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Balance sensory organization in children with profound hearing loss and cochlear implants

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Summary

Objectives: (1) To determine the feasibility of the use of a modified postural control test under altered sensory conditions in children over 8 years of age, and (2) to assess how deaf children use sensory information for postural control when they have normal or abnormal vestibular responses, and if hearing input from a unilateral cochlear implant, changes their postural behavior.
Patients: We selected 36 children, 8 to 11 years of age, with congenital or early-acquired profound sensorineural hearing loss, 13 of them with unilateral cochlear implantation and 22 normal-hearing children.
Methods: The Postural Control (PC) test consists of a force platform with 2 stimulation paradigm conditions: (1) standing on the platform with opened eyes; (2) standing on foam placed on the force platform with closed eyes. Implanted children were tested with the implant turn on and turn off in this condition, in order to evaluate eventual change in the postural control parameters when they have hearing habilitation. The body center of pressure distribution area (COP) and the body sway velocity (SV) were the parameter to evaluate the postural control.
Results: Deaf children were classified into two groups according with the vestibular responses: group A ($n = 28$) Children with normal vestibular rotary responses; group B ($n = 8$) children with hypoactive responses. Children in group A had diagnoses of syndromic and non-syndromic hereditary deafness, and children in group B had inner ear malformations, post-meningitis deafness, and one child had non-syndromic hereditary deafness with hypoactive vestibular response. In condition 1, when vestibular, somatosensory and visual information were enabled, the COP and SV values did not show any statistically significant differences between groups A, B and control. In condition 2, when visual information was removed and the somatosensory

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input strongly modified by standing on the foam, group B showed significant higher COP and SV values than groups A and control ($p < 0.05$). In addition, the scalograms by wavelets of children in group B had higher amplitudes increasing the sway frequencies contents up to 3 Hz, not allowing them to maintain the up right stance in similar stimulation than in condition. Implanted children of the group A and B with the implant turn on, in the condition 2, did not show any significant difference in the SV, comparing when they had the implanted turn off. Group A $p = 0.395$ and group B $p = 0.465$ (Wilcoxon ranked test).
Conclusion: These findings allow us to confirm that this postural test can be performed in children over 8 years old. Also our results suggest that deaf children with associated hypoactive vestibular responses included in our study, despite the etiology of the deafness, primarily use visual and somatosensory information to maintain their postural control. Hearing habilitation with a unilateral cochlear implant has no effect on the observed sensory organization strategy.
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1. Introduction

The mature vestibular system is responsible for stabilizing the position of the eyes, head and body in space, and helps to maintain an upright stance. It is composed of two parts, each with different roles: (1) the vestibular—ocular system, responsible for visual stabilization; and (2) the vestibular—spinal system, which maintains the orientation of the body in space and contributes to the postural tone necessary for the acquisition of motor developmental milestones. The development and maintenance of postural stability is a multisystem process that does not depend solely on vestibular input. Maturational changes in other sensory systems (primarily visual and proprioceptive), central nervous system (CNS) processing, and coordination of motor output are responsible for the changes in postural skills observed through adolescence. From the sensory systems perspective, young children are dependent on the visual system to maintain balance; as they grow older, they progressively begin to use somatosensory and vestibular information until reaching full maturity by the age of ten. Similarly, the coordination of the motor response and the gait pattern reach adult-like maturity by seven to ten years of age [1—3].

Auditory deprivation from birth brings about functional plastic changes in the CNS. One of these changes is the activation of the "meaning brain areas" by different sensory sources as illustrated by the role of visual input in lip reading and sign language communication [4]. Significant plastic changes also occur in deaf patients who receive cochlear implants, as demonstrated by the auditory adaptation that occurs due to a modified peripheral frequency map [5] and by the activation of the brain areas necessary for auditory processing. Imaging technologies [6] and psychophysical testing [7,8] have contributed to the understanding of the role of these plastic properties of the CNS in aiding communication in sensory impaired individuals.

Children with deafness are at risk of vestibular dysfunction because in some forms of inner ear deafness the damage extends to the vestibular receptor as well. There are reports of peripheral vestibular dysfunction and delayed postural control in some types of congenital or early-acquired deafness such as in inner ear malformations, meningitis, viral labyrinthitis, and some forms of hereditary deafness. Children with bilateral vestibular loss since birth or early life present with delayed gross motor development. These children stand and walk later than healthy children. However, the postural disturbances that result from isolated peripheral dysfunction are usually corrected by the time these children grow to be teenagers [9]. The postural disturbances are corrected through a process of compensation whereby input from proprioceptive, visual, and other sensory systems substitute for the absent peripheral vestibular input. The well known fact that postural recovery after vestibular lesions in adults occurs despite no regeneration or recovery of the vestibular apparatus indicates that changes in the CNS are likely responsible for the processing of substitutive sensory input that leads to this clinical recovery. As it is the case with central auditory plasticity, peripheral vestibular loss may bring about plastic changes in the CNS that are responsible for the adequate processing of substitutive sensory information necessary for the acquisition of postural skills in deaf children.

Although there are numerous reports of vestibular and balance dysfunction in hearing-impaired children found in the literature, most studies fail to control for type, degree and etiology of the hearing loss, as well as for other confounding variables [10]. The presence and severity of the peripheral vestibular dysfunction

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