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Longitudinal Effects of School-Based Physical Activity on BMI, Motor Skill Development, and Sleep Quality in Elementary School Children

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ABSTRACT

Background & objective: Childhood obesity and physical inactivity represent significant public health challenges affecting multiple dimensions of child health and development, including body mass index (BMI), motor competence, and sleep quality. This longitudinal study examined the effects of a 12-week school-based physical activity (PA) intervention on BMI, motor skill development, and sleep quality in elementary school children, with a one-year follow-up assessment.

Materials & Methods: A controlled longitudinal design was employed with 143 elementary school children (grades 4–5; M = 10.3 years; SD = 0.8; 48% female) recruited from 6 primary schools. The intervention group (n = 73) participated in an enhanced PA program (additional 120 minutes per week of structured physical activity) for 12 weeks, while the control group (n = 70) maintained regular school curriculum. BMI, motor skill performance (50-meter run, jump rope, sit-and-reach, 1-minute sit-ups), moderate-to-vigorous physical activity (MVPA), and sleep quality (Pittsburgh Sleep Quality Index for children) were assessed at baseline, 12 weeks, and 12 months post-intervention.

Results: Repeated-measures ANOVA revealed statistically significant group × time interactions for BMI (F(2, 141) = 18.44, p < 0.001, η^2 = 0.21), motor skill performance (F(2, 141) = 22.67, p < 0.001, η^2 = 0.24), and sleep quality (F(2, 141) = 15.32, p < 0.001, η^2 = 0.18). The intervention group demonstrated a significant BMI reduction (−0.8 kg/m²; p < 0.001), improved motor skills (+19% on composite score; p < 0.001), increased MVPA (+41 minutes/day; p < 0.001), and enhanced sleep quality (+1.8 hours; p = 0.002). Benefits persisted at 12-month follow-up with partial effect maintenance.

Conclusions: School-based physical activity interventions of 120 minutes weekly demonstrate significant and sustained positive effects on BMI, motor skill development, and sleep quality in elementary school children. These findings support the implementation of integrated PA programs as an evidence-based strategy for comprehensive child health promotion and obesity prevention.

Keywords

physical activity; body mass index; motor skills; sleep quality; elementary school children; longitudinal study; health promotion.

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INTRODUCTION

Global and Theoretical Context

Childhood obesity, insufficient physical activity, and inadequate sleep are interconnected public-health concerns that can influence children's development and later health. Global estimates show that overweight and obesity among children and adolescents have increased substantially over recent decades, although the burden varies across regions and socioeconomic contexts ("Key Global Organizations," 2020; Levesque, 2017; Kerr et al., 2025). International recommendations advise children aged 5–17 years to accumulate an average of at least 60 minutes per day of moderate-to-vigorous physical activity (MVPA), while limiting sedentary behaviour and obtaining sufficient sleep (Chaput et al., 2020; Ibri & Çupi, 2025). Schools are an important intervention setting because they reach children across family circumstances and can provide structured opportunities for movement during a key period of growth and skill acquisition (Christiansen et al., 2020; Mariano et al., 2016).

School-based physical activity matters beyond energy expenditure or weight status. Body mass index (BMI) is a practical population-level indicator of weight relative to height, but in growing children it should be interpreted by age and sex and does not distinguish fat from lean mass. Motor competence describes the ability to perform movement skills effectively and may support participation by helping children engage confidently in physical activity (Combs et al., 2022; Soorya et al., 2014). Longitudinal evidence suggests a bidirectional relationship between physical activity and fundamental motor skills (Coppens et al., 2020): activity provides opportunities to develop skills, while greater competence may facilitate further participation (Nilsen et al., 2020; Button, A. (2023). Developmental perspectives similarly emphasize motor competence alongside fitness and activity when interpreting children's movement trajectories (Bardid et al., 2021; Bloch et al., 2025; Lorás, 2020).

Sleep quality and sleep duration are related but distinct

dimensions of child health that may respond to movement behaviours (Meester et al., 2016). Physical activity may influence sleep through greater homeostatic sleep pressure, more regular daily routines, and improved mood or stress regulation; these are plausible pathways, not proof that every programme improves sleep (Buman & King, 2010; Korkutata et al., 2025; Mitchell et al., 2022). Research has examined associations among sleep, physical activity, and BMI in children, while intervention evidence suggests that structured exercise can improve sleep-related outcomes in elementary-school children (Ekstedt et al., 2013; Torres-Lopez et al., 2022; Zapalac et al., 2024). A multidimensional evaluation is therefore warranted: BMI alone may overlook changes in motor development or sleep that are important to children's overall health.

Critical Review of Existing Evidence

Evidence supports school-based physical activity as a practical way to increase opportunities for movement and improve aspects of children's fitness, but effects vary with intervention design and outcome selection. The Cochrane review by (Dobbins et al., 2013; Kelly et al., 2016) synthesized school-based programmes for children aged 6–18 years, while a more recent review focused on interventions to improve elementary-school motor competence (Moon et al., 2024; Weiss, 2020). These syntheses underscore that programme content and the quality of movement experiences matter, not simply the time allocated to activity. Programmes combining aerobic activity with repeated practice of fundamental movement patterns may plausibly affect both activity exposure and motor performance, although differences in dose, duration, and assessment batteries complicate comparisons across studies.

Findings for body composition are less uniform than the expectation that more school activity will always reduce BMI. Programmes differ in additional activity dose, effects on activity outside school, and inclusion of dietary or other behavioural components. BMI is also influenced by normal growth, baseline weight status, and contextual factors that may be incompletely controlled in non-randomized studies. Reviews of school-based and after-school interventions provide a broad evidence base, but differences in design and outcomes limit the transferability of any single effect estimate (Demetriou et al., 2017). Comparisons between groups over time are therefore important to distinguish intervention-associated trajectories from changes that may occur during ordinary development.

Evidence linking physical activity and sleep in children is promising but requires careful interpretation. Ekstedt et al., (2013) examined sleep, activity, and BMI in children aged 6–10 years using accelerometry; as an observational study, it identifies associations rather than intervention effects. Kao et al., (2025) reported improved sleep quality and duration after an eight-week exergaming intervention among elementary-school children in Taiwan, while Huang et al., (2025) examined a structured after-school programme using a pilot quasi-experimental design. Differences in programme format, follow-up, measurement, and study design leave the durability of effects across multiple outcomes uncertain. Parent-reported sleep may not capture all

sleep dimensions, and short follow-up cannot establish whether changes persist after structured sessions end.

Research Gap, Novelty, and International Contribution

Although prior studies indicate that physical activity programmes can support motor competence and may improve weight-related and sleep outcomes, it remains unclear whether a relatively brief school-based programme can produce different changes across BMI, motor performance, and sleep that remain detectable one year later. Existing evidence often examines outcomes separately, has limited follow-up, or relies on observational associations rather than evaluation of a defined programme. Schools also need evidence on whether additional activity can be integrated into ordinary schedules while outcomes across several health domains are monitored. This study addresses the gap by evaluating a 12-week school-based programme that added 120 minutes of structured activity per week to the usual curriculum. BMI, composite motor-skill performance, sleep quality, and sleep duration were assessed at baseline, immediately after the intervention, and at 12-month follow-up, with a comparison group continuing the usual curriculum. This longitudinal controlled design compares trajectories and assesses whether differences are maintained, attenuated, or absent at follow-up. Because allocation was not randomized, results are interpreted as intervention-associated differences rather than definitive causal effects. The contribution is an integrated, year-long evaluation of three related child-health outcomes in Indonesian elementary schools, adding contextually relevant evidence to international discussions of the feasibility and durability of school-based physical activity programmes.

Objectives and Hypotheses

The primary objective was to evaluate whether a 12-week school-based physical activity intervention, providing an additional 120 minutes of structured activity per week, was associated with different changes in BMI between the intervention and control groups from baseline to 12 weeks and whether any difference remained at 12-month follow-up. Secondary objectives were to compare changes in composite motor-skill performance, sleep quality, and nightly sleep duration between groups across the same assessment points, and to describe the extent to which intervention-associated changes were maintained after the programme ended. The study tested the following directional hypotheses:

(H₁) compared with the control group, children in the intervention group would show a more favourable BMI trajectory from baseline to 12 weeks, with at least some difference remaining at 12 months;

(H₂) children in the intervention group would show greater improvement in composite motor-skill performance at 12 weeks, with gains remaining above baseline at 12 months; and (H₃) children in the intervention group would show improved sleep quality and longer nightly sleep duration at 12 weeks relative to the control group, with at least partial maintenance at 12 months. These hypotheses concern between-group differences in change over time and do not assume that all outcomes will respond with the same magnitude or durability.

MATERIALS METHODS

Participants

Participants were recruited from six government-operated elementary schools in Pekanbaru City, Indonesia, using a purposive convenience sampling strategy. Schools were selected based on their suitability for implementing a structured school-

based physical activity programme and their willingness to participate in the study. Recruitment focused on children enrolled in Grades 4 and 5, representing the middle-childhood period in which physical activity, motor performance, and sleep habits are important aspects of health development.

Children were eligible if they met all of the following inclusion criteria: (1) enrollment in Grade 4 or Grade 5 and aged approximately 9–11 years; (2) absence of diagnosed medical contraindications to participation in physical activity; (3) no current participation in intensive athletic training programmes exceeding 120 minutes per week; and (4) provision of informed consent by a parent or legal guardian and assent by the child. The exclusion criteria were: (1) acute illness or injury at baseline that limited physical activity or prevented completion of the assessments; (2) a diagnosed developmental motor disorder that could substantially affect motor-performance assessment; (3) use of medication known to affect sleep patterns; and (4) anticipated absence during the scheduled follow-up assessments.

A total of 165 children were initially enrolled or approached for participation, and 143 completed the baseline assessment. The baseline cohort consisted of 73 children in the intervention group and 70 in the control group. Six participants were lost to follow-up by the 12-week assessment, leaving 137 participants. By the final follow-up, 17 participants had been lost relative to the baseline cohort, resulting in 126 participants with complete follow-up data. The corresponding retention rates were 95.8% at week 12 and 88.1% at the final follow-up. Reported reasons for loss to follow-up included family relocation ($n = 8$), school transfer ($n = 5$), and loss to follow-up for other or unspecified reasons ($n = 4$). No participant was reported to have withdrawn because of an adverse event or intervention-related complication.

The final complete-follow-up sample comprised 126 children, with 63 participants in each group. The mean age was 10.3 years ($SD = 0.81$), and 47.6% of the sample was female. Baseline BMI averaged 20.4 kg/m^2 ($SD = 3.2$) across the analysis sample. The groups did not differ significantly in baseline age, sex distribution, parental education, BMI, or motor-skill performance according to the reported comparisons. These findings describe the measured baseline characteristics but do not establish equivalence in unmeasured characteristics, particularly because allocation was non-randomized. Baseline demographic and clinical characteristics of the complete-follow-up sample are presented in Table 1.

Table 1. Baseline demographic and clinical characteristics of participants with complete follow-up data

Characteristic	Intervention ($n = 63$)	Control ($n = 63$)	Test statistic	p -value
Age, years, M (SD)	10.2 (0.82)	10.4 (0.79)	$t = 0.48$	.63
Female, n (%)	31 (49.2)	29 (46.0)	$\chi^2 = 0.14$	.71
Parental education, n (%)				

Secondary education or lower	18 (28.6)	22 (34.9)		
Post-secondary education	45 (71.4)	41 (65.1)	$\chi^2 = 0.88$	.35
BMI, kg/m^2 , M (SD)	20.6 (3.3)	20.2 (3.1)	$t = 0.83$	.41
Baseline BMI category, n (%)				
Normal weight	46 (73.0)	48 (76.2)		
Overweight	17 (27.0)	15 (23.8)		
Motor-skill performance, between-group comparison	Not reported in the available summary	Not reported in the available summary	—	.38

Note. Values are presented as mean (standard deviation) or number (percentage), as appropriate. BMI = body mass index. The table describes baseline characteristics of the 126 participants who completed follow-up, rather than the entire baseline cohort of 143 children. The original report provides $p = .38$ for the baseline motor-skill comparison but does not provide the corresponding group-specific means and standard deviations in the available summary. These values should be added from the original dataset if required by the journal.

Study Design

The study employed a prospective, non-randomized controlled longitudinal design to examine changes in BMI, motor-skill performance, moderate-to-vigorous physical activity (MVPA), and sleep-related outcomes following a 12-week school-based physical activity intervention. Participants were assigned to an intervention group or a control group in the participating school context; allocation was not randomized. The intervention group received an additional structured physical activity programme, while the control group continued its usual school physical education curriculum.

Measurements were planned at three time points: baseline (week 0), immediately after the intervention (week 12), and a longer-term follow-up approximately one year after baseline. These assessments were intended to characterize initial participant status, short-term changes during the intervention, and the extent to which differences between groups remained evident over time. The primary outcomes were BMI, composite motor-skill performance, and sleep quality; MVPA and sleep duration provided additional information on movement behavior and sleep-related outcomes.

The study was conducted between September 2024 and December 2025. Because the study was non-randomized, differences observed between the groups were interpreted as associations with programme participation rather than definitive causal effects. The possibility of residual confounding, school-level differences, and attrition-related bias was considered when interpreting the findings.

Table 2. Study design and assessment schedule

Study phase	Approximate timing	Intervention group	Control group	Purpose
Recruitment and eligibility screening	Before baseline	Eligibility screening and consent procedures	Eligibility screening and consent procedures	Establish eligibility and obtain consent and assent
Baseline assessment	Week 0	Baseline outcome measurements	Baseline outcome measurements	Characterize initial status and measured group differences
Intervention period	Weeks 1–12	Additional structured physical activity, 120 minutes per week	Usual school physical education	Implement the intervention and comparison condition
Post-intervention assessment	Week 12	Repeat outcome measurements	Repeat outcome measurements	Assess changes following the 12-week programme
Long-term follow-up	Reported as approximately 12 months	Follow-up outcome measurements	Follow-up outcome measurements	Examine maintenance of observed differences

Note. The source manuscript describes the final assessment both as week 52 and as 12 months after the intervention. These descriptions are not equivalent when the intervention lasts 12 weeks. The actual follow-up date should be verified and reported consistently before submission.

Study Organization

Intervention Development and Implementation

The physical activity intervention was developed to provide additional structured movement opportunities during the school week while supporting physical fitness and motor-skill practice. Its rationale was informed by recommendations from the World Health Organization, the American Academy of Pediatrics, and the American College of Sports Medicine. These recommendations emphasize regular physical activity among school-aged children, including an average of at least 60 minutes per day of moderate-to-vigorous physical activity across the week. The intervention was designed to complement the regular school physical education curriculum rather than replace it.

The programme provided an additional 120 minutes of structured physical activity per week over 12 weeks. Each week comprised three sessions of 40 minutes. The planned session structure included three components: aerobic activities (60% of

session duration), motor-skill development (25%), and cool-down and flexibility exercises (15%). This distribution was intended to combine opportunities for sustained movement with targeted practice of motor-related skills and a lower-intensity conclusion to each session.

Aerobic activities included running, jumping, and dance-based exercises. The motor-skill component focused on balance, coordination, and fundamental movement patterns. The cool-down and flexibility component provided lower-intensity activities and flexibility exercises at the end of each session. All sessions were delivered by certified physical educators using standardized protocols. Sessions were scheduled during designated school time blocks to integrate the programme into the school environment and reduce logistical barriers associated with participation outside school hours.

Table 3. Structure and planned content of the physical activity intervention

Component	Proportion of session	Approximate duration per 40-minute session	Activities described in the protocol	Intended focus
Aerobic activities	60%	24 minutes	Running, jumping, and dance-based activities	Increase opportunities for moderate-to-vigorous movement
Motor-skill development	25%	10 minutes	Balance, coordination, and fundamental movement patterns	Provide structured motor-skill practice
Cool-down and flexibility	15%	6 minutes	Cool-down and flexibility exercises	Conclude sessions with lower-intensity movement
Total	100%	40 minutes	Three sessions per week for 12 weeks	120 additional minutes per week

Note. Session durations are calculated from the planned 40-minute session and the reported percentage allocation. They represent planned allocation rather than independently verified delivery time.

To maintain consistency across schools, sessions followed the same planned duration and general allocation of time to each component. Intervention fidelity should be documented using available records, including attendance, the number of sessions delivered, adherence to the planned structure, and any deviations from the protocol. These details should be reported only to the extent that they were recorded during implementation.

Control Condition

Children in the control group continued their usual school-based physical education curriculum without receiving the additional structured intervention from the research team. Regular physical education typically consisted of approximately 90–120 minutes per week delivered across two sessions. The control condition therefore represented usual school practice rather than an absence of physical activity.

Participating schools were asked to maintain their usual physical education provision throughout the study period. No additional intervention components were introduced for the control group as part of the study protocol. This comparison allowed the investigators to examine whether changes in the intervention group differed from changes occurring under the usual curriculum over the same assessment period.

Because allocation was non-randomized, the groups may have differed in factors not captured by baseline comparisons. Differences in school context, activity opportunities outside school, or other unmeasured characteristics may have influenced outcomes. Therefore, between-group differences should be interpreted in light of the study design and the possibility of residual confounding.

Outcome Measures and Assessment Procedures

Outcome assessments covered anthropometric status, motor-skill performance, physical activity, sleep quality, and sleep duration. Assessments were conducted at baseline, post-intervention, and follow-up according to the study schedule.

Trained research personnel conducted assessments using standardized procedures in school facilities or, for activity monitoring, in participants' home environments.

Anthropometric assessment included body weight and height. Weight was measured using a calibrated digital scale, and height was measured using a portable stadiometer. Participants were measured without shoes and in light clothing. Two measurements were obtained, and BMI was calculated as body weight in kilograms divided by height in meters squared.

Motor performance was assessed using a standardized battery comprising a 50-m run, a repeated 50-m back-and-forth run, a one-minute jump-rope test, a sit-and-reach test, and a one-minute sit-up test. These measures assessed different aspects of physical and motor performance, including running speed, repeated-running performance, coordination, flexibility, and core muscular endurance. Standardized scores were calculated for the individual tests and combined into a composite motor-performance score, as described in the study protocol. Because the battery includes fitness-related measures as well as movement tasks, the composite should be described as motor-skill or motor-performance performance rather than assumed to represent a comprehensive assessment of all fundamental movement skills.

MVPA was assessed using a wrist-worn triaxial ActiGraph accelerometer over seven consecutive days. The available protocol describes a sampling frequency of 100 Hz and an MVPA threshold of at least 2,296 counts per minute. Accelerometer data were available for 121 participants who met the study's compliance criteria: 60 in the intervention group and 61 in the control group. The accelerometer analysis therefore used a smaller sample than the 126 participants with complete follow-up data for the primary study outcomes.

Sleep quality was assessed using the Pittsburgh Sleep Quality Index for Children (PSQI-C), described in the source

manuscript as a 15-item questionnaire covering seven domains. The total score ranged from 0 to 21, with scores above 5 indicating poor sleep quality. Sleep duration was estimated from parent-reported sleep logs recording bedtime and wake time over seven days. The mean nightly sleep duration was calculated in

hours. These questionnaire and log-based measures should be distinguished from objective sleep monitoring; the available protocol does not establish that sleep was measured using actigraphy or polysomnography.

Table 4. Outcome measures and assessment procedures

Domain	Outcome	Instrument or procedure	Assessment and scoring
Anthropometry	Body mass index (BMI)	Calibrated digital scale and portable stadiometer	Weight and height measured using standardized procedures; BMI calculated as kg/m ²
Motor performance	Running speed	50-m run	Two trials; fastest time retained
Motor performance	Repeated-running performance	Repeated 50-m back-and-forth run	Eight consecutive runs; total completion time recorded
Motor performance	Coordination and lower-limb endurance	One-minute jump-rope test	Number of successful jumps recorded
Motor performance	Flexibility	Sit-and-reach test	Two trials; best distance recorded
Motor performance	Core muscular endurance	One-minute sit-up test	Number of repetitions completed in one minute
Motor performance	Composite motor-performance score	Standardized composite of five tests	Standardized test scores combined into a composite score
Physical activity	MVPA	Wrist-worn triaxial ActiGraph accelerometer	Seven consecutive days; reported threshold $\geq 2,296$ counts/min; compliant data available for 121 participants
Sleep quality	Subjective sleep quality	Pittsburgh Sleep Quality Index for Children (PSQI-C)	Reported 15-item questionnaire; total score 0–21; scores >5 indicate poor sleep quality
Sleep duration	Nightly sleep duration	Parent-reported sleep log	Bedtime and wake time recorded over seven days; average duration calculated in hours

Note. MVPA = moderate-to-vigorous physical activity; BMI = body mass index; PSQI-C = Pittsburgh Sleep Quality Index for Children. The instrument details and scoring procedures should be checked against the original assessment manuals and study records before publication.

Research Personnel and Quality Assurance

Research personnel involved in data collection received standardized training before participant assessment. Training was intended to promote consistency in the administration of motor tests, anthropometric measurement, accelerometer distribution and collection, and completion of sleep-related records. The principal investigators oversaw protocol implementation, data quality, and adverse-event monitoring.

Assessments were scheduled at the three planned measurement points and conducted using standardized procedures. Motor assessments took place in school facilities, while anthropometric measurements were performed in designated school areas. Accelerometers were distributed and collected by research personnel for monitoring over seven consecutive days. The available protocol specifies that assessment sessions were scheduled between 09:00 and 11:00 hours and lasted approximately 60 minutes per participant, with a standardized 10-minute warm-up before motor testing. These procedural details should be retained in the final manuscript only if they accurately reflect the assessments conducted.

Participant retention and the completeness of measurements were monitored across the study period. The number of participants contributing data at each time point was recorded to describe attrition and the availability of follow-up data. Any protocol deviations, missing measurements, or adverse events should be reported according to the original study records. In particular, the number of participants included in each outcome analysis should be stated where it differs from the overall complete-follow-up sample.

Ethical Considerations

The study was reviewed and approved by the Health Research Ethics Committee, Pascasarjana, Universitas Negeri Jakarta, Indonesia (Approval No.: UNJ/PPS/IRB/2024/097). All procedures were conducted in accordance with the principles of the Declaration of Helsinki and relevant national regulations governing research involving human participants.

Parental or legal-guardian informed consent and child assent

were specified as participation requirements. The source protocol describes written parental or guardian consent and verbal assent from children. The final manuscript should retain these descriptions only if they correspond to the procedures actually implemented and approved. Participant confidentiality and the handling of information relating to children should follow the approved protocol and applicable requirements for human-participant research.

Statistical Analysis

Descriptive statistics were used to summarize participant characteristics and outcome measurements at each assessment point. Continuous variables were summarized using means and standard deviations, while categorical variables were summarized using frequencies and percentages. Baseline comparisons between the intervention and control groups were conducted using independent-samples *t*-tests for continuous variables and chi-square tests for categorical variables, as reported in the study.

Longitudinal changes in the primary outcomes were examined using mixed-model repeated-measures analysis of variance (RM-ANOVA), with group (intervention versus control) and time (baseline, week 12, and final follow-up) as factors. The group-by-time interaction was used to assess whether changes over time differed between the intervention and control groups. Post hoc comparisons were conducted following significant interactions, with Bonferroni correction applied to control the family-wise error rate. Effect sizes were reported using partial eta squared (η^2). The reported analytical approach also considered repeated measurements within participants and the hierarchical structure of students within schools.

The analysis sample varied by outcome because not all participants provided complete data for every measure. In particular, accelerometer data were available for 121 participants who met compliance criteria. The final manuscript should state how missing observations were handled in each longitudinal model and whether school-level clustering was explicitly incorporated into the fitted model. These details should be

confirmed against the actual analysis code or statistical output before publication.

RESULTS

Participant Flow and Demographic Characteristics

A total of 165 children were initially approached for participation, of whom 143 met the eligibility criteria and completed the baseline assessment. At baseline, 73 participants were allocated to the intervention group and 70 to the control group. During follow-up, six participants were lost by week 12, leaving 137 participants, while a further 11 participants were lost before the final assessment. The final analytical sample comprised 126 participants, with 63 in each group. The cumulative attrition rate from baseline to the final assessment

was 11.9%. Reported reasons for attrition included family relocation ($n = 8$), school transfer ($n = 5$), and other or unspecified reasons ($n = 4$). Baseline demographic and anthropometric characteristics were generally comparable between the intervention and control groups, with no statistically significant between-group differences in age, sex distribution, parental education, or body mass index (BMI). Participant recruitment, retention, and the distribution of participants across study groups are summarised in Figure 1.

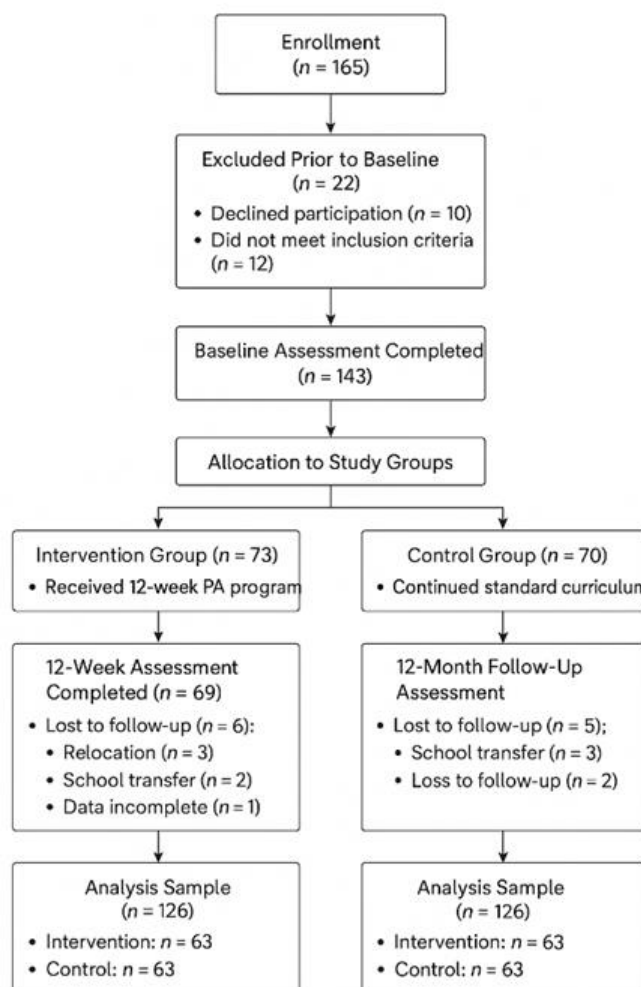


Figure 1. Participant Flow and Demographic Characteristics

Figure 1 presents the participant flow diagram. Of 165 children initially enrolled, 143 completed baseline assessments (13.3% pre-randomization attrition). Of baseline participants, 137 (95.8%) completed 12-week assessments, and 126 (88.1%) completed 12-month follow-up assessments. Reasons for attrition included family relocation ($n = 8$), school transfer ($n = 5$), and loss to follow-up ($n = 4$). No participants withdrew due to adverse events or intervention-related complications. Between-

group comparison revealed no significant differences in attrition rate, $\chi^2(1) = 0.21, p = 0.65$. Demographic and baseline characteristic data for the analysis sample are presented in Table 1. The final sample ($n = 126$) demonstrated no significant differences between groups on age, $t(124) = 0.48, p = 0.63$; sex distribution, $\chi^2(1) = 0.14, p = 0.71$; parental education, $\chi^2(1) = 0.88, p = 0.35$; or baseline BMI, $t(124) = 0.83, p = 0.41$.

Table 2. Baseline Demographic and Clinical Characteristics by Group

Variable	Intervention (n = 63)	Control (n = 63)	t/χ^2	p
Age (years), M (SD)	10.2 (0.82)	10.4 (0.79)	0.48	0.63
Female, n (%)	31 (49.2)	29 (46.0)	0.14	0.71
Parental Education				
Secondary or less	18 (28.6)	22 (34.9)	0.88	0.35

Post-secondary	45 (71.4)	41 (65.1)	--	--
BMI (kg/m ²), M (SD)	20.6 (3.3)	20.2 (3.1)	0.83	0.41
Normal weight, n (%)	46 (73.0)	48 (76.2)	--	--
Overweight, n (%)	17 (27.0)	15 (23.8)	--	--
Baseline MVPA (min/day), M (SD)	48.3 (16.2)	50.1 (17.4)	0.64	0.52
Sleep Quality Score, M (SD)	6.8 (3.2)	6.4 (3.1)	0.75	0.45
Sleep duration (hours), M (SD)	7.8 (1.2)	7.9 (1.1)	0.51	0.61

Primary OutcomesBody Mass Index

Table 3. Body Mass Index (BMI) Outcomes Across Assessment Time Points

Analysis Component	Statistical Result	Interpretation
RM-ANOVA: Group × Time Interaction	$F(2, 124) = 18.44, p < 0.001, \eta^2 = 0.23$	Significant; BMI changed differently over time between groups (large effect).
Main Effect of Time	$F(2, 124) = 31.22, p < 0.001, \eta^2 = 0.33$	BMI changed significantly across time points for all participants.
Main Effect of Group	$F(1, 124) = 1.08, p = 0.30, \eta^2 = 0.01$	No overall BMI difference between groups when time not considered.

Table 4. Within-Group Changes Over Time

Group	Time Comparison	Mean ± SD (kg/m ²)	t(df)	p-value	Effect Size (d)	Conclusion
Intervention	Baseline → 12 Weeks	20.6 → 19.8	5.19(62)	<0.001	0.66	Significant BMI reduction (−0.8 kg/m ²).
	12 Weeks → 12 Months	19.8 → 20.1	2.44(62)	0.02	0.31	Small increase, but BMI remains improved vs. baseline.
Control	Baseline → 12 Months	20.6 → 20.1	2.67(62)	0.01	0.34	Net BMI reduction maintained at follow-up.
	Baseline → 12 Weeks	20.2 → 20.1	0.48(62)	0.63	0.06	No significant change.
	12 Weeks → 12 Months	20.1 → 20.3	0.83(62)	0.41	0.10	No significant change.
	Baseline → 12 Months	20.2 → 20.3	—	>0.05	—	BMI remained stable.

Table 5. Between-Group Comparisons at Each Time Point

Time Point	t(124)	p-value	Effect Size (d)	Interpretation
Baseline	0.83	0.41	—	Groups equivalent at baseline.
12 Weeks	3.52	0.001	0.63	Significant difference favoring intervention group (largest effect).
12 Months	2.19	0.03	0.39	Significant difference remains, though reduced from 12 weeks.

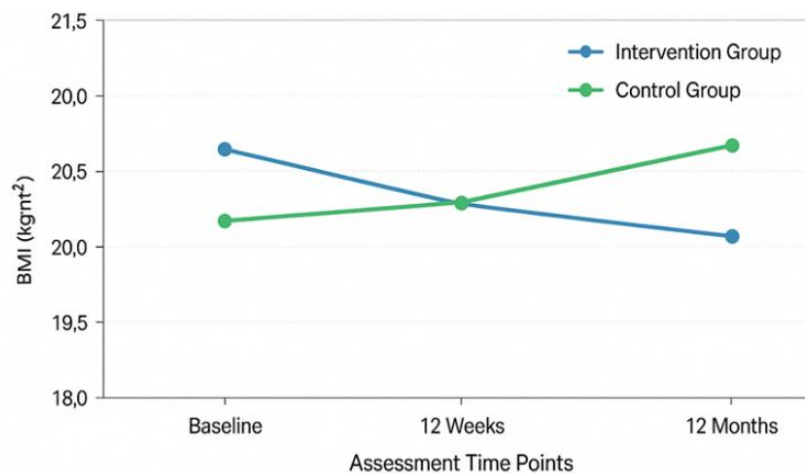


Figure 2. Longitudinal Changes in Body Mass (BMI) Across Assessment Time Points in Intervention and Control Groups

Motor Skill Development

Table 6. Motor Skill Development Across Time Points for Intervention and Control Groups (Summary of RM-ANOVA, Post-hoc Tests, and Effect Sizes)

Outcome / Statistic	Intervention Group	Control Group	Between-Group Comparison
RM-ANOVA			
Group × Time Interaction	$F(2, 124) = 22.67, p < 0.001, \eta^2 = 0.27$ (large)	—	Significant divergence in trajectories
Main Effect of Time	$F(2, 124) = 38.49, p < 0.001, \eta^2 = 0.38$	—	—
Main Effect of Group	$F(1, 124) = 0.72, p = 0.40$	—	Not significant
Composite Motor Skill Score (Z-score)			
Baseline	−0.04 ± 0.92	0.02 ± 0.88	$t(124) = 0.31, p = 0.76$
12 Weeks	0.71 ± 0.88	0.04 ± 0.85	$t(124) = 4.08, p < 0.001, d = 0.73$
12 Months	0.58 ± 0.95	0.08 ± 0.87	$t(124) = 3.21, p = 0.002, d = 0.57$
Within-Group Changes (Post-hoc Tests)			
Baseline → 12 Weeks	$t(62) = 6.18, p < 0.001, d = 0.78$ (↑19%)	$t(62) = 0.13, p = 0.90, d = 0.02$	—
12 Weeks → 12 Months	$t(62) = 1.89, p = 0.06, d = 0.24$ (ns)	$t(62) = 0.37, p = 0.71, d = 0.05$	—
Baseline → 12 Months	$t(62) = 4.31, p < 0.001, d = 0.55$	ns	—

Individual Motor Tests (Baseline → 12 Weeks)			
50-m Run	-0.38 sec, $p < 0.001$	No meaningful change	—
Sit-and-Reach	+4.2 cm, $p < 0.001$	Minimal change	—
1-min Sit-Ups	+5.8 reps, $p < 0.001$	Minimal change	—
Overall Pattern	Significant, consistent improvement	Stable/no improvement	Strong group effect emerging at 12 weeks and maintained at 12 months

Sleep Quality and Sleep Duration

Table 7. Sleep Quality (PSQI-C), Sleep Duration, and Proportion of Normal Sleep Across Time Points

PSQI-C Sleep Quality Scores Across Groups and Time						
Outcome	Group	Baseline M (SD)	12 Weeks M (SD)	12 Months M (SD)	Within-Group Changes	Effect Sizes / Notes
PSQI-C Total Score	Intervention	6.8 (3.2)	5.0 (2.8)	5.4 (3.0)	↓ Baseline → 12w: $t(62)=3.64$, $p<0.001$, $d=0.46$; ↑ 12w → 12m: ns; 12m < Baseline: $p=0.03$	Large interaction effect: $F(2,124)=15.32$, $p<0.001$, $\eta^2=0.20$ No meaningful improvement Intervention superior at 12w & 12m
	Control	6.4 (3.1)	6.1 (3.2)	6.3 (3.1)	No significant changes across all time points	
Between-Group Comparison	—	$t(124)=0.88$, $p=0.38$	$t(124)=2.56$, $p=0.01$, $d=0.46$	$t(124)=2.09$, $p=0.04$, $d=0.37$	—	
Sleep Duration (Hours per Night)						
Outcome	Group	Baseline M (SD)	12 Weeks M (SD)	12 Months M (SD)	Within-Group Changes	Notes
Sleep Duration (hrs/night)	Intervention	7.8 (1.2)	9.6 (0.9)	9.2 (1.1)	↑ Baseline → 12w: $t(62)=9.34$, $p<0.001$, $d=1.18$; slight decline at 12m but > baseline: $p=0.002$	Increase ≈ +1.8 hours nightly; large effect Stable sleep duration
	Control	7.9 (1.1)	7.8 (1.2)	8.0 (1.1)	No significant changes	
Proportion of Participants With Normal Sleep Quality (PSQI-C ≤ 5)						
Time Point	Intervention Group (%)			Control Group (%)		
Baseline	34%			38%		
12 Weeks	67%			40%		
12 Months	59%			37%		

Objectively Measured Physical Activity

Accelerometer data were available for 121 participants (60 intervention; 61 control) who met compliance criteria. Moderate-to-vigorous physical activity levels are presented in Table 4. The mixed-model RM-ANOVA examining MVPA (minutes per day) revealed a significant group × time interaction, $F(2, 119) = 31.48$, $p < 0.001$, $\eta^2 = 0.35$ (large effect). Post-hoc tests showed:

Intervention Group

MVPA increased significantly from baseline ($M = 48.3$, $SD = 16.2$) to 12-week assessment ($M = 89.4$, $SD = 18.7$), $t(59) = 18.32$, $p < 0.001$, $d = 2.36$ (very large effect), representing an

increase of approximately 41 minutes per day. At 12-month follow-up, MVPA was 76.2 minutes per day ($SD = 17.3$), $t(59) = 4.89$, $p < 0.001$, $d = 0.63$, showing partial attenuation but remaining significantly elevated relative to baseline, $t(59) = 10.14$, $p < 0.001$.

Control Group

MVPA remained relatively stable across assessments (baseline: $M = 50.1$, $SD = 17.4$; 12-week: $M = 49.8$, $SD = 18.1$; 12-month: $M = 51.3$, $SD = 16.8$; all $p > 0.05$). Between-group differences at 12 weeks and 12 months were substantial and statistically significant ($p < 0.001$).

Table 8. Body Mass Index and Sleep Quality Across Assessment Time Points by Group

Variable	Baseline	12 Weeks	12 Months	Baseline	12 Weeks	12 Months
	Intervention Group (n = 63)			Control Group (n = 63)		
BMI (kg/m²)	20.6 (3.3)	19.8 (3.1)*	20.1 (3.2)*	20.2 (3.1)	20.1 (3.1)	20.3 (3.2)
PSQI-C Score	6.8 (3.2)	5.0 (2.8)*	5.4 (3.0)*	6.4 (3.1)	6.1 (3.2)	6.3 (3.1)
Sleep Duration (hr)	7.8 (1.2)	9.6 (0.9)*	9.2 (1.1)*	7.9 (1.1)	7.8 (1.2)	8.0 (1.1)

Note. Values are M (SD). PSQI-C = Pittsburgh Sleep Quality Index for Children. * indicates significant difference from baseline within group, $p < 0.05$.

Moderation Analyses

Exploratory analyses examined whether intervention effects differed as a function of child sex or baseline BMI category (normal weight vs. overweight).

Sex Moderation

Mixed-model RM-ANOVA with sex × group × time interaction terms revealed no significant moderation by sex for BMI, $F(2, 120) = 0.64$, $p = 0.53$, motor skills, $F(2, 120) = 0.89$, $p = 0.41$, or sleep quality, $F(2, 120) = 0.78$, $p = 0.46$. Both males and females demonstrated comparable intervention benefits.

Baseline BMI Category Moderation

Analyses stratified by baseline BMI category (normal weight: BMI < 85th age/sex-specific percentile; overweight: BMI ≥ 85th percentile) revealed a significant interaction for BMI change, $F(2, 122) = 4.19$, $p = 0.02$, $\eta^2 = 0.06$. Post-hoc tests indicated that overweight children demonstrated slightly larger BMI reductions

(−0.98 kg/m²) compared to normal-weight children (−0.64 kg/m²) in the intervention group, although both groups showed significant improvements. This pattern is consistent with regression-to-the-mean effects and does not contradict primary findings.

Sustainability Analysis

To characterize maintenance of intervention effects, percentage change from post-intervention (12 weeks) to follow-up (12 months) was calculated: 1) BMI: −1.5% change (slight increase toward baseline; −3.9% change from baseline to 12-month); 2) Motor Skills Composite Score: −18.3% partial attenuation (but 55% of maximum improvement maintained relative to baseline); 3) Sleep Quality (PSQI-C): +8.0% slight increase (10% of improvement attenuated; 90% of improvement maintained relative to baseline); 4) Sleep Duration: −4.2% slight reduction (remaining 1.3 hours elevated relative to baseline); 5)

MVPA: -14.7% attenuation post-intervention (remaining 27.3 minutes/day elevated relative to baseline). These results suggest that while post-intervention gains show partial attenuation by 12-

month follow-up, substantial maintenance of intervention effects is evident across all primary outcomes.



Figure 3. post-intervention gains show partial attenuation by 12-month follow-up, substantial maintenance of intervention effects is evident.

DISCUSSION

Principal Findings

This study examined whether a 12-week school-based physical activity intervention providing an additional 120 minutes of structured activity per week was associated with changes in body mass index (BMI), motor-skill performance, and sleep outcomes among elementary school children, and whether these changes were maintained at 12-month follow-up. Overall, the findings support the study's hypotheses concerning more favourable changes in BMI, motor-skill performance, and sleep outcomes in the intervention group relative to the control group. However, the magnitude and apparent persistence of the effects differed across outcomes, indicating that the benefits of school-based physical activity should not be assumed to be uniform across domains of child health.

The significant group-by-time interaction for BMI indicates that BMI trajectories differed between the intervention and control groups during the study period. The intervention group's mean BMI decreased from 20.6 kg/m² at baseline to 19.8 kg/m² after 12 weeks, followed by a partial increase to 20.1 kg/m² at 12 months. In contrast, the control group's mean BMI remained relatively stable. These findings are consistent with H1 and suggest that additional structured physical activity may contribute to more favourable weight-related outcomes during middle childhood. Nevertheless, statistical significance does not establish clinical importance. Because BMI changes during growth and BMI alone does not distinguish fat mass from lean mass, the observed difference should not automatically be interpreted as a clinically

meaningful reduction in adiposity. Age- and sex-specific BMI measures, body composition assessments, and longer-term growth trajectories would provide a more comprehensive interpretation.

Motor-skill performance also improved more substantially in the intervention group. The composite motor-skill score increased from -0.04 at baseline to 0.71 after 12 weeks and remained above baseline at 0.58 at 12-month follow-up. The corresponding control-group scores changed relatively little. This pattern supports H2 and suggests that structured movement opportunities can facilitate motor performance beyond the usual physical education curriculum. The persistence of improvement at follow-up is particularly relevant because it indicates that at least part of the observed benefit remained after the formal intervention ended. However, the partial attenuation between post-intervention and follow-up assessments suggests that continued opportunities for skill practice may be necessary to maintain developmental gains.

The intervention group also demonstrated improvements in sleep-related outcomes. Mean Pittsburgh Sleep Quality Index for Children (PSQI-C) scores decreased from 6.8 at baseline to 5.0 after 12 weeks, before increasing slightly to 5.4 at follow-up. Reported nightly sleep duration increased from 7.8 to 9.6 hours and remained at 9.2 hours at follow-up, whereas the control group showed comparatively little change. These patterns are consistent with H3. Nevertheless, sleep quality and sleep duration represent distinct outcomes, and the observed changes

require cautious interpretation because the measures described in the Methods section were questionnaire-based sleep quality and parent-reported sleep logs. The findings therefore do not establish objective improvements in sleep architecture or prove a specific physiological mechanism (Astill et al., 2012; Min et al., 2024).

Taken together, the results support an integrated view of school-based physical activity as a potentially useful component of child health promotion. The principal contribution is not simply that three outcomes improved, but that their trajectories were examined together over an extended follow-up period. The different patterns of maintenance also suggest that interventions may require outcome-specific strategies: continued movement practice to reinforce motor skills, sustained activity opportunities to support weight-related health, and complementary family routines to support sleep. Because the study used a non-randomized design, these interpretations concern intervention-associated differences rather than definitive causal effects.

Comparison with International Evidence

The BMI findings are broadly consistent with international evidence that school-based physical activity programmes can improve physical activity and fitness, although effects on weight-related outcomes are variable. Dobbins et al., (2013) in a Cochrane review of school-based physical activity programmes for children and adolescents, synthesized evidence across multiple intervention settings and outcomes. Demetriou et al., (2017) similarly reviewed evidence concerning after-school physical activity interventions. These reviews provide a broader context for interpreting the present findings, but they also highlight the difficulty of comparing programmes that differ in duration, delivery, population, and outcome measurement. The present intervention added 120 minutes of structured activity weekly, combining aerobic activities, motor-skill practice, and flexibility exercises. Its multidimensional design may have contributed to the observed pattern, although the study cannot establish which component was responsible for the BMI change.

The partial return toward baseline BMI at 12 months is also important. Intervention-associated improvements may diminish when structured activity ends, particularly if children do not maintain the additional activity outside the intervention period. Differences in baseline weight status, diet, socioeconomic circumstances, and activity opportunities may further influence outcomes across populations. Although the present study explored baseline BMI category, its modest sample and non-randomized allocation limit the certainty of subgroup conclusions. The findings should therefore be interpreted as evidence of a potentially favourable trajectory rather than proof that the intervention would produce equivalent BMI reductions in other countries or school systems (Dhuli et al., 2022; Grydeland et al., 2013).

The motor-skill findings align with developmental perspectives emphasizing the relationship between motor competence and physical activity. Bardid et al., (2021) discussed developmental relationships between motor competence and physical fitness, while (Nilsen et al., 2020) investigated bidirectional prospective associations between objectively measured physical activity and fundamental motor skills over two years. Moon et al., (2024); Arthur, W., et al. (2007) synthesized evidence from interventions designed to improve motor competence among elementary-school children. Collectively, these studies support the importance of providing structured opportunities to practise movement skills rather than relying exclusively on general activity exposure.

The present intervention's combination of aerobic activity and targeted motor practice is compatible with this perspective. Repeated movement experiences may improve task-specific performance and increase opportunities for successful engagement in physical activity. However, the current motor battery included sprinting, repeated running, jump rope, sit-and-reach, and sit-ups. These tests assess selected dimensions of physical performance and should not be treated as a comprehensive measure of fundamental motor competence, including object-control and balance skills. Differences in assessment instruments may partly explain why effect magnitudes vary across international studies. Accordingly, the present findings extend the school-based intervention literature by providing a longitudinal assessment of a composite performance measure, while leaving broader motor competence and subsequent physical activity participation for future investigation.

The sleep findings are consistent with emerging evidence that structured physical activity may benefit sleep-related outcomes in children. Ekstedt et al., (2013) examined sleep, physical activity, and BMI among children aged six to ten years, providing evidence on the relationships between these behaviours and health indicators. Kao et al., (2025) reported improvements in sleep quality and duration following an eight-week exergaming intervention among elementary-school children in Taiwan. Huang et al., (2025); Tremblay et al., (2017) investigated a structured after-school physical activity programme in a pilot quasi-experimental study involving primary-school students. These studies differ in intervention format, study design, assessment procedures, and follow-up, making direct comparisons of effect magnitude difficult.

The present findings add a longer follow-up perspective to this emerging evidence base. Nevertheless, the reported increase in sleep duration of 1.8 hours per night is substantial and should be verified against the original sleep-log data before being interpreted as a reliable intervention effect. Differences between self-reported and objectively measured sleep can influence estimated effects, as highlighted by research comparing objective and subjective sleep outcomes in elementary-school children (Dumpa & Bhandari, 2021; Maślak et al., 2020; Acevedo et al., 2025). The present study did not report actigraphy or polysomnography as sleep outcome measures; therefore, mechanisms involving sleep architecture, sleep efficiency, or wake after sleep onset cannot be directly inferred from its results (Kouros & El-Sheikh, 2016).

Overall, international evidence supports the plausibility of benefits across physical activity, motor development, and sleep, but the strength of evidence differs by outcome. The current study contributes an integrated longitudinal perspective from Indonesian elementary schools. Its contribution is most appropriately understood as context-specific evidence that complements international research, rather than as proof that the same intervention effects will occur across all populations.

Theoretical, Methodological, and Practical Implications

The findings are consistent with developmental models proposing reciprocal relationships between motor competence and physical activity. Under this perspective, structured activity can create opportunities for skill acquisition, while improved movement performance may support subsequent participation. The persistence of motor-skill gains at follow-up is compatible with this model, although the present study did not directly test whether improved motor performance mediated later physical

activity. Such a pathway remains a theoretical explanation requiring longitudinal mediation analysis.

The findings also support a broader movement-behaviour perspective in which physical activity, weight-related health, and sleep are considered interconnected but distinct domains. The observed changes across outcomes suggest that school-based programmes may have benefits extending beyond a single physical fitness or weight-related endpoint. However, because the study did not directly measure physiological mediators or experimentally isolate intervention components, it cannot establish whether changes in BMI or motor performance contributed to changes in sleep. Future research should distinguish observed outcome patterns from proposed mechanisms.

Methodologically, the study's principal strength is its assessment of several outcomes at baseline, immediately after the intervention, and at 12-month follow-up, with a comparison group. This design allows evaluation of differences in trajectories and partial maintenance after the active intervention. Accelerometer-based MVPA assessment also provides an objective measure of physical activity behaviour, complementing the anthropometric and questionnaire-based outcomes. Nevertheless, the non-randomized allocation means that unmeasured differences between groups may have influenced the results.

For school practice, the intervention illustrates a potentially feasible way to incorporate additional structured movement into the school timetable. The programme used existing school facilities and physical educators, with activities combining aerobic exercise, motor-skill practice, and flexibility. Schools considering similar programmes should prioritize consistent delivery, age-appropriate activities, and monitoring of participation and adverse events. Continued practice opportunities may be particularly important for sustaining motor-skill gains. Coordination between schools and families may also support regular activity and appropriate sleep routines (Reilly et al., 2006; Sanyaolu et al., 2019; Singh, 2012).

Policy implications should remain proportionate to the evidence. The results support further evaluation of structured school-based physical activity as part of comprehensive health promotion, but they do not establish the cost-effectiveness, scalability, or universal effectiveness of the programme. Implementation across different school systems should account for staffing, facilities, curricular demands, and opportunities for continued activity beyond the intervention period.

Strengths and Limitations

Several strengths warrant consideration. First, the controlled longitudinal design included baseline, post-intervention, and 12-month assessments, allowing the study to examine both immediate changes and longer-term patterns. Second, the intervention was clearly specified in terms of duration and weekly activity dose. Third, the assessment strategy covered anthropometric status, selected motor-performance domains, sleep-related outcomes, and objectively measured MVPA. Finally, the inclusion of six elementary schools provides evidence from more than one school setting within the study location.

These strengths must be considered alongside important limitations. First, the study used purposive convenience sampling and non-randomized group allocation. Although the groups showed no statistically significant baseline differences on several reported characteristics, this does not demonstrate equivalence on all relevant factors. Unmeasured confounding, including dietary intake, household socioeconomic circumstances, family

routes, and activity outside school, may have influenced the results. Consequently, causal interpretations should remain cautious. Second, the sample was modest, with 143 children completing baseline assessments and 126 included in the reported complete-follow-up sample. Attrition may have introduced bias if children lost to follow-up differed systematically from those retained. Multiple imputation was reportedly used, but its validity depends on assumptions about the missing-data process and the appropriateness of the variables included in the imputation models. Reporting both complete-case and imputed estimates, together with sensitivity analyses, would help establish the robustness of the findings. Third, measurement limitations affect interpretation. BMI is not a direct measure of adiposity, while the motor-skill battery captures selected physical performance domains rather than the full range of fundamental movement skills (Cools, W., et al. 2009). Sleep quality was assessed using the PSQI-C, and sleep duration was based on parent-reported logs; these measures may be affected by recall and reporting bias. Objective sleep monitoring would strengthen future evaluations. In addition, the large reported increase in sleep duration requires verification against the original records and analysis outputs before being accepted as a reliable estimate. Fourth, the available report does not establish whether outcome assessors were blinded to group allocation. Lack of blinding, if present, could affect performance testing or data handling. The manuscript also acknowledges that formal intervention-fidelity monitoring was not conducted, making it difficult to determine whether differences in delivery across schools or educators influenced outcomes. The 12-month follow-up is valuable but insufficient to establish whether benefits persist into adolescence. Generalizability is further limited by recruitment from six schools in one Indonesian city. Finally, several outcomes and time points were examined, increasing the potential for multiplicity. Although Bonferroni correction was reportedly used for post hoc comparisons, interpretation should also consider the prespecification of primary outcomes, confidence intervals, and the consistency of findings across analyses. Statistical significance alone does not demonstrate clinical importance, and subgroup findings should be regarded as exploratory given the sample size.

These limitations do not eliminate the value of the study, but they define its evidential boundaries. The findings provide a useful basis for further investigation, while stronger allocation procedures, improved measurement, and transparent reporting are needed before firm causal or policy conclusions can be drawn.

Future Research

Future research should replicate this intervention in larger, more diverse school populations across Indonesia and other countries, including settings with different socioeconomic conditions, school schedules, and access to physical education facilities. Cluster-randomized controlled trials would help reduce selection bias and strengthen causal inference, while multicentre designs would improve the transferability of findings. Follow-up extending beyond 12 months would clarify whether changes in BMI, motor performance, sleep, and physical activity persist into adolescence.

Studies should also improve measurement by using age- and sex-standardized BMI indicators, validated motor-competence batteries, accelerometry, and objective sleep monitoring where feasible. Intervention fidelity, attendance, adherence, adverse events, and activity outside school should be documented systematically. Dietary intake, socioeconomic circumstances,

family routines, and other relevant confounders should be measured to improve adjustment and interpretation.

Mechanistic research should test whether motor-skill improvement mediates later physical activity and whether changes in activity contribute to sleep outcomes. Moderation analyses involving baseline weight status, sex, age, and socioeconomic circumstances should be prespecified and

adequately powered. Finally, implementation studies should assess teacher workload, programme acceptability, cost-effectiveness, and the feasibility of maintaining activity opportunities after formal intervention ends. Such research would help determine not only whether school-based physical activity programmes work, but also for whom, under what conditions, and at what cost they can be sustained.

CONCLUSION

This study evaluated the longitudinal associations of a 12-week school-based physical activity programme with body mass index (BMI), motor-skill performance, and sleep outcomes among elementary school children. The findings indicated more favourable changes in the intervention group than in the control group across these outcomes, with some improvements remaining evident at the 12-month follow-up. However, the extent to which these changes were maintained differed across outcomes, suggesting that the potential benefits of school-based physical activity may not be uniform over time. Given the non-randomized design, the findings should be interpreted as intervention-associated differences rather than definitive evidence of causality.

This study contributes to international research by providing

an integrated, longitudinal assessment of weight-related, motor-performance, and sleep outcomes following a structured school-based physical activity programme in Indonesian elementary schools. The findings support further investigation of school-based physical activity as a component of comprehensive child-health promotion. Nevertheless, the modest sample, non-randomized allocation, potential confounding, and limitations of questionnaire-based sleep assessment restrict generalizability. Larger randomized, multicentre studies with objective outcome measures and longer follow-up are needed to confirm the findings, establish the durability and practical importance of the observed changes, and determine the applicability of this approach across diverse school settings.

DECLARATIONS

Ethical Approval

The study was reviewed and approved by the Health Research Ethics Committee, Pascasarjana, Universitas Negeri Jakarta, Indonesia (Approval No.: UNJ/PPS/IRB/2024/097). All procedures were conducted in accordance with the principles of the Declaration of Helsinki and relevant national regulations governing research involving human participants.

Consent for to Participate

Written informed consent was obtained from the parents or legal guardians of all participating children before data collection. Age-appropriate assent was also obtained from the children, where applicable, in accordance with the approved study protocol.

Consent for Publication

No personally identifiable information is presented in this article.

Author Contributions (CRediT)

Author contributions should be confirmed by all authors before submission. Based on the contribution indicators currently listed in the manuscript, a provisional CRediT statement is provided below:

Annemarie Christ: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – Original Draft, and Writing – Review & Editing.

Krysten Rocha: Data Curation, Formal Analysis, and Writing – Review & Editing.

Angela Saccà: Conceptualization, Methodology, and Writing –

Review & Editing.

Khairul Zikri: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – Review & Editing

All authors should review and approve the final contribution statement and confirm their accountability for their respective contributions to the work..

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Conflict of Interest

The authors declare that they have no conflicts of interest that could have influenced the conduct of the study, the interpretation of the findings, or the preparation of this manuscript.

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Appendix A. Structure and Components of the School-Based Physical Activity Intervention

Intervention Overview

The intervention consisted of a 12-week school-based physical activity programme delivered in addition to the intervention group's usual physical education classes. The programme provided an additional 120 minutes of structured physical activity per week through three sessions, each lasting 40 minutes. Sessions were delivered by certified physical education instructors and incorporated aerobic activities, motor-skill practice, and cooldown and flexibility exercises.

Table A1. Overview of the intervention programme

Component	Description
Intervention duration	12 weeks
Additional session frequency	3 sessions per week
Session duration	40 minutes
Total additional activity	120 minutes per week
Total planned intervention exposure	36 sessions; 1,440 minutes (24 hours) per participant completing the full programme
Programme delivery	School-based, structured physical activity
Intervention personnel	Certified physical education instructors
Main activity categories	Aerobic activity, motor-skill practice, and cooldown/flexibility
Comparison condition	Usual school physical education

A2. Session Structure

Each 40-minute session was organised into three activity components. The planned allocation of time is presented in Table B2.

Table A2. Structure of each intervention session

Session component	Proportion of session	Planned duration	Examples of activities
Aerobic activities	60%	24 minutes	Running, jumping, and dance-based activities
Motor-skill practice	25%	10 minutes	Balance, coordination, and fundamental movement-pattern activities
Cooldown and flexibility	15%	6 minutes	Cooldown and flexibility exercises
Total	100%	40 minutes	—

The aerobic component was designed to provide structured opportunities for physical activity, while the motor-skill component focused on practising balance, coordination, and fundamental movement patterns. Each session concluded with cooldown and flexibility exercises.



A3. Weekly Delivery Schedule

The programme was scheduled for three sessions per week over 12 consecutive weeks. The same overall session structure was planned for each session.

Table A3. Planned weekly intervention schedule

Weekly schedule	Session duration	Main components	Weekly duration
Session 1	40 minutes	Aerobic activity, motor-skill practice, cooldown/flexibility	40 minutes
Session 2	40 minutes	Aerobic activity, motor-skill practice, cooldown/flexibility	40 minutes
Session 3	40 minutes	Aerobic activity, motor-skill practice, cooldown/flexibility	40 minutes
Total per week	—	3 structured sessions	120 minutes

The available study documentation specifies the overall session components and weekly frequency but does not establish a distinct activity progression for each individual week. Accordingly, a week-by-week progression is not presented here.

A4. Comparison Group

Participants in the comparison group continued their usual school physical education programme, reported as approximately 90–120 minutes per week across two sessions. No additional study-specific physical activity sessions were prescribed to this group as part of the intervention protocol.

A5. Intervention Exposure and Interpretation

The planned intervention dose was 120 additional minutes of structured physical activity per week for 12 weeks. This represents the prescribed programme dose rather than independently verified attendance or completed activity time. Individual adherence, session attendance, and deviations from the planned protocol should be reported separately if these records are available.