Effects of Maths on the Move on Children's Perspectives, Physical Activity, and Maths Performance

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Morris, J.L.[1,2], Archbold, V.S.J. [2], Bond, S.J.[2] & Daly-Smith, A.[3, 4, 5]

1. Centre for Society and Mental Health, Department of Health Service and Population Research, Institute of Psychiatry, Psychology & Neuroscience, King's College London, London, UK.

2 Centre of Active Lifestyles, Carnegie School of Sport, Leeds Beckett University, Leeds, UK

3 Faculty of Health, University of Bradford, Bradford, UK.

4 Wolfson Centre for Applied Health Research, Bradford, UK.

5 Faculty of Education, Arts and Sports, Western Norway University of Applied Sciences, Norway.

Corresponding Author:

Dr Jade Lynne Morris

Room 0.11 Virginia Woolf Building, Centre for Society and Mental Health,

King's College London, 22 Kingsway, London,

WC2B 6LE, UK.

Jade.Morris@kcl.ac.uk

ORCID 0000-0003-1900-3001

Abstract

Purpose: To assess the impact of a six-week 'Maths on the Move' (MOTM) physically active learning programme on primary school children's physical activity (PA) levels and maths performance.

Method: Randomised control trial. Year 5 children's PA was assessed using accelerometry for five consecutive school days at baseline and during the final intervention week (final sample: *n*=97, age M=9.61±0.29, 52.6% female). Two maths performance tests were used; one assessing mathematical content taught during MOTM and one assessing math's fluency (MASSAT). Both tests were conducted at baseline and following the intervention (week seven). Focus groups were conducted in week seven with intervention children (*n*=12), randomly choosing an even split of children classified with pre-intervention low or high PA levels.

Results: On average, during a typical 45-49 minutes MOTM lesson, children obtained an additional five minutes of moderate-to-vigorous PA and 5.7 minutes of light PA counteracted by a reduction of 9.5 minutes of time spent sedentary compared to children that remained in the classroom (control condition). The maths attainment test performance significantly improved over time for children in the MOTM compared to the control (+6.1 versus +0.9, $p \leq 0.0001$, d=1.507). No significant improvements were found in the MASSAT total score.

Seven emerging themes were derived from the child focus groups. Children felt the MOTM sessions resulted in social and environmental improvements, which improved learning during the sessions. Children described the MOTM sessions as enjoyable, fun, engaging and invigorating – resulting in positive associations to learning and activity.

Conclusion: Collectively, the findings identify the MOTM programme improves pupil's PA levels, academic outcomes and identifies pupil's willingness, enjoyment, and engagement.

Key words:

1. Academic performance
2. Primary school children
3. Elementary school
4. Physically active learning
5. Moderate-to-vigorous physical activity

Children’s Perspectives and Performance on MOTM

Introduction

Moderate-to-vigorous physical activity (MVPA) levels in children are at an all-time low (1, 2). In response, the UK government's Primary Physical Education (P.E.) and Sport Premium fund (~£320million) supports primary schools to provide 30-minutes of in-school MVPA for all pupils (3, 4). Yet, challenges persist with schools receiving little evidence-based guidance on how best to allocate resources. One approach to increasing MVPA that is gaining traction through practice and research alike, is physically active learning, the integration of movement within academic lessons (5-7). In the recent Creating Active Schools Framework (CAS), PAL was highlighted as a premium opportunity for increasing MVPA due to the expansion of MVPA into a traditionally highly sedentary segments of the school day (8-10).

Recent systematic reviews and meta-analyses support the positive impact of PAL on MVPA and subsequently, enhanced time-on-task (11), yet findings on academic performance are often varied and lack consensus (12). Thus, empirical research has yet to sufficiently demonstrate the efficacy of PAL lessons in improving pupils' learning (6, 11).

To advance the evidence base on the effects of PAL, there is a need to move beyond studies which assess the reinforcement of previously learnt concepts (13), to understand the potential effects of PAL in regard to learning new academic content (12). With reference to math's, PAL has shown beneficial effects in both acute and chronic studies of varied durations (14-16). While qualitative studies on teachers often highlight perceived pupil enjoyment and engagement (17, 18), there is a limited understanding of the children's perspectives of PAL engagement. Studies that have explored the perspectives of primary school children engaging in PAL interventions have focused on specific interventions such as virtual field trips (19) or an outdoor learning programme (20). Both interventions are quite distant from the Maths on the Move (MOTM) programme, highlighting the gap in the evidence base for exploring pupil's perspectives when engaging in a physically active maths programme. Furthermore, drawing

upon a mixed-methods approach may help highlight potential mechanisms behind improvements in learning following PAL implementation.

This study progresses our understanding by assessing the impact of PAL to deliver a specifically defined scheme of work on numeracy. This provides a step-change in the focus of PAL, shifting towards assessments of specific academic outcomes. Therefore, this study will aim to (i) assess the impact of a six-week PAL, MOTM programme on children's PA levels and maths performance, and (ii) explore children's perspectives over the MOTM programme.

Method

Recruitment and Participants

Four two-form entry schools in Birmingham (UK) were recruited into a randomised controlled trial using a between-subjects design, with randomisation at the class level. Recruited schools had previously signed up to receive the free six-week Aspire Maths on the Move (MOTM) programme (https://www.aspire-sports.co.uk/programme/maths-move). Following headteacher consent, 225 Year Five children were invited to take part; however, one school withdrew due to poor recruitment (2/56). Across three schools, parental consent and child assent was obtained (N=140, MOTM n=76; Control n=64). Ethical approval was obtained by Leeds Beckett University Ethics Committee (Ref:60567).

Protocol

Data collection took place between September-to-December 2019. Aspire programme leads were trained by the lead researcher (JLM) to support data collection. On day one (Monday) children's' height was measured, after which they completed a familiarisation of the Maths Addition and Subtractions, Speed and Accuracy Test (MASSAT) and were fitted with accelerometers. Instructions were given to children (and teachers) to ensure the accelerometers were taken off before leaving the school and put back on the following morning

upon arrival. One week later, accelerometers were returned, and children completed the baseline MASSAT (21) and then the maths attainment test (MAT) in the classroom following morning registration. After this, the MOTM programme commenced and lasted for a duration of six weeks. During the final delivery week, children were re-fitted with accelerometers. The following Monday, children completed the post MASSAT and MAT after morning registration. Next, children in the MOTM classes (*n*=76) were asked to express their own thoughts and opinions on MOTM using a write and draw activity (22), expressing; (i) 'what you do in a typical maths lesson', (ii) 'how you feel during a typical maths lesson', (iii) 'what you do in a MOTM lesson' and (iv) 'how you feel during a MOTM lesson'. Finally, following a categorisation of children into high-active (>30 mins MVPA) and low-active (<30 mins MVPA) based on pre-intervention data, four children per MOTM class (two high-active, two low active, N=12) were randomly selected (www.random.org) for three school-based focus groups.

Experimental Condition

The MOTM intervention has been designed to offer primary schools additional support to enhance maths outcomes. As aforementioned, primary schools within the UK are given Primary P.E. and Sport Premium funding from the government (3, 4) to support increases in MVPA levels. Resultantly, interventions such as the MOTM can be sought to increase physical activity levels while also contributing to educational outcomes.

Children in the MOTM intervention engaged in one ~50-minute lesson each week for six weeks. Adhering to Aspire's typical learning approach, the class was split into two groups. (~n=15 children per group) and taken into a hall to complete the lessons. The qualified teacher from Aspire taught the MOTM lessons to both groups, one after the other. The MOTM programme followed a standardised lesson structure, with each lesson using a specific numeracy objective from the UK Year Five National Curriculum. The final lesson recapped all objectives. Objectives included: (i) problem solving with numbers up to three decimal places, (ii) identify, name and write equivalent fractions of a given fraction, represented visually,

including tenths and hundredths, (iii) read and write decimal numbers as fractions, (iv) multiply proper fractions and mixed numbers by whole numbers, supported by materials and diagrams, (v) recognise mixed numbers and improper fractions and convert from one form to the other. Refer to Supplemental Digital Content 1 for the instructor notes for an example activity from a lesson and Supplemental Digital Content 2 for an example page from the workbooks pupils use during the MOTM lessons. The curricular content was combined with a range of multi-skills physical activities and challenges to create the game-based lessons. Children in the MOTM group had a workbook to facilitate the completion of the activities within the MOTM lessons. The Aspire instructor confirmed all six lessons were completed across the six groups within the three classes that took part in the MOTM programme. Children in the control condition and continued with usual maths provisions, focusing on the same learning objectives.

Outcomes Variables

Physical Activity

Physical activity was assessed during school-time for five consecutive days using waist worn accelerometers (right hip; combination of GT1, GT3x, GT3x+, wGT3X+ and GT9; ActiGraph, Pensacola, FL). Children wore the same monitor at both pre and post timepoints. High levels of compatibility between models has previously been demonstrated (23, 24). Data were collected in 15-second epochs, using Evenson (25) cut-points for sedentary time, light PA and MVPA.

Data were downloaded using ActiLife (v.6, Pensacola, FL, USA) and analysed in KineSoft (v3.3.75, KineSoft, Loughborough, UK). Non-wear time was identified by a period of ≥60 minutes of zeros which allowed for a period of 2-minute non-wear time, with a total duration of these blocks representing non-wear time. Valid wear criteria was ≥3 school days (26) with a

wear time of ≥300 minutes per school day. School timetables were used to explore activity thresholds across school day segments (e.g., MOTM lessons).

Maths Performance

Maths fluency was assessed using the MASSAT (100% construct validity; four-day test-retest reliability (r=0. 85); replicating a previous protocol (21). Outcomes included correct answers, errors, and a total score (correct minus errors). The 25 question (30 minutes) MAT assessed the MOTM learning objectives. The questions were age-appropriate and aligned to the English national curriculum (27). Two versions of the MASSAT and MAT were used to enable a random counterbalanced approach to eliminate order effects. The Aspire team ensured test version difficulty was matched by (i) duplicating each question, (ii) changing the numbers within the questions, and (iii) ensuring that the level of challenge was maintained (see Supplemental Digital Content 3 for an example). While the MAT is in line with similar, school-based studies (28, 29), the results should be interpreted with caution. The MAT is not a research grade test, and does not come with validity and reliability assessments, however, some issues were dealt with by counterbalancing the order of the tests.

Biological Maturity

Biological maturity (offset maturity) was established using the standing height simplified equations for age from peak height velocity for boys and girls (30).

Focus Groups

Focus groups were conducted in a quiet school space, lasting 22 to 32 minutes. Children used their write and draw activity to explore their perceptions and experiences of the MOTM programme compared to their usual maths lessons.

Statistical Analysis

Data analysis was conducted in RStudio (v.1.2.5033). To estimate the effect of MOTM on maths performance over time (continuous variable: MAT total score; MASSAT correct responses, errors, and total score), a series of two-level regression models were conducted, controlling for offset maturity. Models allowed for nesting of measurement occasions (level 1), within pupils (level 2) and random slopes for the time.

Qualitative Data Analysis

Focus groups were transcribed verbatim before two authors (JLM and SJB) analysed the data using Braun and Clarke (31) thematic analysis methodology. Inductive coding removed restrictions on coding in line with a prior framework (32). Reviewing and re-defining the themes (JLM, SBJ and VSJA) helped ensure clear definitions and names were produced for each theme (31).

Quantitative Results

Ninety-seven children provided complete data (age *M*=9.61±0.29, 52.6% female) and are included in all subsequent analysis (Figure 1, consort flow diagram; Table 1, baseline characteristics).

Physical Activity Levels

Table 2 highlights the number of minutes spent in each activity threshold during the school day. Based on the number of daily minutes varying, the percentage of time spent in activity threshold were calculated and used for analyses. There was a significant interaction between time and condition for the percentage of time spent in school-based MVPA (*b*=1.49, SE=0.70, 95% CI: 0.13, 2.86, *p*=0.036, *d*=458); This was due to higher levels of MVPA during week six of the MOTM condition (*b*=1.79, SE=0.82, 95% CI: 0.20, 3.38, *p*=0.031, *d*=2.12). There were no significant interactions in LPA (*p*=0.177, *d*=0.289) or sedentary time (*p*=0.106, *d*=0.348).

Fifty-nine percent of children achieved the 30-minute in-school MVPA guideline on the MOTM day compared to 34% on a non-MOTM day, showing a 28% increase. Children were significantly more active in MOTM lessons compared to control traditional lessons, with children accumulating five mins additional MVPA (*M*=6.4±3.6 minutes, *M*=1.4±2.1 minutes, retrospectively, *p*<0.0001), 5.7 minutes additional LPA (*M*=19.8±5.2, *M*=14.1±7.7 minutes, retrospectively, *p*=0.0002) and reducing sedentary time by 9.5 minutes (*M*=18.0±7.5, *M*=27.5±9.9, *p*<0.0001).

Maths Performance

Maths Attainment Test

With a greater performance improvement for children in the MOTM condition compared to the control (+6.7 versus +0.9, retrospectively), there was a significant interaction between time

and condition for maths test scores (*b*=5.85, SE=0.81, 95% CI: 4.26, 7.43, p≤0.0001, d=1.507). On closer inspection this was due to a larger significant effect over time in the MOTM condition (b=6.99, SE=0.67, 95% CI: 5.66, 8.31, p≤0.0001, d=1.480) in comparison to the control condition (*b*=1.14, SE=0.42, 95% CI: 0.31, 1.97, *p*=0.010, *d*=0.426). There was also a significant difference between the post maths test scores between conditions (*b*=7.09, SE=1.12, 95% CI: 4.91, 9.26, *p*≤0.0001, *d*=1.301).

Maths Addition and Subtraction, Speed and Accuracy Test

Baseline and post scores for the MASSAT can be found in Table 3, revealing no significant interactions between time and condition for MASSAT correct responses (*p*=0.288, *d*=0.227) or total score (*p*=0.261, *d*=0.237). For the total errors made, there was a significant interaction between time and condition (*b*=3.02, SE=0.83, 95%: 1.40, 4.65, *p*=0.0005, *d*=0.801). This was due to a significant decrease in the number of errors made over time for the control condition (*p*=0.004, *d*=0.081) and a significant difference between the condition in the baseline scores (*p*=0.004, *d*=0.633).

Qualitative Results

Analysis of the focus groups transcripts revealed seven key themes: (i) facilitating learning, (ii) building confidence in maths and PA, (iii) fostering cooperation and competitiveness, (iv) environmental modifications, transforming learning, (v) welcoming cognitive and physical challenges, (vi) inclusion improving fitness, (vii) positive feelings towards MOTM.

Facilitated learning

Many of the children discussed the role that MOTM played in *improving their own learning*. For example, Rafie suggested MOTM offers three benefits: enhanced learning, increased engagement in PA and teamwork: *"So, I think the first one, number one rule is based on getting*

smarter, number two is getting smarter whilst getting active and number three is getting along with partners I think that's what it means."

Another child felt MOTM helped improve their maths, learning in a different way: *"I've learnt like a different way to work things out." Matteo.* Children also touched on the structure of MOTM lessons, suggesting the integration of movement and teaching enhanced their learning:

> *"We do maths at the same time and we kind of do the same ways of learning [to] what we do in P.E. instead... we learn maths in this way…. it's like maths and P.E." Aisha*

Building confidence in maths and physical activity

Children expressed newfound confidence during MOTM, which was transferred back into the classroom. For example, some children felt more confident putting their hand up in class:

> *"I want to say like… kind of boosts up my confidence because some of [the] questions I don't know, and I never used to put my hand up, but some things I know now, and I can put my hand up in class then." – Aisha*

Fostering cooperation and competitiveness

Within this theme there were two sub-themes: (i) *teamwork and social support,* and (ii) *healthy competition*. In the first sub-theme, children explained how they worked together, and in some instances helped one another learn something new.

> *"We had to work as a team because you had to tell everybody like… you can write this, and then you had to… I mean you had to like interact with other people to know what they got." – Laila*

Through the use of mixed groups, MOTM promoted interaction with new children which, in turn, increased the inclusivity of the session. Sabir highlighted this nicely: *"I like it because some people don't have any friends in their group, where it's better just mixed because you*

get to interact with other people." These comments highlighted the importance of changing the social environment to support new social interactions and collaborations.

In the second sub-theme, children felt MOTM encouraged healthy competition between peers. In some of the activities, they were racing against each other to win against another team, as described by Aisha: *"It makes me feel competitive because… to me, it feels like we're racing, whoever can find all the emojis first."*

Environmental modifications transforming learning

Children identified that working in half classes (~15 children) had positively affected the learning environment. Smaller numbers promoted group cohesion, resulting in a more fun and enjoyable session. Some children felt if the whole class were together, it would be too loud and chaotic. Moreover, children suggested that the disruptive behaviour of some children could negatively impact the learning experience.

> *"These boys [in our class].. they're always being silly and [one of them is] always rocking on his chair or walking across while we're supposed to be sitting down. And he kind of ruins [the] fun because half the lesson is basically him being told off and his friends, because they're either talking or being silly." Sana*

Welcoming the cognitive challenge

Children suggested seated, traditional maths lessons were quite boring, repetitive, and lacked sufficient challenge:

> *"I have one simple sentence... like watching paint dry." Eva*

> *"Sometimes it's not much fun because it's basically just writing sums... Sometimes I'm excited if we get to learn something new, and it's sometimes boring and it's too easy and it's challenging, and I have different feelings depending on my mood." Sana*

Children wanted to be challenged and felt the MOTM lessons offered that. For example, Aisha said: *"When they challenge us it's better though… you can push yourself to, like, if you think that you don't know that and if you do it you'll be able to like gain more."* However, other children wanted more challenges, with more progressions to keep everyone engaged:

> *"All I want is for maths on the move to be more challenging…… I like the extensions' part, they're nice…… In the booklet, yeah, once you did like the post… once you used the postings because they're extensions, and they're way harder, only some people did it." Matteo*

Inclusion improving fitness

The MOTM sessions offer an inclusive approach to getting all children involved in PA. Contrary to P.E., where some children felt left out due to "not being good enough", MOTM prevented isolation from occurring and was inclusive for all.

> *"Sometimes I just don't like it [sport] because some people are… like, don't include other people who aren't that good in games." – Sabir*

Another child felt that improving their fitness provided a coping mechanism for emotion in response to bullying:

> *"Maths on the Move helps you stretch your muscles, and you can get more physical so you can actually cope with people bullying you as well. It helps with bullying as well and it helps you with your emotions as well." Rafie*

Positive feelings towards MOTM

Children reported immediate and longer term, positive feelings towards participating in MOTM. Children often described feeling happy, excited, and having fun. This was typically due to the games they played to learn and solve maths problems:

> *"I drew a picture of me with a big grin on my face because I'm happy, I also drew me running, and I also drew stick men dancing and having fun because that's what it was like, we had fun." – Zia*

In addition, some children associated enjoyment levels with their ability to learn new things. Laila described this nicely: *"I wrote here that I feel really excited. It's the most funnest lesson I do in school, and I learn new things, and I feel happy."*

Children also emphasised how they didn't want the sessions to end; feeling sad that they would not receive any more sessions. For example: *"The sad thing is that it is ending." – Rafie.* Other children saw the benefits of MOTM not just in the short term, but looking forward and in helping their grades, and even helping them towards a better future.

> *"If it continues [MOTM] it will help us learn more Maths, it would help us generate even better grades, and soon we also get a better future as well." – Rafie*

Discussion

The dual aims of the current study were to assess the impact of a six-week MOTM programme on children's PA levels and maths performance, and to explore children's perspectives of the MOTM programme. The MOTM programme increased MVPA levels, securing an additional five minutes in comparison to traditionally seated math's lessons, equating to one sixth of the in-school daily MVPA guidelines. Furthermore, the proportion of children achieving the guidelines increased by 28% on MOTM days. While no change was observed in math fluency scores, the MOTM programme resulted in large positive and significant effects on math performance - assessed by the MAT. Children perceived that MOTM facilitated improvements in learning and building confidence in maths and PA. The engaging social and physical environment within MOTM sessions helped foster learning and encourage new social dynamics within the class. Consistently, children highlighted that engaging in MOTM resulted in a range of positive feelings: building confidence, having fun, working with peers, and encouraging healthy competition.

In agreement with previous PAL research, the MOTM programme significantly improved levels of MVPA (33, 34). Specifically, the five additional minutes of MVPA resulted in an additional

30% of children meeting the in-school MVPA guidelines of 30-minutes a day. Such findings expand the research understanding of PAL, confirming that when teaching new academic content, the MOTM lessons made a substantial contribution to pupils' in-school MVPA levels. These outcomes are of great importance; lessons involving maths and English have recently been deemed the most inactive period of a child's day (8).

Similar to previous studies on the impact of PAL on learning performance (e.g., 14), the current study observed large effects on the number of correct answers in the MAT. The findings support other maths-based PAL interventions that found improvements in maths performance when taking part in active maths lessons compared to a control condition (16). The improvements in the MAT may be due to a combination of the MOTM programme consisting of smaller teaching groups, a workbook and physically active delivery. Further research is warranted to understand the impact of each element. However, these results support the use of PAL to teach new academic material and move beyond the heavy focus on repetition of previously learnt material. However, no improvements were observed within maths fluency, unlike studies that showed performance immediately following an acute bout of walking/ running (e.g., 21). These findings may be explained by the lack of a PA immediately prior to the testing and/or the short- duration of the MOTM program being insufficient to lead to chronic adaptations seen in longer-term studies. Further studies are required to confirm these assumptions.

In agreement with previous PAL studies, pupils perceived that the MOTM lesson revealed a richer learning experience compared to classroom lessons (35, 36). Moving beyond the previous literature, the current study provides pupils insights that may explain the observed improvements in maths performance. The findings align to previous studies that used time on-task (37), intrinsic motivation inventory (15) and perceived enjoyment scales (38). While this study did not test enhanced self-efficacy, confidence and pupil engagement, the qualitative findings of children's perceptions of MOTM suggest it may have the potential to engage those

pupils who typically disengage in traditional classroom settings. Furthermore, the combined quantitative and qualitative insights support some previous studies (15, 37, 38) that PAL improves children's confidence, engagement, and academic performance. These insights are essential in communicating the impact of PAL programmes to the different school stakeholders.

While previous studies have focussed on the importance of directly assessed measures of academic performance and cognition to influence teacher adoption of PAL, the perceptions of the pupils provides further evidence of the wider benefits PAL may offer for pupil health and broader academic development. Children described the MOTM sessions as enjoyable, fun, engaging and invigorating – resulting in positive associations to learning and activity. Further the different- more open- learning environment- sparked inclusivity and cooperative learning. Instead of working with their peers all the time, children felt they had an opportunity to work with new peers which also sparked healthy competition throughout the various maths activities. Similar themes around quality learning environments and the benefits of working together during group activities emerged in the Easy Minds Programme (36). In line with Fredricks, Blumenfeld (39) conceptualisation over school-based engagement, the MOTM children highlighted the alternative physical and social environment facilitated greater engagement. Children were engaged based on the positive feelings described about the support from the instructors learning the MOTM sessions, facilitating their learning and giving them a sense of accomplishment. Pupil's perceptions around greater learning during MOTM were akin to a similar maths-based PAL intervention revolving around children perceiving a deeper understanding of concepts multifaceted activities (36).

Strengths and limitations

The current study was able to objectively assess children's MVPA using accelerometers at baseline and week six of the intervention, providing a detailed understanding of the impact of

the intervention. A further strength of the study was to utilise a class-level randomised controlled study design. In comparison to individual level randomisation, class-level randomisation reduces contamination of the intervention which may reduce the probability of a type II error by increasing the point estimate of the intervention effectiveness (40). However, a limitation of this approach may be problems of recruitment bias (selecting different sorts of participants for different arms of the trial defeats the objective of randomisation) and needing larger sample sizes (41). The current study did not conduct an a priori power equation which may have resulted in type II error. This may have been exacerbated with one school dropping out before the evaluation commenced. While this study did not attempt to blind either the children or the researchers of the study condition, such an attempt was unfeasible given the study design used. As physical activity was assessed during the final week of the intervention, the increases in MVPA levels for MOTM pupils may have increased due to the implementation effect of the intervention, which we cannot confidently discount from the analysis. Moreover, as the maths tests took 35 minutes to complete, there may have been a potential fatigue effect, however, the testing battery was identical at each time point so any fatigue is likely to have been consistent.

Conclusion

In conclusion, the MOTM PAL programme improved MVPA and had a large positive effect on maths performance aligned with the learning content. Pupils perceived that the MOTM lessons increased enjoyment and engagement with the learning content. This was facilitated through learning in a more open environment and having the opportunity to interact with different peers. The combined quantitative and qualitative understanding presented in the current study suggests the wide beneficial impact of the MOTM programme on PA, health, and academic outcomes. For policy and practice, the study emphasises the central role that PAL can play in supporting schools to improve PA levels for all children (9). To progress the evidence-base, a

full-scale control trial is warranted to assess the impacts of the MOTM programme on PA and academic performance.

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Figures

Figure 1: Consort flow diagram

Supplemental Digital Content

Supplemental Digital Content 1: Maths on the Move Lesson Example. The example covers identifying equivalent fractions. The supplement is in PDF format.

Supplemental Digital Content 2: Maths on the Move Example from Y5 booklet. The lesson example covers fractions and decimals. The supplement is in PDF format.

Supplemental Digital Content 3: Maths Attainment Test (MAT) example of how the difficulty of each question across the two versions (blue and red) were matched. The supplement is in PDF format.