

Effects of Hybrid Active Learning Classrooms on Cognitive Performance and Physical Activity Among School-Age Students

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Article Info	Abstract
Article type: Research Article Article history: Received 14 March 2026 Received in revised form 16 May 2026 Accepted 02 June 2026 Available online 29 June 2026 Keywords: Physical Activity, Cognition, Classroom Environment, School Children, Active Learning.	Introduction: Prolonged sedentary behavior in classrooms may reduce physical activity and impair cognitive performance in school-age students. Hybrid active learning classrooms (HALCs), which integrate structured movement and interactive learning into daily instruction, may support both cognitive and physical development. Objective: To examine the effects of hybrid active learning classrooms on cognitive performance and physical activity among school-age students. Method: A quasi-experimental study was conducted with 140 students (ages 8–12 years) assigned by classroom to an intervention ($n = 70$) or control group ($n = 70$). The six-week intervention incorporated flexible seating, brief movement tasks integrated with academic content, and interactive learning activities. Cognitive performance was assessed using a composite of the Digit Span, Flanker, and Trail Making tasks. Classroom physical activity was measured with accelerometers. Post-intervention outcomes were compared using ANCOVA. Results: Students in HALCs showed significant improvements in cognitive performance compared to controls ($F = 34.7$, $p < 0.001$, partial $\eta^2 = 0.21$). Physical activity increased substantially in the intervention group: classroom steps ($F = 152.6$, $p < 0.001$, partial $\eta^2 = 0.53$), moderate-to-vigorous activity ($F = 126.4$, $p < 0.001$, partial $\eta^2 = 0.48$), and sedentary time decreased ($F = 98.1$, $p < 0.001$, partial $\eta^2 = 0.46$). Conclusions: Hybrid active learning classrooms enhance cognitive performance and increase physical activity in school-age students. Embedding movement and interactive learning into classroom routines provides a practical, evidence-based strategy to support both cognitive and physical development. Cite this Article: Can Koc, M. (2026). Effects of Hybrid Active Learning Classrooms on Cognitive Performance and Physical Activity Among School-Age Students. <i>Physical Activity in Children</i>, 3(1), 23-29. https://doi.org/10.22034/pach.2026.582421.1088

1. Introduction

Traditional classroom instruction often emphasizes prolonged periods of sedentary learning, which can limit opportunities for physical movement and reduce student engagement (1). For school-age students, extended sedentary time has been associated with decreased physical activity, increased mental fatigue, and suboptimal cognitive performance (2). Given that childhood and early adolescence are critical periods for both cognitive and motor development (3), there is growing interest in innovative classroom designs that integrate learning and movement to enhance student outcomes.

One promising approach is the integration of hybrid active learning classrooms (HALCs), which combine flexible classroom design, structured movement opportunities, and interactive learning strategies within routine academic instruction. Research indicates that movement integrated into classroom instruction can enhance blood flow, increase physiological arousal, and improve neurocognitive functioning (4,5). In such environments, students may alternate between seated learning and dynamic, activity-based tasks, promoting not only physical activity but also cognitive engagement (6,7). Hybrid classrooms leverage

educational technology, flexible seating, and modular spaces to create a learning environment conducive to both movement and focused academic work (4,8). By embedding movement within instructional time, HALCs aim to address the dual objectives of maintaining physical activity and enhancing cognitive performance.

The rationale for hybrid active learning classrooms can be understood through several theoretical frameworks. Developmental theories emphasize that school-age students are in a critical stage of cognitive maturation, particularly in executive functions such as working memory, attention control, and cognitive flexibility (9,10). Evidence indicates that physical activity supports neurodevelopment, increasing cerebral blood flow, stimulating prefrontal cortex activity, and facilitating neurochemical processes that underpin learning (11-13). Integrating movement into learning activities may therefore help students maintain optimal cognitive arousal, prevent mental fatigue, and improve task performance.

From an ecological perspective, the classroom environment plays a pivotal role in shaping learning outcomes. Traditional classrooms often constrain movement, creating sedentary conditions that may undermine both physical and cognitive development



(9,10). Hybrid active learning classrooms modify these environmental constraints, providing affordances for movement, collaboration, and active engagement (14,15). By altering spatial arrangements and instructional strategies, educators can create contexts that support both physical activity and cognitive engagement, highlighting the importance of environment-behavior interactions in educational outcomes.

Motivational frameworks, including self-determination theory, further support hybrid active learning approaches. Incorporating movement and interactive learning opportunities can enhance intrinsic motivation, perceived competence, and engagement, which in turn positively influence cognitive outcomes (16,17). Students who are physically active during learning may experience enhanced arousal, increased attentional capacity, and greater readiness to learn, translating into improved cognitive performance (18). Motivational support embedded within classroom design ensures that students participate willingly, maximizing the benefits of integrated movement and cognitive tasks.

Despite growing evidence, research on classroom-based physical activity has often focused on either cognitive outcomes or physical activity behaviors, with relatively few studies simultaneously examining both domains within integrated classroom environments. Previous investigations have commonly evaluated isolated strategies such as activity breaks, standing desks, or flexible seating, rather than comprehensive hybrid active learning classrooms that combine environmental redesign with movement-integrated instruction (19-21). Furthermore, relatively few studies have combined objective accelerometer-derived measures of classroom physical activity with a composite assessment of executive functioning that incorporates working memory, inhibitory control, and cognitive flexibility. Consequently, the extent to which a comprehensive HALC model may simultaneously influence cognitive performance and classroom physical activity remains insufficiently understood.

Accordingly, the novelty of the present study lies in evaluating a comprehensive hybrid active learning classroom model implemented under authentic school conditions, while simultaneously examining objectively measured classroom physical activity and multiple domains of executive functioning within the same intervention. Such evidence may contribute to a more integrated understanding of how classroom design and instructional practices jointly influence children's cognitive and behavioral outcomes.

The present study aims to address these gaps by examining the effects of hybrid active learning classrooms on cognitive performance and physical activity among school-age students. Specifically, the study investigates whether integrating movement and interactive learning within classroom instruction is associated with improvements in executive functioning and classroom physical activity. Based on ecological and neurocognitive theory, it is hypothesized that students participating in hybrid active learning classrooms will demonstrate higher cognitive performance and greater physical activity compared with students receiving traditional classroom instruction.

2. Methods

2.1. Study Design

This study employed a quasi-experimental, classroom-based pretest-posttest design to examine the effects of Hybrid Active Learning Classrooms (HALCs) on cognitive performance and classroom physical activity among school-age students. Because the intervention was implemented at the classroom level, intact classrooms rather than individual students were allocated to the intervention or control condition to minimize disruption to routine teaching practices and reduce contamination between students within the same classroom. Consequently, the study should be interpreted as a quasi-experimental classroom-level intervention rather than an individually randomized controlled trial.

Although students were nested within classrooms, the primary analyses were conducted using ANCOVA while statistically controlling for baseline scores, age, sex, and body mass index (BMI). Because only a small number of classrooms participated, multilevel modeling was considered statistically unstable. Nevertheless, the potential influence of classroom clustering is acknowledged as a limitation when interpreting the findings.

2.2. Participants

A total of 140 students (8–12 years) were recruited from four public primary schools. Eight intact classrooms (two classrooms per school) participated in the study, with four classrooms assigned to the intervention condition and four classrooms assigned to the control condition. Whenever possible, classrooms within the same grade level were matched on class size and academic characteristics before allocation to minimize baseline differences between groups. Inclusion criteria required that participants be enrolled in grades 3–6, able to participate in normal classroom activities, and free of medical or neurological conditions that could restrict physical activity. Exclusion criteria included recent musculoskeletal injuries, diagnosed cognitive or attention disorders, or an inability to engage in classroom tasks. Participants were assigned by classroom to either the intervention group ($n = 70$) or control group ($n = 70$). Assignment occurred at the classroom level rather than at the individual level to avoid contamination between students receiving different instructional approaches within the same classroom. Teachers remained with their own classrooms throughout the study, and no teacher delivered both intervention and control lessons. Written parental consent and child assent were obtained prior to participation, and ethical approval for the study was granted by the Institutional Review Board, in accordance with the Declaration of Helsinki.

2.3. Intervention: Hybrid Active Learning Classrooms

The intervention lasted six consecutive weeks and was integrated into routine classroom instruction. The HALC model incorporated four complementary components:

2.3.1. Flexible learning environment

Students were encouraged to alternate between conventional chairs, standing workstations, wobble stools, and collaborative learning stations according to instructional activities. Teachers encouraged students to change posture approximately every 20–30 minutes whenever appropriate.

2.3.2. Curriculum-integrated movement

Rather than isolated exercise breaks, movement was embedded directly into academic instruction. Examples included solving mathematics problems while completing step-pattern sequences; spelling and vocabulary activities performed at movement stations; science activities requiring students to rotate among learning stations; and collaborative problem-solving tasks involving short walking intervals. Each movement episode lasted approximately 5–8 minutes, with three to five movement sessions implemented daily, resulting in approximately 20–30 minutes of accumulated classroom movement each school day.

2.3.3. Interactive learning activities

Students participated in cooperative learning tasks, educational games, hands-on experiments, peer discussions, and technology-supported problem-solving designed to increase behavioral and cognitive engagement.

2.3.4. Technology-supported instruction

Interactive whiteboards, tablets, and modular learning stations were used to facilitate self-paced learning while encouraging frequent transitions between learning locations.

Teachers participated in a standardized 6-hour training workshop before the intervention and received a written implementation manual containing identical lesson examples and activity protocols. To monitor intervention fidelity, teachers completed daily implementation logs documenting the number and duration of movement sessions delivered. In addition, trained research staff conducted weekly classroom observations using a standardized fidelity checklist. Across the intervention period, approximately 94% of planned movement sessions were delivered, with no major protocol deviations observed.

Control classrooms continued conventional teacher-centered instruction using traditional desks with no structured movement activities beyond routine classroom practice.

2.4. Measurements

2.4.1. Cognitive Performance

Cognitive performance was assessed using three standardized neurocognitive measures including Digit Span Task (Forward and Backward), Flanker Task, and Trail Making Test (Parts A and B). Because these instruments assess complementary domains of executive functioning (working memory, inhibitory control, cognitive flexibility, processing speed, and attentional control), an overall cognitive composite score was calculated to represent global executive performance. Prior to averaging, raw scores from each test were transformed into standardized z-scores to ensure comparability across measurement scales. Scores were oriented so that higher values consistently reflected better cognitive performance before calculating the composite score. Internal consistency of the composite measure was acceptable (Cronbach's $\alpha = 0.81$), supporting its use as an overall indicator of executive functioning. Assessments were administered individually by trained research assistants who were blinded to classroom allocation whenever feasible.

2.4.2. Physical Activity

Classroom physical activity was objectively measured using ActiGraph wGT3X-BT accelerometers worn on the right hip during school hours. Accelerometers recorded activity using 15-second

epochs to capture the intermittent movement patterns characteristic of children. Moderate-to-vigorous physical activity (MVPA) was classified using Evenson cut-points, which are widely recommended for pediatric populations. Participants were required to provide at least four valid school days, including one day with physical education where applicable, with a minimum of 80% classroom wear time per day. Only classroom instructional periods were included in the analyses. Wear-time corresponding to recess, lunch breaks, and physical education lessons was excluded using school timetables and teacher logs to isolate classroom-related physical activity. Non-wear periods of ≥ 20 consecutive minutes of zero counts were removed following established ActiGraph processing guidelines. Outcome variables included classroom steps, sedentary time, light physical activity, and moderate-to-vigorous physical activity (MVPA).

2.4.3. Covariates

Age, sex, and BMI were included as covariates because these variables may influence children's physical activity behavior and cognitive performance. Although socioeconomic status, habitual physical activity outside school, previous academic achievement, and teacher-related characteristics may also influence study outcomes, these variables were not available for inclusion in the statistical models and are acknowledged as potential sources of residual confounding.

2.4.4. Procedure

Baseline cognitive testing and accelerometer assessments were completed one week before intervention implementation. The intervention was conducted during regular classroom instruction over six weeks. To reduce variability between classrooms, intervention activities were scheduled during the same morning instructional period (approximately 9:00–11:00 a.m.) across participating schools whenever feasible. Teachers completed daily fidelity logs, while research staff conducted weekly monitoring visits to ensure protocol adherence. Immediately following the intervention, identical post-intervention assessments were administered using the same standardized procedures. Outcome assessors were not involved in intervention delivery and were unaware of group allocation whenever possible.

2.5. Data Analysis

Statistical analyses were performed using IBM SPSS Statistics Version 28 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as means $\pm$ standard deviations or frequencies. Independent-samples t-tests and χ^2 tests were used to evaluate baseline equivalence between groups. Paired-samples t-tests examined within-group pre-post changes. Analysis of covariance (ANCOVA) compared post-intervention cognitive and physical activity outcomes between groups while adjusting for baseline scores, age, sex, and BMI. Effect sizes were reported using Cohen's d for within-group comparisons and partial η^2 for ANCOVA. Given the classroom-level allocation, the findings should be interpreted cautiously because the analyses did not explicitly model classroom clustering. This analytical decision was based on the limited number of participating classrooms, which precluded stable estimation of multilevel models. Statistical significance was established at $p < 0.05$.

3. Results

3.1. Participant Demographics

A total of 140 school-age students completed the study, including 70 students in the hybrid active learning classroom (HALC) group and 70 students in the comparison group. The mean age of participants was 10.0 ± 1.3 years, and 72 (51%) were boys. Baseline demographic characteristics and outcome measures

did not differ significantly between groups (all $p > 0.05$), indicating comparable groups prior to the intervention. However, because allocation occurred at the classroom level, baseline equivalence should not be interpreted as eliminating the possibility of residual classroom- or teacher-level confounding. Participant characteristics are presented in Table 1.

Table 1. Baseline Participant Characteristics.

Variable	Intervention (n = 70)	Control (n = 70)	p
Age (years), Mean $\pm$ SD	10.1 $\pm$ 1.2	9.9 $\pm$ 1.4	0.42
Boys, n (%)	36 (51.4)	36 (51.4)	1.00
BMI (kg/m ²), Mean $\pm$ SD	18.8 $\pm$ 2.9	19.0 $\pm$ 3.0	0.69
Baseline Cognitive Composite Score	83.2 $\pm$ 8.9	82.5 $\pm$ 9.1	0.62
Baseline Classroom Steps/day	1,450 $\pm$ 320	1,460 $\pm$ 310	0.87

3.2. Descriptive Statistics: Cognitive Performance and Physical Activity

Table 2 presents descriptive statistics for cognitive performance and classroom physical activity before and after the six-week intervention. Students in the HALC group demonstrated higher post-intervention

cognitive performance, greater classroom physical activity, higher moderate-to-vigorous physical activity (MVPA), and lower sedentary time than students in the comparison group. These descriptive findings were subsequently evaluated using ANCOVA while controlling for baseline values, age, sex, and BMI.

Table 2. Pre- and Post-Intervention Cognitive Performance and Physical Activity.

Measure	Intervention-Pre	Intervention-Post	Control-Pre	Control-Post
Cognitive Composite Score	83.2 $\pm$ 8.9	90.1 $\pm$ 8.0	82.5 $\pm$ 9.1	83.3 $\pm$ 9.2
Steps per classroom day	1,450 $\pm$ 320	2,210 $\pm$ 350	1,460 $\pm$ 310	1,480 $\pm$ 325
Moderate-to-Vigorous Activity (min/day)	12.5 $\pm$ 4.2	25.3 $\pm$ 5.1	12.3 $\pm$ 4.0	13.1 $\pm$ 4.3
Sedentary Time (min/day)	145 $\pm$ 15	118 $\pm$ 14	146 $\pm$ 16	144 $\pm$ 15

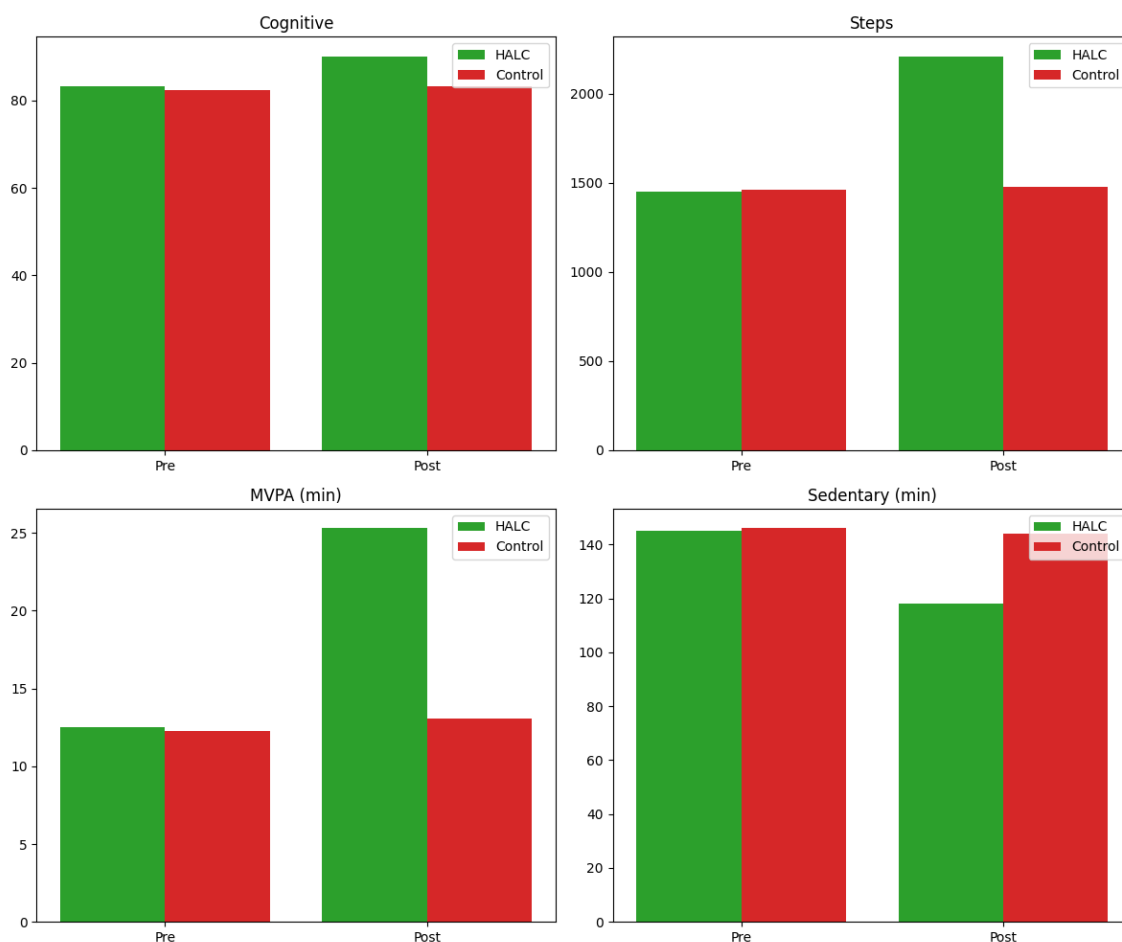


Figure 1. Comparison of Cognitive and Physical Activity Outcomes Between Hybrid Active Learning Classroom (HALC) and Control Groups.

3.3. Pre-Intervention Equivalence

Baseline comparisons indicated no statistically significant differences between the intervention and comparison groups in cognitive performance ($t(138) = 0.50$, $p = 0.62$), classroom steps per day ($t(138) = -0.17$, $p = 0.87$), moderate-to-vigorous physical activity ($t(138) = 0.15$, $p = 0.88$), or sedentary time ($t(138) = -0.33$, $p = 0.74$). These findings suggest that the groups were comparable on the measured baseline variables prior to the intervention. However, because participants were allocated at the classroom level rather than individually, baseline equivalence does not preclude the potential influence of unmeasured classroom- or teacher-level characteristics.

3.4. Effects of Hybrid Active Learning Classrooms

Following adjustment for baseline values, age, sex, and BMI, ANCOVA demonstrated statistically significant between-group differences across all primary outcomes (Table 3). Students in the hybrid active learning classroom (HALC) group achieved significantly higher adjusted cognitive composite scores than those in the comparison group ($F(1,136) = 34.7$, $p < 0.001$, partial $\eta^2 = 0.21$).

Similarly, students in the HALC group accumulated significantly more classroom steps per day ($F(1,136) = 152.6$, $p < 0.001$, partial $\eta^2 = 0.53$) and greater moderate-to-vigorous physical activity ($F(1,136) = 126.4$, $p < 0.001$, partial $\eta^2 = 0.48$), while demonstrating significantly lower sedentary time than students in the comparison group ($F(1,136) = 98.1$, $p < 0.001$, partial $\eta^2 = 0.46$).

Table 3. Post-Intervention ANCOVA Results.

Outcome	F	p	Partial η^2	Group Mean $\pm$ SD (Adjusted)
Cognitive Composite Score	34.7	<0.001	0.21	Intervention: 90.2 $\pm$ 7.9 Control: 83.5 $\pm$ 9.0
Steps per classroom Day	152.6	<0.001	0.53	Intervention: 2,205 $\pm$ 345 Control: 1,482 $\pm$ 320
Moderate-to-Vigorous Activity	126.4	<0.001	0.48	Intervention: 25.2 $\pm$ 5.0 Control: 13.0 $\pm$ 4.2
Sedentary Time	98.1	<0.001	0.46	Intervention: 118 $\pm$ 14 Control: 144 $\pm$ 15

4. Discussion

This study examined the effects of HALCs on cognitive performance and physical activity in school-age students. After adjustment for baseline scores, age, sex, and BMI, students in the HALC group demonstrated higher post-intervention cognitive performance, accumulated more classroom physical activity, engaged in greater amounts of moderate-to-vigorous physical activity (MVPA), and spent less time sedentary than students receiving traditional classroom instruction. Although the quasi-experimental design precludes definitive causal inference, these findings suggest that integrating structured movement opportunities within classroom instruction may provide benefits for both cognitive functioning and physical activity during the school day.

The primary finding of the study revealed that students engaged in hybrid active learning environments exhibited significant enhancements in cognitive performance compared to their peers in traditional classrooms. Specifically, those in the intervention group experienced an average increase of 6.9 points in cognitive composite scores, while the control group demonstrated only slight variations. These outcomes align with existing literature that suggests incorporating brief physical activity into learning activities can bolster executive function, attention, and working memory among school-aged children (25-27). Previous research highlighted improved cognitive performance following activity breaks in classrooms (28), and merging movement with educational tasks enhanced abilities such as task-switching and inhibitory control (30). Theoretical interpretations of these results can be framed within developmental, ecological, and motivational contexts. Developmental theories propose that physical activity activates neurocognitive functions in the prefrontal cortex, thereby improving executive function (9,10). Ecological viewpoints stress the importance of creating

classroom environments that facilitate movement to enhance cognitive engagement (15). Additionally, motivational theories, particularly self-determination theory, suggest that engaging in enjoyable and mastery-focused activities fosters intrinsic motivation and engagement, likely contributing to the observed cognitive gains (17).

The second significant finding revealed a notable increase in physical activity within hybrid active learning classrooms. On average, students recorded an increase of 760 steps per day, while moderate-to-vigorous activity levels doubled, and sedentary time decreased by 27 minutes daily. In contrast, students in the control group exhibited minimal changes. These findings are consistent with earlier research indicating that flexible classroom designs, such as standing desks and integrated movement tasks, promote higher levels of physical activity during school hours (1,6). By incorporating movement into academic activities, students can stay active without compromising instructional time. The ecological framework provides a theoretical basis for this outcome, suggesting that hybrid classroom settings offer opportunities for movement that traditional sedentary classrooms lack (10). Furthermore, from a developmental standpoint, increased physical activity fosters motor skill development, cardiovascular health, and improved attention regulation (15). Motivation also plays a crucial role, as students tend to engage more in physical activity when it is interactive, goal-oriented, and seamlessly integrated into their learning experiences, thereby enhancing both participation and effectiveness (17).

The findings indicate that HALCs can enhance both cognitive performance and physical activity among school-age students, yielding significant dual advantages. By integrating structured movement with interactive learning and adaptable environments, HALCs effectively cater to the cognitive and physical requirements of students. Notably, the observed effect

sizes were moderate to large, highlighting that even brief, repeated interventions in the classroom can lead to substantial improvements.

Several limitations should be considered when interpreting the present findings. First, participants were allocated at the classroom level rather than through individual randomization, and statistical analyses were conducted at the individual level. Consequently, potential classroom clustering and intra-class correlation were not explicitly modeled, and the reported effect estimates should therefore be interpreted cautiously. Second, teacher characteristics, instructional style, and classroom culture may have influenced both implementation fidelity and student outcomes and could not be fully controlled. Third, outcome assessors were not blinded to group allocation, introducing the possibility of measurement bias. Fourth, although accelerometers provided objective assessment of classroom physical activity, monitoring was limited to classroom hours and did not capture total daily physical activity. Fifth, the intervention lasted only six weeks; therefore, the durability of these effects beyond the immediate post-intervention period remains unknown. Finally, the study involved students from four schools within a single geographical region, which may limit the generalizability of the findings to other educational settings.

Despite these limitations, the study has several important strengths. The intervention was implemented under authentic school conditions, enhancing ecological validity, and incorporated objective accelerometer-based assessment of physical activity alongside standardized cognitive testing. In addition, intervention fidelity was supported through teacher training, standardized implementation procedures, teacher logs, and regular monitoring throughout the intervention period. These methodological features increase confidence that the observed differences were associated with implementation of the hybrid active learning classroom model.

From a practical perspective, the findings suggest that hybrid active learning classrooms may represent a feasible educational strategy for increasing movement opportunities while supporting cognitive engagement during classroom instruction. Because the intervention relied primarily on modifications to classroom organization and teaching practices rather than extensive curricular changes, its implementation may be achievable in routine school settings. Nevertheless, larger cluster-randomized trials with longer follow-up periods and multilevel statistical analyses are needed to confirm these findings and determine their long-term educational significance.

4.1. Conclusion

The present study suggests that participation in hybrid active learning classrooms (HALCs) may be associated with improved cognitive performance and higher levels of classroom physical activity among school-age students over a six-week intervention period. By integrating structured movement, flexible learning environments, and interactive instructional strategies into routine classroom practice, HALCs may provide a feasible approach for simultaneously supporting cognitive engagement and reducing

sedentary behavior during the school day.

Authors' Contribution: The author was responsible for the conception and methodological design of the study, coordination of the research procedures, implementation of the intervention, data collection, statistical analysis, interpretation of the findings, and preparation of the manuscript.

Funding Support: This study was conducted without financial support from external governmental, commercial, institutional, or private funding sources.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: The author declares that no generative artificial intelligence or AI-assisted technology was used in the preparation, writing, editing, or revision of this manuscript. The author takes full responsibility for the accuracy, originality, integrity, and overall content of the published work.

Ethical Considerations: The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical considerations were maintained during participant recruitment, intervention implementation, assessment, and management of research data. Written informed consent was obtained from the parents or legal guardians of the participating students prior to their involvement in the study. The students were provided with information about the study procedures in an age-appropriate manner, and their voluntary participation was respected.

Data Availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to relevant ethical, privacy, and confidentiality requirements.

Acknowledgments: The author gratefully acknowledges the participating students, their parents or legal guardians, teachers, and school personnel for their cooperation and support during the study.

Conflicts of Interest: The author declares no financial, personal, or professional conflicts of interest related to this research or its publication.

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