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Impact of loaded sit-to-stand exercises at different speeds on the physiological cost of walking in children with spastic diplegia: A single-blind randomized clinical trial

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ABSTRACT

Purpose: In the present study, we aimed to determine whether similarly loaded sit-to-stand exercises at different speeds improve the physiological cost of walking in children with spastic diplegia.
Methods: This design was a single-blind randomized clinical trial. Sixteen children with cerebral palsy (CP), aged 12–18 years, with a diagnosis of spastic diplegia, were randomly allocated to a slow loaded sit-to-stand exercise group (n = 8) and a self-paced loaded sit-to-stand exercise group (n = 8). Loaded sit-to-stand exercise was conducted at home for 15 min, 4 sets per day, 3–4 days per week, for 6 weeks. The patients were evaluated immediately before the intervention and after the training. Lower limb muscle strength using a hand-held dynamometer, selective voluntary motor control using SCALE, 6-min walk distance (6MWD), and Physiological Cost Index (PCI) were measured.
Results: The 6MWD showed a significant difference before and after intervention. PCI showed a significant difference between the two groups and the two time points. 6MWD and the PCI improved after intervention in the slow sit-to-stand exercise group.
Conclusions: Compared to loaded sit-to-stand exercise at a regular speed, slow low-loaded sit-to-stand exercise improved the 6MWD and PCI in children with CP, suggesting that this decrease in speed during exercise improves the physiological cost of walking in these children.

1. Introduction

Most activities of daily living comprise closed kinetic chain movements involving multiple joints. Therefore, functional strength training with a task-oriented approach and a resistance exercise movement pattern with closed kinetic chain movement of multiple joints has attracted attention in the field of rehabilitation. Several studies have reported that functional strength training is effective in children with cerebral palsy (CP) (Blundell, Shepherd, Dean, Adams, & Cahill, 2003; Faigenbaum et al., 2001; Scholtes et al., 2008) programs such as walking exercises and balance exercises using only the child's own weight, without an additional load (Blundell et al., 2003). However, because functional strength training might

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be insufficient against the overload principle of strength training, several previous studies were designed based on the load determined by the 1 repetition maximum (1-RM) (Faigenbaum et al., 2001; Scholtes et al., 2008; Boyd, 2012). The 1-RM of the loaded STS test for children with spastic diplegia using body vests and lead weights were specially made for the loaded STS test, and loaded STS exercise was reliable for functional muscle strength tests (Gan & Liao, 2002). In children with mild spastic diplegia, 50% of the 1-RM loaded STS exercise was effective for improving motor activity, the 1-RM of the loaded STS, and the physiological cost of exercise (Liao, Liu, Liu, & Lin, 2007). However, since the previous study was conducted in participants aged 7–12 years and with mild spastic diplegia, future studies are needed to investigate effects of the loaded STS exercise in children of different age groups and at different severities of CP.

The corticospinal tract disorder in CP disturbs the ability to control the force, speed, and timing of muscle contractions and disturbs the pattern of voluntary movements (Sanger et al., 2006). Therefore, the loss of selective voluntary motor control causes functional mobility disorders (Staudt, Pavlova, Bohm, Grodd, & Krageloh, 2003). Compared to healthy children, those with CP show impaired selective voluntary motor control and lower muscular strength and endurance (Bohannon, Smith, Hull, Palmeri, & Barnhard, 1995); therefore, children with CP experience difficulty in performing activities slowly (Park, Park, Lee, & Kim, 2003) and have a higher physiological cost index (PCI), which is the physiological cost of walking (Plasschaert, Jones, & Forward, 2011). Many studies have used the PCI to evaluate the efficacy of interventions aimed at improving of walking in children with CP (Liao et al., 2007; DiBiasio & Lewis, 2012; Nene, Evans, & Patrick, 1993). The PCI is calculated as the difference between the heart rate at rest and the maximum heart rate while walking divided by the walking speed. The PCI is closely related to the oxygen cost (EO2) which is expressed in milliliters of oxygen per meter (Ijzerman & Nene, 2002; Bowen, Lennon, Castagno, Miller & Richards, 1998). The PCI of children with CP improved with body weight-supported treadmill walking and load sit-to-stand resistance exercise that were performed 2–3 times a week for 6 weeks (Liao et al., 2007; DiBiasio & Lewis, 2012).

Sit-to-stand (STS) movement is one of the most frequently performed movements in daily life. However, STS movement is a biomechanically demanding task that requires moving the body's center of mass forward and upward in order to shift the body's weight over the feet (Riley, Schenkman, Mann, & Hodge, 1991).

Park et al. indicated that the characteristics of STS transfer in the children with spastic CP showed increased anterior pelvic tilting, hip flexion, and early abrupt knee extension, greater maximum ankle dorsiflexion angle. Furthermore, the maximum power of the hip and knee extensor and the maximum extensor moments of the knee joint reduced significantly compared to that in healthy children (Park et al., 2003). Because the support base is narrowed down to an area limited to the feet, sufficient body balance, equilibrium reaction, and coordination of muscle activation are required at the same time (Riley et al., 1991; Lee & Lee, 2015).

In children with CP, exercise intervention with loading of 50% of 1-RM, as in a previous study, is often difficult in the latter half of the exercise (Liao et al., 2007), and self-paced loaded STS exercise may promote compensatory movements or enhance the characteristic movements of children with CP; i.e. increased anterior pelvic tilting, hip flexion, and early abrupt knee extension. Long term performance of these exercises may cause secondary complications such as low back pain or contractures of joints. Therefore, it is necessary to develop more effective exercises with low loading.

STS movement usually harnesses forward acceleration (flexing trunk) to create upward acceleration (rising from the seat). Because slow STS movement decreases the forward acceleration (flexing trunk) and does not harness it to create to upward acceleration (rising from the seat), the total skeletal muscle activity of a slow STS movement is higher than that for a STS movement at a self-paced speed (Fujimoto & Chou, 2014; Fujimoto & Chou, 2012). However, previous studies have not considered the speed of STS movement. Interventions considering movement speed have not been reported for children with CP. Therefore, we hypothesized that slow low-loaded STS movement is better than loaded STS movement at a self-paced speed for improving the physiological cost of walking in children with spastic diplegic CP.

In the present study, we aimed to determine the effect of similarly loaded STS exercises at different speeds on improvement in the physiological cost of walking in children with spastic diplegia.

2. Methods

2.1. Participants

Participants were individuals with spastic diplegic CP. Before randomization, we asked the physician and physical therapists at 5 hospitals and medical centers in Tokyo and Kanagawa to help us recruit children with spastic diplegia who met the inclusion criteria: (1) male; (2) age, 12–18 years; (3) diagnosis of spastic diplegia; (4) gross motor level I to III based on the Gross Motor Function Classification System-Expanded & Revised version: GMFCS-E&R; (5) able to communicate and follow instructions; (6) able to stand up from a chair independently and maintain a standing position for more than 3 s without falling; (7) no obvious limitation in the passive range of motion of the lower extremities. Exclusion criteria were: (1) orthopedic intervention or botulinum toxin injection to the lower extremities within 6 months and (2) orthopedic problems or medical conditions that prevented children from participating in the exercises. Finally, 26 patients were referred to us; of these 16 patients and/or their parents provided informed consent for participation (Fig. 1). The study was approved by the Tokyo University of Technology of Health Sciences Ethical Review Board (Authorization Number: E14HS-004) and Tokyo Metropolitan University of Health Sciences Ethical Review Board (Authorization Number: 14052).