Neuroscience Letters 603 (2015) 55–59

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research paper

Comparative gait initiation kinematics between simulated unilateral and bilateral ankle hypomobility: Does bilateral constraint improve speed performance?

A. Delafontaine[a,*], J.-L. Honeine[a], M.-C. Do[a], O. Gagey[a,b], R.K. Chong[c]

[a] CIAMS Laboratory, UFR-STAPS, University Paris-Sud, Orsay, France
[b] Service de chirurgie orthopédique, C.H.U Kremlin Bicêtre, Kremlin Bicêtre, France
[c] Department of Physical Therapy, Georgia Regents University, Augusta, GA, USA

HIGHLIGHTS

- Ankle hypomobility during gait initiation was simulated by ankle strapping.
- Forward CoM velocity was measured during APA and step execution.
- Velocity increased during bilateral strapping with respect to unilateral strapping.
- Facilitation of bilateral commands in lower limbs occurs in locomotor tasks.

ARTICLE INFO

Article history:
Received 23 February 2015
Received in revised form 27 June 2015
Accepted 13 July 2015
Available online 18 July 2015

Keywords:
Ankle joint mobility
Unilateral-bilateral constraint
Gait initiation
Speed performance

ABSTRACT

Improvement of motor performance in unilateral upper limb motor disability has been shown when utilizing inter-limb coupling strategies during physical rehabilitation. This suggests that 'default' bilateral central motor commands are facilitated. Here, we tested whether this bilateral motor control principle may be generalized to the lower limbs during gait initiation, which involves alternate bilateral actions. Disability was simulated by strapping to produce ankle hypomobility. Healthy adult subjects initiated gait at a self-paced speed with no ankle constraint (control), or with the stance, swing or bilateral ankles strapped. The duration of the anticipatory postural adjustments lengthened and the center of mass instantaneous progression velocity at foot-off decreased when the ankle was strapped. During the step execution phase, progression velocity at foot-contact was higher when both ankles were strapped compared to unilateral strapping of the stance ankle. These findings suggest that bilateral central motor commands are favored during walking tasks. Indeed, unilateral constraint of the stance ankle should compel the central nervous system to adapt specific commands to the constraint and normal sides whereas the 'default' bilateral motor commands would be utilized when both ankles are strapped leading to better kinematics performance. Bilateral in-phase upper limb coordination and bilateral alternating lower limb locomotor movements may share similar control mechanisms.

1. Introduction

Joint mobility plays an important role in motor skills. Stiffness at the joints needs to be modulated to accommodate the needs of the impending task. Impaired axial mobility due to vertebral ankylosis can produce changes in standing postural control [1]. Similarly, in low-back pain, an increase in postural sway is thought to be due to stiffening of the spine induced by muscle tension, which reduces dynamic mobility [2]. Likewise, a faster sit-to-stand movement may be accomplished through an increase in hip joint mobility by changing the sitting posture from full-thigh contact to sitting on the edge of the chair [3].

In walking, studies have shown that unilateral reduction of lower limb joint mobility, i.e., joint hypomobility, whatever the origin, be it central, peripheral, neuropathic or traumatic, can alter walking speed [4–6]. Furthermore, other abnormalities, such as gait asymmetry may persist despite rehabilitation efforts. Indeed, patients with hypomobility, such as ankle osteoarthritis develop adaptive mechanisms including preferentially initiating gait with

* Corresponding author at: University Paris-Sud, UFR Staps, CIAMS Lab, Rue Pierre de Coubertin, 91405 Orsay Cedex, France. Fax: +33 1 69 15 6222.
E-mail address: arnaud.delafontaine@u-psud.fr (A. Delafontaine).

http://dx.doi.org/10.1016/j.neulet.2015.07.016

the hypomobile limb [7]. Similar adaptations have been found in individuals with unilateral lower limb amputation [6,8] and hemiplegia [4]. Unilateral pain in patients with knee osteoarthritis leads to asymmetrical gait in contrast to bilateral pain [9]. Gait pattern was more symmetrical in bilateral than in unilateral total knee replacement [10].

It has been shown that in unilateral upper limb motor impairment, rehabilitation involving symmetrical bilateral movements improves motor performance of the affected side [11–13]. It may be that the central nervous system (CNS) favors the delivery of 'default' bilateral efferent signals regardless of whether the task is primarily unilateral or bilateral [14]. These signals are thought to originate from prior integration of bilateral inputs to improve coordination [15,16].

In this study, we tested whether the bilateral motor control principle may be generalized to the coordination of the lower extremities during gait initiation (GI). GI is defined as the transitional period between the initial static upright posture and the execution of the first step [17]. GI includes two phases: an anticipatory postural adjustment phase (APA) and step execution phase. APA is put into action in order to overcome the initial posturo-kinetic constraints before step execution. The duration and amplitude (seen as backward displacement of the center of pressure (CoP)) of APA regulate the forward velocity of the center of mass at foot-off [18]. During step execution, the distance between CoM and CoP in the sagittal plane controls the forward velocity of the center of mass at foot-contact [19,20]. To simulate an ankle constraint, a strap was applied unilaterally or bilaterally at the ankle to induce hypomobility [21]. We hypothesized that bilateral constraint at the ankle should enhance GI, assessed as an increase in forward velocity, compared to unilateral constraint.

2. Methods

2.1. Subjects

Nine healthy adults (4 men and 5 women, mean age 25 ± 5 years, height 1.8 ± 0.05 m and body-mass 77 ± 19 kg) participated in the experiment that was approved by the local ethic committee. All subjects gave informed written consent as required by the Declaration of Helsinki.

2.2. Strapping procedure

In this study, ankle hypomobility refers to limiting plantar/dorsal flexion and eversion/inversion movements at the ankle [21] to a maximum range of motion of 5°. This was achieved by strapping with a 6 cm wide × 2.5 m long elastic tape (Elastoplast®, BSN Médical le Mans), as can be seen in Fig. 1.

Subjects performed GI under 6 experimental conditions that lasted 35 min. Strapping has been shown to significantly deteriorate following 45 min of exercise [21]. Efficiency was checked after the 4th and 5th conditions. Each experimental condition comprised 10 trials as follows:

Unstrapped ankles (Control condition):

1) GIr unstrapped (swing leg: right);
2) GIl unstrapped (swing leg: left).

Unilateral ankle strapped:

3) S-Sw swing leg strapped;
4) S-St stance leg strapped.

Bilateral ankles strapped:

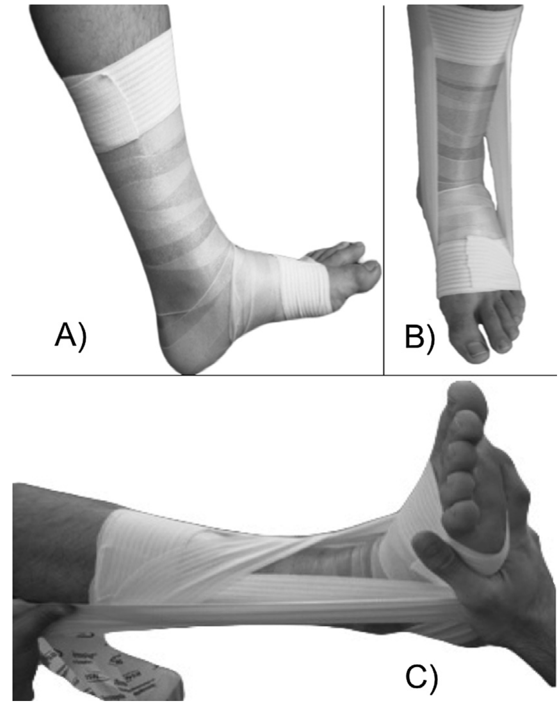

Fig. 1. Strapping procedure.
To significantly limit ankle plantar- and dorsi-flexion. (A) A circular tape was applied over a specialized elastic rubber around the tibia and metatarsal. (B) A strapping tape was applied in a U-shape going under the ankle and forming a right angle with the tibia. (C) Additional tape is applied in order to firmly fixate the calcaneus from both sides resulting in further reduction of ankle degree of liberty (notably eversion/inversion).

5) S2r bilateral (swing leg: right);
6) S2l bilateral (swing leg: right).

Subjects walked bare-footed at a self-paced speed. They first performed the control condition trials, followed by unilateral then bilateral strapping walking. Within each ankle condition the order of starting limb was randomly assigned. In the S-St and S-Sw conditions, the swing leg was considered to be that in which subjects always stepped to recover balance following a push from behind.

2.3. Gait initiation kinematics

Ground reaction forces and moments data from the force platform (0.9 × 1.80 m, AMTI, Watertown, USA, 250 Hz) were transformed to obtain the coordinates of the center of pressure and the center of mass position and velocity [18,19]. Since subjects started from a stationary position, the initial velocity was set at zero. Mediolateral CoP position was used to determine the onset of gait initiation (t0), foot-off and foot-contact see Fig. 2. APA was determined as the period spanning between t0 and foot-off, while the step execution phase started at foot-off and ended at foot-contact. The parameters analyzed were the duration of APA, the duration of stance time, the global duration of gait initiation (i.e., from t0 to foot-contact), step length, the maximum backward displacement of CoP during APA, the distance between CoM and CoP at foot-contact in the sagittal plane (CoM–CoP gap) and the instantaneous forward velocity of CoM at foot off and foot contact (Fig. 2).

2.4. Statistical analyses

One-way repeated-measures ANOVAs were used to test the effect of the 6 experimental conditions on the kinematics param-