REGULAR ARTICLE

Classroom-based physical activity and math performance: Integrated physical activity or not?

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Abstract

Aim: This 8-week intervention examined the effect of two different types of classroom-based physical activity on math performance in elementary school children.

Methods: Students in 4th and 5th grade (N = 560; 32 classes, 9–11 years old) from six schools were assigned to integrated physical activity (Move for Thought [M4T], n = 221), activity break (AB; n = 134) and a control group (n = 205; usual instruction) for eight weeks. Students completed a standardised math test before and after the intervention. Programme fidelity was measured with a teacher daily log, recording the duration and frequency of the physical activity sessions. Linear mixed models were used for the analyses. Grade and gender were explored as moderators.

Results: Move for Thought group outperformed AB (p < 0.001, d = 0.44) and control groups (p = 0.013, d = 0.38). However, subgroup analyses showed that these effects were evident only in Grade 4. No gender differences were found. Intervention fidelity showed that the classroom-based physical activities (M4T and AB) were used about every other day, with higher implementation among 4th graders.

Conclusion: This study indicated that integrating physical activity with mathematics has stronger effects on mathematics than activity breaks and traditional instruction.

KEYWORDS

activity breaks, integrated physical activity, mathematics

Key Notes

• Among different practices of classroom-based physical activity, integrating physical activity with mathematics has the potential to improve children’s math performance.
• Physical activity integrated with mathematics had higher performance than the control and activity breaks groups.
• Fidelity measures showed that the observed effects were apparent only in Grade 4, which had higher implementation rates than Grade 5.
1 | INTRODUCTION

Growing literature has ascertained the benefits of physical activity on a range of educational outcomes, including cognition and metacognition, academic achievement and student engagement. Schools are equipped with necessary resources and infrastructure and, thus, are considered ideal places to promote physical activity. In 2013, Comprehensive School Physical Activity Programs were suggested for promoting physical activity in schools, including quality physical education, physical activity before, during and after school, staff, family and community involvement.

Classroom-based physical activity is receiving great interest among educators, researchers and professional organisations, with intervention programmes rapidly increasing over the last decade. Active learning in the classroom can be categorised mainly into: (i) activity breaks performed at the beginning or as a break from academic instruction, lasting about 5–10 min (e.g., as an energy booster; ‘do 10 jumping jacks’); (ii) physical activities integrated, but of low relevance, with the academic content (e.g., to review learned content; ‘skip around and find the person who has the flashcard with the answer to your math question’); (iii) lessons adjusted to the integration of physical activity into learning with movements being of high relevance with the academic content, usually lasting longer than all other strategies, about 20–45 min (e.g, to teach new concepts through embodied learning; “learn about shapes while using your own body”). Overall, according to Bassett et al., activity breaks can add up to 19 min per day of physical activity in the classroom.

Existing evidence from both chronic and acute studies reports positive effects of active learning on children’ academic outcomes such as academic achievement. The vast majority of research has compared one type of movement strategies in the classroom (e.g., active breaks) against usual practice and of the few studies that compared the effects of different movement strategies the results were inconsistent.

For instance, a 9-month intervention engaged primary school children with aerobic movement infused within the academic content, or aerobic-only movement breaks found no significant differences on math performance among groups. In Mavilidi et al. study, mathematics performance was higher in the activity breaks group compared to the control and physical activity integrated with mathematics groups. In contrast, integrated physical activity with cognitively engaging tasks is the one that benefited most on math performance, whereas the aerobic group (i.e., active break) remained unaffected after a 20-week intervention with elementary school children.

Systematic review evidence reports that active learning has a positive impact on math performance in primary school children, with more than half of studies (6/11) showing improvements, whereas none of the studies reported a decline. However, more research is needed in order to understand the effect of different movement strategies on academic performance and specifically in mathematics.

Therefore, the present study evaluates the effectiveness of a short 8-week intervention programme that integrated physical activity of low relevance during mathematics lessons, on children’s math performance, compared to activity breaks and traditional lessons, in fourth- and fifth-grade students. This duration has been shown to be the most common in classroom-based physical activity research. This present study extends current research of the ‘Move for Thought’ (M4T) elementary programme that has been found to increase children’s math performance and physical activity levels, compared to traditional instruction.

Based on the evidence of the positive effects of physical activity and particularly on active learning on mathematic achievement, it was hypothesised that children in both experimental conditions will outperform the control group. We will also explore whether the group with integrated physical activity will have higher performance than the activity break group.

2 | METHOD

2.1 | Participants

Participants included 560 primary school children from 31 classes (15–25 students per class) of 6 rural elementary classrooms across the State of Iowa. The usual age range of children attending Grade

| Sample characteristics | M4T group (n = 221) | AB group (n = 134) | Control group (n = 205) |
|------------------------|---------------------|-------------------|------------------------|
| Grade 4                | 107 (6 classes)     | 72 (4 classes)    | 93 (4 classes)         |
| Grade 5                | 114 (6 classes)     | 62 (3 classes)    | 112 (8 classes)        |
| Gender distribution (Male/ Female) | 107/114             | 62/67 (5 Missing)           | 98/107                 |
| Ethnicity (%)          |                     |                   |                        |
| Caucasian              | 78.3                | 74.8              | 82.4                   |
| Hispanic               | 7.9                 | 11.6              | 2                      |
| African American       | 2                   | 2.7               | 1.6                    |
| Other                  | 7.2                 | 4.2               | 4.5                    |
| Missing                | 4.3                 | 6.8               | 9.4                    |

TABLE 1 Means (and Standard Deviations) for the sample characteristics in the three experimental groups
4 and 5 is 9–11 years. Using a convenient sample, students were assigned to the physical activity integrated with academics (M4T; \(n = 221\)), the activity breaks (AB; \(n = 134\)) or the control (traditional lesson; \(n = 205\)) group. Children’s demographic characteristics are presented in Table 1. The schools serve primarily European American students (>74%).

2.2 | Experimental design

The study involved a three-group quasi-experimental design. Teachers who declared their willingness to add physical activity in the academic classroom, either in integration with math lessons (M4T; \(n = 12\)) or as activity breaks (AB; \(n = 7\)), were assigned to the experimental conditions, whereas 12 teachers were willing to serve as the control group. Children were not aware of the purpose of the study or the experimental conditions. Implementation was done at the class level by the classroom teacher during regular classroom activities and school hours.

The implementation of the intervention was pragmatic based on the perceived value or importance assigned to classroom-based physical activity by the teachers and not by the researchers. Further, no incentives were provided to encourage participation. This approach was followed to increase external and ecological validity in order to better understand if targeted classroom-based physical activity strategies and programmes can increase the ‘buy-in’ on the part of teachers, which, based on the research literature, remains low.\(^{20,21}\) Studies that evaluate new teaching strategies under optimal conditions may exaggerate the level of teacher motivation to continue using the strategy after external support or incentives are withdrawn.\(^{22}\)

The control classes used their standard instructional strategies, without adding movement in the classroom. For example, students were sitting on their chairs and were solving math problems, using paper and pencil. The study was exempted from the State University Institutional Review Board as the activities were offered as part of the regular instructional strategies by teachers and no children were identified in the data collection (coded by...
teachers). Teacher’s and school’s consent were obtained before the implementation of the programme. Children’s assent was obtained before each testing.

2.3 Procedure

Move for thought and the AB groups participated in an 8-week intervention. Math performance was assessed before and after the implementation period. The M4T classes utilised a kit, named ‘Move for Thought’ which offers options for integrating physical activity with academic subjects and is freely available on the website of Iowa State University (see, eg, Figure 1). The kit includes ten activities that can be adapted for any elementary grade and for any subject area. For this study, teachers used the activities in integration with math. The designed activities allowed students to remain focused on the academic instruction while at the same time being physically active.

In order to integrate the math content in the M4T games, flashcards were developed by the teachers based on the curriculum-specified math content they had planned for each lesson. In addition, teachers could modify the content of the activities (e.g., movement pattern, formations and use of equipment). Teachers were encouraged (but not required) to integrate one activity with mathematics three times per week, by selecting the most preferable ones to the students and themselves. Each activity was designed to be repeated multiple times for a period of approximately 10–12 min. This duration has been found to be feasible and effective.²,¹⁹

The M4T package includes activities that were simple, easy-to-perform, appropriate and safe for the classroom environment, of moderate intensity, and were based on developmentally appropriate fundamental motor skills (mainly locomotor skills, like jumping, skipping and animal-like walking). The majority of activities could be performed in the classroom (8/10), while students could work as a group (‘Curious Ball’, ‘To the wall’, ‘Over/under’, ‘Messsed-up train’) or with a partner (‘Red light’, ‘Find your pair’). Only two activities could be performed individually (‘Jump the answer’, ‘Move around’). For example, in the activity ‘Find your pair’ (Figure 1), students were asked to perform one activity (e.g., skipping), collect a card scattered on the floor that included either a math problem or the answer to a problem and find the classmate with the matching card (answer or problem, respectively).

The AB classes were offered a package of an equal amount of simple, easy-to-perform and safe activities (total of 10) of the most commonly used classroom-based activity breaks that were also freely available in the Web (e.g., Ref.14). The activities included fitness exercises (e.g., stations, use of deck of cards, 12 days of fitness, with movements like high knees, squats, planks, running in place), team games for a limited space (e.g., ‘hide and seek’ with jumpers and joggers for ‘yes’ and ‘no’ answers, triangle tag, freeze/balance challenges), as well as individual exercises like practising a dancing routine and stories in motion. Both packages included the same introductory information. Teachers in both experimental groups were given the autonomy to select whether, when and how to implement the activities.

2.4 Measures

2.4.1 Math performance

Timed comprehensive grade-level appropriate and standardised math tests in algebra and equations (16 items) were used (easyCMB Light Edition). Alternate forms, designed to be of comparable difficulty, were used as a pre-test and post-test, to control for learning effects within each grade. Correct answers were scored as one; missing or incorrect answers were scored as zero. The test had a total duration of four minutes and was administered to the whole classroom simultaneously by research assistants.

2.5 Process evaluation

To ensure intervention fidelity, intervention teachers (M4T and AB groups) recorded the frequency and duration of the activities they used in a daily log.

2.6 Statistical analyses

Analyses of the outcomes were conducted using linear mixed models in IBM SPSS Statistics, version 26.0 (2010 SPSS Inc., IBM Company). This statistical approach is consistent with the intention-to-treat principle because missing data, assumed to be missing at random, are modelled using a likelihood-based analysis.²² Linear mixed models provide an estimation of missing data reducing inherent bias, greater controlling type 1 and 2 errors.²³

Linear mixed models adjusted for clustering at the class level were used to assess the impact of the group (M4T, AB or control), time (treated as categorical with levels baseline and 8 weeks) and the group-by-time interaction. A random intercept was used to account for the repeated measures of each participant. Alpha levels were set at p < 0.05. Grade and gender were explored as a potential moderators of intervention effects using interaction tests (ie group-by-time-by-moderator). Cohen’s d was also calculated and interpreted as follows: d = 0.2, ‘small’ effect size, d = 0.5, ‘medium’ effect size and d = 0.8, ‘large’ effect size.²⁴

3 RESULTS

3.1 Math performance

A summary of the results is presented in Table 2. Significant group-by-time effects were observed for students’ math performance in favour of the M4T group compared to the M4T (adjusted mean...
difference = 1.43, 95% CI, 0.32–2.55, p = 0.013, d = 0.38). Non-significant group-by-time effects were found on students’ math performance when compared AB to the control group (adjusted mean difference = −0.36, 95% CI, −1.40 to 0.68, p = 0.487, d = −0.01). M4T also outperformed AB groups (adjusted mean difference = 1.80, 95% CI, 0.82–2.77, p < 0.001, d = 0.44).

Age was a significant moderator. Results showed that the interactions between time, group and grade (F(2, 580.80) = 4.11, p = 0.017) were significant. As such, subgroup analyses were conducted. In Grade 4, the interaction between group-by-time for M4T and control was significant (adjusted mean difference = 1.21, 95% CI, 0.47–1.97, p = 0.002, d = 1.15). However, the interaction between group-by-time for AB and control was not significant (adjusted mean difference = −0.32, 95% CI, −1.15 to 0.51, p = 0.448, d = −0.02). The interaction between group-by-time for M4T and AB was significant (adjusted mean = 1.54, 95% CI, 0.73 to −2.35, p < 0.001, d = 1.16).

In Grade 5, none of the interactions among the three groups was significant (M4T vs. control: adjusted mean difference = −0.05, 95% CI, −0.64 to 0.52, p = 0.841, d = −0.31; AB vs. control: adjusted mean difference = −0.49, 95% CI, −1.18 to 0.20, p = 0.163, d = −0.86; M4T vs. AB: adjusted mean difference = 0.43, 95% CI, 0.26–1.12, p = 0.219, d = 0.55).

Gender was not a significant moderator (F(1, 572.4) < 1, p = 0.867), and thus, subgroup analyses were not performed.

### 3.2 Process evaluation

As shown in Figure 2, teachers in both the M4T and the AB group implemented the physical activities to a similar degree in both the 4th and the 5th grade, with the 4th grade to have a higher level of implementation. Excluding the days that school was not in session or the teacher was absent, implementation was about every other day for the 4th grade classes (~16 out of 30 days) and a little bit lower for the 5th grade classes (~12.5–14.3 days out of 30). A 2-way ANOVA showed no significant differences on implementation among groups,
grades or an interaction effect ($p > 0.41$). The average duration of the activities in minutes was 10.84 (SD = 2.24; range = 7.5–14.06) for the M4T group and 10.72 (SD = 2.64; range = 8.33–15.17) for the AB group, with no significant differences among groups ($t = 0.011$, $p = 0.919$).

4 | DISCUSSION

This study evaluated the effectiveness of the M4T integrated physical activity with mathematics programme on children's math performance, compared to activity breaks or traditional lessons. Results showed that integrating physical activity with math lessons, using the freely available and easy-to-use ‘Move for Thought’ kit, had a positive effect on math performance among 4th grade students. This effect was stronger for the M4T compared to the non-physically active traditional lessons, as well as activity breaks that had no connections to the subject being taught.

Confirming our hypotheses, the effects were the highest in the M4T group, involving physical activities related to the math curriculum, than the mere aerobic exercise breaks and control groups. This study is consistent with previous literature on the benefits of active learning, involving physically active lessons and activity breaks (chronic and acute effects$^{11}$; acute effects$^{12}$), active lessons (chronic and acute effects$^{13}$) or activity breaks (chronic and acute effects$^{14}$) on educational outcomes. Research comparing activity breaks related or unrelated to the curriculum has found improvements on math$^{16}$ and reading performance,$^{17}$ favouring the mere aerobic exercise group. The combined physical and cognitive benefits arising from integrating physical activity with learning have been previously confirmed.$^9,^{25}$

Another finding of this study is that the group that implementing only activity breaks had no changes on math performance, with effects similar to the control (non-active) group. It is possible that the dose or intensity of activity breaks was not enough to provoke larger effects on math performance. In our study, the average duration of the activities, as reported by the teachers, was about 10 min for both the M4T and the AB group, with no significant differences among groups. Considering that a measure of physical activity intensity was not included in this study, we cannot exclude that the M4T and AB groups may have had different intensities.

Previous studies examined different duration or intensity of acute physical activity on children's math performance. Using a within-subject design, Howie et al.$^{24}$ looked at the effects of a 5-, 10- and 20-min exercise, or a 10-min sedentary break on primary school children's executive function and math fluency. Higher math scores were observed after 10 and 20 min of acute exercise compared to the sedentary condition.

Of note, Masini et al.$^{14}$ found that the most common duration of activity breaks was between 3 and 15 min (ranging from 3 to 5 with maximum 20 min), which is consistent with the findings of our study. In addition, Chang et al.$^{27}$ found that acute exercise had the highest effects on cognitive outcomes between 11 and 20 min, smaller positive effects >20 min, and negative effects between 0 and 11 min. However, none of these meta-analyses explored the duration along with the different types of physical activity.

Research on the physiological mechanisms of physical activity suggests that physical fitness may elicit changes occurring in children's brain function that enhances their cognitive function.$^{28}$ This hypothesis cannot be confirmed in this study. Future research, using appropriate measures and validated tools, may disentangle the different underlying mechanisms of physical fitness, brain structure and math performance in school children.

Importantly, as a new method, there is need for additional evidence regarding the effectiveness as well as the dose-response effects of different types of classroom-based physical activity on academic performance. We attempted to contribute to this gap by identifying what type of activity breaks might be most beneficial (linked or not to academic content), instead of incorporating only a traditional sedentary usual practice. More research is needed related to the interaction of the type of physical activity in the classroom with the dose (intensity and duration) of the exercise.

Further, we investigated whether grade would moderate the relationship of different activity breaks on math performance. Subgroup analyses showed that the effects of grade were more evident in Grade 4, with the M4T group outperforming the AB and control groups. In contrast, in Grade 5 there were no significant differences on students’ math performance. The null results in Grade 5 can be explained by the fidelity implementation outcomes. Teacher daily logbooks showed that Grade 5 had lower implementation rates of both M4T and AB interventions compared to Grade 4.

These results are very important, as they present a real indication of how physical activity interventions are applied in real-world settings. M4T sessions were feasible and implemented about every other day throughout the week of the days school was in session (~54% of sessions). As such, to ensure pragmatic implementation, teachers were given no incentives on participation, allowing teachers to maintain their autonomy in their instructional practices in the classrooms, rather than limiting them to follow a regimented experimental protocol. In fact, a recent systematic review concluded that half (out of 72 assessed) of the studies on active learning conducted in elementary schools were researcher-driven.$^8$ In addition, there was a clear lack of reporting fidelity during delivery, undermining the sustainability of movement integration as a routine practice by classroom teachers.

Possible reasons for the discrepancies in implementing the M4T and AB across grades could be the extra commitments and pressure to complete the recommended syllabus included in the older year range. Indeed, teachers report lack of time due to the crowded curriculum as the most common reason for the limited physical activity opportunities during the school day.$^{29}$ Alternatively, classroom teachers’ own perceptions about physical activity are determinant of the physical activity promotion in the classroom.$^7,^{30}$

Concluding, apart from the novel design of this study with a clear emphasis on implementation, limitations include the non-randomised design and the absence of an objectively measured dose of the
exercise for both intervention groups. Furthermore, since a convenient sample was used, with teachers knowing that they were part of the experimental group, teachers’ expectancy effect might have occurred. However, the math test was administered and marked by research assistants to eliminate teacher involvement and potential bias.

Lastly, although a daily teacher log was used to assess intervention fidelity, we acknowledge that multiple methods should be used for process evaluation, including random observations with valid instruments. Nevertheless, this study demonstrated that physical activities that are integrated with academic content are more beneficial for students’ mathematics performance, compared to activity breaks and mathematics lessons. However, these effects were apparent only in Grade 4 that also had higher implementation. Future research needs to further investigate the different types of classroom-based physical activity interventions, and tailor them to address specific individual characteristics, such as age, gender and learning style, as well as dose of exercise. Lastly, these interventions need to target classrooms where academic pressure is highest for teachers (e.g., 5th grade).

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CONFLICT OF INTEREST
The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS
MM drafted the manuscript, performed analyses and interpretation of the results. SV contributed in all steps of the study (conceptualisation, methodology, supervision, analysis and writing).

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