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Potential predictors of changes in gross motor function during various tasks for children with cerebral palsy: A follow-up study

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ABSTRACT

Very few studies have investigated predictors of change in various gross motor outcomes in ambulatory children with cerebral palsy (CP). The aim of this study was to identify potential predictors for change in gross motor outcomes measured during various tasks in children with CP. A group of 45 children (age, 6–15 years) with CP and 7 potential predictors were identified, including age, gender, CP subtypes, gross motor function classification system (GMFCS) levels, abdominal muscle endurance, and muscles strength of knee extensor and knee flexor measured by isokinetic dynanometer. Motor outcome was assessed by means of the gross motor composite (GMC) of Bruininks–Oseretsky Test of Motor Proficiency (BOTMP), including four gross motor subtests: running speed and agility (RSA), balance (BAL), bilateral coordination (BCO), and strength (STR). The outcomes were measured at baseline and 12-week later (follow-up). The regression analyses showed that knee extensor strength was a robust predictor of change in BAL, BCO, and GMC (adjusted $R^2 = 0.07–0.19$, $P < 0.05$). Additionally, abdominal muscle strength was a negative predictor for the changes in the RSA (adjusted $R^2 = 0.08$, $P < 0.05$). However, STR model revealed no significant predictors. These findings suggest that ambulatory children with greater knee muscle strength may benefit more from therapy than those with lower strength. The knee muscle strength can be used as a biomarker to predict the changes in the gross motor functions.

1. Introduction

Motor manifestations associated with cerebral palsy (CP) include positive and negative features of upper motor neuron syndrome, such as spasticity, loss of selective motor control, and muscle weakness (Burke, 1988). Muscle weakness is a strong central component of motor deficit in CP (Rose & McGill, 2005). Children with CP are unable to recruit higher

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threshold motor units or to drive lower threshold motor units to higher firing rates (Rose & McGill, 2005). Strength is highly related to function and has a far higher explained variance compared to spasticity in participants with spastic diplegic CP capable of ambulation with or without assistive devices (Ross & Engsberg, 2007). Muscle weakness is associated with reduced gross motor functions in children with CP (Chen, Hong, et al., 2012; Chen, Lin, et al., 2012; Hong et al., 2012; Ross & Engsberg, 2007) and bone densities (Chen, Hong, et al., 2012), which further limit daily activities, participation in daily life (Givon, 2009) and quality of life.

For cross sectional studies, various potential predictors are proposed to be associated with motor or functional outcomes in children with CP. For example, postural muscle (knee flexor) strength is a better indicator of gross motor function, balance, and strength tasks in ambulatory children with CP compared with antigravity muscle (knee extensor) strength (Hong et al., 2012). Abdominal muscle endurance is also known to contribute to gross motor function (Hong et al., 2012). In children with CP, gross motor function classification system (GMFCS) level is a good predictor of motor function, performance of everday activities such as sitting and standing (Rodby-Bousquet & Hagglund, 2010), mobility skills (Oeffinger et al., 2004; Ohrvall, Eliasson, Lowing, Odman, & Krumlinde-Sundholm, 2010; Palisano et al., 2000), and everyday functioning (Ohrvall et al., 2010; Ostensjo, Carlberg, & Vollestad, 2003; Phipps & Roberts, 2012). The CP subtypes have also revealed associations with motor function in children with CP (Chen et al., 2010; Chen, Lin, et al., 2011; Lee et al., 2010). Finally, age (Hong et al., 2012; Palisano et al., 2000) and gender were correlated with motor functions in CP (Maanum, Jahnsen, Froslie, Larsen, & Keller, 2010). Therefore, these studies suggested significant predictors of motor outcome or functional performance of individuals with CP include muscle strength, GMFCS level, CP subtype, age, and gender.

In terms of follow-up studies, a 2-year follow-up study of children with CP (aged 9–15 years and GMFCS levels I–V) by Voorman et al. showed that muscle strength, limb distribution, selective motor control, range of motion, and spasticity were linked to the course of gross motor function measure (GMFM) scores (corrected for GMFCS) (Voorman, Dallmeijer, Knol, Lankhorst, & Becher, 2007). The GMFM scores were stable over the 2 years in the entire group of these children (Voorman et al., 2007). However, analysis of age-related trends in children aged 4–16 years revealed that GMFM scores continued to improve until age 13 years and daily activities continued to improve until age 14 years, before deteriorating in another study (Kerr, McDowell, Parkes, Stevenson, & Cosgrove, 2011). In fact, the GMFCS of some participants actually declined one level from adolescence to adulthood (Maanum et al., 2010). The evolvement of motor functions and daily activities with age is also known to differ in children with various CP subtypes (Chen et al., 2010). Wright et al. reported poor-to-fair change score relationships between measures of body functions and structures, activity, and participation in CP children who had received botulinum toxin type A injection (Wright, Rosenbaum, Goldsmith, Law, & Fehlings, 2008). However, very few studies have investigated potential predictors of change in gross motor outcome measured during various tasks in ambulatory children with CP.

Children with CP have diminished peak torques at the knee (Chen, Hong, et al., 2012; Chen, Lin, et al., 2012; Hong et al., 2012). In the present study, knee muscle strength was measured by the isokinetic dynanometer rather than manual muscle testing since manual muscle testing is less objective and less discriminative for measuring the muscle strength in ambulatory CP children associated with spasticity (Hong et al., 2012). Isokinetic testing has proven reliable for measuring muscle strength in the knee flexor and extensor for children with CP (Ayalon, Ben-Sira, Hutzler, & Gilad, 2000). To measure gross motor function, the Bruininks–Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks, 1978) was used instead of the Gross Motor Function Measure (GMFM) (Russell et al., 2000) because GMFM-66 scores tend to achieve ceiling levels in some CP children with high motor ability, especially in those with GMFCS level I. The BOTMP is a well-validated measure of motor coordination, including gross and fine motor function performed during various tasks. The BOTMP was used in children with mild motor impairment such as developmental coordination disorder (Wuang & Su, 2009) and in ambulatory children with CP (Chen, Chen, et al., 2011; Hong et al., 2012).

Identifying potential predictors of change in motor outcomes can help clinicians target individuals who are likely to benefit the most from the therapy. This study aimed to identify predictors of change in gross motor outcomes during various tasks in ambulatory children with CP. The potential predictors selected in this study included age, gender, GMFCS levels, CP subtypes, abdominal muscle endurance, and muscles strength of knee extensor and knee flexor. Abdominal muscle endurance was measured by curl-up test. Strength in the antigravity muscle (knee extensor) and postural muscle (knee flexor) were measured by isokinetic dynanometer. Gross motor outcome was measured by the Bruininks–Oseretsky Test of Motor Proficiency (BOTMP). We hypothesized that age, gender, GMFMS levels, CP subtypes, abdominal muscle endurance, and knee muscle strength are associated with changes in motor outcomes in these children.

2. Methods

2.1. Participants

Forty-five children with CP (31 boys and 14 girls) with a mean age of 9 years and 1 month (SD: 2 years and 7 months) were recruited from the Physical Medicine and Rehabilitation Department of a tertiary hospital (Table 1). All participants were independently examined by a single physiatrist to determine their eligibility for inclusion. The eligibility criteria for participants were diagnosis of CP with spastic diplegia or spastic hemiplegia, age 6–15 years, ability to walk independently, ability to undergo a motor function and isokinetic muscle test, and ability to comprehend commands and cooperate during an examination. Exclusion criteria were (1) recognized chromosomal abnormalities; (2) progressive neurological disorder or