Effects of a physical activity program on physical fitness and executive functions in children with developmental language disorders

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submitted
Abstract

Children with developmental language disorders (DLD) have lower physical fitness and executive functioning performance than typically developing peers. As research on typically developing children shows positive benefits of extra physical activity on physical fitness and executive functioning, children with DLD might also benefit from these exercise-induced effects. The aim of this study therefore was to evaluate the effects of a 22 week physical activity program on the physical fitness levels and executive functioning of 8 to 11 year old children with DLD (n = 27; 12 intervention, 15 controls). The physical activity program consisted of aerobic exercise, circuit training and various games. Physical fitness was measured using four tests of the Eurofit test battery (standing broad jump (SBJ), sit-ups (SUP), 10 x 5 m shuttle run (10 x 5 m SR), and the 20 m shuttle run test (20 m SR)). Executive functions were assessed using tasks measuring visual working memory (Visual Memory Span test) and planning (Tower of London). Children in the intervention group showed greater improvement on the SUP than children in the control group. No differences were found on the executive functioning measures. This study reveals that providing extra physical activity at school for children with DLD is feasible, and can be a means to improve specific aspects of physical fitness. Improving executive functions with extra physical activity might need a more personalized approach to be effective. Recommendations are made for future intervention studies in children with DLD.
6.1 Introduction

Language is a complex social behavior that depends on a wide range of specialized sensory, motor, and cognitive skills (Jacob, 2013; Knudsen, 2004). The development of language competency is essential for children to engage in and interact with their physical and social environment and access the school curriculum. Children with developmental language disorders (DLD) are characterized by language problems in the absence of an underlying mental or physical handicap or a specific sensory or emotional cause (Bishop, 1992). In the Netherlands, the prevalence of language delay in children has been estimated to be between 5 and 10% (Reep-Van den Berg, De Koning, De Ridder-Sluiter, Van der Lem, & Van der Maas, 1998), and more boys than girls are affected. Children with DLD show nonverbal intelligence quotients in the average range. However, DLD are not limited to language, but co-occur with other disorders such as Attention Deficit Hyperactivity Disorder (Ullman & Pierpont, 2005). Furthermore, several studies have shown that children with DLD have difficulties with motor skills (Visscher, Houwen, Scherder, Moolenaar, & Hartman, 2007; Webster et al., 2006) and executive functions (Henry, Messer, & Nash, 2012; Vugs, Hendriks, Cuperus, & Verhoeven, 2014). Executive functions refer to the cognitive processes responsible for purposeful and goal-directed behavior (Banich, 2009), and encompass processes like strategic planning, flexibility of thought and action, inhibition and working memory (Miyake et al., 2000). In other words, executive functions are the cognitive control processes that regulate thought and action (Friedman et al., 2008), which highlights the importance of inner speech in these processes. Language and executive functioning are thus intertwined and co-emerge throughout various phases of development (Ardila, 2008; Nip, Green, & Marx, 2011).

Research in typically developing children shows that executive functioning can be improved by increasing levels of physical activity (Davis et al., 2011; Hillman et al., 2014; Tomporowski, Davis, Miller, & Naglieri, 2008). It is suggested that chronic exercise at moderate to vigorous intensity will induce neurochemical changes in brain areas associated to executive functioning (Hötting & Röder, 2013), or that the cognitive demand inherent in most physical activity and play will impact executive functioning directly (Best, 2010). In addition, regular involvement in physical activity is essential for promoting physical fitness of children (Strong et al., 2005). Physical fitness is a set of attributes associated with the capacity to perform a variety of physical activities (Ortega, Ruiz, Castillo, & Sjöström, 2008), and consists of several dimensions like muscular strength, muscular endurance,
speed and cardiovascular endurance. Physical fitness has been related to general health and mental well-being in children (Ortega et al., 2008). Moreover, physical fitness has been shown to be related to executive functioning (Van der Niet, Hartman, Smith, & Visscher, 2014), and cardiovascular fitness to language skills like reading and spelling (Scudder et al., 2014) in typically developing children. A recent study by Van der Niet et al. (2014) showed that children with DLD display lower performance on physical fitness than typically developing peers. In addition, Müürsepp, Aibast, Gapeyeva and Pääsuke (2014) showed that 5-year-old children with mild DLD performed significantly worse on a vertical jump test compared to typically developing children, probably due to a deficient ability to coordinate the leg muscles. Children with DLD can thus benefit from extra physical activity, as it might increase their physical fitness and executive functioning.

To date, no studies have investigated the effects of a physical activity program on physical fitness or executive functioning in children with DLD. Only a few studies have examined the effects of an exercise intervention in atypical target groups. For example, improved physical fitness was found after a six months individually designed physical exercise program in children with mild intellectual disorders (Golubović, Maksimović, Golubović, & Glumbić, 2012). Westendorp et al. (2014) found improvements on balls skills, but not on executive functioning after a 16 week ball skill intervention in children with learning disorders. However, children in the intervention group who showed larger improvements in ball skills also showed larger improvements in problem solving. Two other studies (Reynolds, Nicolson, & Hambly, 2003; Reynolds & Nicolson, 2007) showed improved motor skill, speech/language fluency, phonology, and working memory in children with reading difficulties, after a six months home based exercise program. However, the possible exercise-induced positive effects on physical fitness and executive functions in children with DLD are unknown.

The aim of this study therefore was to evaluate the effects of extra physical activity at school on physical fitness and executive functioning in children with DLD aged 8 to 11 year old. More specifically, effects on both cardiovascular fitness and strength components of physical fitness were analyzed. In addition, as DLD are thought to be related to some sort of procedural memory and sequencing deficiencies (Ullman & Pierpont, 2005), working memory and planning were measured to analyze effects on executive functioning. The physical activity program consisted of aerobic exercise, circuit training and various games, as it was expected that this would be most beneficial to have an effect on physical fitness and executive functioning (Diamond & Lee, 2011). To minimize the effect of impaired
verbal skills, two executive functioning tests were selected in which the child was able to solve problems without verbal communication to an experimenter (Lum, Conti-Ramsden, Page, & Ullman, 2012). It was hypothesized that children in the intervention group would show more improvement on physical fitness and executive functioning measures than children in the control group who didn't participate in the physical activity program.

6.2 Materials and methods

Participants and study design
All children were within a specialized school setting, with no interaction with typically developing children during school hours. A total of 36 children with DLD (26 boys, 10 girls) between 8 and 11 year old were recruited for this study. All children had been diagnosed as language-impaired, with both severe receptive and expressive deficits, and received special education for children with DLD in the northern Netherlands. A quasi-experimental design was used. Children from four classes, representing two grades, participated. Two classes were assigned as the intervention groups, and the other two classes as control groups. Three children were excluded from analyses because they were categorized as having impaired hearing (loss of > 35dB). Six children were excluded as they had an IQ below 80. The final sample consisted of 27 children (18 boys, 9 girls), of which 9 children were diagnosed with Attention Deficit Hyperactivity Disorder or Attention Deficit Disorder. Table 6.1 shows the scores on two subtests of the CELF-4-NL (Clinical Evaluation of Language Fundamentals-4th edition-NL) (Kort, Schittekatte, & Compaan, 2008) and the PPVT-3-NL (Peabody Picture Vocabulary Test-3rd edition-NL) (Schlichting, 2005), for children in the intervention and control group. Statistical differences were found between the intervention and control group on age and height, with children in the intervention group significantly older and longer than children in the control group. No statistical differences were found between the intervention and control group on weight, BMI, the percentage of children with normal and overweight/obese, non-verbal intelligence quotient (IQ) and scores on the CELF-4-NL subtests and PPVT-3-NL (Table 6.1).
Table 6.1. Descriptive statistics for children in the intervention and control group at baseline.

<table>
<thead>
<tr>
<th></th>
<th>Intervention</th>
<th>Control</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects (n)</td>
<td>12 (4 girls)</td>
<td>15 (5 girls)</td>
<td></td>
</tr>
<tr>
<td>Age (year)</td>
<td>9.1 (0.8)</td>
<td>8.2 (0.6)</td>
<td>.002**</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>141.0 (6.7)</td>
<td>134.4 (6.8)</td>
<td>.02*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>34.3 (8.0)</td>
<td>31.2 (6.1)</td>
<td>.29</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>17.0 (2.8)</td>
<td>17.2 (2.4)</td>
<td>.90</td>
</tr>
<tr>
<td>% normal weight</td>
<td>83</td>
<td>71</td>
<td>.47*</td>
</tr>
<tr>
<td>% overweight/obese</td>
<td>17</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Nonverbal IQ</td>
<td>98.0 (9.0)</td>
<td>92.0 (9.0)</td>
<td>.10</td>
</tr>
<tr>
<td>CELF-4 language structure</td>
<td>65.9 (9.8)</td>
<td>61.6 (8.3)</td>
<td>.23*</td>
</tr>
<tr>
<td>CELF-4 language content</td>
<td>74.8 (12.8)</td>
<td>74.8 (11.2)</td>
<td>.99*</td>
</tr>
<tr>
<td>PPVT-receptive</td>
<td>90.6 (10.9)</td>
<td>84.3 (10.5)</td>
<td>.14*</td>
</tr>
</tbody>
</table>


* p < .05

Procedure

All children followed their normal daily school routine, including two physical education lessons per week. Children in the intervention group received additional physical activity programmed on two non-physical education days. Physical fitness and executive functions were assessed at baseline and posttest. All children were tested individually by trained examiners, who were unaware of the child's experimental condition. One week after the baseline tests, the physical activity program started. As all children had continuous school days, the time of the intervention was fit within the timetable.

Training program

A 22 week, twice a week physical activity program was designed, that included both aerobic exercise, games and circuit training. Examples of aerobic exercise included running exercises, relay games or obstacle runs. Games included team games like dodgeball, handball, football or floorball. During circuit training, children had to perform various exercises individually, like rope jumping, sit-ups and jumping jacks, for a short time interval, and were encouraged to try to improve their previous score. All exercises were executed in pairs or small groups, to maximize time spent active. The emphasis in all activities was on intensity, but also on understanding and execution of the rules of the games or circuit training. The program lasted approximately 30 minutes each session, and
The intervention was provided by a student physical education teacher specialized in teaching atypical groups of children, under supervision of the physical education teacher of the school.

**Instruments**

**Physical fitness test.** Physical fitness was assessed using four tests from the European physical fitness test battery (EUROFIT) (Adam, Klissouras, Ravazzolo, Renson, & Tuxworth, 1988). The tests included were the standing broad jump (SBJ, in cm), the number of sit-ups (SUP, number in 30 s), the 10 x 5 m shuttle run test (10 x 5 m SR, in s), and the 20 m shuttle run test (20 m SR, in stages). The SBJ is measuring explosive leg strength. In this test, the child is asked to jump as far as possible with two feet from a standing position. Each child has two attempts, the best attempt is taken as a measure for SBJ. In the SUP test the child has to perform as many sit-ups as possible in 30 s. The test measures trunk strength and endurance. The 10 x 5 m SR test measures speed and agility. In this test, the child is asked to run back and forth between two lines 5 m apart, 10 times, as fast as possible, covering a total distance of 50 m. In the 20 m SR test, children have to run back and forth between two lines 20 m apart, on the pace of a beep that progressively increases in difficulty. Children run until they are unable to make it to the line on the sound of the beep. The test measures cardiovascular endurance. The 20 m SR test was assessed during a regular physical education lesson, while the remaining three tests were assessed in a circuit form during another regular physical education class. The test-retest reliability, ranging from .62 to .97, and construct validity of the four tests for children are adequate (Léger, Mercier, Gadoury, & Lambert, 1988; Van Mechelen, Van Lier, Hlobil, Crolla, & Kemper, 1991).

**Executive functioning.** Executive functioning was measured using two tests that reflected working memory skills and planning. The Visual Memory Span test (VMS) is measuring visuo-spatial working memory. In this test the child is presented with colored squares on a paper, at which the examiner is pointing in a predefined order. The child
is asked to replicate this sequence of movements in reverse order. This implies that the child will hold and manipulate the information in mind (Diamond, 2013). The test starts with two sequences and increases to seven sequences. The child gets two attempts at each level, resulting in a maximum of 12 attempts. Each correct trial is awarded with one point, resulting in a maximum of 12 points. The test discontinues when the child is unable to repeat two sequences of the same length. The VMS test has been used in children from age 6, and shows reliability ranging from .70 to .90 (Strauss, Sherman, & Spreen, 2006). Visuo-spatial working memory tests similar to the one adopted here have been used in children with DLD (Marton, 2008; Vugs et al., 2014).

In the Tower of London (ToL) test, a child has to solve a problem by moving three colored balls between three pegs of differing heights, from a fixed start state to a depicted target pattern. This implies that the child creates a strategy and keeps in mind the target pattern while evaluating the progress after each move. The test measures the ability to plan and sequence behavior towards a goal. A total of 12 problems have to be solved, in which the prescribed number of moves increases from two to five. Three attempts can be made for each problem, and points are assigned when a child solves the problem, ranging from 0 (not solved in three attempts) to 3 (solved in one attempt). The maximum score therefore is 36. The ToL has been tested and validated for use with children from age 7 (Anderson, Anderson, & Lajoie, 1996), and has also been used in children with DLD (Marton, 2008).

Data analysis
Data analyses were performed using SPSS 20.0 for Windows (IBM Corp., Armonk, NY, USA). A two (baseline and posttest) by two (condition: intervention and control group) repeated measures analysis of variance (ANOVA) was used to examine group differences on the change in mean scores on physical fitness and executive functioning measures. It was assumed that this test is most powerful to detect effects in a small sample size (Field, 2005). Covariates (gender, age, IQ) were included if they were related to the posttest score of the dependent variable. Level of significance was set at 5% (\( \alpha = .05 \)).

6.3 Results

One child in the intervention group was excluded from analyses as this child missed half of the physical activity program. The total sample for analyses therefore was 26. As we found
a difference between the intervention and control group on age, this variable was included as covariate in all analyses. In addition, gender correlated to posttest scores on the SBJ test \( r = -.52, p = .007 \) and 10 x 5 m SR test \( r = .65, p = .001 \), and was included as covariate in the corresponding analyses. No significant correlations were found between IQ and any of the posttest scores of the physical fitness measures, and no significant correlations were found between gender and IQ and posttest scores of the executive functioning measures visual working memory and planning.

Table 6.2 shows the results of the repeated measures ANOVA for the physical fitness and executive functioning measures. Significant differences between the intervention and control group were found on the SUP \( F(1, 23) = 6.8, p = .01, \eta^2_p = .24 \), indicating that children in the intervention group showed greater improvement on trunk strength and endurance than children in the control group. The accompanying effect size was large (Stevens, 1996). No significant effects of the physical activity intervention were found on the other physical fitness measures or on the executive functioning variables visual working memory and planning.
Table 6.2. Scores on physical fitness and executive functioning by group at baseline and posttest, and estimated means at posttest adjusted for covariates.

<table>
<thead>
<tr>
<th></th>
<th>Intervention group (n = 11)</th>
<th>Control group (n = 15)</th>
<th>Group p-value 1-sided</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post</td>
<td>Adjusted post</td>
</tr>
<tr>
<td><strong>Physical fitness</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBJ(^a) (cm)</td>
<td>121.3 (29.9)</td>
<td>127.0 (23.4)</td>
<td>123.9 (6.3)</td>
</tr>
<tr>
<td>SUP(^a) (n)</td>
<td>10.1 (6.7)</td>
<td>16.0 (4.3)</td>
<td>15.3 (1.5)</td>
</tr>
<tr>
<td>10 x 5m SR(^b) (s)</td>
<td>23.6 (2.6)</td>
<td>24.8 (3.0)</td>
<td>24.5 (0.9)</td>
</tr>
<tr>
<td>20 m SR(^c) (stage)</td>
<td>5.2 (2.6)</td>
<td>6.5 (2.7)</td>
<td>6.1 (0.7)</td>
</tr>
<tr>
<td><strong>Executive functioning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMS(^a)</td>
<td>6.7 (1.7)</td>
<td>6.9 (1.2)</td>
<td>7.1 (0.5)</td>
</tr>
<tr>
<td>ToL(^a)</td>
<td>27.4 (2.2)</td>
<td>28.9 (2.0)</td>
<td>29.0 (1.0)</td>
</tr>
</tbody>
</table>

Note. \(^a\) A higher score indicates a better performance. \(^b\) A lower score indicates a better performance. Values are expressed as means (SD) or estimated means (SE). Adjusted means at posttest adjusted for age at pretest (all variables), and gender for the variables SBJ and 10 x 5 m SR. SBJ = Standing broad jump. SUP = Sit-ups. 10 x 5 m SR = 10 x 5 m shuttle run. 20 m SR = 20 m shuttle run. VMS = Visual memory span test. ToL = Tower of London. \(^*\) p < .05
6.4 Discussion

This study was primarily designed to study the effects of extra physical activity during school time on physical fitness and executive functioning of children with DLD. The main findings revealed that children in the intervention group showed significantly greater improvements than children in the control group on one aspect of physical fitness, reflecting trunk strength and endurance. No effects of the physical activity intervention were found on the other physical fitness measures or on the two executive functioning measures visual working memory and planning.

To our knowledge, this is the first study that focused on increasing physical fitness and executive functioning in children with DLD by offering a physical activity program at school. Apart from the SUP, no significant effect was found for the SBJ, 10 x 5 m SR and 20 m SR test. Performance on the SBJ, SUP and 10 x 5 m SR test require a high degree of motor competence, good coordination and explosive movement (Hands & Larkin, 2006), and might be limited by possible motor impairment of children with DLD. Trunk strength was practiced in the circuit training of the physical activity program. The difference found between the intervention and control group on the SUP may therefore be the result of the circuit training within the physical activity program, making the training effect rather specific. Although performance on the 20 m SR test, reflecting cardiorespiratory endurance, was not significantly different between the intervention and control group, performance improved dramatically in both groups, especially in the intervention group. Cardiorespiratory endurance in children has a strong genetic component (Ortega et al., 2008). The improvements in both groups might therefore indicate that performance in the post-test more closely resembles their maximum performance in comparison to the baseline test, as a result of a maturation or practice effect. In addition, it should be noted that considerable variation in performance of children might have had an effect on the physical fitness results, as has also been reported in other studies on children with DLD (Rintala, Pienimäki, Ahonen, Cantell, & Kooistra, 1998).

No significant effects of the physical activity program were found on VMS and ToL performance, reflecting respectively visuo-spatial working memory and planning. It was expected that executive functioning would benefit from increased cardiovascular fitness, or that the games in the physical activity program would challenge aspects of executive functioning, as rules had to be kept in mind or strategies planned for optimal performance. However, while it has been shown that children with DLD have impairments in visuo-
spatial working memory performance (Hick, Botting, & Conti-Ramsden, 2005; Vugs et al., 2014), and planning (Marton, 2008), the mechanisms involved in these impairments remain unclear. This makes it difficult to know if impairments in executive functioning are manifest in physical activity situations, and if these situations are suitable to target impairments in executive functioning. For example, if the cognitive demand of physical activity tasks are greater than the resources of the children, performance might suffer (Im-Bolter, Johnson, & Pascual-Leone, 2006), and it is questionable if executive functions are trained. In addition, it should be noted that in the field of executive functioning research the question of the ecological validity of the tasks measuring executive functioning has emerged (Chaytor, Schmitter-Edgecombe, & Burr, 2006), especially for the assessment of children with disorders such as DLD. Future studies should therefore also include observational rating scales to get a more comprehensive view of executive functioning in various physical activity contexts (Vugs et al., 2014), which can then be used to design more carefully targeted (physical activity) interventions.

The strengths of this study are the pre and post measures of physical fitness and executive functioning in children with DLD and the implementation of the physical activity intervention (systematic training). It shows that offering extra physical activity is feasible in this atypical target group. In addition, a process evaluation showed that children enjoyed the program, which was also reflected by significant improvements from baseline to posttest on the athletic competence and physical appearance scale of the self-perception profile for children that was part of this evaluation. However, some limitations should be taken into account. It was not possible to randomly assign children to the intervention and control group, due to the complex and individually designed schedules of children involved. Therefore, we cannot completely rule out the possibility that improvements found were due to alternative explanations (e.g. attention, enjoyment). In addition, while the current intervention focused on increasing executive functioning by increasing physical fitness, there might be other programs that can stimulate executive functioning. Reynolds and Nicolson (2007) already demonstrated that balance, timing and coordination training rather than cardiovascular fitness was effective in stimulating a range of cognitive skills in children with reading difficulties. Last, given the heterogeneity of the DLD group, physical activity interventions that use a more personalized approach, in which goals are set for each individual child, will probably be more efficient to increase physical fitness and executive functioning. Nevertheless, this study contributes to the knowledge on effects of extra physical activity on physical fitness and two important aspects of executive functioning in children with DLD.
6.5 Conclusions

This study shows that it is feasible to implement a physical activity intervention at school for children with DLD. It was found that children in the intervention group showed significantly more improvement on abdominal muscle strength and endurance compared to the control group. This finding indicates that children with DLD can benefit from systematic training, but that the benefits on fitness are rather specific. No significant effects were found on executive functioning. Also, children with DLD enjoyed the physical activity program. Promoting children with DLD to be physically active is very important as it can increase their general health and well-being, which in turn might impact participation in physical activity and enhance physical fitness. Further research is required before conclusions can be drawn about the possible effects of physical activity on physical fitness and executive functioning in children with DLD.
References


Physical activity: Effects on fitness and executive functions in children with DLD