Better Movers and Thinkers (BMT): An Evaluation of How a Novel Approach to Teaching Physical Education can Impact Children's Physical Activity, Coordination and Cognition.

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Abstract

This study aimed to identify what impact a novel approach to teaching Physical Education (PE) had on children's physical activity, coordination and cognition compared to current provision. 150 children were recruited from 6 primary schools in Scotland. Outcome measures were the "Cognitive Assessment System (CAS," (Naglieri, 1997), the "Physical Activity Habits Questionnaire for Children (PAQ-C)," (Kowalski, 2004) and fundamental locomotor skills (crawling, creeping, marching and skipping). Pre-, post- and 6-month follow-up testing was conducted and data analysed comparing a control and an intervention group. Each group received 2 hours of PE each week during the 16-week intervention. Current provision in PE was delivered in the control group and a Better Movers and Thinkers (BMT) approach to PE delivered in the intervention group. Significant effects of intervention relative to the control group were identified in cognition ($p = <.001$, $d = 0.76$) and coordination ($p = <.001$, $d = 0.97$). No significant effects of intervention were identified for physical activity ($p = > .200$, $d = 0.24$). The improvement in the outcome measures remained at the 6-month follow-up testing. The present study has identified cognitive and coordination improvements as a result of a novel PE intervention with benefits maintained 6 months later. This supports the need for modification in current PE provision to optimise the potential for learning across the curriculum.

BACKGROUND

Emerging research indicates a link between increasing levels of physical activity (PA) and improved levels of cognitive function and brain health in childhood (Álvarez-Bueno et al., 2017; Donnelly et al., 2016; Lubans et al., 2016; Khan & Hillman, 2014). Indeed, studies report that children who have good aerobic fitness achieve higher scores on standardised achievement tests than their less fit counterparts (Castelli et al., 2007; Donnelly et al., 2009). However, low-levels of PA are common and are held to have reached pandemic proportions (Kohl et al., 2012). A recent study indicated that there is much work to be done in order to improve the health and wellbeing of children if improvements in their cognitive function and brain health are then to be realised (Booth et al., 2013).

Participation in PA is thought to benefit cognition as a result of structural and functional brain health changes. A recent review has outlined that the 'posited PA-related' impact on cognition is due to regular PA altering neurogenesis, angiogenesis and enhancing central nervous system metabolism (Singh et al., 2018). In addition, regular PA has been suggested to increase the availability of certain growth factors such as brain-derived neurotropic factor (BDNF) which is involved in the maintenance and change in the structure and function of the brain with direct access to aspects of learning and memory. (Cotman, Berchtold & Christie, 2007; Van Pragg, 2008). There is also consideration that classroom learning behaviours (specifically on-task behaviour) improves following bouts of PA which could account for improvements in academic achievement (Daly-Smith et al., 2018).

Increasing opportunities for daily Physical Education (PE) lessons within school is one way to try and counteract the problems associated with inactivity (Strong et al., 2005) although there are concerns from some educators that this approach may detrimentally impact on academic progress in other curricular areas (Bailey et al., 2009; Biddle & Asare, 2011). However, there is strong evidence that there is no detrimental influence on academic subjects as a result of increasing time spent in PE classes in schools (Coe et al., 2006; Donnelly et al., 2009; Hillman et al., 2005). Indeed some studies have identified improvements in on-task behaviour as a result of increased PA (Howie & Pate, 2012). Improved on-task behaviours are known to positively influence learning and have been shown to lead to academic progress (Donnelly et al., 2009). Increased access to PE (and PA in general) may therefore provide educational benefits through improved cognition across childhood and through adolescence.

Experimental evidence in children is limited and there is clearly a need for more research in this area to establish any cognitive effects of increasing PA or in modifying the approach in delivering PE in schools and to identify the nature of these gains (Dalziell et al., 2015b; Fisher et al., 2011; Schaeffer et al., 2014). One of the critiques of previous studies has been that the quality of study design within this area has not been able to consider moderators of the direct relationship between PA and cognitive gains (Biddle & Asare, 2011). Reviews on PA and cognitive functioning have provided evidence in support of cognitive and academic performance gains along with increased PA although these associations are usually small and inconsistent (Biddle & Asare, 2011; Etnier et al., 2006). Some of these inconsistencies have been associated with a lack of understanding as to whether there is a direct or indirect effect from increasing levels of PA in children and gains in their cognitive performance. A review concluded that children's cognitive functioning can be enhanced through PA but this is mainly in respect of executive functioning tasks (Tomporowski et al., 2011). Executive functioning relates to goal-directed behaviours and includes: working memory, inhibition, attention, planning, and task shifting (Diamond & Lee, 2011). What remains unclear from the research is what types of activities (for example, aerobic or complex movement patterns) have the greatest effect and what levels of activity (for example, acute or chronic bouts) needs to be achieved for gains to be identified (Best et al., 2011). Further research is needed to clarify the types and levels of activity in order to better understand if and of how this relates to improved cognitive performance. A recent study identified that physical activity that demanded a significant cognitive engagement had a more beneficial impact on executive functioning when comparing 3 group conditions; non-active, aerobic activity with low-level cognitive engagement and team games with high levels of cognitive engagement (Schmidt et al., 2015). This supports findings from an earlier review where cognitively-engaging exercise appeared to have a more significant impact on children's executive functioning than non-cognitively engaging exercise (Best, 2010).

Some research has assumed that all school-aged children have the physical attributes allowing them to easily access PE in school; however, this may not be the case. Some children have not developed enough motor competence, balance and postural control in order to participate effectively within their school PE lessons. Evidence from a study carried out by Biotteau et al. (2017) indicated that children with specific neurodevelopmental difficulties such as 'Developmental Coordination Disorder (DCD)' are not able to proficiently develop procedural learning in the same efficient way as those without neurodevelopmental difficulties (Biotteau et al., 2017). Children with DCD may therefore not be in a position to easily access PE in schools due to their motor coordination limitations and therefore not be able to access cognitively engaging exercise in order to elicit the same benefits on their levels of cognition as previous cited research has outlined. Motor development is affected by maturation and genetic factors (Malina, 2014). Motor development begins in infancy with pushing, turning, crawling and eventually walking and progresses to more complex patterns of movement thereafter (Strong et al., 2005). Only a few studies have compared aerobic and motor exercise in relation to cognitive functions among children and therefore it is important to compare PA levels and motor skills in future studies (Haapala, 2013). The common finding amongst these types of studies is that there is often a relationship between aerobic and motor exercises to changes in cognition but the evidence suggests that this interaction is not a direct effect (Biddle & Asare, 2011; Shepherd & Trudeau, 2010; Tomporowski et al., 2008).

In order to establish if the approach to delivering PE lessons in school is a contributing factor on children's coordination, cognition and/or PA habits, this study evaluated the impact of a novel approach to PE compared to traditional PE where the nature and demands of the PE lessons were specifically different.

Better Movers and Thinkers (BMT)

BMT was designed as a novel approach to PE that directly targets the development of physical competence, cognitive skills and personal qualities (Education Scotland, 2015). Physical competence refers to the development of balance and postural control, gross and fine muscle coordination, and, rhythm and timing. The cognitive skills relate to the specific targeting of key executive functioning such as working memory, focus of attention, inhibition, planning, and task-shifting whilst personal qualities focus on the development of specific areas such as: determination, resilience, perseverance, and motivation.

PE lessons that are informed by the BMT method primarily give the responsibility of learning over to the learner where increasingly more complex problems are provided for the learner to solve. These problems can be physical, cognitive or a combination of both depending on the level and needs of the learner. The BMT PE lesson begins with a basic motor action that is overlapped with a cognitive demand (for examples, following every 3rd step, accent a knee lift. Once achieved, count 5 of these accents and then change direction). As the physical and cognitive demands are realised, the physical task is then accentuated (e.g. when the left knee is accented, touch the left shoulder with the right hand and when the right knee is accented, touch the right shoulder with the left hand). If the increase in the physical task is successful then an increase in the cognitive aspect of the task is presented (e.g. after touching each shoulder once, the 3rd knee accent should have both hands cross the chest to touch opposing shoulders) (Education Scotland, 2016). A visual demonstration of this type of activity can be found at https://education.gov.scot/improvement/learning-resources/Better%20movers%20and%20thinkers.

Learners therefore have to build on previous task knowledge and adjust to the additional demands, whilst remembering the rules from before (for example, change direction after 5 knee accents). These types of tasks demand a considerable amount of neuro-cognitive processing. Challenging motor skills are shown to cause synaptogenesis or an increased number of synapses (Adkins et al., 2006). The synergistic interactions between neuronal activity and synaptic plasticity make it an ideal and essential regulator of cellular processes that underlie cognition and other complex behaviours (Lu et al., 2014). It is the purpose of this study to demonstrate if these task demands, presented through BMT, have a direct influence on improved cognitive performance.

Traditional Physical Education (PE)

Traditional PE (in this study) refers to lessons that involve three phases; a general warm up, a period of skills training leading to a final game or performance and then a generic cool down phase. The curriculum is designed to involve blocks of activity that run for a period of 4 weeks and may involve a range of aesthetic activities, team sports, net-invasion games and athletics. It differs from the BMT approach in that it focuses on the development of sports/activity specific skills as the outcome leading to a final performance whereas BMT focuses on the development of physical competencies, cognitive skills and personal qualities and less on the specific skills within a sport/activity.

AIM

The present study aimed to explore the impact of BMT on children's coordination, cognition and PA habits in comparison to more traditional approaches to PE. The primary outcome measure was cognition.

METHODS

A pilot study was conducted prior to finalising the methodological approach (Dalziell et al., 2015b). Results from the pilot study identified significant score changes between pre- and post-test conditions in phonological skills (p = .042, d = 0.22), and working memory (p = .040, d = 0.07) in favour of pilot BMT intervention following a 16-week intervention phase. The pilot study evaluated the efficacy and feasibility of the intervention within primary schools. There were certain limitations identified within the pilot study that has informed the current study. For example, teaching expertise was identified as a possible contributing factor to the gains made in favour of intervention. There were limitations with some of the outcome measures used within the pilot study, however, and this in turn informed the design of the main study. Further details may be found in the pilot study results paper (Dalziell et al., 2015b).

Participants and Methods

150 Primary 6 students (10 – 11 years) from 6 mainstream state schools in Scotland were invited to take part in the study. Parents gave informed written consent and students gave informed written assent. The study was approved by the University of Edinburgh Ethics Committee and permission granted by the Ethics Committee of the Local Authority within which the study took place. All children were eligible to be included in the study including those with additional support needs with no exclusions applied. Head teachers of each of the 6 schools granted permission for their school to be used within the study and class teachers agreed to their class being involved. Substitute schools were available but were not required. A published protocol paper can be accessed for more information (Dalziell et al., 2015a).

Power Calculation

Our sample size was determined using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) and assumed a medium effect size (Cohen's f = 0.25), power of 0.80, an alpha of .05, and an ANCOVA with two groups (intervention versus control) and one covariate (pre-intervention baseline score). This indicated a sample of 128 (64 participants in each of the two groups). To control for possible attrition over the two post-intervention time-points, we increased this by 17%, yielding the final sample of 150 used in the study.

Study Design

Neither a randomized controlled trial (RCT) with the unit of randomization the individual participant nor a cluster RCT with the unit both of randomisation and of analysis the school class were feasible for the present study for operational reasons in the case of the former, and logistical reasons in the case of the latter. Accordingly, we identify the design as a pre-post quasi-experimental design which randomized six intact school classes which had been selected as being as similar as possible in regard to size and socio-economic variables (Handley et al, 2018). A 16-week intervention was implemented in six Primary 6 (ages 10 – 11 years) classes in six primary schools within the same local authority in Scotland. Three schools were in a control condition and received traditional PE provision from one PE specialist who did not have any insight into BMT and three schools were in an intervention condition and received the BMT approach from one PE specialist who had been trained in the BMT methodology. Each of the schools received a one hour PE lesson, twice each week, for a 16-week period. Random allocation to intervention and control conditions was achieved by the sealed envelope system (Torgerson & Roberts, 1999). The study was presented in 4 phases as shown in Figure 1.

Figure 1. Chronology of pre-test (T1), intervention, post-test (T2) and follow-up testing (T3)

Following initial recruitment, and upon receipt of parental consent and pupil assent a pre-test (T1) of CAS, PAQ-C and GMC was undertaken prior to the beginning of the 16-week intervention phase. Post-test (T2) was completed within 6 weeks of the conclusion of the intervention phase, and finally, follow-up (T3) testing was completed within 6 months from post-test. The time between testing completed at T2 and T3 was maintained throughout the study and schools were re-assessed in the same order as originally tested.

Outcome Measures

Cognitive Assessment System (CAS) (Naglieri, 1997)

A literature search and contact with an educational psychologist prior to the present study indicated the suitability of the CAS as a measure of cognitive performance in school-aged children. There are two forms of the CAS and the basic battery form (involving 8 subtests) was used due to the logistical demands of running research within a school environment as well as the demands on time of the study. The planning subtests measured problem solving skills, the attention task measured inhibition control, the simultaneous processing measured the ability to integrate separate stimuli into a single whole or group and successive subtests measured working memory. All subtests were administered to children individually in a quiet location within the school, and presented in the order as outlined in the procedural handbook associated with the CAS (Naglieri, 1997). Verbal instructions presented for each subtest were prescribed within the handbook and used for each child at T1, T2 and T3 testing. The time taken to complete the CAS ranged from 40 – 52 minutes. Higher scores are equal to better performance and scaled scores were used for analysis in keeping with the procedures as laid out in the interpretive handbook (Naglieri, 1997). The reliability coefficients of the basic battery full scale is .87. Further reliability and validity data is also available from the interpretive handbook (Naglieri, 1997).

Physical Activity Habits Questionnaire for Children (PAQ-C) (Kowalski, 2004)

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 each school day (i.e. interval/break time). The PAQ-C is a 7-day recall instrument that measures general PA levels during the school year. Generally the PAQ-C has had relatively strong correlation coefficients ($r = 0.80$) with other PA measures compared to other recall measures (Kowalski et al., 1997). The PAQ-C was administered to the whole class, with the first author reading through each question before the students completed their answer. The questions relate to the level of activity that the individual has achieved at different times of the day (for example, during school interval, lunch time, after school and after evening meal). The questionnaire also asks what types of activities are done and how often each week as well as asking if there is any health reason that has stopped the individual achieving their usual activity habits during the last week. Scoring is based on a 1 – 5 scale for each sub-item and which are then totalled to form an overall score which was used in analysis here. Previous studies have demonstrated the suitability and reliability of conducting the PAQ-C in this manner (Niven et al., 2007).

Gross Motor Coordination

Students were asked to perform four GMC tasks. These four tasks involved the fundamental locomotor skills of: 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). Fundamental locomotor skills have been widely used for a number of years in clinical and educational research and are considered reliable methods when evaluating the development of gross motor coordination in school-aged children (Henderson, 2007). Each pupil had a 5 metre distance to travel and was asked to perform each task twice. The assessments were video recorded and movement patterns were coded for the purposes of data collection using a 5-point scoring system. The scoring system was 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 were accumulated to create an overall score which was used for the purpose of analysis.

Data Analysis

Baseline data collection for all three outcome measures was completed prior to the start of the intervention phase and T2 testing was completed within 6 weeks of the intervention phase ending. T3 testing was completed at a 6-month interval from T2 testing. The time between T1 and T2 testing and between T2 and T3 testing remained constant in all schools. Cross marking of all outcome measures was undertaken by independent researchers with expertise in the use of the outcome measures to reduce the risk of bias and to help verify the data. Statistical analysis was undertaken by repeated measures ANOVA and follow up ANCOVA using SPSS version 19 with baseline scores as covariate (Field, 2009). ANCOVA was conducted on T2 scores controlling for T1, then also on T3 scores controlling for T2, and then finally on T3 scores controlling for T1. Analysis of the CAS and PAQ-C was completed using standard scores as outlined in the procedure manual of both tests. The GMC analysis was done using the accumulated raw score. The study was adequately powered for the number of pupils whose data was analysed (Dalziell et al., 2015a).

Results

Table 1 shows the means and standard deviations for all of the outcome measures for the control and intervention condition participants at T1, T2 and T3.

Table 1

CAS

A total of 143 children (78 students for control and 65 students for intervention) presented a full data-set at T2 testing using the cognitive outcome measure; representing 95% of those from the original data set of 150 students at T1 testing. The data was not normally distributed and therefore bootstrapping was applied.

The repeated measures ANOVA demonstrated a significant group-by-timeinteraction for CAS score [F (2, 278)=87.94), p <0.001, partial η^2 =0.39]. In the follow up ANCOVA there was a significant effect of the intervention on CAS scores [F (1, 140) = 88.29, p = .001, partial η^2 = 0.39] between pre- and post-testing (T1 – T2). The difference between Intervention and Control schools was statistically significant and the effect was maintained at 6 month follow-up [F (1, 141) = 53.18, p = .001, partial η^2 = 0.27].

GMC

A total of 139 children (74 students for control and 65 students for intervention) presented a full data-set at T2 testing using the coordination outcome measure; representing 93% of those from the original data set of 150 students at T1 testing. The data was not normally distributed and therefore bootstrapping was applied.

The group-by-time interaction for GMC was statistically significant [F(2, 266) = 21.52, p <0.001, partial η^2 = 0.14]. In follow up analysis there was a significant effect of intervention on GMC scores [F (1, 136) = 49.76, p = .001, partial η^2 = 0.27] between pre- and post-test (T1 – T2). The difference between Intervention and Control schools was statistically significant and the effect was maintained at 6 month follow-up [F (1 , 138) = 35.54, partial η^2 =0.21].

PAQ-C

A total of 146 children (78 students for control and 68 students for intervention) presented a full data-set at T2 testing using the cognitive outcome measure; representing 97% of those from the original data set of 150 students at T1 testing. The data was not normally distributed and therefore bootstrapping was applied. The group-by-time interaction for PAQC was not statistically significant [F(2, 284) = 2.40, p >0.05 partial η^2 = 0.02]. Follow up analysis revealed no significant effect on levels of PA between intervention and control conditions [F(1, 143) = 1.66, p = .200, partial η^2 = 0.01] between pre- and post-test (T1 – T2) or at 6 month follow-up [F (1, 142) = 1.47, p = .228, partial η^2 =0.01].

Appendix 1 provides the CONSORT flow diagram at each stage of the study.

Table 2 shows the adjusted mean scores and associated effect sizes for the outcome measurements at time 3.

Table 2

Process Evaluation

Each of the intervention and control schools recieved two 60-minute sessions of PE each week during the 16-week intervention phase. Visits to the control and intervention schools were conducted during the 16-week intervention phase by the first author with the addition of lesson plans being provided by the PE teacher who was responsible for delivering the BMT intervention. All lessons in each of the 6 schools took place on Tuesday and Thursday to avoid any Monday or Friday holidays to ensure the students had exposure to all 32 lessons in both conditions. The observed sessions of both control and intervention school adhered to the deisgn of the study. The control condition schools received their sessions from a qualified PE teacher following a traditional approach and the intervention schools receiving BMT from a qualified PE teacher following the BMT approach.

Student focus groups and class teacher interviews were conducted at the end of the 16-week intervention phase by an independent researcher to gauge the experiences of students and staff. Both the focus groups and the interviews were audio recorded and the main researcher then provided a verbatim transcription that was analysed thematically. The main themes of the student focus groups included; enjoyment levels; perceptions of what had been learned in the PE lessons and, perceived transfer of learning in PE lessons into other lessons. The main themes of the class teacher interviews included; impact of teaching of PE to students' engagement within PE, student behaviour in class, and the perceived impact on students' learning across the curriculum.

The overall exposure to the intervention was positively received by the students and influenced by key factors including; challenge within lessons, competition, cooperation, student choice, range of activities experienced, learning and pedagogy. The class teachers exposed to the BMT intervention commented on improved levels of engagement within the PE lessons, perceived increases in levels of students' attention and concentration levels during the BMT lessons and perceived transfer of on-task behaviour within other lessons – most notably immediately after the BMT lesson.

Discussion

Main findings and study implications

We found a significant improvement in children who received the BMT intervention on cognitive performance at T2 which was maintained at T3. Similar significant improvements for those receiving BMT were identified for GMC at T2, and again maintained at T3. These improvements were not shown with the control condition in which children were taught with a more traditional PE approach. Previous studies have identified that improvements in motor coordination positively impacts children's cognition and the findings from this study support this (Adkins et al., 2006). However, what remains unclear is the nature of the tasks that children are being asked to perform in other intervention studies. Studies differentiate between whole body and manual dexterity functioning in children's coordination and the impact that this has on aspects of cognition (Niederer et al., 2011; Piek et al., 2008). The BMT intervention included both gross motor coordination and fine motor control tasks and therefore it is not possible from this study to evaluate the different impact that whole body or manual dexterity movements have on cognitive performance. The improvements in cognition in favour of the BMT intervention found in this study may be attributed to the content of the BMT intervention specifically layering cognitive tasks onto coordination tasks throughout the PE lesson. Direct targeting of certain aspects of cognition – specifically key executive functions (for example, working memory, inhibition and task-shifting) is a primary focus of the BMT intervention which appear to have led to improvements in the CAS outcome measure. Previous evidence from the literature has shown links between specifically targeting executive function skills in an intervention with improvements in children's cognition and the findings from this study support this (Diamond et al., 2007; Diamond & Lee, 2011). However, these other studies have not taken into account improvements in GMC but have focussed on tasks of a sedentary nature that specifically target learning behaviours associated with executive functioning rather than integrating movement and thinking skills simultaneously (Tomporowski et al., 2011). The findings from the present study therefore provide a unique insight into the value of directly targeting children's physical literacy and thinking skills in an integrated manner and teaching PE with an approach that provides that.

The literature reveals complex associations between PA levels and executive function (Booth et al., 2013; Castelli et al., 2007; Fisher et al., 2011). Recent studies have concluded that PA is beneficial for some aspects of executive function (Booth et al., 2013; Guiney & Machado, 2013). However, in the present study there was no significant effect of BMT on PA levels suggesting that any change identified in the CAS and GMC outcome measures are not as a result of changes in PA levels. Some studies have found that increased levels of MVPA in school-aged children do have a positive impact on their cognitive performance but findings from the present study do not support this (Khan & Hillman, 2014). The cited studies used accelerometer data to measure levels of PA, and this is considered more accurate than self-reported levels of PA which were used in the present study. It may be that the PA measurement tool used within the present study was not sensitive enough to monitor change in PA levels and therefore our conclusion about lack of evidence for PA levels influencing cognitive performance is cautious. What we can say from other studies is that PA levels decline as children (aged 6 – 11 years) transition into adolescence (aged 12 – 19 years) (Long et al., 2013). The cohort of the present study ranged from ages 9- to 10-years at T1 and 10- to 11-years of age at T3. Thus the present study cohort was entering the transition into adolescence which may account for their reduced levels of PA from T1 to T3 across both control and intervention conditions.

The present results demonstrate that benefits from a novel approach to PE do improve children's cognition and coordination and that this improvement is maintained over time. The effect sizes from the data are large (partial $\eta^2 = 0.39$ and partial $\eta^2 = 0.27$ respectively) supporting the promotion of BMT within schools.

Our findings point towards an exciting avenue of investigation for those who wish to investigate the value of differing approaches to the delivery of PE within schools. Subsequently, as executive function and cognition are often associated with developmental and psychological difficulties in children and adults (Micco et al., 2009) and is related to the development of social and emotional well-being, (Zelazo, 2007) findings which suggest improvements in these areas may have far reaching implications. If causal, these realtionships may also add empirical support that provides educators and policy makers with added evidence to promote PE lessons within our primary schools.

Study Strengths and Limitations

This present study had a number of strengths: the inclusion of a control group with pre-, post- and follow-up testing; large sample size; involving children with additional support needs as well as typically developing children; the objective measurement of cognition and coordination; a high percentage of the original sample population presenting full data at post- and follow-up testing with missing data entered as a user-defined missing value to ensure all collected data could be used in the analysis; and fidelity checks for data collection and scoring as well as the delivery of PE for both conditions. One of the limitations within the study was the self-reported levels of PA obtained from the PAQ-C. As with all self-reported measures they are open to misinterpretation although the main researcher being there to conduct the testing will have helped to reduce this impact. Although previous studies have justified whole-class use of the PAQ-C, peer pressure may have exerted an influence on the results obtained (Niven et al., 2007). Whilst the study has shown significant effects of intervention on cognitive performance, a lack of academic testing does not allow for an evaluation to be made as to the impact that improved cognition has on academic achievement or attainment. In a similar vein, a further limitation was that the scale of the study precluded adjustments for possible effects of clustering. Further research with this programme should utilise a cluster RCT design (Torgeson & Torgeson, 2008). Finally, what is not clear from the present study is the levels of activity that are achieved during a traditional PE lesson compared with that of the BMT lesson. It may be that children within the intervention condition achieved higher and more prolonged levels of MVPA during their 2 hours of PE each week compared with their control counterparts and that this may act as a causal factor in improvements in cognition. Therefore future work should try to capture both academic testing and MVPA levels during intervention to better understand the complex nature between BMT - PE, PA, coordination and children's cognition.

Conclusions

The significant effects as a result of the BMT approach to PE identified within this study clearly outline a need for BMT to be considered as an approach to PE with appropriate materials and training made available. Further studies are required to understand the value that PE, PA and coordination have on children's cognition. In particular, further research is needed to examine the levels of MVPA being achieved during PE lessons, the improvements in gross motor coordination and fine muscle control and what differential benefits they may have on executive function and how this relates to improvements in academic performance over short, medium and long-term.

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Competing Interests

One of the papers authors is one of the co-authors of BMT.

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Figure 1: Chronology of pre-test (T1), intervention, post-test (T2) and follow-up testing (T3)

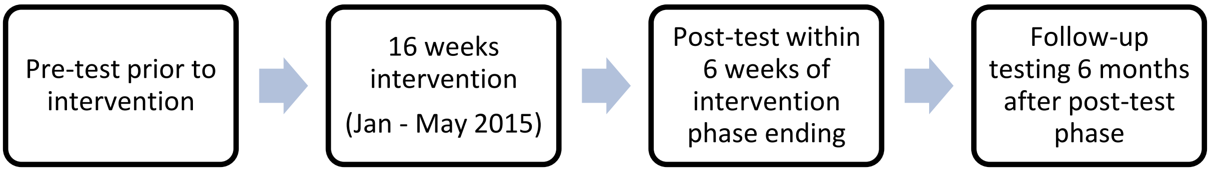

Table 1:

Means and standard deviations (SDs) for CAS, GMC and PAQ-C Outcome Measures for intervention and control conditions at T1, T2 and T3

	Mean scores (SD) T1		**Mean scores (SD) T2**		**Mean scores (SD) T3**	
Outcome Measures	**Control**	**Intervention**	**Control**	**Intervention**	**Control**	**Intervention**
CAS	100.18 (12.19)	88.97 (13.30)	97.71 (11.84)	106.31 (10.63)	101.26 (10.24)	105.53 (11.45)
GMC	16.93 (2.25)	16.47 (2.23)	16.57 (2.40)	18.54 (1.58)	16.22 (2.51)	18.18 (1.84)
PAQ-C	3.51 (0.68)	3.53 (0.62)	3.39 (0.63)	3.47 (0.56)	3.12 (0.67)	3.06 (0.65)

Table 2

Time 3 outcomes adjusted for Time 1: Adjusted mean, SE, 95% Confidence Intervals and effect size

Outcomes	Control		Intervention		Partial Eta^2
	Mean (SE)	95% CI	Mean (SE)	95% CI	
CAS	98.42 (0.93)	96.58 to 100.26	108.89 (1.02)	106.87 to 110.90	0.27
GMC	16.17 (0.24)	15.70 to 16.64	18.23 (0.25)	17.74 to 18.72	0.21
PAQ-C	3.18 (0.07)	3.04 to 3.32	3.06 (0.08)	2.91 to 3.20	0.01

Appendix 1: CONSORT Flow Diagram