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Objective measurement of weekly physical activity and sensory modulation problems in children with attention deficit hyperactivity disorder

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ABSTRACT

This study aimed to objectively compare the daily physical activity (PA), as indicated by moderate-to-vigorous physical activity (MVPA) during a week and metabolic equivalents (METs) per minute, between children with attention deficit hyperactivity disorder (ADHD) and typically developing children. Moreover, sensory modulation problems were examined using behavioral and physiological measures. Twenty boys with ADHD (mean age 8.64 ± 2.57 years), and 20 matched typically developing boys (mean age 9.10 ± 1.79 years) participated in our study. Each child wore a PA monitor for 14 h a day, seven days a week. All participants' parents were asked to fill out daily activity logs for their children. The problems of sensory modulation were detected using sensory profile (SP) questionnaires and Sensory Challenge Protocol that measured electrodermal response (EDR) to repeated sensory stimulation. Compared with the controls, the children with ADHD had a generally higher level of PA (1.48 ± 0.10 vs. 1.60 ± 0.12 METs/min; $p = 001$), and tended to spend more time in MVPA on weekdays (35.71%) and the weekend (57.14%). However, when analyzing hourly recorded PA, the group differences were obvious only for certain hours. Our data suggested that children with ADHD were more hyperactive in structure-free than structured settings. The ADHD group showed their sensory modulation problems on the SP but not on the EDR. We found some correlations between sensory modulation problems and hyperactivity in children with ADHD.

1. Introduction

Attention-deficit hyperactivity disorder (ADHD) is a developmental disorder with high prevalence worldwide, 3–10% (Graetz, Sawyer, Hazell, Arney, & Baghurst, 2001; Wolraich, Hannah, Pinnock, Baumgaertel, & Brown, 1996), and around 50% of referrals to pediatric psychiatric clinics are for the assessment and treatment of ADHD (McGee, Clark, & Symons, 2000). One of its core symptoms, hyperactivity (American Psychological Association, 2000), often causes substantial disturbances for children with ADHD and for their parents (Barkley, 1998; Lin & Chung, 2002; Taylor, 1998). For example, hyperactivity may cause children with ADHD to run in a class that requires sitting quietly, and may interrupt their learning, result in rejection by their peers, and increase pressure for their parents (Lin & Chung, 2002).

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1.1. ADHD and physical activity

To better understand hyperactivity in children with ADHD, prior studies have measured the children's physical activity (PA) (e.g., Dane, Schachar, & Tannock, 2000; Halperin, Matier, Bedi, Sharma, & Newcorn, 1992; Porrino et al., 1983). Although these studies consistently confirmed that children with ADHD have a higher level of PA than typically developing children, some important questions remain unclear about the characteristics of PA, such as its intensity and frequency in children with ADHD. Some prior studies used subjective measures (Edwards et al., 2005; Luk, 1985), which could be biased by observers' perspectives (Edwards et al., 2005). Some used objective measures to decrease the observers' bias in laboratory situations on one particular day (Dane et al., 2000; Halperin et al., 1992, 1993; Teicher, Ito, Glod, & Barber, 1996), which would have worse reliability than recording PA for a week and would limit the understanding of children's general PA in daily life (Trost, Pate, Freedson, Sallis, & Taylor, 2000). Recording PA for an entire week would be more representative of daily life because school life is normally considered to recur in weeks per semester. Therefore, some studies (Imeraj et al., 2011; Porrino et al., 1983; Tsujii et al., 2007) assessed the PA of the children with ADHD in their daily life, including their time at school, for 7 days by asking the children to wear an objective activity monitor that recorded data as the number of movements the child made. However, using these units as an assessment of PA may limit the interpretation of the findings; that is, the connection between the number of movements and the intensity of PA may not be as clear as other units, such as metabolic equivalents (METs) per minute. For example, it may not be applicable to use number counts to understand whether a sufficient amount of PA is reached or to interpret the meaning of the differences between various levels of PA.

Activity monitors that can record PA using METs should be more helpful than using number counts for a better interpretation of the collected data. PA measured using METs can be classified into 4 levels of intensity: light (<3.00), moderate (3.00–5.99), vigorous (6.00–8.99), and very vigorous (>9.00) (Ekelund et al., 2001). Of these four levels, it is often suggested that time spent on moderate-to-vigorous physical activity (MVPA; 3.00–8.99 METs) be used to estimate a person's PA (Guerra, Santos, Ribeiro, Duarte, & Mota, 2003; Lin, Su, & Ma, 2012). At least 420 min of MVPA per week is recommended (Cavill, Biddle, & Sallis, 2001). Average PA in daily life can also be presented as total METs divided by time (METs/min). Sufficient or more than recommended PA in children with ADHD has been assumed because of their hyperactivity (Holtkamp et al., 2004). However, this assumption has not been fully investigated. Information about MVPA might prompt new strategies for treating children with ADHD (Tsujii et al., 2007).

1.2. ADHD and sensory modulation

Sensory processing could influence PA (Parham & Mailloux, 2005), and the problems of sensory processing in children with ADHD have already raised concerns (Ahn, Miller, Milberger, & McIntosh, 2004; Cheung & Siu, 2009; Engel-Yeger & Ziv-On, 2011; Miller, Nielsen, & Schoen, 2012; Mulligan, 1996; Parush, Sohmer, Steinberg, & Kaitz, 1997; Roid & Miller, 1997; Wang, Wang, & Ren, 2003; Yochman, Ornoy, & Parush, 2006; Yochman, Parush, & Ornoy, 2004). One primary pattern of sensory processing problems is difficulty in sensory modulation, which causes problems in responding to sensory input relative to its degree, nature, or intensity (Miller, Anzalone, Lane, Cermak, & Osten, 2007). Some children with ADHD have also been identified with sensory modulation problems, measured by behavioral (e.g., Cheung & Siu, 2009; Engel-Yeger & Ziv-On, 2011; Miller et al., 2012) and physiological assessments (e.g., Mangeot et al., 2001; Miller et al., 2012).

Several studies (Herpertz et al., 2003; Mangeot et al., 2001; Miller et al., 2012; Rosenthal & Allen, 1978; Shibagaki & Yamanaka, 1990; Spring, Greenberg, Scott, & Hopwood, 1974; Zahn, Abate, Little, & Wender, 1975) used electrodermal response (EDR) to assess the physiological reaction to sensory stimuli in children with ADHD. The EDR, which is regulated by the cholinergic fibers of the sympathetic nervous system, has been used to characterize the problems of sensory modulation (Mangeot et al., 2001; McIntosh, Miller, Shyu, & Hagerman, 1999; Miller et al., 1999). In contrast to the consistent results of those studies in the 1970s (Rosenthal & Allen, 1978; Spring et al., 1974; Zahn et al., 1975), which showed smaller phasic reactivity to stimuli in children with ADHD than in typically developing children, recent research has reported inconsistent results. For example, the physiological reactions in children with ADHD were reported as smaller than (Shibagaki & Yamanaka, 1990), larger than (Mangeot et al., 2001), and the same as (Herpertz et al., 2003; Miller et al., 2012) those in typically developing children. Thus, additional studies are needed to better understand this issue.

Additionally, to the best of our knowledge, few studies have examined the association between PA and sensory modulation problems in children with ADHD. A better understanding of their association may help clinicians develop better treatment strategies.

1.3. Purposes of this study

This appears to be the first study to record the PA in children with ADHD in METs for 7 consecutive days in natural settings, and to examine the association between PA and problems in sensory modulation. Specifically, we aimed to (1) examine the general difference in objective PA during one week between children with ADHD and their peers; (2) improve our understanding of the frequency and intensity of hyperactivity in children with ADHD in daily life, separately on weekdays and weekends; (3) examine the sufficiency of PA in children with ADHD; (4) use behavioral and physiological reports to understand reactions to sensory stimuli; (5) examine the relationship between PA and sensory modulation problems in children with ADHD.