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# Walking-induced muscle fatigue impairs postural control in adolescents with unilateral spastic cerebral palsy

Damien Vitiello [a,b], Ludmilla Pochon [c], Davide Malatesta [c,d], Olivier Girard [c,d], Christopher J. Newman [e], Francis Degache [b,c,*]

[a] *Laboratory of Fundamental and Applied Bioenergetics, Inserm U1055, University of Grenoble, Grenoble, France*
[b] *University of Health Sciences, University of Applied Sciences and Arts Western, Lausanne, Switzerland*
[c] *Institute of Sport Sciences University of Lausanne (ISSUL), University of Lausanne, Lausanne, Switzerland*
[d] *Department of Physiology, Faculty of Biology and Medicine, University of Lausanne, Lausanne, Switzerland*
[e] *Pediatric Neurology and Neurorehabilitation Unit, Lausanne University Hospital, Lausanne, Switzerland*

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ABSTRACT

*Background:* Fatigue is likely to be an important limiting factor in adolescents with spastic cerebral palsy (CP).
*Aims:* To determine the effects of walking-induced fatigue on postural control adjustments in adolescents with unilateral CP and their typically developing (TD) peers.
*Methods:* Ten adolescents with CP (14.2 ± 1.7 yr) and 10 age-, weight- and height-matched TD adolescents (14.1 ± 1.9 yr) walked for 15 min on a treadmill at their preferred walking speed. Before and after this task, voluntary strength capacity of knee extensors (MVC) and postural control were evaluated in 3 conditions: eyes open (EO), eyes closed (EC) and with dual cognitive task (EODT).
*Results:* After walking, MVC decreased significantly in CP (−11%, $P < 0.05$) but not in TD. The CoP area was only significantly increased in CP (90%, 34% and 60% for EO, EC and EODT conditions, respectively). The CoP length was significantly increased in the EO condition in CP and TD (20% and 21%) and was significantly increased in the EODT condition by 18% in CP only.
*Conclusions:* Unlike TD adolescents, treadmill walking for 15 min at their preferred speed lead to significant knee extensor strength losses and impairments in postural control in adolescents with unilateral spastic CP.



## 1. Introduction

Spastic cerebral palsy (CP) is a lifelong cause of disability affecting the development of movement and posture, causing activity limitations attributed to non-progressive disturbances that occur in the developing fetal or infant brain (Rosenbaum et al., 2007). This pathology is the most common cause of motor disability in childhood, with an overall prevalence worldwide of approximately 2 per 1000 live births (Oskoui, Coutinho, Dykeman, Jette, & Pringsheim, 2013).

* Corresponding author at: University of Health Sciences, University of Applied Sciences and Arts Western Switzerland, Av Beaumont 21, Lausanne 1011, Switzerland. Tel.: +41 21 316 81 28.
*E-mail address:* francis.degache@hesav.ch (F. Degache).

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Children with spastic CP, characterized by a stretch dependent increase in muscle tone in affected body segments, frequently develop musculo-skeletal deformities secondary to a multifactorial impairment of muscle growth (Gough & Shortland, 2012). They typically present reduced muscle fiber size (Barrett & Lichtwark, 2010) and diameter (Smith, Lee, Ward, Chambers, & Lieber, 2011), smaller muscle cross-sectional area (Smith et al., 2011), suboptimal neural drive (Mockford & Caulton, 2010) and muscle contractures (Barrett & Lichtwark, 2010). Finally, impaired development of motor neurons is classically reported in children with CP, demonstrating a deteriorated muscle innervation (Theroux et al., 2005) accounting for a decrease in the metabolic capacity of active muscles (Smith et al., 2009).

Postural control, defined as the ability to control the body position in space to achieve orientation and stability (Duarte & Freitas, 2010), is largely impaired in children with CP (Woollacott & Shumway-Cook, 2005) since this function relies both on appropriate muscle activity and adequate neuromotor control. One of the major postural dysfunction characterizing this population lies in their inability to coordinate the activation of postural muscles in a timely-efficient manner, especially during the execution of functional tasks (de Graaf-Peters et al., 2007). Previous studies have demonstrated that children with CP preferentially use visual information to compensate for musculoskeletal and neuromotor dysfunction during postural stability tasks (Liao & Hwang, 2003). Children with CP are characterized by an extended time to recover stability and by a larger excursion of their center of pressure (CoP) when recovering balance on a movable platform compared to typically developed children (TD) (Chen & Woollacott, 2007). TD young children experience dual-task interference in postural control in both wide and narrow stance positions, with increased movement amplitudes of the CoP in the frontal plane to compensate for postural perturbations in the sagittal plane while simultaneously standing and executing a visual working memory task (Reilly, Woollacott, van Donkelaar, & Saavedra, 2008). The impact of dual-task interference on postural control in children with CP has been described previously in only one study to our knowledge (Samuel, Solomon, & Mohan, 2013), despite its potential major impact on daily function, where dual-tasking is the rule more than the exception and where postural control underlies both gross and fine motor function. An improved understanding of the mechanisms underlying postural control adjustments while performing a secondary task in adolescents with CP would provide a useful insight into potential added motor limitations related dual-tasking, and could subsequently guide therapeutic intervention.

Neuromuscular fatigue is usually defined as an exercise-related decrease in the maximal voluntary force or power of a muscle or muscle group associated with an increase in the perceived effort necessary to exert the desired force (Enoka & Stuart, 1992). Fatigue manipulations have the potential to shed further light on the mechanisms regulating postural control in children with CP. Reportedly, adolescents and children with CP have been shown to be resistant to muscle fatigue and to have lower fatigability than TD peers and adolescents after repeated voluntary maximal concentric knee extension and flexion (Moreau, Li, Geaghan, & Damiano, 2009) or after repetitive high-rate surface electrostimulation of the quadriceps (Stackhouse, Binder-Macleod, & Lee, 2005). Conversely, it has also been reported that the fatigability of the triceps surae was the same or higher in adolescents with CP than in TD adolescents (Ratel, Duche, & Williams, 2006). Fatigue is likely to be an important limiting factor in adolescents with CP but differing results in the available literature regarding fatigue resistance of adolescents with CP compared to TD adolescents justifies further research. To our knowledge, no studie have investigated the effect of a fatiguing walking task in children with cerebral palsy. However it seems highly relevant because walking is a daily physical activity, which may induce muscle fatigue in this population. Given that walking is the most commonly performed activity of daily living it was considered important to investigate specifically the fatigue effects of walking on gait and postural stability variables. Previously used protocols to induce walking-based fatigue have been limited to preferred speed walking for prolonged periods between 20 min and 3 h (Yoshino, Motoshige, Araki, & Matsuoka, 2004). The motivation for the present study was to determine whether fatigue induced by more intensive short duration walking activity would negatively affect postural stability performance. Consistent with this aim, a previously validated technique (Montes et al., 2010) was employed whereby participants were fatigued by self-selected fast walking on a treadmill for a shorter time (*i.e.* 6 min).

The present study aims at determining (1) the effects of a walking exercise in adolescents with CP and in TD adolescents on voluntary strength production and postural control, with a particular emphasis on the effects a secondary cognitive task. We hypothesized that adolescents with CP would exhibit larger postural control alterations after the 15-min walking and that fatigue effects in this population would be even more visible when introducing a secondary cognitive task while performing a standing position task.

## 2. Methods

### 2.1. Participants

This study involved 10 adolescents with unilateral spastic cerebral palsy (CP) (2 boys, 8 girls, aged 11 to 17 yr old, mean age: 14.2 ± 1.7 yr) recruited from the outpatient clinic of the Paediatric Neurology and Neurorehabilitation Unit, Lausanne University Hospital. Inclusion criteria were (1) age 10 to 17 yr old; (2) spastic hemiplegic CP; (3) low level of spasticity (Ashworth 1 and 2); (4) independent walking in the community; (5) level I and II of the Gross Motor Function Classification System (GMFCS); (6) cognitive ability to understand instructions. They were compared to 10 age-, height-, sex- and weight-matched TD adolescents (2 boys, 8 girls, aged 11 to 17 yr old, mean age: 14.1 ± 1.9 yr). The study was conducted in accordance with the Declaration of