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The effect of galvanic vestibular stimulation on postural response of Down syndrome individuals on the seesaw

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ABSTRACT

In order to better understand the role of the vestibular system in postural adjustments on unstable surfaces, we analyzed the effects of galvanic vestibular stimulation (GVS) on the pattern of muscle activity and joint displacements (ankle knee and hip) of eight intellectually normal participants (control group – CG) and eight control group individuals with Down syndrome (DS) while balancing on seesaws of different heights. The CG individuals adopted a pattern of muscle activation characterized by alternation between ankle agonist and antagonist muscles. The individuals with DS adopted a pattern of muscle co-contraction. The GVS affected neither the ability of CG individuals to maintain balance nor their pattern of muscle contraction. On the other hand, the individuals with DS showed greater sensitivity to GVS while balancing on a seesaw and were not able to select the appropriate motor strategy to efficiently balance and compensate the effects of GVS. These increased vestibular sensitivities observed in individuals with DS can reflect deficits in the proprioceptive system.

1. Introduction

Several atypical behaviors in the postural control of individuals with Down syndrome (DS) have been described in the literature (Ulrich, Haehl, Buzzi, Kubo, & Holt, 2004; Virji-Babul & Brown, 2004). Down syndrome individuals are unable to respond rapidly to changes in the environment (Haley, 1986). Typically they take longer to initiate and complete a motor task and have difficulty maintaining equilibrium (Galli et al., 2007; Vuillerme, Marin, & Debu, 2001). Adults with DS show significantly higher postural sway velocity than control subjects during a resting stance (Galli et al., 2007; Webber, Babul, Edwards, & Lesperance, 2004) and adopt different patterns of anticipatory postural adjustments (Aruin & Almeida, 1997). Specifically they react using a generalized pattern of co-activation. The simultaneous activation of agonist and antagonist (co-contraction) muscles has also been described during quiet conditions (Gomes & Barela, 2007), gait (Galli et al., 2007; Smith, Kubo, Black, Holt, & Ulrich, 2007) and balancing on seesaw (Carvalho & Almeida, 2009b).

There has been debate in the literature over the real cause of atypical postural behaviors observed in individuals with DS. Possible explanations are related to cognitive limitations (Latash & Anson, 1996), biomechanical deficits (Cioni et al., 1994), neurological disorder (Moldrich, Dauphinot, Laffaire, Rossier, & Potier, 2007) abnormal sensorimotor integration (Vuillerme et al., 2001), compromised somatosensory system (Brandt & Rosen, 1995) or adaptive choice (Latash & Anson, 1996). Among

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the explanations for the postural deficits found in individuals with DS, the favored explanatory hypothesis is that of a compromised somatosensory system (Carvalho & Almeida, 2009a).

One of the most widely used experimental approaches for understanding the sensory contribution to postural control is the manipulation of sensory information during postural disturbance. Galvanic vestibular stimulation (GVS) can induce postural reactions that are useful in determining the influence of vestibular function on balance (Fitzpatrick & Day, 2004).

In order to better understand the sensory contribution to postural adjustments, we analyzed the effect of bipolar galvanic stimulation (GVS) on the pattern of muscle activity and joint displacements of control group (CG) while balancing on seesaws of different heights. Next, we studied the GVS-effect on postural responses of individuals with DS. Finally, we compared the strategy used by CG participants receiving GVS with those used by individuals with DS, who supposedly have a somatosensory deficit. It is known that individuals with somatosensory deficits such as neuropathy sufferers are more sensitive than healthy subjects to vestibular stimulation because they re-weight their sensory orientation away from surface somatosensory signals (Maurer, Mergner, & Peterka, 2006). When we relate the hypothesis proposed by some authors on deficits in the somatosensory system of individuals with DS to the behavior observed in individuals with peripheral neuropathy, we expect to find a greater sensitivity to GVS in DS individuals compared to the CG, which would demonstrate the somatosensory deficit.

2. Methods

2.1. Participants

Eight individuals with DS (four males, four females, average age 27.2 ± 4.22 years, average weight 67.4kg $\pm$ 6.80) and eight age and sex-matched control subjects (CG) (average age 28.2 ± 5.68, weight 66.3 ± 8.9) were studied after they or their parents had signed an institutional term of informed consent (from UNICAMP) which was approved by the University of Campinas Ethics Committee, indicating that this study was conducted in accordance with relevant ethical principles. All individuals with DS had good hearing, were able to independently walk on flat terrain as well as up and down stairs, were not currently on any medications and were able to communicate well and understand the simple instructions needed to maintain balance on the seesaw. Participants with DS were recruited via a local Down syndrome support group. CG participants were recruited from the university population.

2.2. Apparatus

All participants balanced on three moveable seesaws (30 cm wide $\times$ 45 cm long) that varied in height (7, 12 and 17 cm) (Fig. 1).

The coordinates of the light emitting diode (LED) marks were recorded using a 3D-motion-analysis system (OPTOTRAK 3020). The LED marks were attached on the left side of the shoulder, hip, knee, ankle and foot, recorded at 100 Hz and used to calculate the ankle, knee, and hip angular displacements.

The activities of the gastrocnemius medialis (GM), tibialis anterior (TA), biceps femoris (BF), rectus femoris (RF), erector spinae (ES), and the rectus abdominis (RA) were recorded using bipolar surface EMG electrodes (DeLsys).

All EMG data were band pass filtered (45–450 Hz), amplified (2000$\times$) and digitized at 1000 Hz. The EMG signals were rectified and smoothed using a second-order Butterworth filter with 10 Hz cutoff frequencies.

2.3. Procedure

Each individual participated in one separate test session of about 1 h conducted at the Motion Analysis Laboratory at the University of Campinas. Individuals were instructed to try to keep their balance on the seesaw. No instruction was given as to how to keep balance and each individual was free to choose any strategy.

The investigator helped the individual to stand on a seesaw, and ensured that his/her feet were arranged on the center. Initially, the individual was blindfolded with a mask, the ankle was kept in a neutral position with the top of the seesaw parallel to the floor and the face toward the right shoulder. The bipolar and binaural transmastoidal current of 1.5 mA was randomly applied via 2.5 cm carbon–rubber electrodes placed behind the subject's ears over the mastoid processes. The anode was placed on right ear. The balance began after 2 s of stimulation and lasted for 10 s. During the balance on seesaw (self-perturbated movement) the individual held each shoulder with the opposite hand, keeping the upper limbs crossed and in contact with the chest. Two trials of 10 s each were recorded for each seesaw.

2.4. Analysis

The Matlab software version 6.0.0.88 Release was used to calculate the maximum plantar and dorsal ankle flexion and the corresponding angular displacement of the hip and knee joints during this time. The activities of the six muscles cited above were integrated for 50 ms, just before and 50 ms after the maximum dorsal and plantar flexion time.

The integrated EMG muscle activity of all muscles collected and the joint displacements were studied separately for the groups using ANOVA with two factors: stimulation (with or without GVS) and seesaw's height (7, 12 and 17 cm height) for