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Research paper

Balance in subjects with congenital or early onset strabismus: Influence of age

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HIGHLIGHTS

- No studies on age-related changes have been conducted in patients with strabismus.
- Strabismus was found to induce a different postural strategy, especially in children.
- These postural strategies should be considered in tailored rehabilitation treatment.

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ABSTRACT

Few studies have investigated the relationship between strabismus and balance, and those that do exist focused on patients within a limited age range, while no studies on possible age-related changes have yet been conducted. Therefore, the aim of our study was to investigate whether the balance strategies adopted by patients with congenital or early onset strabismus change with age. Forty strabismic patients and 36 healthy subjects were enrolled in the study. Both patients and healthy subjects were divided into three subgroups according to age (children, adolescents, and adults) and underwent a stabilometric evaluation. When we compared the whole group of strabismic patients with the group of healthy subjects, we found that the center of pressure area and the trunk oscillations in the former were significantly different from those in the latter; when we considered the three age groups separately, only values in children with strabismus were different from those in the age-matched control group of healthy subjects. Strabismus was found to affect balance in children by inducing a postural strategy characterized by a reduction in physiological trunk oscillations. Gaining a better insight into postural control in strabismic subjects and its evolution with age may be crucial to improving rehabilitation in such patients and planning tailored rehabilitation treatment.

1. Introduction

Balance, which is the ability to move or to remain in a position without losing postural control or falling, is maintained by postural strategies, namely dynamic and static actions that control the body position in space. Balance is a very complex task that is based on the interaction of vestibular, somatosensory, proprioceptive, cutaneous and visual systems. Reducing the influence of one system leads to postural adaptation, possibly as a consequence of the offsetting of one of the other systems [1–5]. The eyes contribute above all to spatial localization and to the ability to estimate the spatial relationship between objects and the body [6]. Postural stability improves opening of the eyes [7–9] and vision is known to play a crucial role in balance, even though its influence is related to age and the task requirements [10] and depends on the support surface [11] and stance width [12].

Few studies have investigated the relationship between strabismus and static or dynamic balance, and those that do exist focused on patients within a limited age range (children or teens). A greater instability in children with divergent strabismus (exotropia) than in those with convergent strabismus (esotropia) was observed in

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both static [13] and dynamic conditions. Moreover, strabismic children with no binocular vision were more unstable than those with binocular vision [14]. Legrand et al. [15] observed poor balance in strabismic children and showed an improvement in postural control two months after strabismus surgery. Recently, Lions et al. reported abnormal postural control in children with strabismus compared with a healthy age-matched control group [16], both while fixating a target and while making saccades [17]. All these studies suggest that poor postural stability in strabismic children is a consequence of their low or abnormal visual input [11]. Postural strategies used by healthy subjects to achieve a good balance are known to change with age [18], though the timing of the full development of postural stability is still debated. The contributions of visual, vestibular and proprioceptive information vary from the childhood to adulthood [19]. Some authors [20,21] have hypothesized that development-related improvements in postural control may, at least in part, be related to an improved sensory re-weighting ability: Ferber-Viart et al. [22], in particular, reported that somatosensory inputs predominate in adults, whereas vision predominates in children, and Mallau et al. [23] confirmed these findings. As regards the postural strategy adopted by strabismic subjects, to our knowledge no studies on possible age-related changes have yet been conducted.

Therefore, the aim of this study was to investigate whether the balance strategies adopted by patients with congenital or early onset strabismus change with age and, if so, whether such changes are comparable to the changes that occur in healthy subjects.

2. Material and methods

We conducted a prospective comparative study of consecutive patients recruited and examined at the Pediatric Ophthalmology and Strabismus Unit at the Catholic University of Rome from December 2011 to May 2012. The study followed the tenets of the Declaration of Helsinki and informed consent was obtained from each patient or from the parents of participating minors, after the nature of the procedure had been explained.

2.1. Subjects

Forty strabismic patients (Strabismic Group, SG), comprising 18 females and 22 males (age range 5–50 years; mean 13.6 years), were enrolled in our study: 24 had esotropia, 11 exotropia, 5 vertical ocular deviation, 12 horizontal and vertical ocular deviation combined (Table 1). Inclusion criteria were congenital or early onset (within one year of age) strabismus and age ≥5 years. Exclusion criteria included clinical onset of strabismus after one year of age, poor cooperation owing to young age or mental retardation, presence of both neurological and otoneurological symptoms or disorders, and evidence of muscoloskeletal problems. A Control Group (CG) of 36 healthy subjects matched for age, weight and height was also recruited. Both patients and healthy subjects underwent a full ophthalmological and orthoptic evaluation, including visual acuity (measured by means of ETDRS charts), anterior and posterior segment examination, cycloplegic retinoscopy, ocular motility evaluation, prism and cover test in primary gaze, downgaze and upgaze, and stereoacuity by means of TNO test. All the subjects of control group showed no ocular motility disorders and a normal binocular vision with stereoacuity > 60". Both the SG and CG were divided into three subgroups according to age: children (age ≤10), adolescents (age ≥11 and ≤18) and adults (age > 18). According to this classification, our sample contained: 19 strabismic patients and 17 healthy subjects in the group of children; 10 strabismic patients and 10 healthy subjects in the group of adolescents; 11 strabismic patients and 9 healthy subjects in the group of adults. The clinical features in the three age groups were distributed as follows: the children's group contained 3 constant exotropias (with a vertical component in one case), 12 esotropias (with a vertical component in four cases) and 1 pure vertical deviation; the adolescents' group contained 5 constant exotropias (with a vertical component in one case), 7 esotropias (with a vertical component in four cases) and 1 pure vertical deviation; the adults' group contained 3 constant exotropias (with a vertical component in one case), 5 esotropias (with a vertical component in one case) and 3 pure vertical deviations. Normal binocular vision was not detected in any of the subjects.

2.2. Equipment

The experimental procedure was performed at the Rehabilitation Department of the Don Carlo Gnocchi Onlus Foundation in Rome. The stabilometric assessment was carried out by using a bipodalic platform (Prokin B, Technobody, Italy). It consisted of 4 strength sensors oriented in the vertical and horizontal directions and positioned at the vertex of the square inscribed in the platform and under a circular surface with a 50-cm diameter. The system provides, at 40 Hz, the coordinates of the subject's Center of Pressure (CoP). Moreover, a biaxial accelerometer, positioned on the trunk at the level of the sternum and held in place by a chest strap, measured trunk tilts in the antero-posterior and medio-lateral directions.

2.3. Assessment

The patient was positioned on the bipodalic platform using a spacer, a V-shaped frame on which the medial borders of the feet were placed, with the medial malleolus aligned with a red line drawn 3 cm from the median axis of the platform. Once the subject was positioned, the spacer was removed while maintaining the angle between the feet at 30°. Subjects were tested barefoot. First, they underwent a stabilometric test: in the first trial (eyes open condition, EO), they were asked to stand still on the platform for 30 s, while fixating a visual target presented by a 17" LCD monitor placed at the eye level of each subject standing upright on the platform at a distance of about 50 cm, and 1.5 m from a white back wall. The target shape was a red round spot (1 cm in diameter), whose dimension was calibrated to subtend about 1° of visual angle. After that, the same trial was repeated for 30 s with the eyes closed (eyes closed condition, EC). The stabilometric test (one trial with eyes open, followed by one trial with eyes closed) was repeated three times, alternating the EO and EC conditions to avoid any bias. An operator stood behind the patient throughout the protocol to prevent falls. Any trial that was considered to be unreliable by the operator (owing, for example, to gross postural adjustment or to unexpected movements) was discarded and repeated. The exam was carried out in a quiet room equipped with several rehabilitation instruments and common hospital furniture.

2.4. Stabilometric variables

Starting from the instant positions of the CoP, the following variables related to balance performance were computed:

- $Velocity_{AP}$ and $Velocity_{ML}$ [mm/s]: velocity of oscillations along the AP and ML axes;
- Length [mm]: length of CoP trajectory;
- Area [mm^2]: area of the 95% confidence ellipse;
- $Romberg_{Length}$: ratio between the value of the length in the EC condition and the same value in the EO condition;
- $Romberg_{Area}$: ratio between the value of the area in the EC condition and the same value in the EO condition.