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An investigation of gait in children with Attention Deficit Hyperactivity Disorder: A case controlled study

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ABSTRACT

This study aimed to compare the gait of children with ADHD – Combined Type (ADHD-CT) to typically developing (TD) children. Children with ADHD-CT ($n=14$; mean age 10 years 4 months) and a TD group ($n=13$; mean age 10 years 9 months) walked at self-selected slow, preferred and fast speed on an electronic walkway system. Participants completed a total of 15 walking trials; 5 trials per walking condition. Groups were matched on age, intellectual functioning, height and weight. In the preferred walking condition, there was no difference in spatio-temporal gait variables between the ADHD-CT and TD control groups. At self-selected fast speed, children with ADHD-CT were faster and walked with a higher cadence. The subtle alterations in gait pattern that may reflect a timing deficit is consistent with previous ADHD motor studies. In addition, this study extends previous studies in characterising the unique gait profile of non-medicated children with ADHD-CT where a diagnosis of autism spectrum disorder has been ruled out.

1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is the most prevalent childhood onset psychiatric disorder characterised by clinically significant symptoms of inattention, hyperactivity and impulsiveness that are present before 7 years of age (American Psychological Association, 2000). The Diagnostic and Statistical Manual 4th Edition Revised (DSM-IV-TR) defines three subtypes of ADHD; ADHD – Predominantly Inattentive subtype (ADHD-PI), ADHD – Predominantly Hyperactive-Impulsive (ADHD-HI) and ADHD – Combined Type (ADHD-CT) (APA, 2000). In addition to core clinical symptoms, motor disturbance is common in ADHD-CT (Harvey and Reid, 1997; Piek et al.,1999; Reiersen et al., 2008). Indeed, up to 50% of children with ADHD meet diagnostic criteria for Developmental Coordination Disorder (DCD), and individuals with a co-morbid diagnosis of ADHD and DCD experience greater motor difficulties (Pitcher et al., 2003). However, the specific pattern of motor disturbance that characterises ADHD is only emerging in the literature, far more is known about the cognitive profile of the disorder.

Children with ADHD present with an uneven executive function profile, characterised by difficulties on tasks measuring inhibition and sustained attention (Barkley, 2001; Johnson et al., 2007), which occur in the context of relatively intact planning ability and cognitive flexibility (Ozonoff and Jensen, 1999). Given the close overlap in neural networks that underpin cognitive and motor abilities (Diamond, 2000), it is not surprising that the ADHD motor profile is also characterised by specific areas of motor impairment which occur in the context of areas of preserved motor function. For example, the nature of motor problems commonly reported for individuals with ADHD range from poorer motor performance on standardized measures of fundamental movement skills and fitness (Harvey and Reid, 2003) to mild balance problems on posturography tasks (Buderath et al., 2009), and it has been proposed that these motor problems may be associated with core ADHD symptoms.

Pitcher et al., (2003) reported that a greater proportion of individuals with ADHD-PI subtype experienced motor difficulties (58% of $n=50$) compared to ADHD-HI (49% of $n=16$) and ADHD-CT (47% of $n=38$) subtypes. More specifically, Piek et al. (1999) found that children with ADHD-PI ($N=16$) had greater fine motor skill difficulties on the manual dexterity subscale of the Movement Assessment Battery for Children (MABC) compared to individuals with ADHD-CT ($N=16$), whereas children with ADHD-CT experienced greater difficulties with gross motor tasks (balance subscale of the MABC) compared to the ADHD-PI group. Furthermore a

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study conducted by Reiersen et al. (2008) reported an association between inattentive symptoms and parent reported motor problems measured on the Child Behaviour Checklist. Despite this, there are very few studies that have investigated the association between ADHD symptomatology (inattention, hyperactivity and impulsivity) and motor performance in ADHD.

In addition to the association between inattentive symptoms and motor features, autistic features have also been shown to be associated with greater motor impairment in children with ADHD (Reiersen et al., 2008). Indeed, this pattern compliments the association found between the severity of core social-communicative features and motor impairment in Autism Spectrum Disorders (ASD) (Qiu et al., 2010; Papadopoulos et al., 2012b). It has been suggested that overlap in social-communicative and motor difficulties in ASD may reflect disruption to common underlying brain pathways thought to develop in parallel (Qiu et al., 2010). It is therefore important for future ADHD motor research to consider co-occurring developmental factors such as DCD and ASD (Reiersen et al., 2008).

There is some overlap in the literature reporting disruption to motor brain regions, specifically fronto-striatal-cerebellar brain circuitry in ASD and ADHD (Bradshaw, 2001). Upper limb motor studies have provided insight in understanding fronto-striatal and cerebellar type motor impairment in these disorders using a range of tasks (Rinehart et al., 2001, 2006a; Papadopoulos et al., 2012a, 2012b). Numerous gait studies have also considered basal ganglia and cerebellar type motor anomalies in children with ASD (Ambrosini et al., 1998; Rinehart et al., 2006b, 2006c; Calhoun et al., 2011; Nobile et al., 2011; Nayate et al., 2012). Quantitative gait analysis techniques report that the gait pattern of children with autism at a preferred walking pace is characterised by a wide base of support (Nayate et al., 2012; Nobile et al., 2011), variation (both increases and decreases) in stride length and stride time variability (Rinehart et al., 2006a, 2006b; Nobile et al., 2011) as well as increased cadence (Calhoun et al., 2011). Investigations using qualitative gait methods in ASD have also reported a wide base of support (Ambrosini et al., 1998) and reduced smoothness of gait and postural abnormalities of the head and trunk (Rinehart et al., 2006c).

Unlike children with ASD who may show characteristic gait disturbances from an early age (Teitelbaum et al., 2004), there have been relatively fewer investigations of gait in children with ADHD. To our knowledge only two studies have measured gait variables in children with ADHD (Leitner et al., 2007; Buderath et al., 2009) using instrumented gait analysis techniques. In a study by Buderath et al. (2009) the gait and postural abnormalities of children with ADHD-CT (on medication; $n=10$) were compared to a cerebellar lesion and typically developing (TD) group. No differences between the ADHD group and TD controls were found in stride length, cadence or stride timing on a treadmill walking task, however ADHD participants scored significantly lower than TD controls when walking backwards on a beam. In a paced stationary stepping task with an external cue (metronome), the ADHD group was slightly slower than TD controls in the fast paced condition. This pattern was consistent with the cerebellar lesion group, providing preliminary support that ADHD may be associated with cerebellar dysfunction. Another study by Leitner et al. (2007) investigated the effect of dual tasking on gait function in children with ADHD without significant motor impairment (9–16 years; $n=16$), off methylphenidate. They reported no difference between the ADHD and TD groups in the preferred walking condition (single task condition; off medication), although a trend to higher stride time variability was noted in the ADHD group ($p=0.09$). In the dual task condition, stride time variability significantly reduced in the ADHD group compared to the baseline (single task) condition. Stride time variability also reduced when ADHD individuals were medicated compared to baseline. It was concluded that methylphenidate had a positive effect on gait, reducing the mildly increased stride time variability in the ADHD group.

The aim of the current study is to characterise the gait of children with ADHD using the same protocol used in Nayate et al.'s (2012) study of gait in children diagnosed with autism and Asperger's disorder to further inform our understanding of disrupted underlying neural circuitry in ADHD. It was hypothesised that there would be no difference in gait variables (speed, stride length, cadence, base of support and double support time) between the ADHD group and the TD group in the preferred baseline walking condition. Further based on the gait studies conducted by Leitner et al. (2007) and Buderath et al. (2009) it was hypothesised that the ADHD group may display subtle timing anomalies. In addition, based on previous research in ASD that indicates a significant relationship between motor disturbance and social-communicative disturbance (Qiu et al., 2010; Papadopoulos et al., 2012b) we predicted a positive association between gait variables characteristic of ASD such as a wider base of support and increased stride length variability and social-communication symptoms in children with ADHD-CT. Lastly, based on the finding that children with ADHD-inattentive type may experience more motor difficulties than other subtypes (Pitcher et al., 2003), the association between inattentive symptoms measured on the Conner's Rating Scale and spatio-temporal gait variables was explored.

2. Method

2.1. Participants

Informed consent was obtained from parents/guardians of all participants, in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Human Research Ethics committee at Southern Health and Monash University, Melbourne Australia.

Fourteen boys diagnosed with ADHD – Combined type (ADHD-CT) aged between 7 and 13 years were recruited from Private Paediatricians in Melbourne. The paediatricians specialised in ADHD with 10–20 years of clinical experience in the field, and undertook further assessment and diagnosis of ADHD-CT. These children fulfilled DSM-IV-TR (APA, 2000) criteria for ADHD – Combined type (ADHD-CT). Diagnosis of ADHD-CT was further confirmed by a doctoral-level trained graduate student (author N.P.) under the supervision of a clinical psychologist (author N.R.) using the Conners Rating Scale (Conners, 2001), parent interviews, direct child observations and information from teachers and therapists. Paediatricians also confirmed that children with a diagnosis of ADHD-CT did not have a co-morbid diagnosis of autistic disorder, Asperger's disorder or pervasive developmental disorder not otherwise specified based on their assessment and medical records. Participants who entered the study were further screened for a possible diagnosis of ASD using the Autism Diagnostic Observation Scale (ADOS) by a qualified researcher. No participants were excluded based on elevated ADOS scores (ASD cut off score=7).

Additional exclusion criteria included co-morbid medical (e.g., tuberous sclerosis), hearing or visual impairments, or genetic (e.g., Fragile X syndrome) disorders. The majority of participants in the study (12/14) was on stimulant medication such as methylphenidate (Ritalin). Participants on medication discontinued medication at least 24 h before testing commenced.

A reference sample of 13 typically developing (TD) boys aged between 7 and 14 years were recruited from local schools and the community. The TD children had no prior history of psychological, neurological or psychiatric diagnosis. This was confirmed by researchers via interview with children's parents, from whom information on developmental, medical and psychiatric history was obtained (i.e. whether children had any previous diagnoses or had received any intervention). All participants in the TD group were also screened for ADHD-CT symptoms using the Conner's Rating Scale (Conners, 2001) and for autistic symptoms using the Social Responsiveness Scale (Constantino and Gruber, 2005). One TD child was excluded for having Social Responsiveness Scale (SRS) scores indicative of clinically elevated (t score >76) social responsiveness difficulties.

The intellectual functioning of TD boys was assessed using the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999) or the Wechsler Intelligence Scale for children 4th edition (WISC-IV) (Wechsler, 2005), and the intellectual functioning of children with ADHD-CT was assessed using the WISC-IV. The WASI and WISC-IV are highly compatible with.87 correlation between their full scale IQ scores (Wechsler, 1999). Motor proficiency was assessed and children were screened for DCD using the Movement Assessment Battery for Children

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