Research in Developmental Disabilities 34 (2013) 3040–3048

Contents lists available at SciVerse ScienceDirect

Research in Developmental Disabilities

Slowed muscle force production and sensory organization deficits contribute to altered postural control strategies in children with developmental coordination disorder

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ARTICLE INFO

Article history:
Received 20 March 2013
Received in revised form 16 May 2013
Accepted 21 May 2013
Available online 3 July 2013

Keywords:
Clumsy children
Muscle contraction time
Motor strategy
Sensory inputs
Balance

ABSTRACT

This study aimed to (1) compare the postural control strategies, sensory organization of balance control, and lower limb muscle performance of children with and without developmental coordination disorder (DCD) and (2) determine the association between postural control strategies, sensory organization parameters and knee muscle performance indices among children with DCD. Fifty-eight DCD-affected children and 46 typically developing children participated in the study. Postural control strategies and sensory organization were evaluated with the sensory organization test (SOT). Knee muscle strength and time to produce maximum muscle torque (at 180°/s) were assessed using an isokinetic machine. Analysis of variance was used to compare the outcome variables between groups, and multiple regression analysis was used to examine the relationships between postural control strategies, sensory organization parameters, and isokinetic indices in children with DCD. The DCD group had significantly lower strategy scores (SOT conditions 5 and 6), lower visual and vestibular ratios, and took a longer time to reach peak torque in the knee flexor muscles than the control group ($p > 0.05$). After accounting for age, sex, and body mass index, the vestibular ratio explained 35.8% of the variance in the strategy score of SOT condition 5 ($p < 0.05$). Moreover, the visual ratio, vestibular ratio, and time to peak torque of the knee flexors were all significant predictors ($p < 0.05$) of the strategy score during SOT condition 6, accounting for 14, 19.7, and 19.8% of its variance, respectively. The children with DCD demonstrated deficits in postural control strategy, sensory organization and prolonged duration of muscle force development. Slowed knee muscle force production combined with poor visual and vestibular functioning may result in greater use of hip strategy by children with DCD in sensory challenging environments.

1. Introduction

Developmental coordination disorder (DCD) is one of the most common pediatric sensorimotor disorders, affecting approximately 6% of typically developing children worldwide (American Psychiatric Association, 2000). The prevalence rate

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0891-4222/$ – see front matter
http://dx.doi.org/10.1016/j.ridd.2013.05.035

of DCD in Hong Kong has not been determined (Child Assessment Service, 2006). Children diagnosed with DCD are characterized by marked impairment in motor coordination that significantly interferes with their academic achievements and daily activities (American Psychiatric Association, 2000). Among the many sensorimotor problems found in children with DCD, poor postural control is the most common, demonstrated in 73–87% of the DCD-affected population (Macnab, Miller, & Polatajko, 2001). The problem requires special attention because suboptimal balance ability may increase the risk of falls, limit activity participation, and affect motor skill development (Fong, Lee, & Pang, 2011; Grove & Lazarus, 2007).

Postural stability requires the optimal reception, processing, and integration of sensory inputs from somatosensory, visual, and vestibular systems along with proper muscle responses and execution of movement strategies such as ankle and hip strategies (Horak & Macpherson, 1996; Nashner, 1997). It has been well documented that children with DCD have widespread impairment in their sensory organization that is associated with greater standing postural sway (Fong et al., 2011; Grove & Lazarus, 2007; Inder & Sullivan, 2005). Yet, how sensory organization deficits influence movement strategies that in turn lead to the greater postural sway is still not known. Moreover, it has been reported that younger children with DCD have lower knee muscle strength (Raynor, 2001) and altered timing of postural muscle contraction (Johnston, Burns, Brauer, & Richardson, 2002). We hypothesize that these neuromuscular deficits may also affect the postural control strategies used by such children. It is important to understand the factors that may affect balance strategies in this pediatric group to design specific remedial interventions to improve their sensorimotor impairments, movement strategies, and balance performance.

To date, only one study has directly examined the postural control strategies used by children with DCD. Fong, Tsang, & Ng (2012) found that DCD-affected children tended to over-rely on hip strategy (i.e., large and rapid motion at the hip joints with antiphase rotations at the ankle joints) rather than ankle strategy (i.e., body sway centered primarily about the ankle joints) to maintain balance when standing in sensory challenging environments, but they did not offer any explanation for this phenomenon (Horak & Macpherson, 1996; Nashner, 1997). Moreover, the Fong et al. (2012a) study sample was too homogenous (i.e., DCD children with no indications of autistic disorder or attention deficit hyperactivity disorder) and small (DCD group, $n = 22$; control group, $n = 19$). Studies with larger sample sizes that use more representative samples (i.e., children with DCD and comorbidities) are needed to accurately detect differences in balance strategies between children with and without DCD and to improve the generalizability of results.

Therefore, this study aimed to (1) compare the postural control strategies, sensory organization of balance control, and lower limb muscle performance of children with and without DCD, and (2) examine the relationship between postural control strategies, sensory organization parameters, and muscle performance indices among children with DCD.

2. Methods

2.1. Participants

This was a cross-sectional, case-control, and exploratory study. All sample size calculations were based on a statistical power of 0.80 and an alpha of 0.05 (two-tailed). Previous studies showed that children with DCD had lower sensory ratios than typically developing children, with effect sizes ranging from 0.3 to 0.8 (Fong et al., 2011; Fong, Tsang, & Ng, 2012). Moreover, based on a sample of 20 children with DCD and 20 control participants, Raynor (2001) showed that a DCD group had significantly lower isokinetic peak torques, with effect sizes of 1.2 and 1.5 for knee extension and flexion, respectively. For the comparison of sensory organization test (SOT) strategy scores between children with and without DCD, our previous study (Fong et al., 2012a) showed that the minimal effect size was 0.8. In light of the overall available scientific evidence, a medium to large effect size of 0.6 was expected for this study. Therefore, the minimum sample size required to detect a significant between-group difference in outcomes was 45 for each group (objective 1). Regarding the multiple regression analyses, if up to four variables were to be modeled at an effect size of 0.25 (medium to large), a minimum of 53 children with DCD were needed (objective 2).

Children with DCD were recruited from local child assessment centers and hospitals. They were diagnosed with DCD (with or without comorbid conditions) after a formal multidisciplinary evaluation at the child assessment centres. The inclusion criteria were (1) a formal diagnosis of DCD made by a pediatrician, child psychologist or child psychiatrist, according to the criteria stated in the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2000); (2) demonstrating motor coordination below that expected of the child's chronological age (i.e., Bruininks Oseretsky Test of Motor Proficiency standard score of less than or equal to 42 according to Bruininks (1978); (3) aged between 6 and 11 years; (4) studying in a mainstream school; (5) having no intellectual impairment as determined by a child psychologist at the child assessment center; (6) Chinese ethnicity; and (7) residing in Hong Kong. The exclusion criteria were (1) a diagnosis of neurological or other movement disorder (e.g., cerebral palsy); or (2) significant congenital, musculoskeletal (e.g., fracture) or cardiopulmonary disorder that could affect movement strategies or muscle force production. Age- and sex-matched healthy control children were recruited by convenience sampling from the local community following the inclusion and exclusion criteria stated above except that they did not have any history of DCD. All children in the control group were screened by a pediatric physiotherapist using the Movement Assessment Battery for Children-2 to ensure that they had a total percentile score of greater than the 15th percentile (i.e., had no movement difficulty). Movement ABC-2 has been shown to have good to perfect test-retest (ICC ranging from 0.73 to 0.80), inter-rater (ICC ranging from 0.95 to 1.00) reliability and criterion-related validity (Henderson, Sugden, & Barnett, 2007).