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Peripheral sensory information and postural control in children with strabismus☆

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ABSTRACT

Background: Sensory feedback from the visual system along with the vestibular and somatosensory systems is essential for the regulation of normal postural control. Children with strabismus and, therefore, with abnormal binocular vision, may have an altered perception of space and use different sets of cues to determine depth perception when compared with children without strabismus.

Objective: To explore the postural control of children with and without strabismus, when the three sensory systems are challenged.

Method: Forty-six children (21 with strabismus and 25 age-matched controls) aged between 5 and 10 years completed ophthalmic screening and then underwent assessment for postural control, which included Paediatric Balance Scale (PBS) and six conditions of the Sensory Organization Test (SOT). Four primary outcome measures were: PBS summary score, Equilibrium Score (ES), Strategy Score (SS) and Sensory Analysis Score of the SOT.

Results: A significant difference ($P < 0.05$) was observed between the strabismus and non-strabismus group in the PBS and, ES and SS of SOT condition 1. The Sensory Analysis scores were significantly different ($P = 0.03$) between the groups for 'Somatosensory'. Simple linear regression analysis suggested that the strabismus condition was significantly ($P \leq 0.02$) associated with the PBS and, the ES and SS of condition 1, with a variance of 14.6%, 16.1% and 12.8%, respectively. Subgroup analysis suggested that age was a significant ($P \leq 0.001$) correlate for balance scores in non-strabismus group (R^2 ranged from 32% to 58.4%), but not for the strabismus group.

Significance: Postural control in children with strabismus is not equivalent to that of children without strabismus, when their somatosensory system is challenged. Additionally, the functional balance performance of children with strabismus is lower than their counterparts without strabismus. Collectively, the results suggest that the usual improvement in balance performance with increasing age is observed in children without strabismus but not in children with strabismus.

1. Introduction

Vision, vestibular and the somatosensory systems are three key sensory systems that play a significant role in the regulation of normal postural control [1]. The vestibular system mainly provides information about head position and orientation in space, whereas the somatosensory system is responsible for relaying feedback regarding body position and orientation. The visual system regulates the head and body in visual space [2]. These three sensory systems collectively work together in the control of posture [3]. In the early years of child development, appropriate visual input is necessary for establishing the effective integration of the sensory systems and for context-dependent reweighting of all three sensory input [2,4,5].

Strabismus (misalignment of eyes) is a relatively common childhood ophthalmic disorder affecting 2% to 5% of preschool and school-aged children, irrespective of ethnic and geographical differences [6,7]. Childhood strabismus may lead to abnormal development of the visual system, in particular affecting binocularity (being able to fuse an image

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from both eyes to form single vision) and stereopsis (depth perception and ability to see three-dimensionally) [8].

Children with a history of constant strabismus since birth may develop compensatory cortico-visual adaptations such as suppression of visual input from the deviating eye in order to avoid diplopia (double vision) [9,10]. Children with strabismus acquired in later years of life after the visual system has matured (after about the age of 9 years) will usually suffer from diplopia (double vision) with significant functional impacts [11,12].

Investigations into postural control of adults reveal impaired vision of even one eye (with resultant impairment of binocular vision) may be associated with poor postural control in altered sensory conditions [13,14]. Thus, children with strabismus and, therefore abnormal binocular vision may have an altered perception of space and may use different sets of cues to depth perception when compared with children with normal vision [15]. Reportedly, children with strabismus have impaired postural control ability when assessed in eyes open condition while standing on a firm and foam surface [16,17], suggesting that they are more reliant on somatosensory input than their other senses. However, there is a need to further this understanding and explore how the alterations in visual processing associated with strabismus may manifest when demands are placed on the dynamic multi-sensory postural control system.

The purpose of this study was to explore postural control of children with strabismus (demonstrating visual suppression from the deviating eye) and of children with normal vision (without strabismus), when the three sensory systems are challenged with a computerised dynamic posturography. It is hypothesised that the measures of postural control and functional measures of balance in children with strabismus are different to that of the children without strabismus, due to the challenges in the organisation of sensory information required for postural control, when the visual, vestibular and somatosensory systems are systematically manipulated.

2. Methods

2.1. Study design

Cross-sectional observational study design.

2.2. Setting

The study was undertaken at the University of Otago Balance Clinic and the Ophthalmology Outpatient Clinic of Dunedin Hospital.

2.3. Participants

Children aged between 5 and 10 years with constant strabismus (including fully accommodative esotropes who demonstrate constant esotropia when not wearing refractive correction) were recruited for the experimental group (EG) from patients who attended the Ophthalmology Outpatient Clinic of Dunedin Hospital. Age-matched participants for the control group (CG) were recruited from the community via flyers, newspaper advertisements and word-of-mouth. All children were required to be free from any known neurological impairment. Children with a history of delayed milestones, intellectual disability and/or any musculoskeletal injuries to the lower limb in the past six months were excluded from the study. Children with other ocular pathology such as congenital cataract, glaucoma, retinal or optic nerve disease or a history of penetrating/perforating ocular trauma, dense amblyopia (defined as worse than 1.0 LogMAR) were also excluded from the study.

A detailed eye examination carried out by a registered orthoptist on all participants in both the experimental and control groups, including measurement of visual acuity using age-appropriate testing methods (with and without correction), stereopsis (using Titmus stereopsis testing), fusion/binocularity (using Worth four-dot test), and strabismus examination. Only children with definite complete suppression of the deviating eye (as demonstrated by Worth four-dot testing) were included in the experimental group. For the control group, only children demonstrating normal visual acuity (with or without refractive correction), normal binocularity (normal sensory fusion), full stereopsis (100" to Titmus testing or better), and orthotropia for distance and near (with and without refractive correction), were included.

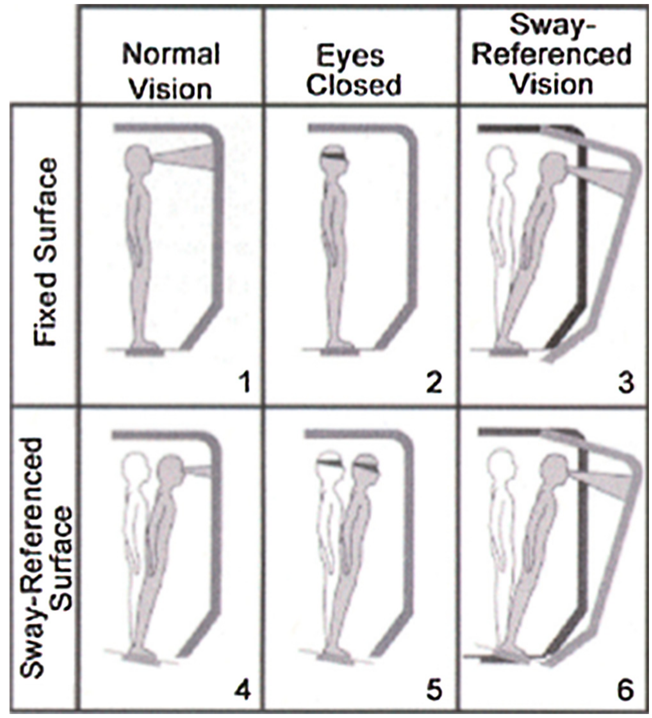

Fig. 1. The six sensory testing conditions (Sensory Organization Test) of the NeuroCom Smart Equitest®.
Image courtesy of Natus Medical Inc.

2.4. Tools and instruments

2.4.1. Sensory Organization Test

The Sensory Organization Test (SOT) was administered to all participants using the NeuroCom SMART EquiTest® (version 8.4.0), to evaluate the sensory weighting in postural control. The EquiTest consists of two AMTI force platforms (22.86 cm × 45.72 cm) mounted on a servo-motored base [18]. The EquiTest also included a visual surround screen which was servo-motored. The data were sampled at the default sampling rate of the SMART EquiTest® (100 Hz). The Sensory Organization Test comprised six sensory testing conditions (Fig. 1) standing with eyes open or closed on a fixed or movable platform and visual surround [19]. The sensory system available were systematically manipulated in each testing condition.

2.4.2. Paediatric Balance Scale (PBS)

The 14-item balance assessment scale designed to be administered by a health care professional was used as the clinical assessment of balance [20]. The 14-items included a range of functional and balance assessment activities such as standing with eyes open or closed with feet apart/close, sit-to-stand and functional reach [20]. Each of the 14-items were scored on a scale of 0–4 where '0' requires moderate to maximal physical assistance and '4' is able to perform the task independently.