Neuroscience Letters 617 (2016) 127–133

Contents lists available at ScienceDirect

Neuroscience Letters

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

Research paper

Importance of visual inputs quality for postural stability in strabismic children

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HIGHLIGHTS

- Strabismic children use visual inputs to control their posture.
- Postural stability is better when the non-squint eye is viewing.
- Binocular vision plays an important role in postural control.
- Strabismus surgery improves postural stability.

ARTICLE INFO

Article history:
Received 4 November 2015
Received in revised form 22 January 2016
Accepted 2 February 2016
Available online 10 February 2016

Keywords:
Strabismus
Children
Posture
Squint eye
Romberg quotient
Surgery

ABSTRACT

Objective: The first goal of the present study is to analyze the postural control in strabismic children in four different visual conditions (eyes open, eyes closed and monocular viewing with squint eye and non-squint eye). Secondly, we wish to explore the effect of strabismus surgery in postural control.
Method: Postural stability was recorded with a platform (TechnoConcept®) in 23 strabismic children aged from 4.4 to 14.8 years old (mean age: 8.4 years); 12 of these children were also examined at least two months after strabismus surgery. We analyzed the surface, the length, and the mean speed of the Center of Pressure displacement (CdP), and we calculated the Romberg's Quotient (that is for each postural parameter the ratio between eyes closed relative to eyes open).
Results: Strabismic children are significantly more stable when they can use their visual information to control their posture. Also, postural stability was better when the non-squint eye was viewing. For the first time, we observed the important role of vision (by calculating Romberg's Quotient) in strabismic children with binocular vision in comparison of strabismic children without binocular vision. Finally, we found that eye surgery improves postural stability.
Conclusion: Strabismic children use visual inputs to control their posture. Moreover, binocular vision plays an important role in postural control. Strabismus surgery improves postural stability.
Significance: Visual inputs from the non-squint eye and binocular vision are important to control stability.

1. Introduction

Posture is defined as the position of the various segments of the body, relative to each other and relative to the environment at a given time. Postural control allows the body to maintain a specific position through sensory systems, and it is controlled by visual, vestibular and proprioceptive information that is integrated by the cerebellum to obtain a good postural body stability [1]. Bair et al. [2] showed that intra-modal reweighting was exhibited by young children of 4 years old, unlike inter-modal reweighting which was only observed in older children. These authors provided further evidence that the development of multisensory reweighting was an important property of postural control, leading to more stable and flexible control of upright stance, which ultimately serves as the foundation for functional behaviors such as locomotion and reaching. A deficit of one of these sensory inputs may lead to instability, such as when one sensory input is defective, and the other subsystems may compensate for the impairment by playing a more important role and making up for such deficit. Peterka [3] and Friedrich et al. [4] reported that when the vestibular or the visual system was perturbed, the other sensorial systems could compensate for such deficits by adaptive mechanisms.

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http://dx.doi.org/10.1016/j.neulet.2016.02.008

The first question that appears is to explore the role of vision on postural control in subjects having a visual deficit as strabismic. Indeed, approximately 2% of children under 7 years old suffer from strabismus [5]. Strabismus is due to an abnormal alignment of the eyes; it can be convergent or divergent, horizontal or vertical. In most cases, this leads to loss of binocular vision. Few studies have examined the relationship between strabismus and postural control in children. In 1984, Odenrick et al. [6] observed a greater instability in children with divergent strabismus when compared to children with convergent strabismus. Legrand et al. [7] explored the role of visual inputs on postural stability in 9 strabismic children (aged from 4 to 8 years) and we showed that postural sway was smaller in the eyes open condition than in the eyes closed condition, in line with prior observations showing that children were more visuo-dependent than adults, even if their vision is deficient. Taken together all of these findings extend prior observations showing that children are more visuo-dependent than adults, even if their vision is impaired [8].

Based on these studies, we wonder to explore whether postural stability changes depends upon which eye (squint or non-squint eye) is viewing. Gentaz [9] suggested that normal subjects have one eye, the so-called "postural eye", allowing a better stability when subjects are viewing with both eyes. Furthermore, Fox [10] found that in normal subjects postural control was better under binocular fixation relative to under monocular fixation, and this difference persisted in total darkness, also suggesting that visual influence on postural stability resulted from a complex synergy of multimodal inputs. In 2001, Li and Shen [11] studied extraocular muscle proprioceptor of patients with concomitant strabismus by microscopy and found evidence that both the reception and transmission of proprioceptive information are abnormal in strabismic subjects. Interestingly, Barrett et al. [12] showed the limited role of suppression in the central field in ten strabismic amblyopia adults. In other words, they showed that instead of suppressing the image of the squint eye, the visual system may act to maximize the possibilities for binocular cooperation, suggesting that binocular mechanisms in strabismic amblyopia subjects could be well functioning, and performance with both eyes is better than with the non-squint eye alone. In contrast, Wang et al. [13] showed that binocular visual functions (eye movements, visual attention, visual perception, visual acuity, etc.) are disrupted in strabismic subjects, and also monocular visual functions in both squint and non-squint eye. Przekoracka-Krawczyk et al. [14] observed that when viewing with non-squint eye or with eyes closed, postural stability was worse than when viewing with squint eye. These authors suggested that when fixation is controlled by the squint eye, eye muscle tonicity must increase to keep stable fixation. This muscle action may then increase extra-ocular signals and improve postural control.

The role of binocular vision on postural control in strabismic children has been poorly evaluated. Matsuo et al. [15] studied the role of binocular vision on postural stability in a group of 28 strabismic children (aged from 3 to 12 years). They showed that strabismic children with no binocular vision were more unstable than strabismic children with binocular vision, under both eyes open and eyes closed conditions. These authors suggested that binocular vision influences postural body stability. In 2010, Matsuo et al. [16] observed similar results in adults. These authors noted that constant divergent strabismic adults with no binocular vision were less stable in eyes open condition than intermittent divergent adults with binocular vision.

The final question of this study is to explore whether postural stability changed two months after eye surgery, particularly whether the visual inputs via the squint eye operated to allow a better postural stability. Indeed, several authors [7,15,17] have shown modification of postural control after strabismus surgery. Some days after the surgery, postural control was impaired [15], but after a few months, postural control improved in strabismic children [7]. No studies existing deal with the effect of strabismus surgery on postural control according to which eye is operated upon (squint or non-squint eye). However, posturography seems to be a useful behavioural tool to detect any compensatory effects which occur or develop after eye surgery.

To summarize, in the present study we examined postural stability in twenty-three children with strabismus in four different visual conditions (eyes open, eyes closed and monocular viewing with squint eye and non-squint eye) before and after surgery on their strabismus. Based on previous studies reported above, we put forward the hypothesis that when children have eyes closed and/or when they are viewing monocularly with their squint eye, and/or in the absence of binocular vision postural capabilities will be different depending on the visual condition. In particular, strabismic children will be more unstable when vision is not present (eyes closed condition), when they are looking with the squint eye and also in the absence of binocular vision. Finally, we explored the effect of realignment of the ocular axis by surgery on postural control. We put forward the hypothesis that postural stability will improve after surgery.

2. Materials and methods

2.1. Subjects

Twenty-three strabismic children between 4.4 and 14.8 years old (mean age: 8.4 years) participated in the study. Strabismic children were recruited from the Department of Ophthalmology, Robert Debré Children's Hospital in Paris.

The investigation adhered to the principles of the Declaration of Helsinki and was approved by our institutional Human Experimentation Committee. Informed parental consent was obtained for each subject after the nature of the procedure had been explained.

2.2. Ophthalmologic and orthoptic examination

All children underwent ophthalmologic and orthoptic examination to evaluate their visual function. Clinical data of each strabismic child are shown in Table 1.

The visual acuity was measured for each eye separately from far distance (5 m) with the Monoyer chart (an optometric chart containing 10 rows of letters, each row corresponding to 1/10 visual acuity). Heterotropia (i.e. the manifest deviation of one eye) was measured from near (33 cm) and far distance (5 m) using a base-in and base-out prism bar. Stereoacuity threshold, based on disparity detection, was evaluated with the TNO random dot test for stereoscopic depth discrimination.

The monocular visual acuity was between 20/63 and 20/20. Nine children (C1, C2, C6-9, C12C22-23) had early onset esotropia (i.e., esotropia which began before the age of 2 years old), and one child (C21) had acquired esotropia (i.e., esotropia which began after the age of 2 years old). All of them had no binocular vision. Eleven children (C3-5, C10, C11, C14-17, C19-20) had intermittent exotropia with binocular vision (between 120″ and 60″ s of arc), except one (C11). Two children (C13 and C18) had acquired exotropia without binocular vision.

To resume, in our study children with constant strabismus (convergent or divergent) had no binocular vision responses, while all but one child with intermittent strabismus had binocular vision capabilities.

2.3. Platform

A platform (AFP40/16 Stabilotest, principle of strain gauge), consisting of two dynamometric clogs (Standards by *Association*