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Examining a teacher-led physically active mathematics intervention: teachers' perceptions of the facilitators and barriers to implementation in UK primary schools

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Introduction: This study aimed to address a gap in the literature by examining Key Stage One teachers' perceptions of the facilitators and barriers to implementing physically active mathematics lessons in UK primary schools after administering a physically active mathematics intervention for 6 weeks. Incorporating physical activity into academic lessons presents a unique approach to increasing physical activity among children without compromising the time allotted for academic lessons.

Methods: The intervention was designed in collaboration with the participants and the research team. The study employed a mixed methods approach, utilizing a parallel design in which 14 current key stage one teachers (men = 1, women = 13) participated. The participating teachers delivered 6 weeks of physically active mathematics lessons in their respective schools. Training (through two preparatory workshops), schemes of work, and equipment were provided to participants before the intervention began. Survey data were collected through pre- and post-intervention surveys and a weekly intervention delivery log. Participants engaged in individual semi-structured interviews post-intervention. Survey data were analyzed using descriptive statistical analysis.

Results: The combined average number of minutes participants could implement physically active mathematics lessons each week was 59 min. Paired samples t-tests revealed a significant increase in participants' confidence in delivering physically active mathematics lessons from pre-intervention ($M = 2.86$, $SD = 2.23$) to post-intervention ($M = 8.31$, $SD = 1.07$; $t(12) = -6.739$, $p < 0.001$). Interview data were transcribed *verbatim* and analyzed through thematic analysis. Several facilitators and barriers to implementing PALs were identified. Key facilitators identified in this study included training, availability of ready-to-use resources, and increased teacher confidence. Furthermore, physically active lessons (PALs) were easier to implement in contexts where play-based learning approaches from the early years foundations stage could naturally extend into subsequent years. However, key barriers included classroom management challenges, time constraints, and space limitations. Additionally, the specific timing of implementation posed challenges, with cold weather restricting outdoor activities and Christmas-related commitments detracting from the time available for PALs.

Discussion: This study highlights the feasibility of implementing physically active mathematics lessons into the curriculum of UK primary schools and provides key considerations for schools aiming to successfully implement these lessons to best aid the implementation of physically active mathematics lessons.

KEYWORDS

physically active lessons, pedagogy, children, education, physical activity

1 Introduction

Physical activity levels among children and young people are a cause for concern. Recent statistics indicate that for the 2022–2023 academic year, 53% of children and young people aged 5 to 16 years did not meet the Chief Medical Officer's guidelines of participating in 60 min or more of physical activity each day (Hollingsworth, 2023). Given the widely reported and accepted literature that highlights how living an active lifestyle during childhood not only lowers the risk of health complications—such as reducing the risk factors for cardiovascular disease and the development of type 2 diabetes (Lessiani et al., 2016)—but also improves various aspects of cognitive functioning and mental well-being (Zhang et al., 2023; Ganjeh et al., 2021), it is crucial to address these alarmingly low levels of physical activity. School-based physical activity interventions have been suggested as an effective way to enhance physical activity levels (Hills et al., 2015); however, prioritizing educational outcomes makes it challenging to find time within the school day to implement physical activity initiatives (Stylianou et al., 2016). Therefore, integrating physical activity into academic lessons has been proposed as a viable intervention to increase physical activity levels without compromising the time allocated for academic learning, often referred to as physically active lessons (PALs) (Bartholomew and Jowers, 2011).

PALs are teacher-led academic lessons that seek to integrate bursts of moderate to vigorous physical activity into the classroom while teaching academic content (Dunlosky et al., 2013). Recent literature has outlined a number of benefits of PALs. For example, participation in these lessons has been shown to significantly improve aerobic fitness (Vetter et al., 2020a,b) and gross motor skill development (locomotion and object control) compared to control groups (Magistro et al., 2022; Boat et al., 2022). Crucially, research has highlighted that engaging in PALs leads to lasting improvements in cognitive function. For instance, two studies conducted in Italy demonstrated enhancements in working memory, attention, and executive function after participating in 16 weeks (Boat et al., 2022) and 2 years (Magistro et al., 2022) of PALs compared to control groups. Furthermore, participation in PALs has been shown to enhance academic achievement. A 2-year longitudinal study found that pupils who participated in these lessons were 4 months ahead in learning gains when compared to a control group, with significantly greater improvements observed in a mathematics speed test, general mathematics ability, and spelling (Mullender-Wijnsma et al., 2016). This is further supported by studies reporting significant improvements in multiplication test scores (Vetter et al., 2020a,b) and time on task within the classroom (Mullender-Wijnsma et al., 2015; Sneek et al., 2023) after pupils engaged in PALs.

Despite these well-documented benefits highlighting a promising method of teaching to increase physical activity levels in children and young people, research examining PALs specifically within UK schools is limited, as indicated by recent systematic reviews and meta-analyses (Vetter et al., 2020a,b; Norris et al., 2020). The majority of studies conducted in the UK have sought to examine the impact of PALs on physical activity levels and academic outcomes (Bacon and Lord, 2021) or have explored these lessons alongside other

school-based physical activity initiatives, such as movement breaks (Routen et al., 2024). However, few studies have specifically investigated the feasibility of PALs within UK schools. Quarmby et al. (2019) conducted semi-structured interviews with UK primary school staff (teachers, headteachers, subject leads) and identified several key barriers to implementing PALs, including teacher confidence, concerns about pupil behavior, and classroom space and layout. Similarly, another study conducted focus groups with key stakeholders (teachers, researchers, and policymakers), revealing that teachers often lack the necessary resources to implement PALs effectively, such as ready-made lesson plans, equipment, additional time for lesson planning, and training on how to deliver these lessons efficiently (Daly-Smith et al., 2020). These barriers should be considered when designing and implementing future physically active lesson (PAL) interventions, focusing on ensuring that teachers feel adequately trained and confident in delivering the PAL intervention while also providing ready-made lesson plans that consider the available space and equipment in schools. While these studies offer valuable insights into potential barriers to the widespread implementation of PALs, the perceptions of key stakeholders are based on their expectations of a physically active learning intervention rather than their actual experiences administering this type of intervention. To date, no study has sought to examine teachers' perceptions of the barriers and facilitators to implementing PALs within UK schools after they have implemented a physically active learning intervention designed in collaboration with the teachers delivering it.

Therefore, the aims of the current study were twofold: (1) to design and implement a 6-week PAL intervention in Key Stage One (grades one and two) mathematics, collaborating with the participants (teachers) and considering previous research (e.g., Quarmby et al., 2019; Daly-Smith et al., 2020) to address barriers to successful implementation; (2) to assess the feasibility of implementing PALs in UK schools by exploring Key Stage One teachers' perceptions of the facilitators and barriers to active mathematics lessons after administering a 6-week physically active mathematics intervention.

2 Materials and methods

2.1 Design and participants

Considering the goals of the current study, a mixed methods approach using a parallel design was implemented. This was evident through the simultaneous collection and analysis of both quantitative and qualitative data before and after the implementation of the intervention. By collecting data in parallel, immediate insights into the effects of the intervention were captured, allowing each method to independently address different aspects of the research questions. This, in turn, facilitated a comprehensive understanding of the research problem by integrating exploratory and confirmatory elements, enhancing the overall impact and effectiveness of the intervention. A total of 14 current Key Stage One teachers from 12 different primary schools in the East Midlands area of the UK were recruited to participate in the study. No data were gathered from

pupils who took part in the PAL intervention. Participants (teachers) were recruited through opportunistic sampling and were required to give consent before participating in the study. Prior to the commencement of the study, ethical clearance was provided by a university ethics committee. Participants had varying degrees of teaching experience, ranging from less than 1 year to over 10 years as qualified teachers (see [Table 1](#)). Before the intervention began, participants attended two preparatory workshops.

2.2 Workshop one

During the first preparatory workshop, details regarding the 6-week intervention and the timeline for data collection were shared with the participants. They were required to complete a pre-intervention survey that included questions regarding personal information (e.g., name, teaching experience), relevant demographic details about their schools, and their existing knowledge and confidence in delivering PALs. The research team then provided an overview of PALs to the participants. Additionally, a practical example of a PAL activity, along with guidance for implementation, was provided. The example activity was “dice times tables.” In pairs, each pupil rolls a die and performs a physical activity (e.g., jump, star jump, and so on indicated on a card held by the class teacher) the number of times shown on the die. Pupils then add their two rolled numbers together and collaborate to multiply the total by a designated number (e.g., 5 or 10), performing the physical activity that many times. Finally, toward the end of the first workshop, participants were asked to describe their Mathematics curriculum design and lesson structures (e.g., how many lessons per week, duration of lessons, and so on), along with the topics they would be teaching in their Mathematics classes at their respective schools during the 6-week intervention. After completing the first workshop, the research team created a personalized activity pack for each participant, detailing PAL activities tailored to the topics they would be covering during the 6-week intervention period. The majority of the activities were designed to

be ‘classroom friendly,’ using exercises that require minimal space, such as star jumps or push-ups, instead of those needing more room (e.g., running). The PAL activities and resources were based on a 2-year PAL intervention previously conducted in Italy ([Magistro et al., 2022](#)) but adapted for the UK context.

2.3 Workshop two

During the second preparatory workshop, participants were provided with a brief recap of the program requirements, as well as the training and information from Workshop One. They were then given personalized activity packs and allotted time to review them, allowing them to familiarize themselves and provide input on any aspects of the activities that might need adjustments. Participants were also provided with their resource packs, which included all the necessary equipment for teachers to implement the intervention. This included mathematics flashcards for each activity and various materials, such as beanbags, small and large dice, 2D and 3D shapes, hula hoops, and counters. Each participant was assigned an intervention mentor, a designated member of the research team, and was informed that they could contact their mentor for guidance throughout the intervention. After completing the workshop, the research team made final revisions to the program activity packs based on participants’ feedback before sending both a digital and a physical copy to the participants’ schools.

2.4 Procedure

The 6-week intervention took place during the autumn term (6th November–15th December 2023). Participants were asked to implement bouts of physically active learning in their Mathematics lessons throughout the intervention. They were advised to aim for 2 h of physical activity in their Mathematics lessons each week. Participants had autonomy over how and when they implemented these bouts of physically active learning; however, it was recommended

TABLE 1 Participant characteristics.

Participant	Sex	Year group taught	Additional roles	Teaching experience (y)
1	Female	Year 1 and 2 mixed	Mental health lead, PSHE lead	10+
2	Female	Year 2	N/A	10+
3	Female	Year 1	RE lead, ECT tutor	10+
4	Male	Year 1 and 2 mixed	Maths lead, SLT	10+
5	Female	Year 1	Maths & phonics lead	6–9
6	Female	Year 2	PE coordinator	1–2
7	Female	Year 1	Science lead	3–5
8	Female	Year 1 and 2 mixed	SENCO, governor, key stage one lead, lead for RE, history, and reading	10+
9	Female	Year 2	PSHE lead	6–9
10	Female	Year 1	ECT tutor	6–9
11	Female	Year 1	N/A	~1
12	Female	Year 1	Phonics and early reading lead	1–2
13	Female	Year 1	N/A	~1
14	Female	Year 2	Geography and DT lead	6–9

that the optimal times for this were at the beginning and/or the end of the lessons, to be used for reflection and reinforcement or as feedback for the next lesson (Dunlosky et al., 2013; Boat et al., 2022; Magistro et al., 2022). Considering that this intervention is one of the first of its kind conducted within UK schools, both the intervention length (6 weeks) and the 2-h weekly target were chosen by balancing feasibility with intervention dosage. Participants were informed that the 2-h weekly target was advisory, not mandatory. At the end of each week, participants were required to complete a delivery log detailing how the delivery had gone that week, the activities used, and the minutes of physically active learning they were able to implement (see [Supplementary material 1](#)). They also had the opportunity to attend optional fortnightly check-in meetings with the research team on Microsoft Teams to discuss any queries or problems they encountered. Additionally, participants attended feedback sessions halfway through the intervention (two sessions were held due to participant availability) to discuss the challenges faced and share ideas for best practices. Upon completion of the 6-week intervention, participants completed a post-intervention survey assessing their perceptions of the physically active Mathematics lessons and the provided materials, training, and implementation throughout the intervention. Finally, individual semi-structured interviews with participants were conducted online via Microsoft Teams to discuss their in-depth perceptions of the intervention and the key facilitators and barriers to implementation (see [Supplementary material 2](#) for further information on the interview guide).

2.5 Data analysis

Survey data from pre- and post-intervention surveys and weekly delivery logs were transferred to Microsoft Excel, where descriptive statistical analyses and paired sample *t*-tests were conducted using IBM SPSS Statistics. Semi-structured interviews were transcribed *verbatim* and analyzed through thematic analysis (Braun and Clarke, 2006). Interview transcripts were systematically coded, with two authors independently identifying recurring themes and patterns, organizing them into key categories that reflect the participants' perspectives and experiences. In cases of disagreement between the two authors, a third author was consulted to reach a consensus, ensuring the accuracy and reliability of the identified themes.

3 Results

3.1 Survey data

Regarding adherence to the intervention, the average number of minutes spent in physically active Mathematics lessons delivered each week was as follows: Week one = 66, week two = 68, week three = 64, week four = 53, week five = 55, week 6 = 49 (see [Table 2](#)). The overall average number of minutes of PALs delivered each week throughout the 6-week intervention was 59 min. An improvement in the participants' perceptions of their knowledge of PALs was noted. With '1' representing excellent and '5' indicating insufficient, an average rating of 4.36 (SD = 1.11) was recorded pre-intervention, which improved to an average rating of 1.86 (SD = 0.52) post-intervention ($t(12) = 8.45, p < 0.001$). Similarly, there was a significant increase in the

TABLE 2 Average number of minutes spent in PALs each week.

Week	$M \pm SD$
One	66 \pm 24
Two	68 \pm 27
Three	64 \pm 30
Four	53 \pm 29
Five	55 \pm 29
Six	49 \pm 29

participants' confidence in using PALs between pre- and post-intervention ($t(12) = 6.74, p < 0.001$). Specifically, participants were asked, 'On a scale of 1–10, how confident are you with using PALs?' at both pre-intervention ($M = 2.86, SD = 2.23$) and post-intervention ($M = 8.31, SD = 1.07$).

3.2 Semi-structured interviews

To highlight the facilitators and barriers to the successful implementation of PALs in Key Stage One Mathematics, the following results are organized around key themes that emerged from the interview data obtained from teachers who administered the intervention, with supporting illustrative quotes provided. The themes have been divided into two categories: facilitators and barriers.

3.3 Facilitators

3.3.1 Ready-made resources

All participants highlighted that having ready-made resources significantly aided their ability to implement the intervention effectively. Specifically, they noted that the provision of ready-made schemes of work (PAL activities) helped limit any additional preparation time required to successfully run the intervention.

"And the fact that you did go away and provide us with the ideas for games and the resourcing. I mean, that's such a massive part, really. I think that would put a lot of people off, umm, doing it because obviously it's another element to the lesson that you've got to resource with something different, and if it's already there and provided for you and the idea is there, then that takes away that element of us needing to prepare, umm, so that was great." (Participant 2)

The majority of participants also expressed that being provided with all the necessary equipment to run the activities allowed them to implement the intervention more effectively. This enabled teachers to save preparation time by having access to all the equipment within their classrooms and allowed teachers whose schools may not own the required equipment to conduct all activities appropriately.

"The resources, the actual physical equipment you gave us that was good. So that was that was useful to have a big bag of that and have them in the classroom, umm, and they matched with the what the activities were." (Participant 4)

3.3.2 Adaptability

Participants described the freedom to adapt the intervention to best suit their classes as crucial for its effective conduct. This adaptability allowed teachers to adjust activities to target different learning outcomes or fit the specific needs and requirements of their individual classes. Participants specifically outlined how difficult it is not to adapt pre-made schemes of work due to the uniqueness of their pupils and classes.

“But I would say as an experienced teacher, I was adapting it all the time. I found it quite difficult almost to not do that and say no I need to do what it says on the piece of paper and evaluate that, not make it my own. But actually we did. In the end, we it was like, well, you know, that is part of it to adapt it. So we did.” (Participant 8)

3.3.3 Networking with other teachers

Collaboration with other teachers was perceived by the majority of participants to be beneficial in facilitating the implementation of PALs. Participants detailed that this enabled them to share ideas about best practices, as well as discuss specific challenges they faced in an attempt to foster solutions for smoother implementation.

“And I love the fact that there were other year one teachers that were following the same as me and got the same, It was nice to talk to people who had got the same concerns or the same challenges, and it made you feel like you were less alone and that you you were actually doing.” (Participant 12)

3.3.4 PAL experience

The majority of participants noted that as their experience delivering PALs grew, so did their proficiency in implementation. Participants specifically highlighted that the preparatory workshops delivered prior to the start of the intervention helped develop their knowledge and understanding of these lessons.

“Umm actually what it meant, because I didn't have a clue before I was like ohh yes, physically active. That's great. We'll do that, but actually what it meant in a classroom situation I've never done before. So I came away with like, ah, that is what it is.” (Participant 14)

All participants expressed that their confidence in delivering PALs increased after completing the 6-week intervention. Participant 4 stated, ‘Well, I think I'm more confident because I think I know what I'm trying to achieve. So yeah, I think I'm more confident.’ This confidence resulted in participants being more willing to independently implement PALs in the future.

The majority of participants highlighted that their pupils' experience of taking part in PALs facilitated smoother implementation. It was noted that the pupils' familiarity with the activities and the expectations of a PAL—which increased over the course of the 6-week period—led to reduced setup and preparation time, allowing pupils to better achieve learning outcomes.

“I think once they, it's been establishing the children understand the the you know the game or whatever activity we're doing, umm, then that becomes easier in itself because they can

self-access, umm, but no, I think I think it's been brilliant.” (Participant 11)

3.3.5 Support from SLT

Participants described receiving support from colleagues within the senior leadership team (SLT) as vital for their adherence to the PAL intervention. Members of the SLT were also crucial in the participants' initial involvement in the intervention, as they were the ones who suggested that their school take part.

“Yeah. So the maths lead is part of SLT and he was the one that initially wanted us to go forward for it. Umm, so he has, like, checked in with me, seeing how it's gone, umm, so there's been quite a lot of support from him.” (Participant 9)

3.3.6 Key stage one target population

A number of participants outlined how they felt that key stage one was an appropriate target population for implementing PALs. They suggested that implementing physically active learning in key stage one would be an appropriate continuation of a strong focus on play-based learning within reception (Early Years Foundation Stage; EYFS) and would aid in the transition to more formal learning.

“But I think it suits year one because they are moving from the EYFS where they have continuous provision. They don't have a structured activities and they're doing more formal learning and where they are sitting on the carpet a lot more. So having that break as well, umm, was really it was really beneficial to the children and it's supported that transition as well into more formal learning.” (Participant 13)

3.3.7 Impacts on pupils

All participants discussed the impact that participation in PALs had on their pupils and how these positive effects facilitated continued implementation. Specifically, all participants outlined how highly engaged their pupils were in the PALs and the high level of enjoyment they derived from them. This was particularly evident for the lower attainers, as it was detailed that pupils who usually struggle with Mathematics engagement were taking an active interest in the PALs.

“But the sessions that I did do were successful in making sure that all my learners were engaged. All my learners were having fun. None of my learners were suddenly wanting to go to the toilet, you know, which is kind of is a key indicator in year one of whether they want to be here, umm, and uh, yeah.” (Participant 7)

The majority of participants also suggested that participating in PALs had a positive impact on their pupils' behavior and concentration during formal seated learning.

“Yes, I would say so. If we do it at the start of the lesson, they are a lot calmer for the rest of the lesson. The problem is getting them to stop because they love it so much that you could leave the activity going on forever and ever and ever and they would just keep doing it.” (Participant 14)

Many participants highlighted the positive impact that they felt participation in PALs had on their pupil's mathematics learning. It was

suggested that all pupil's learning benefited from this; however, it was particularly beneficial for the lower attainers.

"Yeah, it definitely we did our, we do what I can end of block assessment and as a trust. So we're part of an, a, like a a trust with multi schools in the trust and all our data gets collected. So our data at the end of at the end of term, so in the December it all goes on to this thing called O Track and then our school improvement manager who works across the trusts, umm he then collates all that data and maths was really strong for us this this term, which was like the only thing that had changed was how much more physical maths we were doing so." (Participant 12)

3.4 Barriers

3.4.1 Time of year

All participants highlighted that the time of year when the intervention was implemented was a critical barrier to the integration of PALs. Participants commented on consistently poor weather conditions negatively impacting their ability to go outside for lessons. This resulted in schools with limited indoor space being unable to conduct some activities or requiring additional preparation time for activities to be adapted to fit the available space.

"And again, I suppose some of that as well comes down to the time of year. It was because obviously because it's blowing a gale out there, you can't, even though they're only going out for 10-15 minutes like I can't send them out without coating them up. So by the time, so that all eats into it, whereas again if I, and I will try some of these bits in the summer again, maybe if we can literally just run out, get on and run back in, that, that would probably take, shave some of the time off as well." (Participant 5)

The majority of participants also commented that the intervention taking place over the Christmas period led to time being taken away from Mathematics lessons to focus instead on preparation for Christmas activities, such as Nativity plays and Christmas carol concerts.

"I think it got harder because of the actual time of year when it was and they (unintelligible) disruptions that happened, umm, and it was Christmas and there was all sorts of other things going on and it wasn't just that, it became hard to fit everything in." (Participant 3)

3.4.2 Space limitations

Several participants detailed how having access to limited indoor space resulted in various activities not being able to be conducted. This led to adapting activities so they could be performed within the classroom space, resulting in less physical activity due to health and safety concerns.

"Well, we're not doing that in the classroom cause basically it's just children tripping over chairs and they they couldn't move that moving around the classroom to do something just wasn't wasn't gonna work in in, in our rooms, which are it is, is quite

an old classroom and it's quite tight, umm, space wise." (Participant 4)

3.4.3 Classroom management

All participants highlighted that difficulties in class management resulted in a more challenging implementation of PALs. For example, the availability of staff, such as a teaching assistant, was significant in effectively managing the classes during a PAL. This support allowed teachers to monitor pupils more closely or split the class into two smaller groups. Participants noted that implementation became much more challenging when they had to manage their classes alone, without the support of a teaching assistant.

"So I would find it much harder without her because I can split the class in half the different year groups, which means you've got 15 children doing the activity. We have, obviously, you know there are days where one of us hasn't been there, of course, and you've got the whole class. That's very different in terms of outcomes, I would say." (Participant 8)

Participants specifically highlighted that large class sizes contributed to their difficulties in class management, making the PALs less effective. Participant 6 explained, "So I think the sessions had to be kept quite short because of that, so maybe they were not as effective as they could have been if we had smaller class sizes."

Challenges in differentiating activities for varying levels of academic ability were discussed as a potential barrier to implementation. It is crucial that higher attainers are appropriately challenged while lower attainers can access the activities.

"I think the biggest challenge is was was was match making sure every child was was actively engaged in every lesson because some of them couldn't do the maths or some of them It was too easy, so it it was just getting that the differentiation right." (Participant 4)

3.4.4 Time constraints

Participants highlighted that constraints on available time for PALs, due to inconsistent school timetabling, resulted in some sessions being cut short or not implemented at all. It was discussed that on days when the timetable was full, PALs were the first to be cut.

"Umm yeah, I would. I just think, just consistencies like some weeks that there wasn't, their timetable wasn't as jam packed so we could get more done, but then probably the next week it wasn't as flexible, so we really struggled to get everything and fit those times in as well." (Participant 13)

3.4.5 Pupil inactivity

Concerns over pupils not being physically active at all times during the active lessons were raised by several participants. It was noted that 'turn-taking,' due to either the type of activity or large class sizes, resulted in pupils not always obtaining the maximum benefits from the sessions.

"So we we don't like it if you you have an activity where there's you know, you know, ten children in a row then doing 1 jump on a leap or whatever and the rest of the other nine are just watching. So we want everyone to be active most of the time." (Participant 14)

4 Discussion

This study is the first to examine teachers' perceptions of the facilitators and barriers to implementing PALs in UK primary schools, following a physically active mathematics intervention developed in collaboration with the teachers. The study successfully identified several key facilitators and barriers to implementing PALs. Key facilitators included training, access to ready-made resources, adaptability, networking with other teachers, support from SLT, experience with PALs, positive impacts on pupils, targeting Key Stage 1 (KS1) for implementation, and teacher confidence. In contrast, key barriers included the time of year for implementation, classroom management, time constraints, pupil inactivity, and space limitations. Recognizing these facilitators and barriers can lead to recommendations for the design, development, and implementation of future PAL interventions in UK primary schools.

Adherence to the intervention was demonstrated through the weekly recording of the number of minutes of PALs delivered by each participant. Although the combined average of 59 min per week across the 6-week intervention fell short of the recommended target of 120 min per week, this can be partly attributed to the fact that, as the intervention approached Christmas, the majority of participants had to sacrifice time allotted for mathematics lessons to rehearse for Nativity performances and Christmas carol concerts, as highlighted during the semi-structured interviews. Nevertheless, an additional hour of physical activity each week is significant for increasing children's physical activity levels toward the recommended 60 min of moderate-vigorous physical activity per day (World Health Organization, 2020). Considering that 30 out of the 60-min daily target should be achieved in school, PALs make a positive contribution to this goal without detracting from curriculum time. Participants' knowledge of PALs, along with their confidence in delivering these lessons, increased from the start to the completion of the intervention. This indicates that the training provided prior to the intervention, along with effective management, successfully enhanced participants' proficiency in utilizing physically active mathematics lessons, an aspect previously identified as a barrier to their adoption (Daly-Smith et al., 2020). Furthermore, the training was recognized as a key facilitator for implementing PALs in primary schools; thus, future interventions should integrate this essential training component for staff.

This study identified several key facilitators for implementing PALs. One key facilitator highlighted by all participants was the provision of ready-made schemes of work (activity cards) and the supply of necessary equipment, in addition to the aforementioned teacher training. The availability of these ready-made resources reduced planning and preparation time for teachers, facilitating a smoother implementation of physically active mathematics lessons. These findings strongly support the observations made by Daly-Smith et al. (2020) and Quarmby et al. (2019) regarding previously identified barriers. Therefore, future interventions for PALs should ensure that ready-made resources are accessible to teachers, minimizing planning time and ultimately enhancing adherence to and success of the intervention.

Building on these previous findings, the current study has identified several new facilitators for successful implementation. First, Key Stage One was highlighted as an ideal target for implementing PALs due to the strong emphasis on play-based

learning in the Early Years Foundation Stage (EYFS). This aligns with prior research in education and pedagogy, which argues that a significant change in the curriculum between EYFS and Key Stage One is not developmentally justified (Fisher, 2011). Therefore, implementing physically active mathematics lessons at this age could facilitate a smoother transition to more formal learning in Key Stage One. Second, this study is the first to observe a steady increase in confidence and proficiency in administering physically active mathematics lessons throughout the intervention. Given that Quarmby et al. (2019) identified a lack of confidence among teachers as a significant barrier to adopting PALs, the current study highlights a need for adequate training, possibly facilitated through online training resources, as well as patience during the initial implementation of these lessons. Both factors are essential for successful implementation and long-term adoption.

Some key barriers to implementing physically active mathematics lessons include a lack of available space for activities and difficulties in classroom management. These barriers have been highlighted in previous research (e.g., Daly-Smith et al., 2020; Quarmby et al., 2019; Sneek et al., 2023). While this study attempted to ensure that many PAL activities were 'classroom friendly' by using activities that require stationary exercise, such as star jumps, this approach was not possible for all activities. Therefore, further research and refinement of PAL activities are required to fully address the challenges of implementing indoor PALs. A significant finding of the current study was that the timing of the intervention was a crucial factor affecting the implementation of physically active mathematics lessons. This situation was dual-faceted. First, since the intervention took place in November and December, as it approached Christmas, much of the time that could have been allocated to physically active mathematics lessons was instead sacrificed for Christmas commitments, such as Nativity rehearsals. This was reflected in a 30% decrease in minutes allocated between week 1 and week 6, resulting in fewer minutes recorded on the delivery log in the later weeks of the intervention. This challenge is not unique to PALs; it applies across the school curriculum. Therefore, future interventions should be mindful of this when planning implementations during this time. Second, due to regular poor weather throughout the intervention, many teachers struggled to conduct physically active mathematics lessons outside. Considering that a lack of available space was also identified as a barrier, this inability to go outside regularly led to many activities either not being conducted or requiring considerable adaptation, which added further preparation time for teachers. This aspect has been recognized as a significant barrier in previous work (Daly-Smith et al., 2020; Riley et al., 2021). Future PAL interventions should consider the potential impact on fidelity when implementing them in the autumn and winter months.

While this study reports on a successful intervention involving physically active mathematics lessons and highlights key facilitators and barriers to future implementation, it is not without limitations. For example, the intervention lasted only 6 weeks, so factors affecting implementation across an entire academic year require further investigation. Specifically, since the time of year when the current intervention was implemented was identified as a barrier, it would be wise to examine whether conducting PALs in the spring and summer months leads to smoother implementation. Additionally, including a control group could have strengthened the validity of the results by providing a baseline against which the intervention could be measured more

rigorously. Moreover, this study did not consider the perceptions of the pupils participating in the PALs, such as their views on enjoyment, engagement, exercise intensity, and whether they believe the lessons benefit their mathematics learning. Therefore, future studies should aim to conduct focus groups with pupils who have participated in a PAL intervention to assess whether they feel it positively impacts physical fitness, well-being, and education. Finally, the present study relied heavily on self-report measures, which could have led to inaccuracies in reporting data, such as the number of minutes of physically active mathematics lessons that participants implemented each week. Future studies should attempt to implement more objective measures when exploring the feasibility and efficacy of implementing PALs.

5 Conclusion

The findings from the current study highlight that the implementation of physically active mathematics lessons in UK primary schools is feasible. The study also examines teachers' perceptions after they delivered these active lessons during an intervention, identifying key facilitators (training, access to ready-made resources, targeting KS1 for implementation, and teacher confidence) and barriers (timing of implementation, classroom management, time constraints, and space limitations). Furthermore, this study presents novel findings by identifying factors, such as the time of year and the target age group, that may affect the implementation of PALs, which have not been previously reported. This contribution aims to help design a feasible and accepted model of PALs for UK primary schools. Finally, the study outlines avenues for future research, particularly the need to examine the feasibility of implementing PALs over longer periods and to explore the perceptions of the pupils participating in such interventions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Nottingham Trent University Human Invasive Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants.

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NW: Data curation, Formal analysis, Investigation, Project administration, Resources, Writing – original draft. SC: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. KD: Conceptualization, Methodology, Supervision, Writing – review & editing. DM: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. RB: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2025.1569479/full#supplementary-material>

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