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Obstacle crossing in 7–9-year-old children with Down syndrome

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ABSTRACT

This study aimed to investigate obstacle crossing in 7–9-year-old children with Down syndrome (DS). Fifteen children with DS, age- and gender-matched with 15 typically developing (TD) children, were recruited to walk and cross obstacles with heights of 10%, 20% and 30% of their leg lengths. End-point and kinematic variables of obstacle crossing were obtained using a three-dimensional motion analysis system. The results showed that children with DS tend to adopt a lower speed and larger step width when they perceive instability. Moreover, unlike TD children, children with DS adopt a pelvic strategy (i.e., greater pelvic leading-side listing and forward rotation) to achieve a higher leading toe clearance with a longer step length, presumably for safety reasons. This pelvic strategy increased the frontal plane motion of the whole leg and trunk, and thus possibly stability, during obstacle crossing. However, this strategy may be inefficient. Trailing toe clearance did not differ significantly between two groups. The results of this study suggest that children with DS tend to use inefficient and conservative strategies for obstacle crossing. Knowledge of both end-point and kinematic control of obstacle crossing in children with DS is useful for understanding the mechanisms of obstacle-related falls. Moreover, obstacle crossing can be used as a task-oriented rehabilitation program for children with DS.

What this paper adds?

Children with DS may have trouble crossing obstacles, leading to an increased frequency of trip-related falls. However, few studies have addressed obstacle crossing in individuals with DS, and of those few, most have focused on adults. Only one study has investigated the motor control strategy of obstacle crossing in children with DS. However, that study investigated only end-point variables (i.e., step length and toe clearance). Since the end-point trajectory of the foot is controlled by the intersegmental coordination of the locomotor system, kinematic data on the locomotor system during obstacle crossing, including joint angles and pelvic motion, may provide more information regarding the motor control strategies of obstacle

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crossing in children with DS. The results showed that unlike TD children, children with DS adopted a pelvic strategy to achieve a higher leading toe clearance, presumably for safety reasons. This pelvic strategy increased frontal plane motion, and thus possibly stability, during obstacle crossing. However, this strategy may be inefficient. The results of this study suggest that children with DS tend to use inefficient and conservative strategies for obstacle crossing. Knowledge of both end-point and kinematic control of obstacle crossing in children with DS is useful for clinicians, as it can improve their understanding the mechanisms of obstacle-related falls. Moreover, obstacle crossing can be used as a task-oriented rehabilitation program for children with DS, for it provides simultaneous training in both central stability control and end-point precision control.

1. Introduction

Children with Down syndrome (DS) often exhibit hypotonia, ligamentous laxity, poor postural control, and perceptual-motor difficulties (Gupta, Rao, & Kumaran, 2011; Shumway-Cook & Woollacott, 1985b; Wuang, Chiang, Su, & Wang, 2011), which may affect their motor development. Owing to these problems, children with DS may have trouble crossing obstacles, leading to an increased frequency of trip-related falls (Vimercati, Galli, Rigoldi, & Albertini, 2013). Knowledge of the control strategy of the locomotor system during obstacle crossing would be helpful for identifying potential risk factors for tripping and in planning effective prevention and training programs.

Children with DS have been reported to begin walking one year later than typically developing (TD) children (Black, Chang, Kubo, Holt, & Ulrich, 2009; Ulrich, Ulrich, Angulo-Kinzler, & Yun, 2001). Researchers have attributed this condition to insufficient stability, suggesting that children with DS may not begin independent walking until they attain greater stability and motor control than their TD peers (Mulvey, Kubo, Chang, & Ulrich, 2011). To increase stability during walking, children with DS may increase their step width and reduce step length and gait velocity (Galli, Rigoldi, Brunner, Virji-Babul, & Giorgio, 2008; Rigoldi, Galli, & Albertini, 2011; Smith, Stergiou, & Ulrich, 2011; Ulrich, Haehl, Buzzi, Kubo, & Holt, 2004). This end-point control is achieved by reducing the distal joint motion in the sagittal plane with increased hip movement in the frontal plane (Rigoldi et al., 2011). Children with DS also exhibit kinetic patterns unlike those of TD children during level walking (Wu & Ajisafe, 2014; Wu, Beerse, & Ajisafe, 2014). Children with DS adopt a lower vertical ground reaction force, indicating that they may use an immature control strategy during push off (Wu & Ajisafe, 2014). The aforementioned features of walking suggest that children with DS utilize different strategies to increase their stability when performing a walking task. However, whether children with DS employ the same strategies in a more challenging situation, such as obstacle crossing, is currently unclear.

Obstacle crossing requires precise control of the swing foot while maintaining body balance through highly coordinated joint movements of both limbs (Lu, Chen, & Chen, 2006a). Moreover, children need to determine when and how high they need to lift their legs for crossing obstacles, and this judgment is related to their perception of bodily proportions (Gibson, 1977). When crossing an obstacle with a height of 15% leg length, TD children demonstrate adult-like foot displacement but immature anticipatory locomotor adjustment (i.e., absence of the antagonistic knee extensor power burst around toe-off) (McFadyen, Malouin, & Dumas, 2001). However, when crossing a higher obstacle (20 cm high), TD children adopt larger leading toe clearance than adults (Berard & Vallis, 2006). Increasing task difficulty, such as crossing two obstacles or crossing an obstacle while simultaneously performing a cognitive task, further affects the motor control strategy of obstacle crossing in TD children (Berard & Vallis, 2006; Boonyong, Siu, van Donkelaar, Chou, & Woollacott, 2012; Vallis & McFadyen, 2005). In general, TD children use a more careful strategy (e.g., decreased gait velocity and step length) than that of healthy adults to prevent falls during obstacle crossing (Berard & Vallis, 2006; Boonyong et al., 2012; Vallis & McFadyen, 2005). Since obstacle crossing is more challenging than walking, children with developmental disabilities are more likely than TD children to fall during obstacle crossing. Children with DS, who often exhibit both motor and perceptual difficulties, may find the task particularly challenging.

However, few studies have addressed obstacle crossing in individuals with DS, and of those few, most have focused on adults (Hocking et al., 2011; Smith, Ashton-Miller, & Ulrich, 2010; Smith & Ulrich, 2008; Sparrow, Shinkfield, & Summers, 1998; Vimercati et al., 2013; Vimercati, Galli, Rigoldi, Ancillao, & Albertini, 2012). Past research has shown that during obstacle crossing, young adults with DS adopt shorter step lengths and slower gait velocities with larger step widths than those of healthy adults (Salami et al., 2014; Vimercati et al., 2013). The presence of an obstacle, a destabilizing element, requires additional motor strategies for young adults with DS during gait (Vimercati et al., 2012, 2013). Kinematic differences between adults with and without DS have been found in the pelvic and hip joint patterns. Unlike healthy adults, who modify their movement only in the sagittal plane during obstacle crossing, adults with DS tend to increase the amount of movement in the frontal and transverse planes, and they also employ an upper-limb stabilization strategy (Vimercati et al., 2012, 2013). To the best of our knowledge, only one study has investigated the motor control strategy of obstacle crossing in children with DS (Virji-Babul & Brown, 2004). However, that study investigated only end-point variables (i.e., step length and toe clearance). Since the end-point trajectory of the foot is controlled by the intersegmental coordination of the locomotor system, kinematic data on the locomotor system during obstacle crossing, including joint angles and pelvic