Sultan Qaboos University Med J, November 2015, Vol. 15, Iss. 4, pp. e569–571, Epub. 23 Nov 15
Submitted 7 Feb 15
Revision Req. 24 May 15; Revision Recd. 8 Jun 15
Accepted 2 Jul 15
doi: 10.18295/squmj.2015.15.04.025

LETTER TO THE EDITOR

Otoneurological and Postural Assessment in Blind Scuba Divers

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Sir,

The visual system provides approximately 80% of the sensory perception required to maintain static and dynamic balance; this means that those who are visually impaired often have poor balance control.[1] In congenital (CDG) as opposed to acquired (ADG) visual impairment, the visual system relies on other stimuli from birth which leads to higher postural control in situations where vision is ineffectual.[2] When blurred vision is induced in sighted subjects, the result is poor postural control and a predisposition to falling.[3] Visual feedback is essential for dynamic tasks and low-vision/blind subjects have poorer postural stability than normal sighted subjects.[4] Congenitally blind subjects have significantly faster reaction times than healthy controls to somatosensory stimuli triggered by random movements.[5]

A study was conducted between December 2012 and March 2013 in Siena, Italy, to examine results of the sensory organisation test (SOT) and otoneurological tests among blind scuba divers in comparison to blind sedentary subjects. It was hypothesised that blind divers would have better motor and balance control than sedentary blind individuals due to the acquisition of postural control skills from the scuba diving. A total of 10 divers with ADG (n = 7) or CDG (n = 3) visual impairment and 10 sedentary subjects with ADG (n = 7) or CDG (n = 3) visual impairment were recruited from the Otoneurology Unit of the Ear, Nose & Throat Department at the University of Siena in Siena, Italy. Subjects were defined as visually impaired if their visual acuity was ≤20/200 and their visual field was $<10^{\circ}$ from a fixed point. Participants were classified as divers if they had participated in >30 dives per year and sedentary if they did not play sports and needed a guide dog.

Subjects underwent a complete otoneurological examination including an otoscopy, pure tone audiometry and tympanometry as well as tubaric function, head shaking, positional and caloric tests as described by Fitzgerald *et al.*[6] Evidence of spontaneous or gaze-evoked nystagmus was also noted. The SOT was carried out using the NeuroCom® SMART EquiTest® computerised dynamic posturography (CDP) machine (NeuroCom International Inc., Clackamas, Oregon, USA) to evaluate the contributions of the three sensory systems to standing balance control. Participants were evaluated under the following SOT conditions: (1) eyes open on a firm surface with fixed visual surroundings; (2) eyes closed on a firm surface; (3) eyes open with a firm surface but with sway-referenced visual surroundings; (4) eyes open on a sway-referenced surface with fixed visual surroundings; (5) eyes closed on a sway-referenced surface; and (6) eyes open on a sway-referenced surface and with sway-referenced surroundings. These conditions were performed while subjects were standing without shoes on a duel force plate platform of 45.7 cm^2, with their arms by their sides, eyes looking forward and feet positioned according to height. Participants wore safety harnesses to prevent falls.

The CDP machine generated an equilibrium score (ES) for each test using values from 0 (falling) to 100 (balanced) by comparing the anteroposterior centre of pressure sway with the theoretical limit of stability (12.50° in the anteroposterior direction). Composite scores and three sensory ratios (somatosensory, visual and vestibular) were calculated for each participant. Mean results were analysed using the Student's t-test with a significance level of P <0.050. All subjects gave written informed consent and the study was approved by the University of Siena Committee for the Protection of Human Subjects.

The demographic and clinical characteristics of the study population is reported in Table 1. Unilateral vestibular *paresis* was detected in one scuba diver with

Table 1: Demographic characteristics of blind scuba divers and blind sedentary subjects (N = 20)

Characteristic	Mean ± SD		*P* value
	Divers (n = 10)	Sedentary subjects (n = 10)	
Age in years	31.85 ± 6.57	33.35 ± 6.35	0.468
Years of blindness	18.9 ± 7.13	16.65 ± 6.29	0.297
Height in cm	167.9 ± 10.89	170.9 ± 14.36	0.619
Weight in kg	63.33 ± 12.33	64.78 ± 10.43	0.751
Male-to-female ratio	1:1	3:2	>0.050

SD = standard deviation.

Table 2: Sensory organisation test results among blind scuba divers and blind sedentary subjects (N = 20)

SOT	Test condition	Sensory input	Mean ± SD		*P* value
			Divers	Sedentary subjects	
1	Eyes open on a firm surface with fixed visual surroundings	Somatosensory, visual and vestibular	91.83 ± 3.65	93.01 ± 2.49	0.436
2	Eyes closed on a firm surface	Somatosensory and vestibular	94.08 ± 2.05	92.72 ± 1.75	0.130
3	Eyes open on a firm surface with sway-referenced visual surroundings	Somatosensory and vestibular	92.62 ± 3.01	91.23 ± 2.94	0.338
4	Eyes open on a sway-referenced surface with fixed visual surroundings	Visual and vestibular	61.13 ± 8.92	51.18 ± 6.97	0.023*
5	Eyes closed on a sway-referenced surface	Vestibular	66.90 ± 9.20	56.06 ± 11.27	0.040*
6	Eyes open on a sway-referenced surface with sway-referenced visual surroundings	Vestibular	66.83 ± 10.08	55.92 ± 8.40	0.024*
Composite			73.56 ± 6.89	73.22 ± 3.61	0.900
Somatosensory ratio†			1.025 ± 0.02	0.9975 ± 0.03	0.052
Visual ratio‡			0.6667 ± 0.10	0.5513 ± 0.09	0.022*
Vestibular ratio§			0.7300 ± 0.10	0.6039 ± 0.12	0.037*

SOT = sensory organisation test; SD = standard deviation.
**Statistically significant at P <0.05. †Calculated by dividing the mean equilibrium score (ES) of SOT 2 with the mean ES of SOT 1. ‡Calculated by dividing the mean ES of SOT 4 with the mean ES of SOT 1. §Calculated by dividing the mean ES of SOT 5 with the mean ES of SOT 1.*

ADG blindness and one sedentary subject, both of whom were well-compensated with regards to high and low stimulation frequencies. Signs of previous tympanic perforation were noted in three subjects (two sedentary subjects and one diver with ADG blindness), while two divers (one with ADG and one with CDG blindness) had bilateral exostosis in the external auditory canal. Spontaneous eye movements due to chronic deprivation of visual feedback, such as disjunctive and conjugate gaze instability (drifts and nystagmus), were observed in six divers (60%). There was no evidence of nystagmus or vertigo in any of the subjects.

No statistically significant differences were noted in composite CDP or SOT 1, 2 or 3 values between the divers or sedentary subjects. Divers showed superior SOT 4, 5 and 6 results compared to sedentary subjects. Their somatosensory, visual and vestibular ratios were also significantly higher [Table 2]. Subjects with CDG blindness had better SOT 1, 2 and 3 results compared to those with ADG blindness; however, these differences were not statistically significant due to the small sample size. The SOT provides information regarding which input system (somatosensory, visual or vestibular) is being utilised to maintain postural control. In a population of blind subjects, sight is not used and thus the exercises are changed. In the current study, SOT 1 results were very similar to SOT 2 because only a few subjects could perceive faint light; this meant there was little visual contrast between having their eyes open or closed. This suggests that impaired vision does not affect static balance in blind subjects. Additionally, the results of SOT 3 were similar to those for the first two tests; this may be because the blind individuals could not perceive the simulated movement of their surroundings. Finally, the scores of SOT 4, 5 and 6 were similar. This could be because the blind subjects could not use sight to compensate for the movements induced by the platform.

In the blind divers, input from the somatosensory and vestibular systems played a crucial role in postural control as there was a significant difference in the vestibular ratio between the divers and sedentary subjects. This may indicate that blind divers can substitute information from their missing visual system.[4] Values obtained in the first two SOT tests were exceptionally high when compared with reference values for normal sighted subjects, potentially indicating that blind subjects recover postural control more quickly than sighted subjects.[7] This is likely due to modified sensorimotor integration processes which control body orientation in space. The visual ratio was significantly higher among the divers than the sedentary subjects. No significant difference was noted between the divers and sedentary subjects with regards to their somatosensory ratios. For blind subjects, the conditions used to calculate this ratio (SOT 1 and 2) are exactly the same; as such, a very high somatosensory ratio is to be expected.

Divers may have a more effective central vestibular response, as evidenced by their superior performance in SOT conditions 4, 5 and 6. Repetitive stimuli cannot affect the peripheral inner ear but may lead to plasticity in areas of the brain delegated to vestibular control among sedentary blind subjects.[8] Among blind subjects who take part in sports, these are replaced by links to vestibular and proprioceptive areas.[9] This mechanism could explain the results of the current study. However, further research with magnetic resonance imaging is needed to confirm this.

The main limitations of this study were the small sample size and the non-blinded methodology which may have biased the results. In conclusion, in visually impaired divers, the vestibular and somatosensory systems play a fundamental role in balance control and compensate for the lack of visual input.

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