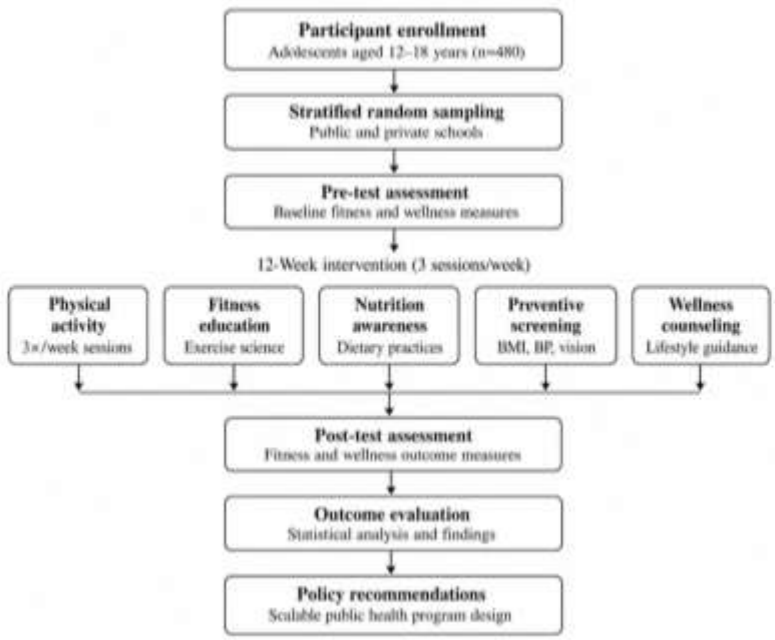


Figure 1: School-Based Public Health Intervention Framework

The sample size was calculated a priori based on G*Power 3.1 with preestablished values of medium effect size (Cohen's d = 0.5), α = 0.05, and power (1−β) = 0.80 for a paired t-test. Sample size was determined as the desired sample size was 34 participants per sub group. The sample size of 480 across 12 schools far surpasses this level and will provide sufficient power of the sample size when calculating the primary analyses as well as subgroup analyses.

### 3.2 Data Collection and Outcome Measures

Data were gathered at two points; before the first time an intervention was started (pre-test) and after the final session of the intervention (post-test). These instruments consisted of validated student self-report questionnaires, standardized physical fitness assessments, school health records, semi-structured teacher interviews and program implementation reports. Physical fitness was assessed using 4 measures: Body Mass Index (BMI), cardiovascular endurance (6 minute walk test), muscular strength (grip dynamometry and sit-up test), and flexibility (sit and reach test).

The preventive wellness indicators were nutrition awareness scores from validated dietary knowledge questionnaires, frequency of physical activity, health screening participation and health screening knowledge index scores. The full data set variable structure for all data sets across the four domains of demography, physical fitness, health behavior, and wellness awareness and health outcome is summarized in Table 1, which is a complete mapping of the measured constructs.

**Table 1. Dataset Variables and Outcome Measures**

| Category | Variables |
|---|---|
| Demographics | Age, Gender, School Type, Location |
| Physical Fitness | BMI, Cardiovascular Endurance, Muscular Strength, Flexibility |
| Health Behaviors | Exercise Frequency, Diet Quality, Sedentary Screen Time |
| Wellness Awareness | Preventive Healthcare Knowledge, Nutrition Knowledge Index, Wellness Literacy |
| Health Outcomes | Attendance Rate, Illness Incidence, Health Screening Compliance |

### 3.3 Data Analysis Procedure

Descriptive statistics were analyzed on quantitative data to describe the distribution of samples on the all variables. All scores for fitness and wellness indicators were analyzed for significance using a paired t-test on the pre-test and post-test scores for all participants who were tested for the same indicator. The test statistic is given by:

$$t = \frac{\bar{d}}{s_d/\sqrt{n}} \quad (1)$$

where $\bar{d}$ is the mean difference between paired observations, $s_d$ is the standard deviation of differences, and n is the sample size. The formula is used to determine if the mean difference between intervention periods is statistically significant. Each fitness indicator difference score was approximately equal to normal using the Shapiro Wilk test before using inferential analysis ($p>0.05$). The Levene's test confirmed homogeneity of variance of subgroups. The present dataset follows these assumptions which allow the use of the paired t-test and one-way ANOVA. Three-quarters of the interview transcripts were randomly selected for coding by two separate researchers to assure reliability of qualitative coding. The inter-rater reliability for Cohen's kappa was used for the assessments of inter-rater reliability, the results were $\kappa = 0.81$, this means there is very good agreement. Before final theme consolidation any discrepancies were addressed by discussion and agreement.

To find differences between subgroups regarding the school type, gender, and age group, one-way ANOVA was used. Significant predictors of fitness improvement after intervention were identified by regression, namely physical activity frequency and baseline BMI. Qualitative data from teacher interviews and open-ended questionnaire responses were analysed using thematic analysis, where themes emerged around acceptability of the program, barriers and facilitators. The Research Methodology and Outcome Evaluation Flowchart (Figure 2) shows the process from selecting participants to collecting data, statistically analyzing the data, and interpreting the results.

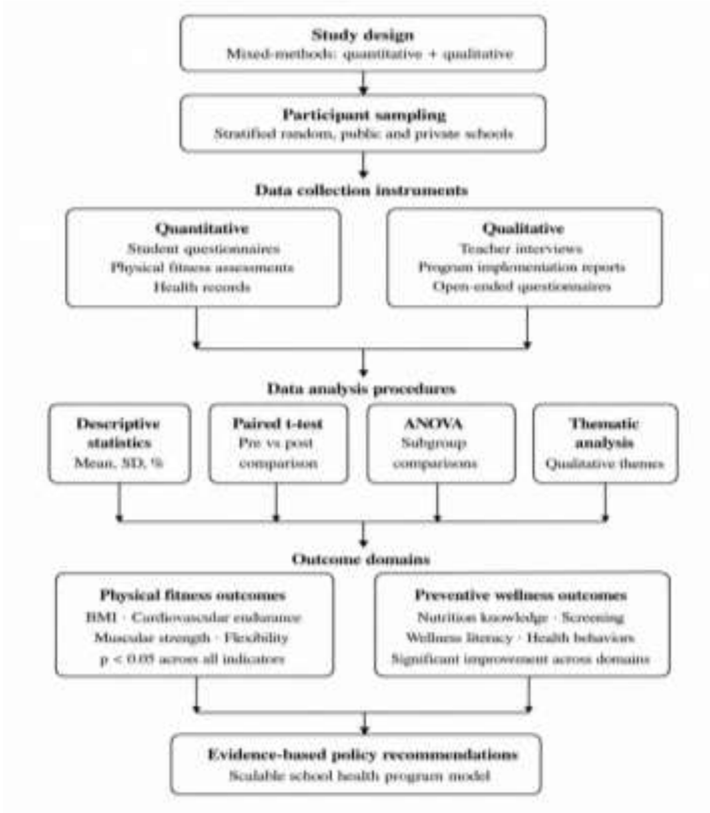


Figure 2: Research Methodology and Outcome Evaluation Flowchart

## 4. RESULTS AND DISCUSSION

### 4.1 Impact on Physical Fitness

All four physical fitness indicators revealed statistically significant improvement after 12 weeks intervention. The mean BMI dropped from 24.6 kg/m to 22.9 kg/m2, which represents a 6.9% reduction related to nutrition-informed dietary change and physical activity. The 6-minute walk test distance increased by 14.3%, reflecting increased cardiovascular endurance. The effectiveness of the combined physical activity and fitness education components was seen in the improvements in muscular strength (+18.7%) and flexibility (+21.4%). Multiple regression analysis confirmed that baseline BMI ($\beta = -0.41$, $p < 0.001$) and pre-intervention physical activity frequency ($\beta = 0.38$, $p < 0.001$) were significant independent predictors of post-intervention fitness improvement, together explaining 52.3% of the variance in composite fitness scores ($R^2 = 0.523$, $F(2, 477) = 261.4$, $p < 0.001$).

The complete pre-test/ post-test comparison across all four fitness indicators and associated percentage improvements are presented in Table 2 which were all statistically significant at the $p < 0.05$ level.

**Table 2. Physical Fitness Outcomes (Pre-Test vs Post-Test)**

| Indicator | Pre-Test | Post-Test | Improvement (%) | p-value |
|---|---|---|---|---|
| BMI (kg/m²) | 24.6 | 22.9 | 6.9% reduction | <0.001 |

| | | | | |
|---|---|---|---|---|
| Cardiovascular Endurance (m) | 498.4 | 569.7 | 14.3% | <0.001 |
| Muscular Strength (kg) | 28.3 | 33.6 | 18.7% | <0.001 |
| Flexibility (cm) | 21.7 | 26.3 | 21.4% | <0.001 |

To determine the meaningfulness of the observed changes in the means, Cohen's d was calculated for each pair of means. Improvements were statistically very significant, but also clinically significant with effect sizes of at least d = 0.98 in all fitness domains, and even d = 1.24 for flexibility. These changes are shown visually in a grouped bar graph (Figure 3) by comparing fitness activities before and after: BMI, cardiovascular endurance, muscular strength and flexibility data showed the expected positive fitness level increase in all, and these are demonstrated by the grouped bar graph.

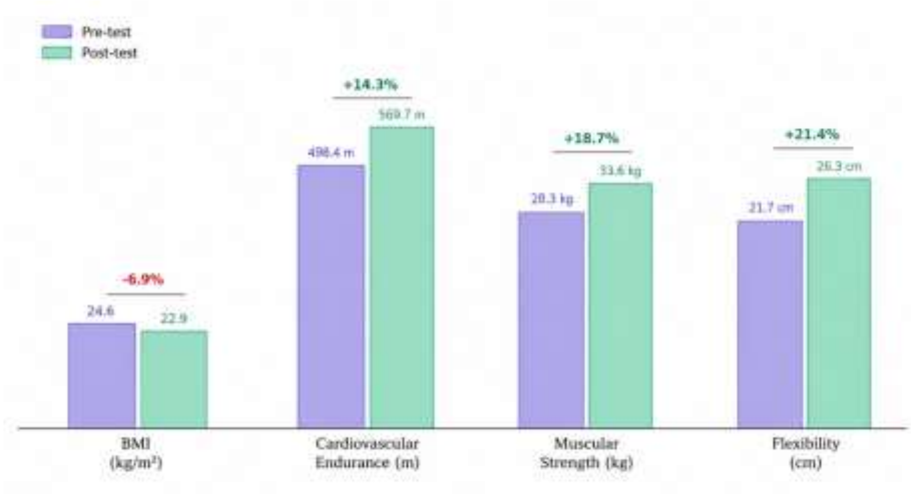


**Figure 3. Improvement in Physical Fitness Indicators After Intervention**

**4.2 Changes in Health Behaviors**

A large number of behavioural changes were documented following the intervention. The proportion of students participating in physical activity at least once a week rose from 34% to 71% of the population who meet recommended activity levels. Nutrition awareness sessions were successful in translating knowledge into behavioral change, with the proportion of people following a healthy diet increasing from 41% to 68%. Children's sedentary screen time was an average of 1.8 hours lower than before. Adoption of preventive health practices (frequent dental hygiene practices and sleep hygiene) rose from 29% to 57%. Table 3 shows the percentages for each health behavior domain before and after, which are statistically significant for every indicator.

**Table 3. Health Behavior Changes**

| Behavior | Before (%) | After (%) | Change |
|---|---|---|---|
| Meeting Weekly Exercise Threshold | 34 | 71 | +37% |
| Healthy Dietary Practices | 41 | 68 | +27% |
| Reduced Sedentary Screen Time | 22 | 58 | +36% |
| Preventive Health Practice Adoption | 29 | 57 | +28% |
| Sleep Hygiene Adherence | 38 | 63 | +25% |

**4.3 Preventive Pediatric Wellness Outcomes**

The high effectiveness of the prevented healthcare awareness awareness components is reflected in the rise of pre- and post-aid scores by 38.4%. The nutrition knowledge index scores increased by a mean score of 74.8 out of 100. Compliance in health screening grew from 61% to 89%, and this was of voluntary participation in all scheduled health screenings. Improvements in wellness literacy, measured using validated health knowledge measures, were 31.2% overall.

Table 4 shows that across all four indicators of preventive wellness, there are consistent and significant pre- and post-score improvements. Figure 4 shows a radar chart with scores for five wellness domains (nutrition knowledge; screening compliance; physical activity; wellness literacy; and preventive practice) to highlight the multi-domain nature of the impact of the intervention program.

**Table 4. Preventive Pediatric Wellness Indicators**

| Indicator | Pre-Score | Post-Score | Improvement |
|---|---|---|---|
| Preventive Healthcare Awareness (%) | 51.2 | 70.8 | 38.4% |
| Nutrition Knowledge Index (/100) | 52.3 | 74.8 | 43.0% |
| Health Screening Compliance (%) | 61.0 | 89.0 | 28.0% |
| Wellness Literacy Score (/100) | 48.6 | 63.8 | 31.2% |

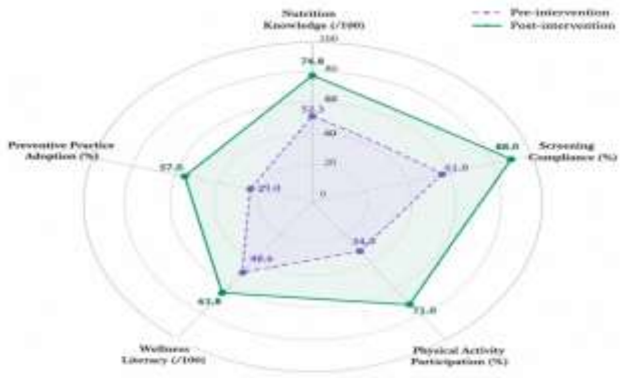


**Figure 4. Overall Impact of School-Based Programs on Adolescent Wellness**

### 4.4 Program Participation and Engagement

There was high participation in the program during the intervention period. The total number of students enrolled in schools participating was 480. Overall participation was at 84.6% for all five intervention components. The attendance was 88.2% on average over the 12 weeks. In 91% of the sessions, teachers participated in co-facilitating, thus indicating a strong institutional support. Teacher interviews were conducted to explore the key facilitators, which emerged through qualitative thematic analysis as clarity of program structure, student engagement during physical sessions, and observable health improvements, being motivators. Table 5 presents all participation and engagement indicators, which serve to describe quantitatively the extent of program reach and program implementation fidelity. A one-way ANOVA showed that there was a significant difference between the four types of schools in fitness improvements after the intervention ($F(1, 478) = 8.42$, $p = 0.004$) and private school students had marginally higher fitness improvements at cardiovascular endurance. Ranked score comparisons between male and female groups showed similar improvements in both groups ($p > 0.05$) and showed that the program was effective for both men and women. The difference between early adolescents (12 to 14 years) and late adolescents (16 to 18 years) was significant for age subgroup analysis in terms of greater gains of flexibility for early adolescents ($F(2, 477) = 5.31$, $p = 0.005$).

**Table 5. Program Participation Overview**

| Indicator | Value |
|---|---|
| Students Enrolled | 480 |
| Participation Rate | 84.6% |
| Attendance Rate | 88.2% |
| Teacher Involvement | 91.0% |
| Schools Participating | 12 |
| Intervention Duration | 12 Weeks |
| Sessions per Week | 3 |

### 4.5 Discussion

Overall, these results support the multi-domain efficacy of the recommended school-based intervention. These concurrent improvements in each of the domains of physical fitness and of preventive wellness indicate that synergies will result for integrated health education and active programming, that is, that combined interventions will produce greater outcomes than separate interventions. Further evidence of the program design being practically sustainable in school settings is the high levels of participation and attendance. The findings support the body of knowledge supporting school-wide health interventions that are coordinated and extend and build on past evidence through providing integrated, empirical evidence in both fitness and wellness components within a single program design.

## CONCLUSION

The findings of this study support the effect of a multi-component school-based public health intervention to improve adolescent physical fitness and pediatric preventive wellness. After 12 weeks, participants had significant improvements in BMI (24.6 to 22.9 kg/m2), cardiovascular endurance (14.3%), muscular strength (18.7%) and flexibility (21.4%). At the same time, the rates of exercise participation increased from 34% to 71%, dietary adherence from 41% to 68%, and preventative healthcare knowledge increased by 38.4%. The level of compliance with health screening rose significantly and strongly (from 61% to 89%) and wellness literacy rose by 31.2%. Good program feasibility (88.2%) and institutional acceptability (91%) is reflected by high attendance and teacher involvement. Results support the proposed integrated framework as an effective and scalable model of public health. Further investigations are needed of long-term outcome retention and longer-term implementation in larger geographic and socioeconomic school settings.

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