



Contents lists available at ScienceDirect

Research in Developmental Disabilities

journal homepage: www.elsevier.com/locate/redevdis

Leg muscle activation patterns during walking and leg lean mass are different in children with and without developmental coordination disorder



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ARTICLE INFO

Number of reviews completed is 3

Keywords:

Developmental coordination disorder
Kinetics
Gait
Muscle mass

ABSTRACT

Background: Previous studies have shown that children with developmental coordination disorder (DCD) have a higher body fat and greater gait variability. Little research has investigated the gait muscle activity and lean mass measures in children with DCD.

Aims: To compare the leg muscle activation patterns of the gait cycle and leg lean mass between children with and without DCD.

Methods: Fifty-one children were in the DCD group (38 males and 13 females; 7.95 ± 1.04 years) and fifty-two in the control group (34 males and 18 females; 8.02 ± 1.00 years). Peak muscle activation patterns of treadmill walking in the right leg for the eight-gait phases were measured by means of surface electromyography, an electrogoniometer, and foot contact switches. Leg lean mass measures were evaluated using a whole-body dual energy X-ray absorptiometry scan.

Results: Children with DCD had a lower leg lean mass and appendicular lean mass index compared to the control group. Furthermore, they exhibited a less-pronounced peak muscle activation during the heel strike (gastrocnemius medialis), early swing (biceps femoris) and late swing phases (gastrocnemius medialis) of gait.

Conclusions and implications: Although lower limb total mass was similar between groups, the DCD group displayed lower lean mass measures than controls. Furthermore, children with DCD illustrated a lower leg peak muscle activation during the heel strike, early swing and late swing phases of gait when walking on a treadmill. Our results emphasize the need to incorporate lower limb phasic muscle strengthening components into gait rehabilitation programs for children with DCD.

What this paper adds

This is one of the few studies to investigate leg lean mass and gait muscle activation patterns in walking from children with DCD. We found that children with DCD had a lower gastrocnemius medialis muscle activation level during the heel strike and late swing phases of gait and lower biceps femoris muscle activation level during the early swing phase of gait compared to controls. These children also had lower leg lean mass and lower appendicular lean mass indices than their typically developing peers. This provides further insight on the different walking strategies they adopt and elements to incorporate into rehabilitation programs for children with DCD.

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<https://doi.org/10.1016/j.ridd.2017.12.014>

Received 13 May 2017; Received in revised form 11 December 2017; Accepted 11 December 2017
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1. Introduction

Developmental coordination disorder (DCD) is a neurodevelopmental condition with a prevalence ranging from 1.8% to 8.6% worldwide (American Psychiatric Association, 2013; Kadesjö & Gillberg, 1999). Motor coordination deficits are diagnosed as early as age 5 years for children with DCD which may persist through adolescence and adulthood interfering significantly with daily activities (APA, 2013; Henderson, Sugden, & Barnett, 2007). Motor deficits include both physical and psychosocial aspects. Children with DCD exhibit a greater lower limb gait variability and lower self-worth in several physical and functional domains (Fong et al., 2011; Rosengren et al., 2009; Skinner & Piek, 2001). A lower self-efficacy level partly accounts for the lower participation in physical activities in children with DCD which may explain the greater likelihood of choosing sedentary activities (Cairney, Hay, Faught, & Hawes, 2005) and higher weight status in this population (Fong et al., 2011).

Most children acquire effective walking skills naturally as they mature. For typically developing (TD) children, temporal gait parameters continually mature starting as early as the first year in growth with a gradual decrease in cadence and an increase in stride length (Sutherland, 1997). Initial heel strike starts to develop after age 1 year and the knee flexion during loading response is not developed until the age of 4 (Sutherland, 1997). Stride-to stride control is not fully developed even at the age of 7 years (Hausdorff, Zeman, Peng, & Goldberger, 1999) suggesting that gait maturation is a complex process.

Muscle maturation (most notably tibialis anterior, gastrocnemius, soleus and vastus medialis) occurs between the ages 1 and 2 years (Sutherland, 1997) where muscles interact intricately to produce a metabolically efficient gait. For a typical gait cycle, rectus femoris extends the knee prior to the heel strike phase followed by tibialis anterior activity to oppose the plantarflexion ground reaction force. Simultaneously, the biceps femoris serves as a hip extensor to control forward rotation of the thigh. Muscles contract synergistically throughout the gait cycle to increase gait efficiency (Di Nardo, Mengarelli, Maranesi, Burattini, & Fioretti, 2015). Children with DCD often adopt an adaptive gait and exhibit a relatively higher cadence compared to their TD peers (Deconinck et al., 2006). This is accompanied by less precise control at the ankle joint with less pronounced ankle plantarflexion during the toe-off phase (Deconinck et al., 2006). Furthermore, the shank (distal) section exhibits greater complexity than the thigh (proximal) segment which suggests that distal segments (ankle) produce greater variability (Rosengren et al., 2009). According to Deconinck et al. (2006), these gait differences are suggestive of an immature gait which may be a compensatory reaction to adopt a safer walking strategy.

Gait differences are also present in running and fast walking which interfere with a broader aspect of daily activities in children with DCD. In running, they demonstrate a deficit in ankle power generation (Diamond, Downs, & Morris, 2014). When examining ankle power generation in fast walking, the differences between children with and without DCD are comparable to the elderly population (Diamond et al., 2014). Since ankle power generation is relatively lower in elderly fallers (Perry, Carville, Smith, Rutherford, & Newham, 2007), the gait deficits seen in this population are of great clinical importance with possible interference to dynamic balance. Chia, Licari, Guelfi, & Reid (2013) also investigated the kinematics and kinetics of running in children with DCD and found that they had a longer stance duration and decreased knee joint moments. However, joint moments and muscle forces were measured indirectly using a force platform, which did not capture individual muscle activations. Thus, it is essential to explore the differential muscle activation patterns of walking and to further understand the complexity of locomotion in children with DCD.

Gross motor difficulties in children with DCD could also be affected by body weight (Cattuzzo et al., 2016). Since body weight includes multiple components, it is unknown which aspect of body composition is more influential to physical performance. What is certain is that children with DCD are less likely to participate in physical activities. This may be related to their higher body fat, body mass index (BMI) (Cairney et al., 2005) and their poorer movement skills (Okely, Booth, & Chey, 2003). Although children with DCD have a higher body fat (Cairney, Hay, Veldhuizen, & Faught, 2011), the pattern may not necessarily translate to lean mass. To the best of our knowledge, no studies have investigated lean mass or related measures in this population. The only study that examined a similar outcome considered fat free mass (FFM) and the authors found no significant difference between children with and without DCD (Cairney et al., 2011). Since FFM also includes bone mineral content (BMC), it does not fully reflect on lean mass which is related to a higher likelihood of weakness in older adults (Cawthon et al., 2014). Given that children with DCD have deficits in fine ankle control (greater variability in ankle control) (Rosengren et al., 2009), it would also be beneficial to investigate lean mass targeted for the peripheral extremities such as appendicular lean mass index (ALMI). Comparing lean mass and the associated outcome measures (i.e. total mass and ALMI) between children with and without DCD may help to inform intervention programs.

The aim of this cross-sectional study was to compare (i) the leg lean mass, leg total mass and ALMI; and (ii) the leg muscle activation patterns throughout the gait cycle performed on a treadmill between children with and without DCD. Due to the previous gait deficits seen during push off in children with DCD with decreased ankle control, we hypothesized that they would exhibit less pronounced muscle activation during the force generating phase especially at the ankle muscles. Given that children with DCD had a higher percentage of body fat, BMI and reported lower strength (Cairney et al., 2005; Raynor, 2001), we hypothesized that their overall lean mass would be relatively lower than TD children.

2. Methods

2.1. Participants

Between March and August 2016, 200 children were recruited from primary schools in Hong Kong and our database of DCD participants through invitation letters, posters and social media advertisements, and personal invitations. One hundred and three volunteer children were eligible to participate in the study. Fifty-one were allocated to the DCD group (38 males and 13 females;

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