Effect of Stimulant Medication Use by Children With ADHD on Heart Rate and Perceived Exertion

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The effect of stimulant medication use by children with attention deficit/hyperactivity disorder (ADHD) on the rating of perceived exertion (RPE)—heart rate (HR) relationship was examined. Children with ADHD ($n = 20$; $11.3 \pm 1.8$ yrs) and children without ADHD ($n = 25$; $11.2 \pm 2.1$ yrs) were studied. Children with ADHD were examined while on their usual dose of medication on the day of study. HR and RPE, using the OMNI RPE scale, were assessed during a graded exercise to peak voluntary effort. The RPE-HR relationship was determined individually and the intercept and slope responses were compared between groups. The intercept was $132.4 \pm 19.5$ bpm for children with ADHD and $120.6 \pm 15.7$ bpm for children without ADHD. The slope was $7.3 \pm 1.9$ bpm/RPE for the children with ADHD and $8.1 \pm 1.6$ bpm/RPE for the children without ADHD. For the group with ADHD the intercept and slope values fell outside of the 95% CI observed in the control group. The altered relationship between RPE and HR with stimulant medication use in children with ADHD has practical implications with respect to the use of HR and RPE to monitor exercise intensity.

Keywords: Attention deficit/hyperactivity disorder, graded exercise testing, perception of effort

Attention-deficit/hyperactivity disorder (ADHD) is a neuropsychological disorder that is characterized by poor attention as well as impulsive and hyperactive movements. In the United States, approximately 3–9% of children are estimated to have ADHD (Dopheid & Pliszka, 2009; Greenhill, 1998) with the diagnosis in boys typically greater than in girls (Rucklidge, 2010). The neurobiological cause of ADHD is thought to be the result of a dysfunctional catecholamine system in the brain, involving dopaminergic and noradrenergic pathways (Biederman, 2005; Swanson & Volkow, 2009). Systemically, it has been shown that children with ADHD also have a blunted catecholamine response to exercise (Wigal et al., 2003) and hypoglycemia (Girardi et al., 1995). ADHD is often treated by pharmacological
means with the use of stimulant medications such as methylphenidate or amphetamine, which have been shown to increase dopamine availability (Swanson & Volkow, 2009). However, behavioral interventions with children afflicted with ADHD, modifications to the living and learning environment, and parent and teacher training may be important adjuncts in the overall management of ADHD (Barkley, 1998; Brown et al., 2005). While effective in curbing disruptive behavior in children with ADHD, there are some undesirable side effects associated with stimulant medication use including increased heart rate (HR) and blood pressure at rest and during submaximal aerobic exercise, appetite suppression, and sleep disturbances (Ballard, Boileau, Sleator, Massey, & Sprague, 1976; Bennett, Brown, Craver, & Anderson, 1999; Brown & Sexson, 1989; Findling, Short, & Manos, 2001; Goldman, Genel, Bezman, & Slanetz, 1998; Vetter et al., 2008; Wilens et al., 2005). It should be noted, however, that the clinical implications and long term consequences of stimulant medication use have been questioned, especially in light of being able to adjust medication dose in the face of these adverse responses while still maintaining a therapeutic effect (Brown et al., 2005; Findling et al., 2001).

Children with ADHD experience diminished motor skill proficiency (Harvey & Reid, 2003; Verret, Gardiner, & Beliveau, 2010), demonstrate disruptive behaviors, and have poor peer and social relationships (Biederman & Faraone, 2005); exercise and physical activity may offer a potential therapeutic benefit in this regard (Bass, 1985; Higdon, 1999; Verret, Guay, Berthiaume, Gardiner, & Beliveau, 2010). Moreover, there is evidence that acute exercise may enhance brain dopaminergic activity in boys and girls with ADHD (Tantillo, Kesick, Hynd, & Dishman, 2002); however, due to the augmented cardiovascular response to stimulant medication use, it is of interest to study the interaction between stimulant medication and exercise. Previously it has been shown that both HR and blood pressure are higher during submaximal aerobic exercise when using stimulant medication compared with the nonmedicated state (Ballard et al., 1976; Boileau, Ballard, Sprague, Sleator, & Massey, 1976; Mahon, Stephens, & Cole, 2008). In that there is a fairly strong linear relationship between HR and ratings of perceived exertion (Robertson et al., 2000), it is likely that stimulant medication use by children with ADHD will alter the relationship between these two variables. Therefore, the purpose of this study was to examine the RPE-HR relationship during a graded exercise test performed to peak exertion in children with ADHD and presently using stimulant medication compared with similarly aged children without ADHD and not using stimulant medication. It was hypothesized that the relationship between RPE, plotted on the abscissa, and HR, plotted on the ordinate, would be altered between these two groups of subjects. Specifically, it was hypothesized that the intercept of the relationship would be higher and the slope of the response would be less based on the observation made by Mahon et al. (2008), who showed that the largest stimulant-induced difference in HR response occurred at the lowest level of exercise and diminished (difference lessened) as exercise intensity increased. The rationale for using two different groups of children to study this issue, rather than the same children on and off medication, was to ensure comparable peak HR responses between groups, since in a previous study it was reported that in the nonmedicated state, some boys with ADHD terminate the exercise test before achieving a peak cardiovascular response.
(Mahon et al., 2008). Ensuring a common endpoint (maximal HR) eliminated a potential confounding effect that could occur with variations in HR at the end of exercise between conditions.

**Method**

**Participants**

Forty-five children volunteered to participate in this study. Twenty (18 boys and 2 girls) children were diagnosed with ADHD and using stimulant medication in the treatment of the disorder at the time of study. For 19 children, it was confirmed that the diagnosis of ADHD was made in accordance with the Diagnostic and Statistical Manual-IV; confirmation could not be obtained for one male child. The average duration for stimulant medication use by the children with ADHD was $4.3 \pm 2.3$ yrs and all subjects reported to be on a stable dose of medication for the six months preceding participation in the study. Parental report indicated that children with ADHD were not using any other medication at the time of study. Twenty-five children (12 boys and 13 girls) served as control subjects. At the time of study, children without ADHD reported no positive history for any neuropsychological disorder and were not using medications that would affect the cardiovascular responses to exercise. The physical characteristics of all subjects and the daily medication disorder for the children with ADHD are reported in Table 1. Before participation, parental permission and child assent were obtained in accordance with the guidelines required by the Institutional Review Board. The results being reported in this study are part of a larger study that examined the acute effect of exercise on measures of attention and impulsivity.

**Procedures**

For this study, the children reported to the laboratory on two separate visits. The first visit provided an orientation to the procedures that would be used in subsequent testing. During this visit, the child’s age was recorded and stature and mass were measured. Following this, the child read a standardized set of instructions on

| Table 1  Demographic Comparison and Medication Amount |
|-----------------|-----------------|-----------------|---|---|
| Variable        | ADHD ($n = 20$) | Control ($n = 25$) | $t (43)$ | $p$ |
| Age (yrs)       | $M$ 11.3, $SD$ 1.8 | $M$ 11.2, $SD$ 2.1 | 0.26 | 0.80 |
| Stature (cm)    | $M$ 146.0, $SD$ 14.6 | $M$ 150.0, $SD$ 12.4 | -1.00 | 0.32 |
| Mass (kg)       | $M$ 39.6, $SD$ 11.5 | $M$ 46.8, $SD$ 15.0 | -1.76 | 0.09 |
| Medication (mg/d) | $M$ 33.5, $SD$ 14.3 | | | |

Note. ADHD = Attention deficit/hyperactivity disorder; Amphetamine use ($n = 8$); Methylphenidate use ($n = 12$)
the use of the RPE scale (Robertson, et al., 2000); after reading the instructions, the child answered several questions regarding the scale to ensure understanding. An opportunity to practice exercising on an electronically-braked cycle ergometer to become familiar with the exercise test protocol that was used on the next visit to the laboratory was then provided. The practice bout commenced at 25 W (W) for 2 min and incremented by 25 W every two minutes until a near-maximal effort became apparent. Typically this meant the HR > 180 bpm and RPE was in the upper third of the 0–10 RPE scale. During this practice trial, HR was recorded every minute and RPE was estimated at the end of each exercise test stage. The RPE scale was in full view of the subject through the entire exercise bout.

Upon arrival to the laboratory on the second day, the child was outfitted with the HR monitor and then performed a graded exercise test to peak voluntary exertion. The protocol began at 20 W for 2 min and the intensity increased by 20 W every 2 min until 60–100 W (based on child size and HR proximity to expected peak HR); thereafter, the power output increased by 10 W/min until peak voluntary effort. HR was recorded at 15-s intervals and RPE at the end of each test stage. The RPE scale was in full view of the subject during the entire exercise test. The children with ADHD performed this trial during the course of the day while on their usual daily dose of medication.

**Instrumentation**

Exercise was performed on a Lode Corival electrically-braked cycle ergometer. Pedal rate was maintained between 60 and 80 rpm. HR was measured using a Polar HR monitor. RPE was assessed using the cycle OMNI 0–10 RPE scale (Robertson, et al., 2000).

**Data Analysis**

Peak exercise responses were defined as the highest measurements obtained during the graded exercise test. Peak HR was taken as the highest two consecutive 15-s averages recorded during the graded exercise test. Peak power output was prorated based on the duration of the last test stage (Bar-Or, 1983). For example, if a child completed the penultimate stage at 100 W and then advanced to the next stage at 110 W, but only completed half (30 s) of the final stage, the peak power output credited was 105 W. The RPE-HR relationship (slope and intercept) was determined within each subject by plotting HR on the ordinate and RPE on the abscissa and using linear regression analysis. Data from the end of the first exercise test stage until peak voluntary effort was achieved were used for this purpose. This process provided an intercept and slope value for each subject. A minimum of four exercise test stages was required for inclusion in this study. The physical characteristics and peak exercise responses were compared between groups using an independent *t* test and are presented as means (M) ± standard deviation (SD). A *p*-value of < .05 was used to establish statistical significance for these evaluations. For the slope
and intercept comparisons, the M, standard error of the mean (SEM), and the 95% confidence intervals (CI) were calculated and are presented. Effect sizes were also determined (Cohen, 1988).

Results

The physical characteristics of the subjects participating in this study are displayed in Table 1. There were no differences, \( t(43) = –1.76 \) to 0.26, \( p > 0.05 \), between groups with respect to age, stature, and mass. The peak exercise responses are displayed in Table 2. There were no differences, \( t(43) = –0.66 \) to 1.42, \( p > 0.05 \), between groups for any of the variables listed in the table.

The RPE-HR relations are presented in Table 3 and displayed graphically in Figure 1. For the group with ADHD the intercept and slope values fell outside of the 95% CI observed in the control group. Specifically, the intercept was higher and the slope was lower. The effect sizes for these comparisons were \( d = 0.67 \) and \( d = –0.46 \) for the intercept and slope, respectively.

Table 2  Peak Exercise Responses

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADHD (( n = 20 ))</th>
<th>Control (( n = 25 ))</th>
<th>( t (43) )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (bpm)</td>
<td>M = 200 SD = 11</td>
<td>M = 200 SD = 9</td>
<td>–0.66</td>
<td>0.51</td>
</tr>
<tr>
<td>Power Output (W)</td>
<td>118.0 33.2</td>
<td>125.2 30.5</td>
<td>1.42</td>
<td>0.16</td>
</tr>
<tr>
<td>Power Output (W/kg)</td>
<td>3.1 0.6</td>
<td>2.8 0.7</td>
<td>–0.06</td>
<td>0.95</td>
</tr>
<tr>
<td>RPE</td>
<td>9.8 0.5</td>
<td>9.8 0.7</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note. ADHD = attention deficit/hyperactivity disorder; HR = heart rate; RPE = rating of perceived exertion

Table 3  RPE-HR Slope and Intercept Responses

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>M</th>
<th>SEM</th>
<th>95% CI (Lower—Upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD (( n = 20 ))</td>
<td>Intercept (bpm)</td>
<td>132.4</td>
<td>4.4</td>
<td>123.9–141.0</td>
</tr>
<tr>
<td></td>
<td>Slope (bpm/RPE)</td>
<td>7.3</td>
<td>0.4</td>
<td>6.5–8.1</td>
</tr>
<tr>
<td>Control (( n = 25 ))</td>
<td>Intercept (bpm)</td>
<td>120.6</td>
<td>3.1</td>
<td>114.5–126.8</td>
</tr>
<tr>
<td></td>
<td>Slope (bpm/RPE)</td>
<td>8.1</td>
<td>0.3</td>
<td>7.5–8.7</td>
</tr>
</tbody>
</table>

Note. RPE = rating of perceived exertion; HR = heart rate; ADHD = Attention deficit/hyperactivity disorder; CI = confidence interval
This study examined the influence of stimulant medication on the relationship between HR and RPE. To accomplish this purpose, the HR and RPE responses during a graded exercise test were compared between children with ADHD who were presently using stimulant medication and children without ADHD who were not using stimulant medication for any purpose. The results indicated that the intercept of the RPE-HR relationship was altered in the children with ADHD such that the intercept of the relationship was higher and the slope of the relationship was lower between the two groups.

The higher HR intercept observed in the children with ADHD and being treated with stimulant medication is consistent with a higher resting HR (Ballard et al., 1976; Findling et al., 2001) and submaximal exercise HR (Ballard et al., 1976; Boileau et al., 1976; Mahon et al., 2008) in children using stimulant medication. The mechanism underlying the effect of stimulant medication on elevating HR is unclear, but it is possible that there is increased catecholaminergic stimulation of pathways involved in cardiovascular control, or perhaps there is a direct effect on the heart itself through alterations in the sino-atrial node firing frequency at fixed metabolic rate. Regardless, the sympathomimetic nature of the medication will augment the sympathetic response on cardiovascular function (Joyce, Nicholls, & Donald, 1984). As peak HR was similar between groups, the greatest effect of

Figure 1 — The effect of stimulant medication on the relationship between HR and RPE in children with ADHD ($n = 20$) and control children without ADHD ($n = 25$). HR = heart rate; RPE = rating of perceived exertion; ADHD = attention deficit/hyperactive disorder.

Discussion

This study examined the influence of stimulant medication on the relationship between HR and RPE. To accomplish this purpose, the HR and RPE responses during a graded exercise test were compared between children with ADHD who were presently using stimulant medication and children without ADHD who were not using stimulant medication for any purpose. The results indicated that the intercept of the RPE-HR relationship was altered in the children with ADHD such that the intercept of the relationship was higher and the slope of the relationship was lower between the two groups.

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stimulant medication use by children with ADHD on exercise HR appears to occur at the lowest intensities. This outcome is consistent with the results reported by Mahon et al. (2008).

While the intercept response was higher, the slope of the response was attenuated in the in the children with ADHD who were being treated with stimulant medication as hypothesized. This would suggest that the rate of change in HR per unit change in RPE was less in this group compared with the control group. A higher starting HR (higher intercept value) and similar peak value would lead to this outcome. Although this outcome is consistent with the observation made by Mahon et al. (2008), it should be viewed with some caution as the effect size was only moderate, and the slope of the response for the control group (8.1 bpm/RPE) fell on the upper limit of the CI for the group with ADHD.

Generally speaking, HR and RPE are related in a linear manner during weight-bearing and nonweight bearing graded exercise (Noble & Robertson, 1996; Robertson et al., 2000). In this regard, the increase in the physiological stress accompanying load-incremented aerobic exercise, as indicated by the rise in HR, is linked to the perceptual strain being experienced by the exercising individual. As such, HR and RPE are often used in concert to gauge exercise intensity, especially when applied in an exercise prescription context (ACSM, 2010). However, it is also well established that the relationship between these variables can become distorted under certain conditions including the use of medications that may affect the HR responses. For example, at a given metabolic rate, the use of beta blocking medications will attenuate HR but increase RPE, thereby changing the relationship between these variables (Wilcox, Bennett, Macdonald, Herbert, & Skene, 1984). Akin to this example is the response observed in the current study—that elements of the relationship were different in the children with ADHD and using stimulant medication compared with the control group. In this case, at a given RPE, HR will be higher and at a given HR, RPE will be lower in children using stimulant medication. Although it should be noted that regardless of group, the linear relationship between RPE and HR was maintained and exercise prescription using RPE and HR can be tailored individually.

Application of exercise in children with ADHD also has potential therapeutic benefits. There are reports that children with ADHD may experience some motor skill deficiencies (Harvey & Reid, 2003; Verret, Gardiner et al., 2010). Generally speaking, facilitating physical activity and exercise opportunities for children with ADHD may aid in developing motor skill proficiency. Physical activity and exercise also can serve as a means to facilitate positive social and peer interactions, which is typically lacking in children with ADHD (Biederman, 2005). In addition, there is mounting evidence, both anecdotal and empirical, that exercise and physical activity may have therapeutic benefits with respect to curbing disruptive behaviors associated with ADHD (Bass, 1985; Higdon, 1999; Verret, Guay et al., 2010). In regard to this last point, further evidence of a neurobiological effect of exercise has been reported (Tantillo et al., 2002). Tantillo et al. (2002) found that indirect measures of dopaminergic function (spontaneous eye blink, acoustic startle eye blink, and motor impersistence) improved to some extent with acute exercise.

There are some limitations to this study that should be recognized. First, medication dose and type varied between children with ADHD as did the time of day for testing; thus the potential stimulatory effect of the medication varied as well.
Second, there was a clear imbalance in the gender distribution between groups. However, given the much higher frequency of ADHD diagnosis in boys versus girls, this is not surprising (Rucklidge, 2010). Third, the cross-sectional nature of the study design means that group differences could be due to variation between subjects independent of a medication effect. Comparing the same children on and off medication would eliminate between subjects differences that may confound the results. In a previous study, however, it was observed that some children with ADHD were unable to provide a peak effort, that is, persist at the graded exercise test long enough to reach a peak cardiovascular response (Mahon et al., 2008). As variations in peak exercise responses would have altered the slope of the relationship, it was determined that standardizing the peak responses was preferred and offsets the limitation associated with a between group comparison. It also should be noted that Mahon et al. (2008) reported that when children with ADHD were examined on and off medication, the RPE (Borg 6–20 scale) was similar at each level of work (25 W, 50 W, and 75 W) but HR was elevated. Thus it seems that medication indeed rather than the disorder itself is the cause of the heightened HR response observed in the group with ADHD. Moreover, the higher HR observed with medication in the children with ADHD is consistent with findings that stimulants elevate HR both at rest and during exercise in children with ADHD (Ballard et al., 1976; Boileau et al., 1976; Brown & Sexson, 1989; Vitiello et al., 2011).

In summary, this study examined the RPE-HR response to a graded exercise test in a group of children with and without ADHD to study the influence of stimulant medication use on this relationship. The results indicated that while the HR intercept was higher during stimulant medication use in children with ADHD, the slope of the relationship was less. In that exercise and physical activity may have therapeutic benefits in children with ADHD, knowledge of the interacting effect of stimulant medication use and exercise is warranted.

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References


