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ORIGINAL ARTICLE

Improved cognitive performance in preadolescent Danish children after the school-based physical activity programme "FIFA 11 for Health" for Europe – A cluster-randomised controlled trial

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Abstract
Objective: Recent studies have shown promising effects of physical activity on cognitive function, but there is a need to investigate this link in real-life settings such as schools. Hence, the objective of the present pilot study was to investigate whether the school-based physical activity programme "FIFA 11 for Health" for Europe could improve cognitive performance in preadolescent Danish children. *Methods:* The pilot study used an 11-week cluster-randomised intervention study design. School classes were randomly assigned to either a control group (CG) ($n = 93$ children, age = 11.8, $s = 0.2$ years), which performed the obligatory daily school-based physical activity (5 × 45 minutes per week); or an intervention group (IG) ($n = 838$ children, age = 11.9, $s = 0.4$ years), which substituted 2 × 45 minutes per week of the daily school physical activity with the "FIFA 11 for Health" for Europe programme. The programme combines small-sided football games, drills and health education. Cognitive performance was evaluated at baseline and follow-up. *Results:* The IG improved their cognitive performance compared to the CG for psychomotor function (56, $s_{\bar{x}} = 22$ ms, $p < .001$), attention (39, $s_{\bar{x}} = 17$ ms, $p = .012$) and working memory (79, $s_{\bar{x}} = 35$ ms, $p = .020$). *Conclusion:* This pilot study provides evidence that the school-based physical activity programme "FIFA 11 for Health" for Europe can improve cognitive performance in preadolescent Danish schoolchildren. Future studies should attempt to disentangle the effects of "FIFA 11 for Health" for Europe on cognitive performance by investigating the characteristics of the programme's physical activity.

Keywords: *Cognition, small-sided football, soccer, drills, health*

Highlights

- Physical activity has been shown to positively affect cognitive performance in children, but information about the effect of school-based physical activity programmes is lacking.
- The present pilot study investigated the effect of participating in the school-based physical activity concept "FIFA 11 for Health" For Europe on cognitive performance in preadolescent children.
- Participation in "FIFA 11 for Health" for Europe improved performance in tests of attention, working memory and psychomotor function.

1. Introduction

An emerging field of research has been focusing on the positive relationship among physical activity, cognitive function and academic achievement in children (Diamond & Ling, 2016; Donnelly et al., 2016; Geertsen et al., 2016; Hillman, Erickson, & Kramer, 2008; Vazou, Pesce, Lakes, & Smiley-oyen, 2016). Cognitive

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function is regarded as a predictor of and a prerequisite for academic learning and achievement (Alloway & Alloway, 2010; Blair & Peters Razza, 2007). Especially, executive function (EF) has been identified to play a critical role in learning and academic achievements during childhood (Van der Niet, Hartman, Smith, & Visscher, 2014). This knowledge has led to multiple studies seeking to improve cognitive function through different types of physical activity interventions. These studies have documented positive effects on cognitive performance in children after acute (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008; Drollette et al., 2014; Hillman et al., 2009) and chronic (Fisher et al., 2011; Hillman et al., 2014; Mullender-Wijnsma et al., 2016) physical activity. Even though physical activity consists of both quantitative (e.g. intensity and duration) and qualitative (e.g. cognitive and motor demands) characteristics, most of the studies have focused on the quantitative characteristics of the physical activity (Drollette et al., 2014; Fisher et al., 2011; Hillman et al., 2009) which have been shown to positively affect the central nervous system through physiological responses to the physical activity (Hillman et al., 2008). Besides studies of quantitative characteristics, recent studies have also highlighted the positive effect of the qualitative characteristics of the physical activity, suggesting that the type of activity is also important (Budde et al., 2008; Gallotta et al., 2015; Jäger et al., 2014; Pesce et al., 2009). The assumption behind this cognitive stimulation hypothesis is that coordinatively demanding and non-automated movement and sports actions engage the same brain regions that are used to control higher order cognitive processes (Tomporowski et al., 2015). One proposed physical activity that complies with this is team games (Diamond & Ling, 2016). Using knowledge of the effect of the quantitative as well as qualitative characteristics of physical activity on cognitive performance, recent studies have applied different types of chronic physical activity programmes in ecologically valid school settings and found promising results. These results range from improved academic performance (Beck, Lind, Geertsen, Lundbye-jensen, & Wienecke, 2016; Mullender-Wijnsma et al., 2016), improved inhibition ability (Crova et al., 2014; Hillman et al., 2014) to improved shifting performance (Schmidt, Jäger, Egger, Roebers, & Conzelmann, 2015). The types of chronic physical activity vary from motor-enriched learning activities (Beck et al., 2016), physical active school lessons (Mullender-Wijnsma et al., 2016), cognitively challenging and engaging activities (Crova et al., 2014; Schmidt et al., 2015), and team-oriented activities aiming at improving cardiovascular fitness (Hillman et al., 2014).

Although a growing body of research is emerging, the field is still in its infancy. Consequently, there are several limitations. Most importantly, there is a myriad of methodologies and outcome measures, which makes comparison between studies difficult (Donnelly et al., 2016). Furthermore, both time constraint and expenses limit studies of brain structure and function. However, school-based programmes also provide a unique opportunity to affect both a large and wide population of children. Therefore, the ecologically valid settings applied in these studies are a great strength (Donnelly et al., 2016). Furthermore, as recent evidence indicates, children do not meet the physical activity recommendations (Kolle, Andersen, & Anderssen, 2010; Verloigne et al., 2012), which not only has a negative health effect (Klakk et al., 2014) but might also influence children's cognitive health negatively (Hillman et al., 2008). Therefore, more knowledge and studies of the impact of school-based physical activity programmes are critical to ensuring and promoting adequate development of cognitive function in children.

"FIFA 11 for Health" for Europe is a school-based physical activity programme that focuses on health education through small-sided football games and drills. The physical activity in the programme focuses on both quantitative elements (i.e. small-sided football with high-intensity interval training) and qualitative elements (i.e. drills and team games that challenge motor and cognitive skills) through 2 × 45 minutes (two sessions) of on-pitch activities per week for 11 weeks. Each football session is related to a health message developed in relation to a communicable or non-communicable disease. The programme is delivered by schoolteachers trained in "FIFA 11 for Health" using an engaging and age-, gender- and culture-sensitive format. The original "FIFA 11 for Health" programme revealed positive effects on preadolescent children's health knowledge in multiple countries (Fuller et al., 2010; Fuller et al., 2015). A subsequently modified programme for the European context has also shown positive effects on health knowledge, body composition, blood pressure and cardiovascular fitness in preadolescent Danish children (Fuller et al., 2016; Ørntoft et al., 2016).

Consequently, the objective of the present pilot study was to investigate the effect of the modified "FIFA 11 for Health" for Europe programme on cognitive performance in preadolescent Danish schoolchildren.

2. Methods

2.1. Participants

Twenty-six Danish schools encompassing 67 fifth-grade classes expressed an interest in participating in and were provided with comprehensive information about the pilot study. From these, 52 classes were accepted into the pilot study. Geographically, the distribution of the classes was 7 from Jutland, 6 from Funen, 11 from the Capital Region of Copenhagen, 26 from the remaining part of Zealand and surrounding islands and 2 from the island Bornholm. The pilot study was designed as a cluster-randomised controlled trial with individual classes as clusters. A member of our research group randomly assigned each class to either a control group (CG) or an intervention group (IG) in a 1:9 ratio (Figure 1). The ratio was found necessary to ensure high commitment by the schools to the programme, as they signed up for the programme voluntarily and all expected to be in the intervention group. In all, 931 children (475 girls, mean age: 11.9 ± 0.0) were included in the pilot study after obtaining written consent, corresponding to 81.7% of the children invited (see Table I for demographic characteristics). The pilot study was approved by the Ethical Committee of Copenhagen, Denmark (H-16026885) and carried out in accordance with the Helsinki Declaration II.

2.2. *Design*

The pilot study, completed between August and December 2016, consisted of a teacher workshop, baseline testing, intervention period (11 weeks) and follow-up testing. The teacher workshop took place before the intervention period. The baseline testing was conducted for both IG and CG, who completed a test battery assessing their cognitive function and body composition. During the intervention period, IG completed 22 sessions of FIFA 11 for Health for Europe (see later). Each week included two 45-minute sessions that replaced two of the five obligatory 45-minute sessions of physical activity per day for Danish schools. In weeks 1–11, CG continued with the normal obligatory weekly physical activity (5×45 minutes per week). The pilot study concluded with follow-up testing for both IG and CG.

2.3. *The "FIFA 11 for Health" for Europe programme*

Previous studies have thoroughly described the structure, content and implementation procedure of the "FIFA 11 for Health" programme in its original form (Fuller et al., 2010) and with the modified content adjusted for Denmark (Fuller et al., 2016; Ørntoft et al., 2016). In this study, the modified version of "FIFA 11 for Health" for Europe was used. Each of the 11 weeks consisted of two 45-minute football sessions, totalling 990 minutes over the 11 weeks. The week was divided into a 45-minute "play football" period (teaching football skills and playing small-sided football) and a 45-minute "play fair" period (teaching a health message and health behaviours). The two sessions within a week had to be separated by at least 1 day. All teachers involved in the pilot study from both CG and IG participated in a 2.5-day workshop run by staff from the University of Southern Denmark and football coaches from the Danish Football Association. The purpose of this workshop was to give the teachers an in-depth understanding of the standardised "FIFA 11 for Health" for Europe programme manual, covering the philosophy behind the programme, demonstrations of football skills and background health knowledge information. Moreover, the aim was to ensure a controlled, engaging and informative presentation for 10–12-year-old children. During the 11-week intervention and control period, the teachers trained 20–25 children per session in accordance with previous studies (Fuller et al., 2016; Ørntoft et al., 2016).

2.4. *Test battery*

The test battery consisted of measurements of the children's cognitive performance and body composition. The battery was completed over two separate test days. It was ensured that no scheduled physical activity was carried out before the children performed the cognitive test battery.

2.5. *Cognitive performance*

2.5.1. Procedure and description. The children's cognitive performance was assessed using the English version of the Cogstate® Brief Battery, which is an objective computer-based cognitive test battery addressing psychomotor function, attention, working memory and visual learning in preadolescent children (Cromer, Harel et al., 2015). The cognitive test battery was completed individually in the classroom on a laptop or stationary computer with a screen, mouse, keyboard, headset and internet access. The overall testing time was around 50 minutes. Although the cognitive battery was verified for unsupervised use among young adults (Cromer, Schembri, Harel, & Maruff, 2015), the teachers administered the battery and provided a unique username and login for each child both at baseline and follow-up. The teachers had been given a *cognitive test manual* and were thoroughly instructed in the cognitive testing procedure during the 2.5-day teacher workshop.

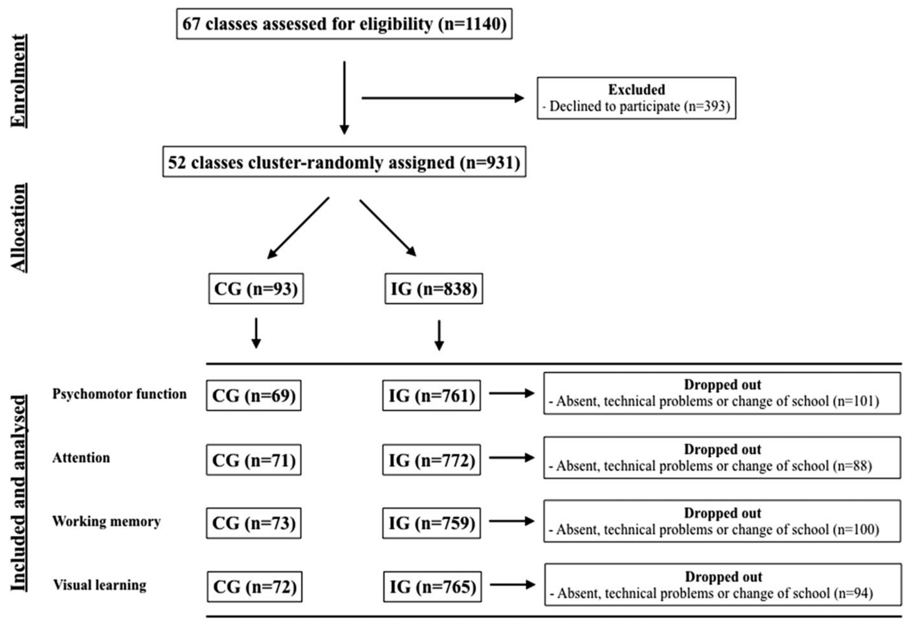

Figure 1. Flow diagram for the pilot study. CG, control group; IG, intervention group.

The cognitive test battery consisted of four different tasks: detection (DET), identification (IDN), one back (OBK) and one card learning (OCL). At the beginning of the test battery, the children learned to respond by using the Yes and No response buttons. The K button on the keyboard was used as Yes and the D button as No. In general, all four tasks followed the same format. Firstly, task information was provided and then the children were presented with a pack of face-down playing cards on their computer screen. When the top card in the pack flipped over to reveal its face (e.g. ace of spades, 8 of hearts, 7 of clubs), the children had to respond Yes or No as quickly and accurately as possible in accordance with the instructions for the particular task (see below). After the response, the face-up card moved away from the pack and the reverse of the next card in the pack became visible (i.e. next trial).

2.5.2. *Measures*

2.5.2.1. Psychomotor function and attention. The DET and IDN tasks were both a measure of attention and alertness. DET was based on a simple reaction time paradigm defined as the average speed to initiate a motor response following presentation of a visual stimulus. The DET task displayed a single playing card (i.e. the black joker) as the visual stimulus of the task. The question to be answered was: Has the card turned over? The children had to respond by pressing Yes as soon as they detected the playing card flipping over to reveal the face of the card. IDN used a choice reaction time paradigm. The IDN task had two possible stimuli, which were either a black or red joker. The children had to respond by pressing Yes or No to the question: Is the card red? The average speed (ms) of correct answers was logged as the effect outcome for both tasks.

Table I. Demographic characteristics of all the children combined and by control group (CG) and intervention group (IG)

	All	CG	IG
Number of participants (*n*)	931	93	838
Gender (% boys)	49	44	49
Age (years)	11.9 ± 0.4	11.8 ± 0.2	11.9 ± 0.4
BMI (weight/height^2)	18.5 ± 3.2	19.3 ± 3.7	18.4 ± 3.2
Weight (kg)	42.1 ± 9.8	43.8 ± 11.1	41.9 ± 9.7
Height (cm)	150.2 ± 7.2	150.0 ± 7.2	150.2 ± 7.3

Note. Data reported as raw mean values ± SD. No significant between-group differences were observed for any of the measures. BMI, body mass index.

2.5.2.2. Working memory. The OBK task, which uses an n-back paradigm, was deployed as a measure of working memory. The children were introduced to 52 standard playing cards as possible stimuli and had to respond to the question: Is this card the same as the previous card? They pressed either Yes or No. The average duration (ms) of correct answers was logged as the effect outcome.

2.5.2.3. Visual learning. The OCL task assessed visual learning and applied a pattern separation paradigm. The children were presented with 52 standard playing cards as possible stimuli, one at a time, and had to respond to the question: Have you seen this card before? (in the current task). They pressed Yes if they thought the current card had previously been presented during the task and No if they did not think they had seen it before. For example: If the first three cards shown (in order) were (1) king of hearts, (2) queen of spades and (3) king of hearts, then the answers would be (1) No, (2) No and (3) Yes. The average accuracy (%) of answers was logged as the effect outcome. The selected effect outcomes of each task were based on previous studies using the Cogstate® Brief Battery (Cromer, Schembri et al., 2015; Cromer, Harel et al., 2015; Louey et al., 2014).

2.6. *Body composition*

2.6.1. Procedure and measures. The measurement of body composition was collected as a part of the children's demographic data. Trained staff from the University of Southern Denmark administered the tests with the support of the responsible teachers. The children's weight (kg) was measured using an InBody 230 multifrequency body composition analyser (Biospace, California, USA), while their height (cm) was assessed with 0.5-cm precision using a Tanita Leicester portable altimeter (Tanita, Amsterdam, the Netherlands).

2.7. *Statistical analysis*

All statistical analyses were carried out in the open-access software R Studio (R Core Team, Vienna, Austria). Demographic characteristics are reported as raw mean values with SD. Differences between groups in age, height, weight and BMI were analysed using model-based *t*-tests; the gender distribution was analysed using a chi-squared test. Cognitive performance at baseline and follow-up are shown as raw mean values with $s_{\bar{x}}$. Data from the cognitive test battery were analysed using linear mixed models with group–time (baseline/follow-up) interactions and age as fixed effects. Random effects were added to the model to account for dependencies between measurements on the same subjects, municipalities, schools and school classes. A visual inspection of residual plots and normal probability plots was used for model validation. To investigate the hypotheses of this study, specific sets of comparisons between and within groups were considered and analysed using global F-tests. Subsequently, linear mixed model-based *t*-tests were used for pairwise comparisons. Adjustment for multiplicity of these pairwise comparisons was carried out using the 'single-step' adjustment, which achieved a less conservative adjustment than Bonferroni adjustment by utilising correlations between tests. All demographic characteristics are reported as raw mean values with SD. A significance level of 0.05 was applied.

3. Results

3.1. *Cognitive performance*

The mean performance figures in the cognitive tests before and after the intervention period for CG and IG are presented in Figure 2.

3.2. *Psychomotor function and attention*

In the DET task, a significant group–time interaction was found [$F_{1,1232} = 13.06$, $p < .001$]. IG improved their reaction time from baseline to follow-up whereas CG decreased their performance (Figure 2(A)). As presented in Figure 2(A), the change in mean psychomotor function performance was greater for IG compared to CG 56, $s_{\bar{x}} = 22$ ms ($p < .001$). A significant group–time interaction was found [$F_{1,1255} = 6.31$, $p = .012$] in the IDN task. From baseline to follow-up, IG improved their attention performance (Figure 2(B)). Furthermore, the change in mean attention performance was significantly greater for IG compared to CG 39, $s_{\bar{x}} = 17$ ms ($p = .012$) (Figure 2(B)).

3.3. *Working memory*

In OBK a significant group–time interaction was found [$F_{1,1215} = 5.41$, $p = .02$]. IG improved their performance from baseline to follow-up, which is shown in Figure 2(**C**). The change in mean working memory performance was also significantly greater for IG compared to CG 79, $s_{\bar{x}} = 35$ ms ($p = .02$) (Figure 2(**C**)).

3.4. *Visual memory*

No significant group–time interaction was found [$F_{1,1231} = 0.39$, $p = .532$] in the OCL task. Nor was

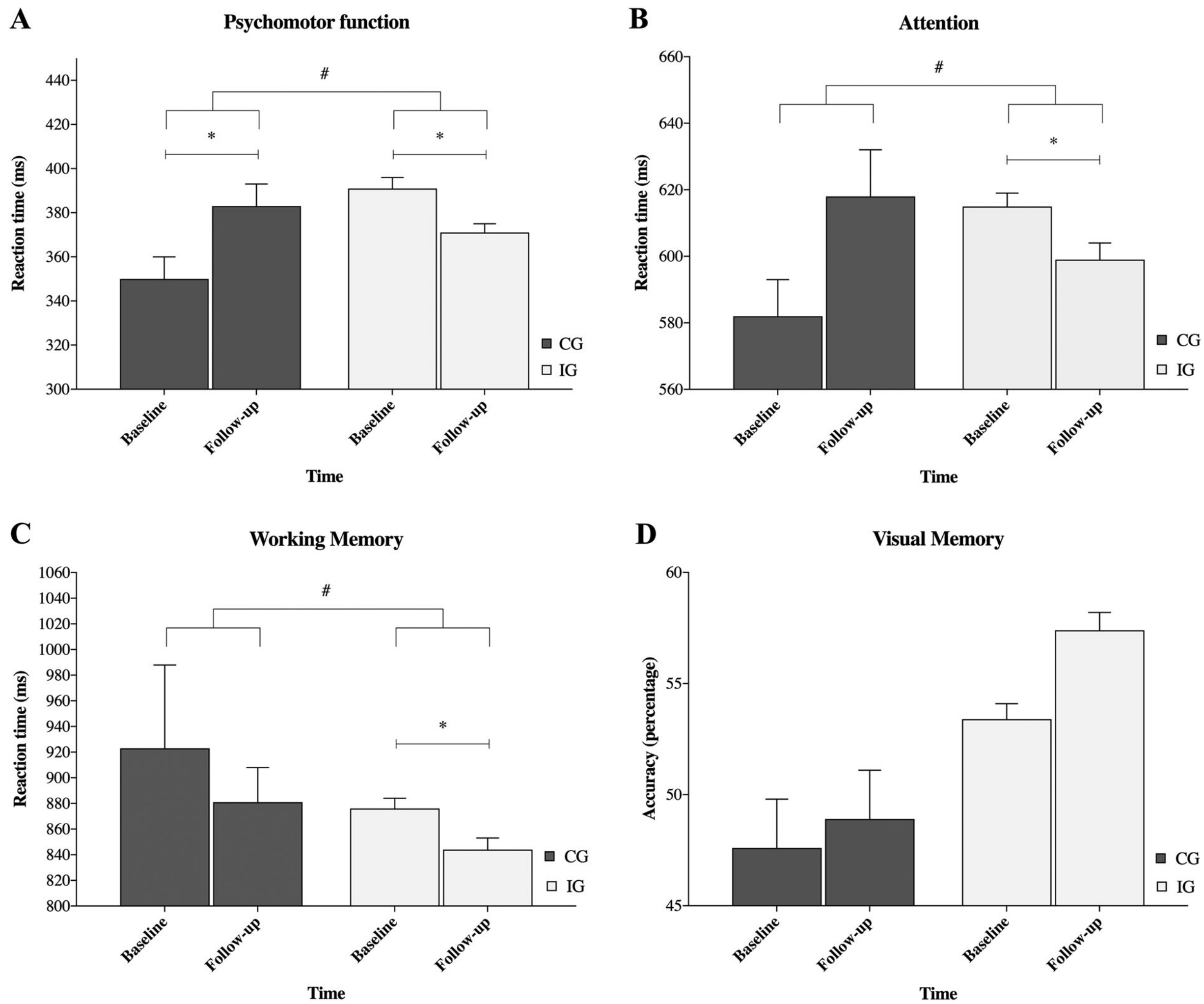

Figure 2. Performance in the cognitive test battery. The baseline and follow-up performance in the cognitive test battery is displayed as mean values with $s_{\bar{x}}$ for psychomotor function (A), attention (B), working memory (C) and visual learning (D). Control group (CG); Intervention group (IG). * Indicates significant within group difference from baseline to follow-up. # Indicates significant between-group difference in the changes between time points ($p < .05$).

any significant improvement observed for either IG or CG from baseline to follow-up (Figure 2(D)).

4. Discussion

The objective of the present study was to investigate the effect of the modified "FIFA 11 for Health" for Europe programme on cognitive performance in preadolescent Danish schoolchildren. The main findings of the pilot study were that IG improved their working memory (OBK), attention and alertness (DET and IDN) performance from baseline to follow-up, and that these improvements were significantly greater compared to CG. These results add to the emerging research showing that school-based chronic physical activity programmes can positively affect cognitive performance in children (Donnelly et al., 2016). Furthermore, together with previously reported positive effects of the modified "FIFA 11 for Health" for Europe programme on health knowledge, psychosocial and physiological health (Fuller et al., 2016; Ørntoft et al., 2016), these results suggest that "FIFA 11 for Health" for Europe could also improve the cognitive performance of preadolescent children.

4.1. *Attention and alertness*

Attention, including alertness, has been proposed as an intermediary of hippocampal-dependent declarative memory formation (Aly & Turk-Browne, 2016), possibly associated with schema-dependent academic learning and cognitive performance (van Kesteren, Rijpkema, Ruiter, Morris, & Fernández, 2014). We may therefore speculate that enhanced attention performance can lead to an improved academic learning in preadolescent schoolchildren. In the current study, attention and alertness were enhanced following the 11-week intervention for IG compared to CG. These findings accord with previous research investigating the effect of physical activity interventions on these cognitive domains in preadolescent children (Chang, Tsai, Chen, & Hung, 2013; Gallotta et al., 2015; Hillman et al., 2009, 2014; Schmidt, Benzing, & Kamer, 2016). In particular, Gallotta and co-workers (2015) found positive effects from a 5-month school-based coordinative physical activity intervention on attention in obese children. A 9-month after-school physical activity programme focusing on improving aerobic fitness also enhanced attention in preadolescent children (Hillman et al., 2014). These behavioural results were supported by changes in electrophysiological biomarkers mediating attention and alertness and were in line with previous findings of studies investigating the electrophysiological mechanism of the effect of physical activity on cognitive performance (Chang et al., 2013; Drollette et al., 2014; Hillman et al., 2009). However, future studies should still try to elucidate the specific electrophysiological adaptations following chronic physical activity interventions in children. This would allow us to gain further insight into the impact of physical activity on the developing brain. Collectively, these studies demonstrate a positive effect of 5–9-month school-based physical programmes on attention and alertness in preadolescent children. The current study adds to this knowledge and further indicates that such changes can be seen after only 11 weeks.

4.2. *Working memory*

An important element of cognitive function is working memory. A part of working memory is proposed to be the central executive (executive functions) (Baddeley, 2010), which is responsible for top-down problem solving (Miyake et al., 2000) and is suggested as a predictor of mathematical ability (Bull & Scerif, 2001) and academic achievement (Alloway & Alloway, 2010). Therefore, intervention that can positively affects working memory positively could therefore lead to better academic achievement in preadolescent schoolchildren. A key finding of the current study was enhanced working memory performance in IG compared to CG. Previous studies have also found positive effects of physical activity on working memory performance in children (Koutsandréou, Wegner, Niemann, & Budde, 2016; van der Niet et al., 2016). By applying 10 weeks of 3 × 45 minutes of after-school cardiovascular exercise and a motor-demanding activity for preadolescent children, Koutsandréou and colleagues (2016) found a positive effect on working memory performance from both the cardiovascular exercise and the motor-demanding activity. Additionally, the improvement was greater for the motor-demanding activity than for the cardiovascular exercise. A newly published intervention study also reported positive effects on working memory performance after 22 weeks of 5 × 30 minutes of aerobic exercise and cognitively engaging physical activities for preadolescent children (van der Niet et al., 2016). In combination, these studies indicate a positive effect of cardiovascular exercise and motor- and cognition-demanding physical activity programme on cognitive performance. The "FIFA 11 for Health" for Europe programme consisted of small-sided football games and football drills. The rules, pitch size and game format of the small-sided football games changed from session to session, ensuring that activities were novel and diverse throughout the 11-week intervention. Furthermore, each week a new football skill was introduced, ensuring that the activity had coordinative complexity. By applying a combination of cardiovascular exercise and motor and cognition demands, the "FIFA 11 for Health" for Europe programme was consistent with recent research showing positive effects of school-based physical activity programmes on cognitive performance. Moreover, the current study also indicates that a physical activity programme based on a well-established team game (football) can have a positive effect on cognitive performance in preadolescent children. Previously, this has mostly been reported in studies using a specially designed physical activity to either improve fitness status (Hillman et al., 2014) or ensure high levels of cognitive engagement (Schmidt et al., 2015) or coordinative demands (Gallotta et al., 2015). The findings of the current study thus add to our knowledge of the effect on cognitive performance of chronic physical activity programmes based on team games. Furthermore, as football is the largest sport in the world measured by number of registered players (FIFA, 2007), the "FIFA 11 for Health" for Europe constitutes a unique possibility to introduce a well-liked physical activity school-based programme to the children. This could heighten the schools' interest in the programme as well as the feasibility of and engagement in the programme for the children. However, future research should try to disentangle both the "FIFA 11 for Health" for Europe programme and, especially, the team game (small-sided football) to investigate both the quantitative (e.g. intensity and duration) and qualitative (e.g. cognitive and motor demands) characteristics. This would allow us to obtain further understanding of the aspects of team games that might be responsible for the observed behavioural effects. This is interesting because previous work in the field reports a diversity of results from different types of physical activity interventions, suggesting that different characteristics of physical activity intervention can have different effects on cognitive performance. Thereby, it will benefit our understanding of what type of physical activity to implement in school settings to most effectively improve cognitive performance.

5. Strength and limitations

This study was strengthened through the ecological value of the design, the large sample size and the identical demographic characteristics between the two groups, which further support the success of the cluster-randomisation. The geographical inclusion of school classes from most of Denmark also strengthens the interpretation of the results. Moreover, by training the teachers and having them follow a standardised programme manual, we controlled what the children were taught. Furthermore, we ensured stability of the intervention by using the children's regular teacher and framework (school setting). However, the results of the pilot study should also be viewed with a few limitations in mind. First, for a cluster-randomised study, a larger sample size in CG would have strengthened the interpretation of the results. Furthermore, if practically feasible future studies should certainly consider other designs (e.g. cross-over designs). Secondly, the pilot study did not collect any information about the characteristics of the teachers teaching the "FIFA 11 for Health" for Europe. Nor was any delayed cognitive testing done, which limits the interpretation of the results in relation to a potentially sustained effect on the children's cognitive performance. Thirdly, defining the exact causes and mechanisms underlying the observed behavioural effects is not feasible because small-sided football and skill drills are a mixture of quantitative and qualitative characteristics. Future studies should investigate the ability of different physical activities involving different quantitative and qualitative characteristics to promote cognitive functioning in children and the electrophysiological correlates of these effects. This would allow us to design evidence-based physical activities specifically targeting promotion of cognitive functioning in children.

6. Conclusion

Participation in the modified "FIFA 11 for Health" for Europe programme, which comprises high-intensity small-sided football games, drills and on-pitch health education, can positively affect cognitive performance, including attention, alertness and working memory, in preadolescent Danish children. From a practical perspective, implementing the modified "FIFA 11 for Health" for Europe programme represents a promising way for schools, in a relative short space of time, to engage with preadolescent children in order to impact cognitive performance.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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