Asymmetric gait results in symmetric muscular demands in affected versus unaffected side ankle and knee extensors in hemiplegic CP children

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Introduction

Children with hemiplegic cerebral palsy (CP) exhibit asymmetric gait due to compromised neuromuscular function of the affected lower limb [1]. According to a longstanding theory, natural gait patterns coincide with the minimal metabolic cost [2]. We hypothesized that biomechanical constraints may also play a critical role in determining the way humans move; for example, leading to compensation strategies that help to accommodate compromised paretic limb force production. To test this, we examined gait pattern asymmetries and relative muscle efforts of the ankle and knee extensors between affected versus unaffected lower limbs in hemiplegic CP children.

Research Question

Whether asymmetric gait in hemiplegic CP children results in symmetric muscular demands (i.e. relative muscle effort) in the lower limb ankle and knee extensors on the affected versus unaffected side.

Methods

Eight hemiplegic CP children underwent 3D gait analysis at self-selected speed and then performed a maximal two-leg hopping test. Step length and contact time as well as ankle and knee extensor moments were analyzed and compared between the affected and unaffected sides. To estimate how hard the ankle and knee extensors have to work during walking, we related joint moments produced by these muscles in walking to the maximal moments obtained from a reference hopping test [3].

Results

While walking at self-selected speed (1.21 ± 0.07 m/s) hemiplegic CP children demonstrated 6% (0.035 s) shorter contact time ($p=0.012$) and 2.5 cm smaller step length ($p=0.026$) on the affected side compared to unaffected side. The walking-related joint moments were 14% ($p=0.019$) and 60% ($p=0.017$) lower, respectively, in the affected side ankle and knee extensors (Fig.1A). During all-out hopping test, the maximal moments developed in the affected side were 22 % ($p=0.044$) and 29% ($p=0.036$) lower, respectively, in the ankle and knee extensors (Fig.1B). However, no differences were found in the relative ankle ($p=0.43$) and knee ($p=0.34$) extensor muscle efforts in the affected versus unaffected lower limbs (Fig.1C).

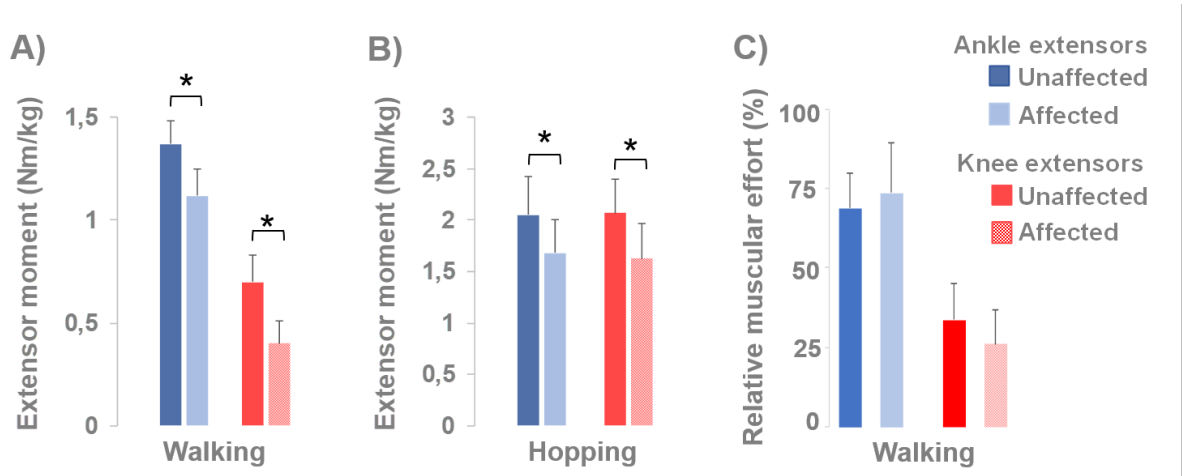

Fig. 1. A) Ankle and knee extensor moments during walking and B) the maximal hopping test. C) The relative muscular effort for ankle and knee extensors during walking.

Discussion

This study in hemiplegic CP children observed well-known deficits in the affected side function during gait; however, no side-related differences were found in the relative ankle and knee extensor muscle efforts. By shifting muscular contributions from the affected side to the unaffected side, hemiplegic CP children can equalize their relative muscular efforts, which, in turn, may be an important strategy for preventing locomotor-induced fatigue of muscles on the affected side. These data extend the findings from earlier work [2] by showing that preferred gait patterns arise not only due to minimization of metabolic cost, but also due to muscular constraints on generating force. Importantly, a hopping test used to assess maximal knee and ankle extensor muscle force and relative muscular efforts can be effectively utilized in routine clinical practice in the quest to identify and understand mechanisms of impaired gait.

References

[1]. Riad et al. Are Muscle Volume Differences Related to Concentric Muscle Work During Walking in Spastic Hemiplegic Cerebral Palsy? Clin Orthop Relat Res 2012

[2] Saibine & Minetti. Biomechnical and physiological aspects of legged locomotion in humans. EJAP 2003

[3] Kulmala et al. Ankle and knee extensor muscle effort during locomotion in young and older athletes: Implications for understanding age-related locomotor decline. Sci Rep 2020