Effect of strabismus on vestibular functions: value of its correction

Mohamed A. Abd Al-Rahman, Badawy S. Badawy

Department of ENT, Sohag University, Sohag City, Egypt

Correspondence to Mohamed Abd Al-Ghaffar Abd Al-Rahman, MD, Assistant Professor of Audiology, Audiology unit, Department of E.N.T., Sohag Faculty of Medicine, Sohag University, Sohag, Egypt. Postal code: 82524; tel: 002 01099055507; fax: 002 093 2310885
E-mail: Dr_mghaffar@yahoo.com

Received 27 February 2014
Accepted 1 April 2014

Advanced Arab Academy of Audiovestibulogy 2014, 01:18–25

Objective
Studies that evaluate the relationship between strabismus and vestibular functions are very scarce with no consensus between their results. Hence, this study was designed to evaluate vestibular functions in patients with strabismus and to find out the effect of surgical correction of strabismus on vestibular functions.

Materials and methods
Thirty patients with strabismus aged between 10 and 33 years constituted the study group. The following procedures were carried out: otological examinations, detailed vertigo history, neurological and ophthalmological examinations, basic audiological evaluation, office tests for vestibular evaluation, videonystagmography, and computerized dynamic posturography. These vestibular tests either office tests or laboratory tests were performed three times, before eye surgery and 1 month and 2 months after eye surgery.

Results
Before surgery, in office tests for vestibular function, 36.6% of patients had abnormal results in dynamic visual acuity, whereas 26.7 and 16.7% had abnormalities in head thrust and head shake tests. In addition, 43.3% had abnormal sharpened Fukuda stepping test, whereas 33.3 and 13.3% had abnormal CTSIB and Fukuda stepping test. Reduction in equilibrium scores as well as condition 3, 5, and 6 of sensory organization test in all patients showed abnormal videonystagmography test results. Improvement occured postoperatively in office as well as laboratory tests.

Conclusion
Vestibular functions in strabismus patients are globally better in postoperative than in preoperative conditions, and this improvement appeared to be stable.

Keywords:
Posturography, strabismus, vestibular functions, VNG

AAAA 01:18–25

2314-8667

Introduction

Strabismus, ocular misalignment, affects up to 4% of the general population [1]. Although many cases of nonsyndromic early childhood strabismus seem sporadic, recessive and dominant inheritance patterns can be inferred from familial cases [2]. In addition to genetic predisposition, both ocular and nonocular factors can also cause strabismus [3].

The function of the mature vestibular system is to stabilize the position of the eyes, head, and body in space, and to help maintain an upright stance. It is composed of three parts, each with its own value. The first part is the vestibulo-ocular pathway, which is responsible for visual stabilization. The second part is the vestibulospinal pathway, which maintains the orientation of the body in space and contributes to the postural tone, and the third part is the vestibulocollic pathway, which is responsible for the movement of the neck muscles [4].

The ability of the vestibulo-ocular reflex to elicit rapid compensatory eye movements that maintain stability of images on the fovea depends on relatively simple patterns of connectivity in the central vestibular pathways [5].

Studies that evaluate the relationship between strabismus and vestibular function are very scarce with no consensus between their results. One study showed that strabismus is accompanied by greater body sway and the other one owe the vestibular deficit to the correction of strabismus.

Hence, this study was designed to evaluate vestibular functions in patients with strabismus and to find out if surgical correction of strabismus affects these functions or not.

Materials and methods

Patients

This study included 30 patients with strabismus aged between 10 and 33 years. Patients in this study were selected from outpatient clinic of Ophthalmology Department, Sohag University hospitals. The study protocol was approved by the ethics committee of the Faculty of Medicine, Sohag University (No 14/2012). Informed consent was taken from all patients participating in this study before their inclusion.

Inclusion criteria

(1) No history of hearing loss.
(2) No history of dizziness.
(3) No history of correction of error of refraction.
(4) No history of orthopedic and/or biomechanical abnormalities that may affect patient mobility.
(5) No history of neurological diseases that may affect postural stability.
(6) No history of diabetes mellitus or hypertension.
(7) Age of the patient more than 10 years as Steindl *et al.* [6] stated that a child only reaches postural maturation at about 10 years of age.

Equipments

(1) Sound-treated room, IAC model, 1602; USA.
(2) Computerized two-channel pure tone audiometer, Madsen model, 922; Denmark.
(3) Immitancemeter, Amplaid model, 775; Denmark.
(4) Computerized videonystagmography (VNG), ICS chartr, with a light bar designed to ensure a visual field of 40° of both horizontal and vertical planes.
(5) Water caloric irrigator, ICS chartr model, NCI-480; USA.
(6) Computerized Dynamic Posturography System, Neurocom; USA (Smart Equi-test).

Methods

All participants of this study were subjected to the following:

(1) Full history taking.
(2) Detailed history of dizziness.
(3) ENT examination.
(4) Neurological examination: our entire patients were neurologically free.
(5) Ophthalmological examination:

Assessment of the visual acuity of each eye: We used the Snellen letters chart method; any patient with visual acuity worse than 6/18 was excluded from the study.
Assessment of ocular alignment: Abnormal head postures may indicate restrictive or paralytic strabismus. Common 'abnormal head postures' include face turn, head tilt, chin up or chin down, or any combination of the above.
Cover tests: Cover tests are objective tests that measure horizontal and vertical strabismus. The 'cover–uncover test' detects tropia/manifest squint. The examiner observes the uncovered eye for movement to take up fixation as the fellow eye is covered with the examiner's hand. A movement toward the nose implies exotropia; a movement temporally implies esotropia; an upward movement implies hypotropia; and a downward movement implies hypertropia.
Assessment of ocular motility: Three cranial nerves innervate six extraocular muscles (some would consider the levator as the seventh extraocular muscle). The fourth cranial nerve (trochlear nerve) innervates the superior oblique muscle; the sixth cranial nerve (abducens nerve) innervates the lateral rectus muscle; and the third cranial nerve (oculomotor nerve) innervates the rest.

There are six positions of gaze in which one muscle is the prime mover of the eye. These are called the six cardinal positions. The six cardinal gaze positions together with the primary gaze, straight up, and straight down positions, a total of nine gaze positions, need to be examined.

(6) Basic audiological evaluation:

(a) *Pure tone audiometry*: Air conduction thresholds were tested at 250–8000 Hz, and bone conduction threshold were tested at 500–4000 Hz.
(b) *Speech audiometry*: This included speech reception threshold testing (SRT) and word discrimination testing at 40 dB sensation level (ref. SRT) or at most comfortable loudness levels.
(c) *Acoustic immitance testing*: It included tympanometry and acoustic reflex threshold measurement.

(7) Office tests for vestibular evaluation:

(a) *Head shake test*: It was performed with Frenzel lenses in place; the patient is instructed to shake the head vigorously about 30 times horizontally with the chin placed 30° downward. Head shaking is stopped abruptly and the examiner looks for any nystagmus.
(b) *Head thrust test*: Brief high-acceleration horizontal head thrust are applied while instructing the patient to look carefully to the examiner's nose. The examiner looks for a corrective saccade [7].
(c) *Dynamic visual acuity test*: The patient shakes the head rapidly in the horizontal plane at ~2 Hz while reading a Snellen visual acuity chart at a standard distance. A decrease in acuity of

more than one line on the chart suggests an abnormal vestibular ocular reflex [8].

(d) *CTSIB (Modified Clinical Test for Sensory Interaction of Balance)*: The patient's ability to maintain quite volitional stance was evaluated as they sequentially stood on:

   (i) A flat firm surface with eyes open.
   (ii) A flat firm surface with eyes closed.
   (iii) A compressible surface with eyes open.
   (iv) A compressible surface with eyes closed.

A special emphasis was given to the fourth condition, by which only the vestibular system was available to provide accurate cues as to the body's position and movement [8–10].

(e) *Fukuda Stepping Test*: The patient was asked to march in place 50 steps with their eyes closed. The amount of rotation to the right or the left during the stepping maneuver was estimated. The test was considered positive if the rotation was 45° or more, indicating an asymmetrical labyrinthine function [11].

(f) *Sharpened Fukuda Stepping Test*: The patients were asked to march in place, as in the previous test, after active head shaking for 30 s. The test was considered positive if the rotation was 60° or more, indicating an asymmetrical labyrinthine function [9].

(8) VNG: VNG is a method of detecting and recording eye movements using digital video image technology. The patient wears goggles housing infrared cameras to record eye movements. Testing comprises the standard ENG test battery, including saccade, gaze, tracking, OPK, positional, positioning, and Caloric test.

Test procedure:

(a) Eye signal calibration: The patient was asked to look back and forth at a moving target with a known angle to give a calibration ratio. This ratio was then used in the actual testing and analysis portions of the program.

(b) Ocular motility testing:

   (i) *Random saccade test*: The patient was asked to fixate on a target in front of him. The target would move to random locations on the light bar at random time interval and the patient followed those jumps. Three parameters would be analyzed and displayed by the computer: latency, accuracy, and velocity.

   (ii) *Smooth pursuit test:* The patient focused on and followed the light target as it moved in a pendular manner from one end of the light bar to the other. Three stimuli were presented: 0.1, 0.2, and 0.4 Hz. The gain was measured and displayed by the computer.

   (iii) *Optokinetic test:* The sinusoidal optokinetic test recorded the patient's nystagmogenic eye movement as he watched a series of stimuli that first moved to the left and then to the right simulating a spinning movement. The gain in each direction was measured.

   (iv) *Gaze test*: The patient was asked to sit upright holding his head in a central position while staring at light either in the center, left, right, up, or down positions. The light bar allowed the patient to gaze at 30° for each direction.

(c) Spontaneous nystagmus, positional and positioning tests:

   (i) Any spontaneous or positional nystagmus was tested with and without fixation while the participant was sitting and lying in the supine and both lateral positions.

   (ii) Positioning test (Dix–Hallpike maneuver): The head of the patient was rapidly moved from the upright position to one with the head hanging and turned 45° off the saggital plane. After at least 1 min of observation for nystagmus, the patient was returned to upright and observed for the reversal of the nystagmus. If the test was positive, it would be repeated to the same side to test for fatigability of the nystagmus. After waiting for 1 min, the test was performed to the opposite side.

(d) Caloric test: Bithermal caloric test was performed by placing the patient in the supine position with the head elevated 30°. The test was conducted without fixation using water temperature 30 and 44°C for cool and warm irrigation, respectively. Irrigation of 250 cc water was performed in 30 s. Proper mental tasks were given and nystagmus was recorded. The patient was then asked to fixate on a stationary target directly above. The patient waited for 5 min before beginning the next caloric test. As in all nystagmus tests, data analysis was an interactive process. Through the computer software, the velocity of nystagmus beats was measured. The computer calculated the unilateral weakness and the directional preponderance.

(9) Computerized dynamic posturography (CDP):

Sensory organization test (SOT) of CDP:

The following steps were performed:

(a) The patient wears a harness to protect himself from falling.
(b) Measurement of the patient's height, which is a critical information for the computer to determine the relative position of the COG, to set the sway angles for the movement of the surface and surround, and in the calculation of the equilibrium score.
(c) The patient stands on the platform and the foot placement is set to position the patient's ankles so that the surface basically rotates about the ankle joint.
(d) The traditional SOT was performed with three trials for conditions, from condition 1 to condition 6.

Vestibular assessment was performed before surgery and twice after surgery (1 month and 2 months after surgery).

The results obtained were statistically analyzed with the help of SPSS software (SAS) (IBM, Armonk, New York, USA).

Results

This study included 30 patients. All those patients were selected according to our previously prepared selected criteria from outpatient clinic of Ophthalmology Department, Sohag University hospitals.

Age and sex distribution

Our study included 30 patients (11 male patients and 19 female patients). The age range was 10–33 years.

There was no statistically significant difference between male patients and female patients regarding their age.

Ophthalmological evaluation results

It includes, Number and percentage of type of strabismus and its angle and Number and percentage of patients according to their visual acuity in both eyes. See Tables 1 and 2.

Audiological test results

Hearing evaluation of our patients showed normal hearing level in our selected patients with excellent speech discrimination, and all patients had type A tympanogram and preserved acoustic reflexes, which reflect normal middle ear function.

Vestibular test results

These vestibular tests, either office tests or laboratory tests, were performed three times, before eye surgery and 1 month and 2 months after eye surgery.

The delay in patient evaluation after surgery was for avoidance of the effect of anesthesia on the patients, as it may have some effect on the body, and therefore on the proprioception of extraocular muscles (Fig. 1).

Comparison between preoperative and postoperative vestibular function tests results

It includes number and percentage of positive cases in office tests,VNG test and t.test for comparison between SOT of CD posturography pre-operative and one and two months after eye surgery. See Tables 3–7.

Discussion

Studies that evaluate the relationship between strabismus and vestibular function are very scarce. To

Table 1 Number and percentage of type of strabismus and its angle

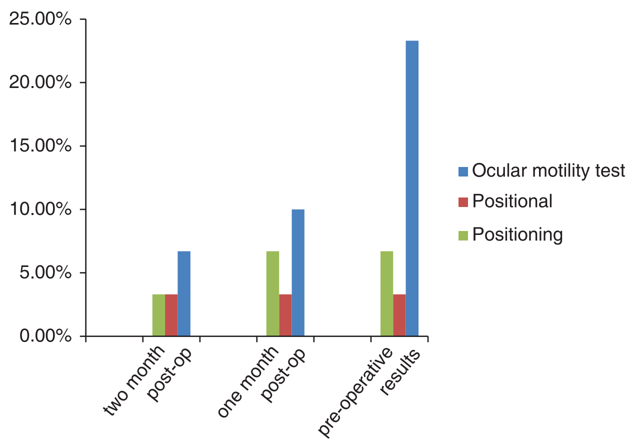
Type of strabismus	*N* (%)
Right esotropia	5 (16.7)
Right exotropia	7 (23.3)
Left esotropia	6 (20)
Left exotropia	7 (23.3)
Alternating esotropia	2 (6.7)
Alternating exotropia	3 (10)

Minimum angle was ±15 and maximum angle was ±45 with mean ±27.37.

Table 2 Number and percentage of patients according to their visual acuity in both eyes

Visual acuity	Right eye [*N* (%)]	Left eye [*N* (%)]
6/6	16 (53.3)	9 (30)
6/9	5 (16.7)	12 (40)
6/12	2 (6.7)	5 (16.6)
6/18	7 (23.3)	4 (13.3)

Figure 1



Videonystagmography test results preoperatively and 1 month and 2 months after eye surgery.

Table 3 Number and percentage of positive cases in office tests (vestibulo-ocular and vestibulospinal pathways) preoperatively and 1 month and 2 months after eye surgery

Office tests	Preoperative [*N* (%)]	1 month postoperative [*N* (%)]	2 months postoperative [*N* (%)]	*P*-value
Head shake	5 (16.7)	4 (13.3)	3 (10)	0.04*
Head thrust	8 (26.7)	5 (16.7)	5 (16.7)	0.02**
Dynamic visual acuity	11 (36.6)	4 (13.3)	4 (13.3)	0.00***
CTSIB	10 (33.3)	7 (23.3)	7 (23.3)	0.03*
Fukuda stepping	4 (13.3)	5 (16.7)	4 (13.3)	0.08
Sharpened Fukuda stepping	13 (43.3)	6 (20)	4 (13.3)	0.00***

*Significant difference; **Highly significant difference; ***Very highly significant difference.

Table 4 Videonystagmography test results, number and percentage of positive cases preoperatively and 1 month and 2 months after eye surgery

VNG test	Preoperative [*N* (%)]	1 month postoperative [*N* (%)]	2 months postoperative [*N* (%)]	*P*-value
Ocular motility	7 (23.3)	3 (10)	2 (6.7)	0.00***
Positional	1 (3.3)	1 (3.3)	1 (3.3)	1
Positioning	2 (6.7)	2 (6.7)	1 (3.3)	0.05*
Caloric test	4 (13.3)	4 (13.3)	4 (13.3)	1

*Significant difference; ***Very highly significant difference.

Table 5 Mean (*X*), SD, and *t*-test for comparison between SOT of CD posturography preoperatively and 1 month and 2 months after eye surgery

	Preoperative		1 month postoperative		2 months postoperative		
Test conditions	*X*	SD	*X*	SD	*X*	SD	*t*-Value
1	89.7	4.6	91.2	4.7	90.4	4.4	0.66
2	87.6	4.4	89.3	4.3	89.5	4.9	0.52
3	89.1	4.1	92.2	4.3	93.1	4.6	0.05*
4	75.6	5.12	77.3	5.1	77.5	4.5	0.07
5	66.2	6.2	69.9	6.6	70.8	5.3	0.03*
6	59.5	5.8	78.3	6.1	79.7	6.5	0.001***
Composite	71.3	4.9	75.9	5.4	76.2	6.3	0.004**

*Significant difference; **Highly significant difference; ***Very highly significant difference.

Table 6 Correlation between six conditions of sensory organization test of computerized dynamic posturography and angle of squint

	Angle					
	15–25		26–35		36–45	
Conditions	*r*	*P*	*r*	*P*	*r*	*P*
1	0.11	NS	0.13	NS	0.24	NS
2	0.25	NS	0.19	NS	0.27	NS
3	0.3	NS	0.32	NS	0.37	*
	0.15	NS	0.2	NS	0.17	NS
5	0.31	NS	0.29	NS	0.38	*
6	0.33	NS	0.35	*	0.46	**

*Significant correlation; **Highly significant correlation.

our knowledge, there are only two studies. The old one, about 30 years ago, was conducted by Odenrick *et al.* [12]. This Swedish study reported that the presence of strabismus was accompanied by greater body sways. The second one is a recent study, which was conducted in Japan by Matsuo *et al.* [13]. These authors reported greater postural instability after strabismus surgery than before, whether the eyes were kept open or close. Hence, there are two contradictory studies. We designed our study to evaluate the effect of strabismus on vestibular functions in one hand and to show the effect of eye surgery on vestibular functions on the other hand.

Hearing threshold level in our 30 patients revealed normal hearing in both ears. In addition, patients under this study had normal middle ear function with excellent speech discrimination. Patients who had any degree of hearing loss were excluded from the study.

Ophthalmological evaluation results

Type of strabismus and its angle in addition to visual acuity of all participants were studied. In the selected 30 patients, who fulfilled our criteria, the most common type of strabismus was exotropia in about half of patients (14 of the 30 patients) followed by esotropia (11 of the 30 patients), and both alternating esotropia and exotropia in two and three patients, respectively (Table 1). The previous two studies were conducted on exotropia type of patients either by Odenrick *et al.* [12] or by Matsuo *et al.* [13].

In the present study, the angle of strabismus was from ±15 to ±45. Because of wide range of the angle, we classified our patients into three subgroups: those with an angle of 15–25 in seven patients, of 26–35 in 15 patients, and an angle of 36–45 in eight patients.

As control of posture is a complex process based on multiple interactions among visual, vestibular, and proprioceptive sensory systems, there is a fact that children are particularly visually dependent, more than the adults are; it is well known that vision plays a major role in postural control in children [14]. Hence, all participants had good visual acuity from 6/6 up to 6/18 (Table 2).

Table 7 Correlation between six conditions of sensory organization test of computerized dynamic posturography and the visual acuity

	Visual acuity							
	6/6		6/9		6/12		6/18	
Conditions	*R*	*P*	*r*	*P*	*r*	*P*	*R*	*P*
1	0.11	NS	0.2	NS	0.18	NS	0.23	NS
2	0.13	NS	0.11	NS	0.12	NS	0.15	NS
3	0.1	NS	0.14	NS	0.32	*	0.33	*
4	0.1	NS	0.23	NS	0.22	NS	0.29	NS
5	0.23	NS	0.25	NS	0.31	*	0.26	NS
6	0.13	NS	0.34	*	0.32	*	0.41	**

*Significant correlation; **Highly significant correlation.

All patients who had visual acuity worse than 6/18 were excluded from the study, as that may affect patient balance.

Vestibular test results

All participants in this study had no history of dizziness after detailed history of vertigo.

Before surgery, all patients underwent vestibular tests either office tests or laboratory tests. Then, these tests were performed again 1 month and 2 months after eye surgery. The delay in evaluation of patients after surgery is to overcome the effect of anesthesia on proprioception of extraocular muscles, which may affect the vestibulo-ocular test results.

In office tests for the vestibulo-ocular pathway, despite all patients had no history of dizziness in preoperative tests, 36.6% of patients had abnormal results in dynamic visual acuity test compared with the other two tests: 26.7 and 16.7% of patients in head thrust and head shake, respectively.

Concerning office tests for the vestibulospinal pathway, 43.3% had abnormal sharpened Fukuda stepping test, followed by (10 patients) 33.3% and (four patients) 13.3% with abnormal CTSIB and Fukuda stepping test, respectively (Table 3).

Both office tests for the vestibulo-ocular and vestibulospinal pathways revealed positive results — that is, abnormal vestibulo-ocular pathway and increased body sway in vestibulospinal pathway with increasing difficulty of the test (dynamic visual acuity and sharpened Fukuda stepping test).

It is well known that VNG completely eliminates optic fixation; hence, it can detect even weak nystagmus that cannot be seen by routine tests.

Seven patients had abnormal ocular motility testing, six of them had abnormal saccades. Five of these six patients had abnormal latency and the remaining one had abnormal accuracy. Gaze test was abnormal in four patients. Only one patient had abnormality in tracking and no one had abnormality in optokinetic. None of those patients had abnormality in more than two tests of ocular motility test buttery.

Unilateral caloric weakness of peripheral origin, that is, positive fixation suppression, occurred in three patients, and only one patient had bilateral caloric weakness (Table 4).

Reviewing the literature, no previous studies were conducted to show VNG findings in strabismus patients.

Sparto *et al.* [15] reported an increase of body sway in case of moving surface in children at the age of 7–12 years. Similarly, in a dynamically moving scene, for example, after presentation of a stimulus reproducing optical flow, the maintenance of standing in children was shown to be more difficult than in adults. This was due to the involvement of two conflicting sensory inputs. They emphasized that the conflict of sensory inputs is difficult to manage for children. For this reason, we selected our patients to be more than 10 years of age.

The present study showed reduction in the mean equilibrium scores as well as in means of condition 3, 5, and 6 in CDP (Table 5). Condition 3, 5, and 6 reflects vestibular pattern of posturography. Reduction in equilibrium scores as well as in condition 3, 5, and 6 of SOT in all patients showed abnormal VNG test results.

Moreover, many cases of normal VNG finding had also abnormal SOT of CDP. These results reflect high sensitivity of CDP compared with VNG testing in detection of subtle changes in equilibrium.

These results disagree with the results of Shepard *et al.* [16] who reported that SOT is relatively insensitive in detecting abnormality in patients with vestibular disorders that are well compensated. In contrast, Sataloff *et al.* [17] emphasized the value of CDP and reported that, although less specific than VNG, CDP provides more global insight into a patient's ability to maintain equilibrium under more challenging environmental circumstances.

The second goal of the study was to compare vestibular functions in patients with strabismus before and after strabismus surgery.

The main findings in the present study were the following: improvement in vestibulo-ocular office test and vestibulospinal office test (Table 3). The improvement was marked in more difficult tests (dynamic visual acuity and sharpened Fukuda stepping test); the improvement was stable after 2 months of the operation.

In addition, in VNG finding postoperatively, there was marked improvement in ocular motility testing, the improvement mainly in latency, as four patients with latency affected reach to their normal value. In contrast, no changes occurred in caloric test results. Positional test revealed only one patient with positional vertigo and remained postoperatively having positional vertigo but with no nystagmus (Table 4).

There was significant improvement in SOT of CDP especially in condition 6, which denotes preferential pattern of posturography. In these conditions, patients rely more in vestibular function and need to neglect the abnormal visual stimuli that occur through visual surrounding in CDP.

Marked improvements in condition 6 occurred after 1 month and remained stable after 2 months of strabismus surgery. This also occured in condition 5 and to a lesser extent in condition 3, which reflects vestibular pattern of SOT of CDP (Table 5). In conditions 3 and 6, patients need to neglect the abnormal visual surrounding.

These findings disagree with the study of Matsuo *et al.* [13]. This disagreement is because Matsuo *et al.* [13] showed postural stability 3 days after strabismus surgery, which means that the effect of surgery on postural stability is different according to the delay of the measures performed.

Extraocular muscles have several proprioceptive receptors, providing information about the position of the eye in its orbit. Most likely, proprioceptive inputs associated with extraocular muscles are also influenced by surgery. Hence, eye surgery alters the proprioceptive information of the derived eye [18].

Interestingly, our results obtained 1 month and 2 months after strabismus surgery revealed improvement in both vestibulo-ocular and vestibulospinal pathways, mostly because tissue healing after 1 month is completed and the realignment of the visual axis facilitates visual perception leading to better results in both pathways.

Trying to find out the association between postural stability in one hand and angle of squint and visual acuity on the other hand, correlation test was performed. There was a weak correlation between squint angle and condition 3 and 5, even with high degree of squint, whereas the correlation was more obvious (moderate positive correlation, $r = 0.46$) with condition 6 of SOT of CDP at high degree of squint angle (group of 36–45).

The same results appeared between visual acuity and SOT of CDP, with more deterioration of visual acuity leading to more affection of postural stability (Tables 6 and 7).

In conclusion, vestibular functions in strabismus patients are globally better in postoperative tests than in preoperative conditions, and this improvement appeared to be stable.

Conclusion

Despite the absence of dizziness,

(1) Preoperative vestibular function tests were affected in both vestibulo-ocular and vestibulospinal pathways.
(2) Vestibular functions globally improved after strabismus surgery.
(3) Condition 6 of CDP, dynamic visual acuity, and sharpened Fukuda stepping test were the most sensitive tests for detection of subtle abnormalities in the vestibular system.
(4) Increase in angle of squint and decrease in visual acuity affect the vestibular function tests markedly.

Recommendations

(1) CDP, dynamic visual acuity, and sharpened Fukuda stepping test should be performed for all patients with strabismus to evaluate vestibular function.
(2) Sensitivity of CDP should be increased by, example, head shake SOT to detect any subtle postural instability in all patients with strabismus.
(3) Patient with high angle of strabismus and bad visual acuity should be operated early so as to obtain more benefit from surgery.

Acknowledgements

Conflicts of interest

None declared.

References

1 Engle EC. Genetic basis of congenital strabismus. Arch Ophthalmol 2007; **125**:189–195.

2 Volk AE, Fricke J, Strobl J, Kolling G, *et al.* Analysis of the CHN1 gene in patients with various types of congenital ocular motility disorders. Graefes Arch Clin Exp Ophthalmol 2010; **248**:1351–1357.

3 Paul TO, Hardage LK. The heritability of strabismus. Ophthalmic Genet 1994; 15:1–18.

4 Suarez H, Angeli S, Suarez A, *et al.* Balance sensory organization in children with profound hearing loss and cochlear implants. Int J Pediatr Otorhinolaryngol 2007; **71**:629–637.

5 Angelaki DE. Eyes on target: what neurons must do for the vestibuloocular reflex during linear motion? J Neurophysiol 2004; **92**:20–35.

6 Steindl R, Kunz K, Schrott-Fischer A, *et al.* Effect of age and sex on maturation of sensory systems and balance control. Dev Med Child Neurol 2006; **48**:477–482.

7 Fetter M, Dichgans J. Three dimensional human VOR in acute vestibular lesions. Ann N Y Acad Sci 1996; **19**:19–21.

8 Shepard, NT, Davis S, Speers R, Mishra A. Head shake computerized dynamic posturography in peripheral vestibular lesions, Am J Audiol 2009; **18**:53–59.

9 Shepard N, Telian S. *Practical management of the balance disorder patient*. San Diego, California: Published by singular publishing group Inc.; 1996. 3–20.

10 El-Gohary M, Kamal N, El Danasoury I, Ghoniem H. Vestibular evoked myogenic potential: a new tool in testing the vestibular system [MD thesis]. Egypt: Ain Shams University; 2005

11 SAS system: Statistical Analysis System. *SAS User's Guide: Statistics. Education: a new statistical analysis system*. Cary, NC: SAS Institute Inc.; 1996.

12 Odenrick P, Sandstedt G, Lennerstrand E. Postural sway and gait of children with convergent strabismus, Dev Med Child Neurol 1984; **26**:495–499.

13 Matsuo T, Narita A, Senda M, Hasebe S, Ohtsuki H. Body sway increase immediately after strabismus surgery. Acta Med Okayama 2006; **60**:13–24.

14 Shumway-Cook MH, Woollacott S. The growth of stability: postural control from a developmental perspective. J Mot Bebav 1985; **17**:131–147.

15 Sparto M, Redfern J, Jasko M, *et al.* The influence of dynamic visual cues for postural control in children aged 7–12 years. Exp Brain Res 2006; **168**:505–516.

16 Shepard NT, Schulz A, Alexander NB, *et al.* Postural control in young and elderly adults when stance is challenged: Clinical versus laboratory measurements. Ann Otol Rhinol Laryngol 1998; **102**:508–517.

17 Sataloff RT, Hawkshaw MJ, *et al.* Abnormal computerized dynamic posturography finding in dizzy patients with normal ENG results. Ear Nose Throat J 2005; **84**:212–214.

18 Weir M, Cleary S, Parks T, *et al.* Spatial localization after different types of retinal detachment surgery Invest Ophthalmol Vis Sci 2001; **42**:1495–1498.