Influence of methylphenidate on motor performance and attention in children with developmental coordination disorder and attention deficit hyperactive disorder

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ABSTRACT

Individuals with attention deficit hyperactive disorder (ADHD) often have coexisting developmental coordination disorder (DCD). The positive therapeutic effect of methylphenidate on ADHD symptoms is well documented, but its effects on motor coordination are less studied. We assessed the influence of methylphenidate on motor performance in children with comorbid DCD and ADHD. Participants were 30 children (24 boys) aged 5.10–12.7 years diagnosed with both DCD and ADHD. Conners’ Parent Rating Scale was used to reaffirm ADHD diagnosis and the Developmental Coordination Disorder Questionnaire was used to diagnose DCD. The Movement Assessment Battery for Children-2 and the online continuous performance test were administered to all participants twice, with and without methylphenidate. The tests were administered on two separate days in a blind design. Motor performance and attention scores were significantly better with methylphenidate than without it (p < 0.001 for improvement in the Movement Assessment Battery for Children-2 and p < 0.006 for the online continuous performance test scores).

The findings suggest that methylphenidate improves both attention and motor coordination in children with coexisting DCD and ADHD. More research is needed to disentangle the causality of the improvement effect and whether improvement in motor coordination is directly affected by methylphenidate or mediated by improvement in attention.

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1. Introduction

Attention deficit hyperactive disorder (ADHD) and developmental coordination disorder (DCD) are two developmental conditions that may cause motor, academic and social dysfunctions (APA, 1994). Their coexistence was documented in several studies, and as many as 35–47% of the children with ADHD were diagnosed as having comorbid DCD (Kadesjö & Gillberg, 2003; Martin, Piek, Baynam, Levy, & Hay, 2010). A number of studies have described the link between motor coordination dysfunction and ADHD (Sergeant, Piek, & Oosterlaan, 2006). Children with ADHD are often clumsy, and have difficulties in gross and fine motor movements and balance (Fliers et al., 2010; Racine, Majnemer, Shevell, & Snider, 2008;
Children with DCD often exhibit problems in attention span, attention focusing, and decreased response inhibition, similar to children with ADHD (Mandich, Buckolz, & Polatajko, 2003). Children with DCD also have difficulties in performing attention-demanding tasks, such as writing. Neuroimaging studies show that children with DCD show decreased activation in the dorsolateral prefrontal cortex, which is involved in attentional control (Zwicker, Missiuna, Harris, & Boyd, 2011) and in the attentional brain network (Querne et al., 2008).

Sensory-motor and attention functions are intimately associated (Davis, Pass, Finch, Dean, & Woodcock 2009; Emanuel, Jarus, & Bart, 2008). Limited recruitment of attention functions is needed for the performance of simple automatic motor actions, whereas massive attentional control is required for the performance of complex motor tasks (Wulf, Shea, & Lewthwaite, 2009). Functional anatomy indicates that the cerebellum is important for both cognitive and motor functions, demonstrating massive reliance on prefrontal cortex-cerebellum connectivity and co-activation during performance and planning of motor actions (Diamond, 2000; Kalmbach, Ohyama, Kreider, Riusech, & Mauk, 2009).

Methylphenidate (MPH) is considered an effective medication for ADHD and is widely used to reduce symptoms in children with this disorder (Buitelaar & Medori, 2010). MPH attenuates behavior problems and improves attention focusing and response inhibition capacities in 60–80% of patients (Devito et al., 2009). Recent findings indicate that the influence of MPH on hyperactivity, impulsivity, and attention, is more robust in children with ADHD who also present with motor problems (Stray, Ellertsen, & Stray, 2010). Thus also pointing to a functional association between certain motor deficits and the behavioral symptoms of ADHD.

Much information is available on the influence of MPH on attention. Much less is known about the influence of MPH on motor function. Extant data suggest that MPH improves fine motor function (Flapper, Houwen, & Schoemaker, 2006) writing skills (Schoemaker, Ketelaars, Van Zonneveld, & Minderaa, 2005) and postural stability and balance (Jaciobi-Polishook, Shorer, & Melzer, 2009; Leitner et al., 2007) in children diagnosed with ADHD. Unlike its widespread use in the treatment of ADHD, MPH is hardly ever being prescribed to children with DCD, and thus, assessment of the influence of MPH on motor function is restricted to populations of children with coexisting DCD and ADHD. A study focusing on the quality of life of children with ADHD and DCD, showed improvement in motor coordination after taking MPH (Flapper & Schoemaker, 2008). A different study assessed the motor performance of children with both ADHD and DCD at two time points; once after having received MPH and once after having received placebo. An improvement in motor function was documented in all children, but it reached a level of significance in only 33% of them (Bart, Podoly, & Bar-Haim, 2010). The authors suggested that the children whose motor function did not improve under the influence of MPH may not have improved attention with MPH either. The aims of the present study were to assess the effects of MPH on both attention and motor function in children with coexisting DCD and ADHD, and to test whether functional changes in both domains are correlated. Therefore in our study we assess, in addition to motor function, attention before and after taking MPH.

2. Method

2.1. Study participants

Thirty children with coexisting ADHD and DCD participated in the study (24 boys, mean age 8.22 years, SD = 1.11, range 5.10–12.7). All the participants were diagnosed with ADHD and DCD by a neurologist or psychiatrist. The diagnosis of ADHD was confirmed by the Conners’ Parent Rating Scale (Conners, Sitarenios, Parker, & Epstein, 1998) and the diagnosis of DCD was confirmed by the Developmental Coordination Disorder Questionnaire (Wilson et al., 2007). Twenty-six of the children had combined type ADHD, and four children had a predominantly inattentive type ADHD. All the children scored above the 70th percentile on the attention difficulties scale, and 55th percentile on the hyperactivity/impulsivity scale of the Connors Parent Rating Scale (CPRS-R). Based on parental reports all children had a score below 46 on the Developmental Coordination Disorder Questionnaire (DCQ), an indication for a clinically significant DCD. All the participants were treated regularly with MPH: Ritalin SR/LA (n = 8, 26.7%); Ritalin 10 mg (n = 7, 23.3%); extended release methylphenidate–Concerta (n = 10, 33.6%); and Ritalin 20 mg (n = 5, 16.7%).

Children with other developmental problems (e.g., autism, cerebral palsy), sensory loss (e.g., hearing difficulties), or other psychiatric diagnoses based on parent-reports were excluded from the study. The study was approved by Tel Aviv University’s Ethics Review Board.

2.2. Measures

The online continuous performance test OCPT; eAgnosis Inc., Newark, DE; (Raz, Bar-Haim, Sadeh, & Dan, 2012) is a standard CPT designed for delivery over the Internet (demonstration available at http://www.checkadh.com/onlineCPTResearch.php). The task uses two geometric stimuli, a triangle and a circle, both presented in a light blue color in the middle of the screen against a gray background. The participants are instructed to respond to the triangle shape as quickly as possible by pressing the space bar on the computer’s keyboard, and not to respond to the circle shape. The task lasts 18 minutes and contains two conditions, low target frequency and high target frequency. The first half of the test (low target frequency condition) is boring and fatiguing, while in the second half of the test (high target frequency condition), the participant expects to respond most of the time but must occasionally restrain the tendency to respond. Three measures can
be extracted for analyses: errors of omission, errors of commission, and response times. These measures are extracted for each frequency condition. This test is reliable and valid and has Israeli norms (Conners, 1997).

The Conners’ Parent Rating Scale (CPRS-R; Conners et al., 1998) includes 80 items and is a commonly used tool for obtaining parental reports of childhood behavior problems. The results of exploratory and confirmatory factor analyses can extract information on seven factors: cognitive problems, oppositional, hyperactivity-impulsivity, anxious-shy, perfectionism, social problems, and psychosomatic. The scales demonstrate good internal reliability, high test-retest reliability, and effective discriminatory power (Conners, 1997). Advantages of the CPRS-R include a factor structure and comprehensive symptom coverage for ADHD and related disorders (Conners et al., 1998).

The Developmental Coordination Disorder Questionnaire (DCDQ; Wilson et al., 2007) is a parent-report screening questionnaire designed to identify children with motor difficulties at the ages of 5–15 years. The questionnaire includes 15 items, grouped into three factors: control during movement, fine motor and handwriting, and general coordination. Each item is scored on a 5-point Likert-type scale (1 = extremely like your child, 5 = not at all like your child). The total score can range between 15 and 75 points, with higher scores indicating better motor function. Norms are divided into three age groups, and a recommended cutoff score for DCD and suspected DCD is provided for each age group. The questionnaire has good internal reliability (Cronbach’s $\alpha = 0.89$) and good temporal stability (Cronbach’s $\alpha = 0.97$). External validity of the measure was obtained by correlation with the Movement Assessment Battery for Children – 2nd edition (M-ABC2; $r = .55$) and with the Beery-Visual Motor Integration test ($r = .42$) (Henderson, Sugden, & Barnett, 2007).

The Movement Assessment Battery for Children – 2nd edition (M-ABC; Henderson et al., 2007) is an individually administered standardized measure of movement impairment for children 3–16.11 years of age. The MABC2 is considered the gold standard for the diagnosis of DCD and contains 8 subtests across 3 domains: manual dexterity, aiming and catching, and balance. Test scores ranges from 0 to 40, where higher scores indicate greater impairment. The M-ABC2 has good test-retest reliability (minimum value at any age is 0.75), good inter-rater reliability (0.70), and good concurrent validity.

2.3. Procedure

We approached the parents of children who were diagnosed by a neurologist or a psychiatrist as having coexisting ADHD and DCD. At the first session, parents signed a consent form and completed the demographic questionnaire. Parents also completed the DCDQ to confirm the diagnosis of DCD and the CPRS-R to confirm the diagnosis of ADHD. The children who met inclusion criteria for the study according to the parents’ reports were invited to participate in two sessions of data collection that were conducted 3–14 days apart. Each session lasted approximately 75 min. In each session, the child completed the OCPT and the M-ABC2 test. The research assistant who administered the tasks was unaware of whether the child was under MPH. The medication was administered to the children by their parents 60 min before the session started (the time needed for the maximal clinical effect of MPH is between 60 and 120 min after injection (Wilens, Biederman, & Spencer, 2002).

Fifteen parents were instructed, by a different research assistant, to provide their child the medication before the first session and the other 15 parents were instructed to provide the medication before the second session. The assignment to each subgroup was random. When children were assessed without MPH they were off medication for at least 20 h. Assessment of whether there were differences in the M-ABC2 scores with/without MPH between the first and the second appointments (to control for a learning effect) revealed no significant differences in all the sub-tests and in the total score of the M-ABC2 test (all $ps > 0.46$). These results enabled us to combine the children with MPH in the first session and the children with MPH on the second session into one group.

2.4. Statistical analyses

Differences in OCPT and M-ABC2 scores with and without MPH were examined using paired $t$-tests. Pearson correlations were used to test associations between motor function (M-ABC2) and attention-related performance (OCPT) with and without MPH. Pearson correlations were also used to test associations between improvement in motor function (motor change = M-ABC2 scores with MPH–M-ABC2 scores without MPH) and the improvement in attention (attention change = OCPT scores with MPH–OCPT scores without MPH). Statistical significance was defined as $p < 0.05$.

3. Results

Comparisons of the motor performance of children with MPH to their performance without MPH revealed significant differences in all the sub-tests of the M-ABC2 test as well as in the M-ABC2 total score (Table 1).

Significant differences were also obtained for the total standard score and the percentile scores of the M-ABC2 ($p < .0001$). The mean score of motor performance under the influence of MPH was greater than the scale’s recommended clinical cut-off of 15 (mean = 26.78, SD = 22.54). Specifically: 20 children (67%) no longer would have been diagnosed as having DCD, four children (13%) improved in motor skills moving from the category of full DCD diagnosis to suspected DCD, and six children (20%) remained with the diagnosis of DCD. For individual scores of participants with and without MPH see Fig. 1.

As expected, MPH significantly improved children’s performance on the OCPT test. With MPH in comparison to without MPH, children had fewer omission and commission errors and faster Reaction Times (Table 1), indicating a positive influence of MPH on attention functions.
Pearson correlations between attention and motor function revealed significant correlations with the use of MPH. Omission scores in the low and high target stages of the OCPT were highly correlated with the total scores of the M-ABC2 ($r = .58$, $p < .001$; $r = .68$, $p < .0001$, respectively). Commission error scores did not correlate significantly with M-ABC2 scores in either low or high target frequency stages ($p < .645$). Generally, children improved their scores after taking MPH. M-ABC2 scores improved (mean = 13.4, SD = 13.73, range 0–53) as well as Omission scores (mean = 5.7, SD = 9.8, range 4–31) and

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Without MPH (n = 30) mean (SD)</th>
<th>With MPH (n = 30) mean (SD)</th>
<th>$t$</th>
<th>$p$</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-ABC2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual dexterity</td>
<td>10.13 (3.94)</td>
<td>19.06 (6.25)</td>
<td>−8.43</td>
<td>0.0001</td>
<td>0.65</td>
</tr>
<tr>
<td>Aiming and catching</td>
<td>11.8 (2.79)</td>
<td>18.46 (3.78)</td>
<td>−9.7</td>
<td>0.0001</td>
<td>0.71</td>
</tr>
<tr>
<td>Balance</td>
<td>15.6 (5.21)</td>
<td>28.26 (7.19)</td>
<td>−10.27</td>
<td>0.0001</td>
<td>0.71</td>
</tr>
<tr>
<td>Total M-ABC2</td>
<td>37 (9.73)</td>
<td>65.8 (14.46)</td>
<td>−11.28</td>
<td>0.0001</td>
<td>0.76</td>
</tr>
<tr>
<td>OCPT</td>
<td></td>
<td></td>
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<tr>
<td>Low target frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Omission</td>
<td>12.43 (9.04)</td>
<td>3.16 (5.23)</td>
<td>6.62</td>
<td>0.0001</td>
<td>0.53</td>
</tr>
<tr>
<td>Commission</td>
<td>12.53 (14.03)</td>
<td>4.2 (3.99)</td>
<td>3.21</td>
<td>0.003</td>
<td>0.37</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>665.44 (140.59)</td>
<td>585.53 (129.56)</td>
<td>2.97</td>
<td>0.006</td>
<td>0.28</td>
</tr>
<tr>
<td>High target frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omission</td>
<td>48.8 (34.39)</td>
<td>8.86 (13.86)</td>
<td>7.07</td>
<td>0.0001</td>
<td>0.61</td>
</tr>
<tr>
<td>Commission</td>
<td>17.93 (11.22)</td>
<td>11.9 (7.43)</td>
<td>2.93</td>
<td>0.006</td>
<td>0.3</td>
</tr>
<tr>
<td>Reaction time</td>
<td>589.33 (109.92)</td>
<td>521.1 (91.12)</td>
<td>3</td>
<td>0.005</td>
<td>0.32</td>
</tr>
</tbody>
</table>

M-ABC2: movement assessment battery for children-2, high scores mean better motor function.

Fig. 1. M-ABC2 individuals’ scores in percentile with and without MPH.

Fig. 2. Correlations between motor improvement and attention improvement with the use of MPH.
Commission scores (mean = 7.7, SD = 7.88, range –2 to 27). Significant high correlations were found between the MPH-related improvement in children’s motor function and their MPH-related improvement in attention in omission change score ($r = –.825, p < .0001$) and in commission change score ($r = .708, p < .0001$) (see Fig. 2). Reduction in the frequencies of omission and commission errors under MPH was related to improvement in motor coordination under MPH.

4. Discussion

This study was designed to determine the effect of MPH on attention and motor performance of children with coexisting ADHD and DCD. Our results demonstrated a significant improvement in all the OCPT scores when MPH was used, in line with many other studies supporting the effectiveness of MPH in improving attention functions (Buitelaar & Medori, 2010; DeVito et al., 2009; Stray et al., 2010).

An interesting observation in the current data is the fact that although MPH improved motor function and reduced both omission and commission type errors on the OCPT, significant associations between scores on motor function and scores on attention were observed only for omission type errors and not for commission type errors. Although this finding does not resolve the question of whether MPH independently affects attention and motor functions or whether some mediation effect is involved, it does suggest that MPH-related attention–motor associations are constricted to the sustained attention domain indexed by omission type errors and is not related to response inhibition.

Use of MPH led to significant improvement in children’s motor function in all the subtests of the M-ABC2 as well as in the total score. Similar results were found in two previous studies reporting a favorable effect of MPH on motor function in this population (Bart et al., 2010; Flapper & Schoemaker, 2008). In the present study the effect of MPH on motor function appears to be somewhat larger than that of earlier reports. Specifically, 67% of the children in the current sample functioned in the normal range with MPH in comparison to only 33% in a previous study by our group (Raz et al., 2012). The marked improvement in motor function with MPH in this population raises the question of the nature of the mechanism underlying such an improvement. The present findings indicate a correlation between children’s motor improvement and reduced frequency of omission and commission type errors on the OCPT as a function of MPH. This may indicate either that attention may serve as a mediator for motor function, or that MPH independently affects both attention and motor function. One possible explanation for the motor improvement after taking stimulants may be found in Diamond’s paper (Diamond, 2000). Using functional neuroimaging, she found that in addition to the prefrontal cortex, many cognitive as well as motor functions require the cerebellum. She demonstrated close co-activation of the neocerebellum and dorsolateral prefrontal cortex in addition to similarities in the cognitive sequelae of damage to the dorsolateral prefrontal cortex and the neocerebellum. Interestingly, there was evidence of motor deficits in cognitive developmental disorders, and of abnormalities in the cerebellum and in prefrontal cortex in motor developmental disorders. According to Diamond (2000) when there are perturbations, be they genetic or environmental, that affect the motor system (as in DCD) or cognition (as in ADHD), it is often the case that both motor and cognitive functions are affected, not just one or the other. The caudate nucleus and the neurotransmitter dopamine play roles in neural systems that serve cognitive and motor functions. These results imply that DCD and ADHD exhibit the same deficit in the central nervous system and thus the same treatment (here, MPH) would be effective for both disorders. In other words, it may be that the same mechanism that improved attention also improved motor function. Another explanation for our results is that attention may serve as a mediator for motor function, but we found no direct support for this possibility in the literature.

5. Conclusions and limitations

DCD was determined based only on a neurologist’s diagnosis and a single parent questionnaire and not based on all the criteria recommended in the DSM-I. In addition we have used the MABC-2 as an outcome measure but this measure was originally designed as a screening measure to identify children with DCD.

However, while our findings suggest that MPH improves both attention and motor coordination in children with coexisting DCD and ADHD, they do not allow strong conclusions on mechanism. Further research, perhaps on the effects of MPH on motor function of children with DCD without ADHD, is needed to shed further light on mechanism. If MPH proves to efficiently and reliably reduce motor deficits in children with DCD, new venue of treatment for DCD could emerge.

Conflicts of interest

The authors declare no conflicts of interest.

References


