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Better movers and thinkers (BMT): A quasi-experimental study into the impact of physical education on children's cognition—A study protocol

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ABSTRACT

This study will extend on a pilot study and will evaluate the impact of a novel approach to PE, Better Movers and Thinkers (BMT), on students' cognition, physical activity habits, and gross motor coordination (GMC).

The study will involve six mainstream state schools with students aged 9–11 years. Three schools will be allocated as the intervention condition and three as the control condition. The design of the study is a 16-week intervention with pre-, post- and 6 month follow-up measurements taken using the 'Cognitive Assessment System (CAS)' GMC tests, and the 'Physical Activity Habits Questionnaire for Children (PAQ-C)'. Qualitative data will be gathered using student focus groups and class teacher interviews in each of the six schools.

ANCOVA will be used to evaluate any effect of intervention comparing pre-test scores with post-test scores and then pre-test scores with 6 month follow-up scores. Qualitative data will be analysed through an iterative process using grounded theory.

This protocol provides the details of the rationale and design of the study and details of the intervention, outcome measures, and the recruitment process. The study will address gaps within current research by evaluating if a change of approach in the delivery of PE within schools has an effect on children's cognition, PA habits, and GMC within a Scottish setting.

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Background

Low levels of physical activity (PA) are common in children, and there has been a clear call for action on the 'pandemic of physical inactivity' (Kohl et al., 2012). Higher levels of fitness in children may be associated with improved neurocognitive processing (Hillman et al., 2008) as well as increased levels of PA positively influencing learning by enhancing school 'on-task' behaviours (Davis and Cooper, 2011). Increased time spent participating in physical education (PE) within the curriculum may provide both cognitive and educational benefits across childhood and adolescence (Coe et al., 2006). The literature is consistent in reporting that increasing the amount of time in PE within school does not adversely affect more academic subjects. Indeed, there are examples of higher levels of time spent in PE enhancing academic attainment (Eide et al., 2010; Davis and Cooper, 2011; Coe et al., 2006; Donnelly et al., 2009; Mahar et al., 2006).

Recently, research has focussed on the possible associations between PE and executive function performance. Executive function¹ is an umbrella term to describe higher-order processes which direct thought and action (Booth et al., 2013). A recent review has suggested that areas of cognition, including working memory, selective attention, and inhibition tasks, are the areas of greatest benefit for children who increase their levels of PA (Coe et al., 2006; Guiney and Machado, 2013). Similarly, another review examined the effect of PA on children's cognition and found that both acute and chronic exercise may produce improvements in cognition (Best et al., 2011). A review of studies on PA examining mental health outcomes also found a positive association with cognition in randomised studies (Ahn and Fedewa, 2011). These positive associations were also identified in another review though there is an acknowledgement that the improvements in cognition and academic achievement are usually small or inconsistent (Biddle and Asare, 2011).

There is a need for studies to focus on the potential longer-term impact of PE in school on children's cognition and to specifically evaluate the nature and quality of PE provision to identify how different

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¹ For the purpose of this paper, the term cognition will be used to cover all aspects of higher-order processes including executive function.

approaches may have differing effects on cognition (e.g. training of cognitive aspects in PE, dose-related response). There is a need for a study to be conducted within a Scottish context.

This paper provides the methodological protocol that will allow a robust evaluation of effects of 'Better Movers and Thinkers (BMT)' on children's cognition, 'Gross Motor Coordination (GMC),' and PA habits in comparison to a traditional approach in PE within the primary school setting in Scotland. In addition to cognitive measures, the current study will evaluate GMC and PA habits in order to account for these potential variables as identified in other studies (Booth et al., 2014; Green and Francis, 1988). If an alternative approach to the delivery of PE in schools can lead to improvements in children's cognition, this would have implications for improvements in academic achievement and help to inform interventions for those children who are not engaging in PE regularly in school and PA in other areas of their lives.

BMT

BMT is a new programme concerned with the development and delivery of quality PE provision for children aged 3–18 years. The programme was developed in Scotland from collaboration between formal education processes, sports performance development, and developmental neuroscience. BMT sets out to offer a novel approach to teaching PE in schools.

BMT methodology encompasses key themes throughout the PE lesson including the development of physical literacy, the enhancement of thinking skills (cognition), and the establishment of personal qualities that could be considered essential for learning (i.e. perseverance, resilience, tolerance, determination, etc.) (Yeager and Dweck, 2012).

BMT primarily focuses on the ability for the learner to move and think in an integrated way. BMT differs from traditional PE as it directly focuses on developing the links between moving and thinking and as such recognises how this contributes to the development of cognition. Traditional PE focuses directly on the technical and tactical skills required to participate in PE, PA, and sport, and in doing so perhaps assumes that cognition will become a by-product of the experience.

BMT begins by engaging the learner by encouraging them to actively listen and focus on the tasks and instructions that are being presented by the teacher. This is achieved by offering the instructions only once and providing some misdirection thereafter. For example, if the children are being asked to jog in the gym hall, the teacher would provide a verbal instruction such as 'when I clap my hands I want you to change direction as fast as you can.' The teacher would then shout 'Go!' (without clapping their hands) creating misdirection. Students who are actively engaged in their learning would not change direction on the command 'Go!' and would not get caught out by the misdirection. Engaged learners would wait for the clapping of the hands command. In traditional approaches, the teacher would often then verbalise and correct the response for learners who responded incorrectly, but in BMT methodology, the misdirection is offered 3 or 4 times until the learning environment has shaped the correct responses from all learners.² This is not achieved successfully with all learners in the first lesson, but over a period of 2 or 3 weeks, the learners become habituated and modify their behaviours in order to remain on task throughout the lesson. In essence, they begin to take responsibility for their own learning by becoming actively engaged from the beginning of the lesson and throughout. Once this has been achieved, and in order to maintain and enhance levels of focus and concentration, the teacher will begin to layer a cognitive task onto a physical task. For example, the teacher may ask for a sequence of 9 movements using a combination of hopping, skipping, side-stepping, and jogging. The learners would then have to create their own combinations which require neurocognitive processing in order to solve, plan, decide, and design goal-oriented performance, key attributes that the

literature strongly refers to when discussing executive function (Diamond and Lee, 2011; Biddle and Asare, 2011). As the learners successfully achieve the task, the teacher would ask for them to come up with an alternative solution, thus developing cognitive flexibility and adaptive behaviours (Etnier et al., 2006). In order to maintain the engagement of learners thereafter, BMT methodology will increase the physical demands and in doing so further develop physical literacy. When successful, the teacher will add another cognitive task onto the new physical task and repeat this process a number of times throughout the lesson. The direct layering of specific physical tasks with specific cognitive tasks is what makes BMT a unique approach to PE and allows for all levels of learners to be challenged throughout the duration of the lesson. The pace of the lesson is deliberately quick to prevent any potential for off-task behaviours and/or disengagement. If off-task behaviours or disengagement become evident, the teacher would return to the misdirection cues and capture the engagement of the learners once again before building on previously covered work.

Aim

The aim of this study is to evaluate if there is a link between BMT and cognition and GMC, to identify if there is an association between levels of PA and cognition and to gain an understanding into the perceptions of students and teachers of BMT as an alternative approach to PE. The main research questions are:

1. Does BMT improve cognition, GMC, and PA habits more than traditional PE provision?
2. Is there a relationship between cognitive development, GMC, and PA habits?
3. What are the students' perceptions and experiences of PE/BMT provision?
4. What are class teachers' views of how PE/BMT provision influences the learning and behaviours of students across the curriculum?

Methods/design

Ethical approval

All procedures have been approved by the local authority and the relevant University Ethics Committees, and written and informed consent will be obtained from all participants.

Study design

The study will involve six mainstream state schools, Primary 6 students (aged 9–11 years) in three schools acting as the control condition and Primary 6 (P6) students in the other three schools acting as the intervention condition. Six schools will be used as logistically this is the maximum number to allow data collection to be gathered within the timescale of the study. The allocation of schools to condition will be undertaken by the Quality Improvement Officer (QIO) within the local authority. There are a number of potential schools and the QIO will choose schools based on two criteria: their proximity with one another ensuring that they are close to each other, and schools where he thinks that it would be feasible to run the research. Once the schools have been identified, they will be placed within opaque-sealed envelopes and a person external to the study will choose 3 schools which will be allocated as the intervention condition leaving the other 3 as the control condition. The design of the study is a 16-week intervention with pre-, post- and 6 month follow-up measurements taken from the 'Cognitive Assessment System (CAS)' (Naglieri and Das, 1997), GMC tests and the 'Physical Activity Habits Questionnaire for Children (PAQ-C)' (Kowalski et al., 2004) gathering quantitative data. These are explained in more detail later. At the end of the 16-week intervention, phase 6 focus groups will be conducted separately for students (approx. 8

² In fact, it is not uncommon for the learners who have demonstrated the correct response to help and support those who are making mistakes.

students in each) in all schools. One-to-one interviews, lasting approximately 10–20 minutes, will be conducted with each of the class teachers. The focus groups and interviews will be analysed qualitatively.

Recruitment procedures

The local authority (LA) will be approached to grant access to involve six primary schools. Six primary schools will be identified by the 'Quality Improvement Officer (QIO)' and if necessary substitute schools will be identified.

Having identified the six schools, letters will be sent to each of the head teachers outlining the research and seeking permission for their involvement. This will be followed-up, 1 week later, with a phone call and a meeting will be arranged between the main researcher, and the head teacher to explain the research in more detail. If each of the head teachers agrees to their involvement, each student will be provided with an information sheet to take home to their parents with a consent form for their parents to sign indicating that they are happy for their child(ren) to be involved in the study. The main researcher will attend a separate meeting with each P6 class outlining the nature of the research study. Students will be provided with an information sheet as the main researcher explains what the student involvement would be. Questions that arise will be answered before students are provided with assent forms to complete and sign if they wish to be involved in the study.

Study sample

With class size potentially ranging from 25 to 30 students in each, the schools identified by the QIO, may yield approximately 150–180 students who could provide assent to be involved throughout the study. Throughout the study, all parents and students will have the right to withdraw from the study.

Primary outcome measures

Cognitive assessment system

The CAS (Naglieri and Das, 1997) was developed to evaluate Planning, Attention, Simultaneous and Successive (PASS) cognitive processes of individuals aged between 5 and 17 years. The PASS theory provides a view of intelligence reconceptualised as cognitive processes and proposes that human cognitive function is based on these four essential activities that employ and alter an individual's base of knowledge (Das et al., 1994). According to this theory, human cognitive functioning includes four components: planning processes that provide cognitive control; utilisation of processes and knowledge, intentionality, and self-regulation to achieve a desired goal; attentional processes that provide focused, selective cognitive activity over time; and simultaneous and successive information processes that are the two forms of operating on information. Planning is a mental process by which the individual determines, selects, applies, and evaluates solutions to problems. Attention is a mental process by which the individual selectively focuses on particular stimuli while inhibiting responses to competing stimuli presented over time. Simultaneous processing is a mental process by which the individual integrates separate stimuli into a single whole or group. Successive processing is a mental process by which the individual integrates stimuli into a specific serial order that forms a chain-like progression. The CAS has two formats that could be used as measurement tools for children's cognition: the Standard Battery (involving 12 subtests, 3 for each category in PASS) and the Basic Battery (involving 8 subtests, 2 for each category of PASS). Due to the logistical limitations of conducting research within the school environment, this study will use the Basic Battery. The Planning subtests are 'Matching Numbers (MN)' and 'Planned Codes (PCd)'. Attention subtests include 'Expressive Attention (EA)' and 'Number Detection (ND)'. 'Non-verbal Matrices (NvM)' and 'Verbal-Spatial Relations (VSR)' make up the Simultaneous subtests while 'Word Series (WS)' and 'Sentence Repetition (SR)' make up the Successive subtests. Each subtest scaled score is set at a mean of 10 and a standard deviation of 3. The CAS is intended to predict academic achievement in children and the full scale standard score will typically be the best overall predictor of achievement.

Reliability and validity

Subtest reliability coefficients were calculated by the split-half method for all Simultaneous and Successive subtests using the entire standardisation sample and obtained from the administrator's manual. The average resulting reliabilities for the Basic Battery are .85 (Planning), .84 (Attention), .90 (Simultaneous), and .90 (Successive). A study into the reliability of the CAS identified reliabilities in all PASS subscales in all age groups ranged from 0.83 to 0.93 (Naglieri and Das, 1997) indicating a high level of reliability and validity in using CAS as the cognitive measurement tool within this study (Naglieri, 1999). Subtest reliabilities are similarly high ranging from .75 to .89 across subtests with a median reliability of .82.

GMC

Students will be asked to perform 4 GMC tasks. These 4 tasks will involve crawling on the stomach (i.e. commando crawl), creeping on hands and knees (i.e. 4-point crawling), marching with an arm swing (i.e. like a soldier), and skipping with an arm swing (i.e. without a rope). These coordinated movements are indicators of developmental milestones and are used to evaluate children's motor development with particular focus on gross motor coordination (Goswami, 2008). Each student will have a 5 m distance to travel between and will be asked to perform each task twice. The assessments will be video recorded and movement patterns will be coded for the purposes of data collection using a 5-point scoring system. The scoring system will be as follows:

- 1 = Unable to perform the task
- 2 = Disintegrated (no consistency in the coordination of both halves and sides of the body)
- 3 = Homologous (upper and lower body not integrated)
- 4 = Homolateral (same sided limbs move in the same direction simultaneously)
- 5 = Contralateral (opposite sided limbs move in the same direction simultaneously)

Individual scores from the 4 tasks will be accumulated to create an overall score which will be used for the purpose of analysis. In order to minimise the risk of bias cross-scoring with an independent researcher who is familiar with these test protocols will be conducted at pre-, post-, and follow-up testing.

Physical Activity Habits Questionnaire for Older Children (PAQ-C) (Kowalski et al., 2004)

The PAQ-C provides a general measure of physical activity from ages 8 to 20 years. The PAQ-C is appropriate for school-aged children (approximately 8–14 years) who are currently in the school system and have a rest interval as a regular part of their school week. The PAQ-C are self-administered, 7-day recall questionnaires that comprise of an activity checklist (21 activities and space for students to add two additional unlisted activities), and questions about context of PA conducted over the last 7 days (including PA during morning break, lunchtimes, PE, after-school, evenings, and weekends). Generally, the PAQ-C has had relatively strong correlation coefficients with other PA measures compared to other recall measures (Kowalski et al., 1997).

Validation studies indicate high reliability in the use of the PAQ-C (Saint-Maurice et al., 2014).

Procedures

The PAQ-C will be conducted with the whole class, and the main researcher will read through each question and be available to answer any queries from the students. Physical testing using the GMC tasks will be carried out with each student, in groups of 4 or 5 before completing the CAS with each student on a separate day. CAS testing will be conducted on a one-to-one basis with the main researcher and will take place within a quiet space within the school. Each student will be thanked by the main researcher on completion of the testing and will be told that they will be tested again at the end of the intervention phase and at 6 month follow-up.

Fidelity measures will be used to ensure the reliability of data being collected using the CAS, PAQ-C, and GMC tests. This will be carried out by an independent researcher at pre-, post- and follow-up testing. Video footage of the BMT approach will be recorded and analysed for fidelity of the approach.

Intervention phase

All schools will be asked to provide two 60 minute sessions of PE each week, for 16 weeks.

Control condition

The control condition will receive their PE provision from a combination of both the PE specialist and the class teacher and will traditionally cover a range of activities. The control condition will be receiving the PE curriculum specific by Curriculum for Excellence in Scotland (2009).

Traditional PE does not specifically involve the development of cognitive skills as a specific outcome but is primarily concerned with the development of technical and tactical skills within specific sports, activities, and games.

Intervention

Participants in the intervention condition will receive their provision from a PE specialist who has received training in the delivery of BMT and will cover a range of activities. The PE specialists will take two sessions per week in each of the intervention schools. No other PE sessions will be provided during the intervention. The BMT practices in PE primarily focus on the development of cognition (and specifically Executive Function skills) and the quality of motor control with the aim that this has transfer to other aspects of learning across the curriculum.

Qualitative study

Students will be offered the opportunity to participate in focus groups (3 for both the control and intervention conditions, each having approximately 8 students taking part at any one time) at the end of the study. Four boys and four girls from each class will be randomly selected by their head teacher drawing out names from a hat. Three main areas will be discussed in the focus groups, including enjoyment levels, perceptions of what has been learned in the PE lessons, and perceived transfer of learning in PE lessons into other lessons (i.e. literacy, numeracy, art, music, drama, etc.). Each of the main areas will have some starting questions to encourage student response. These include

The experiences of the students during their PE lessons

1. Tell me about the activities you participated in during your PE lessons from January to May this year.
2. What did you think about these experiences?

3. How did these experiences make you feel?
4. What experiences would you like in future PE lessons?

Perception of what has been learned in PE lessons

1. What did you learn in your PE lessons from January to May this year?
2. Give an example of what you were doing and how you learned this?
3. How did you feel when you were learning this?

Perceived transfer of learning from PE lessons to other subject lessons

1. How is learning in PE different to learning in other lessons?
2. What similarities exist between learning in PE and learning in other lessons?

Each of the 6 class teachers will be taken through an interview. The main areas to be covered include impact of the teaching of PE to students' engagement with PE, student behaviour in the class, perceived impact of PE on students' learning across the curriculum.

Perceived impact of the teaching of PE to students' engagement with PE

1. How does the approach in delivering PE impact on the students' engagement in PE lessons?
2. What observations in students' learning behaviour have you seen during PE lessons between January and May this year?

Student behaviour in class

1. What observations in students' learning behaviour have you seen during classroom lessons between January and May this year?
2. How do the learning behaviours of the students in the classroom compare to their learning behaviour in PE lessons?

Perceived impact of PE on students' learning across the curriculum

1. What effect do you think PE has on your students' ability to learn across the curriculum?

The focus groups and classroom teacher interviews will be carried out by an independent research assistant who is not involved in the quantitative testing protocols or in the delivery of any of the PE lessons within the study. The research assistant will have specialist skills in the facilitation of focus groups and semi-structured interviews. Each of the student focus groups and class teacher interviews will be audio-recorded for the purposes of transcription and analysis. Data will be coded using an iterative process and cross-coding will be done with the research assistant conducting the focus groups and interviews.

Setting

The PE lessons will be conducted within the gym facilities and outside areas at the schools. Quantitative data will be gathered within a quiet space within the school with the main researcher and the qualitative data will be gathered within a meeting room within the school in the presence of the research team assistant conducting the focus groups and class teacher interviews.

Data management

Quantitative data will be entered into an SPSS Data file and stored in a secure network drive. Qualitative data will be audio-recorded, transcribed verbatim, and anonymised. Digital copies of the transcribed data from the student focus groups and the class teacher interview transcripts will be kept in a secure cabinet.

Data analysis

Quantitative data

CAS

Each of the CAS subtest raw scores is converted to a scaled score based upon the child's age using the appropriate tables in the test manual. Each of the four PASS scales is obtained by summing the subtest scaled scores from each of the subtests within the respective scales. The CAS full scale is obtained from the sum of the standard scores for the 8 PASS scale subtests. For the purposes of data analysis within this study, the overall scaled scores for the CAS basic battery will be used for comparison.

Fundamental locomotor skills—GMC

The GMC tasks will be measured using the following 5-point scoring system:

- 1 = Unable to perform the task
- 2 = Disintegrated (no consistency in the coordination of both halves and sides of the body)
- 3 = Homologous (upper and lower body not integrated)
- 4 = Homolateral (same sided limbs move in the same direction simultaneously)
- 5 = Contralateral (opposite sided limbs move in the same direction simultaneously)

An accumulative score for all 5 subtests will be used for the purposes of comparing results between all 3 time points; baseline, post-test (at the end of the 16 week intervention), and follow-up (6 months). All quantitative data will be cross-checked with 3 independent researchers each of whom specialises in the use of CAS, PAQ-C, and fundamental locomotor skills.

Qualitative data

Focus groups and class teacher interviews will be conducted by an independent researcher who has an expertise in this particular area of qualitative data collection. The focus groups and class teacher interviews will be recorded using audio-recording equipment and the main researcher will then provide a verbatim transcription that will then be analysed thematically.

Statistical analyses

As the study will include all students, including those with additional support needs, it is likely that the data will not be normally distributed. ANCOVA will be used to adjust for any pre-test differences to compare the post-intervention performance of the control condition with that of the intervention condition. ANCOVA will be used to compare the pre-intervention with the 6 month follow-up data. The relationship between levels of cognition, coordination, and PA will be modelled using a multiple regression with bootstrapping if required (Miles and Shevlin, 2001). The focus groups and class teacher interviews will be recorded and transcribed before identifying emergent themes within the data using a grounded theory approach (Corbin and Strauss, 2008).

Discussion

This protocol provides the details of the rationale and design of the study and details of the intervention, outcome measures, and the recruitment process. Effect sizes derived from comparison between the intervention and control conditions from the study will provide information on the effectiveness of delivering BMT as an alternative PE provision within primary schools; evaluate the relationship between levels

of PA, GMC and cognition. A 6-month follow-up at the end of the intervention phase will conclude this study.

The study will address a) the need for a Scottish-based study into the links between PA, GMC, and cognition, b) how the nature of the activities provided during traditional PE and BMT impact differently on the development of cognition, c) documentation and analyses of the experiences and perceptions of PE/BMT lessons from participants within this study and d) if effects are maintained 6 months after the intervention.

Strengths

The study could identify an alternative teaching method that helps to provide quality PE provision for all primary school-aged students. The perceptions of the participants may provide interesting insights that help identify effective strategies that further encourage the government's health agenda and helps get more children within Scotland active on a daily basis. Children from control and intervention conditions will come from a range of socio-economic backgrounds and will include students with and without additional support needs. This is the first study to systematically explore the potential benefits of the BMT approach with such an inclusive cohort. The primary outcome measures used in this study are standardised test scores which have a high-rated inter-rater and test-retest reliability. Fidelity testing will be undertaken by 3 researchers who are independent of the study in order to compare inter-rater reliability to ensure that appropriate procedures are being adhered to. The main researcher is involved in the gathering of the quantitative data but not the qualitative data and will not be involved in the delivery or evaluation of any of the PE/BMT sessions.

Limitations

Variables identified in the literature that may impact upon differences in outcome measures include age, birth weight, gestation, age of mother at delivery, mother's oily fish intake at 32 weeks gestation, maternal smoking in the first 3 months of pregnancy, weight status, pubescent stage, ethnicity, socio-economic status, (SES) and occupational social class (Booth et al., 2013). It has not been possible to control for all of these variables within this study. For example, students from both conditions will not be measured using body mass index (BMI) though previous studies (Aktop, 2010; Davis and Cooper, 2011; Eide et al., 2010) highlight the impact that this can have on the outcomes being measured. Similarly, no information was gathered about the pre-school provision of the students prior to the start of this study and again there are previous studies that have illustrated the impact that pre-school provision can have on cognition (Diamond et al., 2007; Marjanovic Umek et al., 2008).

An additional limitation is the gathering of PA habits through self-reported questionnaires. Self-reported levels of PA may over report actual levels of PA, especially as the data collection will be performed as a whole class. Objective measures of PA would perhaps further enhance this study, but pragmatically is beyond the capacity of this study (Coe et al., 2006).

The short length of intervention phase (16 weeks) may also limit this study. Sufficient time between the pre- and post-test phases may not allow for any change to be identified within the three variables being measured. As this study accounts for only P6 students within one authority, it may be difficult to generalise any findings to a wider population.

Competing Interests

The main researcher is one of three authors of the intervention; however, BMT is not a commercial venture.

Author's Contributions

AD, NM, and JB led the drafting and editing of the manuscript. AD, NM, and JB read and approved the final manuscript.

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