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Computerized dynamic posturography in school-aged children with sensorineural hearing loss

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Abstract

Background

According to embryological and anatomical connection between the cochlea and vestibular end-organs, children with sensorineural hearing loss (SNHL) may exhibit abnormalities of vestibular and balance function. Documentation of vestibular dysfunction in children with SNHL has a long and rich history indicating that 20–70% of children with SNHL demonstrate an element of vestibular end-organ dysfunction. Vestibular dysfunction was proved to correlate with severity of cochlear loss in many research works.

Aim of the work

To assess normative data of sensory organization test (SOT) and head shaking (HS) test according to age, weight, and height of children in control group and to detect any deviation from normal values of SOT and head shacking test in children with SNHL.

Patients and methods

This study was carried out in Audiology and Vestibular Units of Hearing and Speech Institute, Giza, Egypt, and included 50 children (29 males and 21 females). Their age range was from 6 to 12 years. They were divided into two groups: control group, which consisted of 20 children (12 males and eight females) with normal hearing, and case group, which consisted of 30 children (17 males and 13 females) with SNHL. All children underwent full basic audiological evaluation, Fukuda stepping test, videonystagmography, SOT of posturography, and HS–SOT.

Results

There were differences in balance skills between children with normal hearing and children with SNHL in Fukuda stepping test, caloric test, and HS–SOT; otherwise, there were no statistical significant differences between the two groups in smooth pursuit test, Dix–Hallpike test, and SOT.

Conclusion

HS–SOT showed significant difference between the two groups in horizontal, vertical, and roll axes of HS test, especially in horizontal CD5, vertical CD5, roll CD2, and roll CD5. This means that these axes could diagnose vestibular peripheral dysfunction accurately in children with SNHL.

Keywords: Dynamic posturography, head shaking–sensory organization test, sensorineural hearing loss

INTRODUCTION

Vestibular disorders are not as easily recognized in children as they are in adults, in part because children often cannot describe their symptoms well and may be unable to understand the concepts of vertigo and imbalance. Identification of pediatric vestibular dysfunction requires coordinating descriptions offered by the child, symptom reports from parents, and clinical observations by professionals [1].

Computerized dynamic posturography (CDP) is a noninvasive specialized clinical assessment technique used to quantify the central nervous system adaptive mechanisms (sensory, motor, and central) involved in the control of posture and balance [2].

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CDP can be used to test patients who present with complaints that are related to body balance and who have not been diagnosed by conventional tests. Clinically, the importance of these findings lies in the possibility of diagnosing body balance disorders and, subsequently, identifying whether these disorders are a consequence of a problem in afferent or sensory integration, motor response inefficiency, or both [3]. CDP comprises a sensory organization test (SOT), motor control test, and an adaptation test. The individual protocols of each of these tests quantify organization of vestibular, somatosensory, and visual inputs to balance; coordination of automatic motor and voluntary motor responses and strategies; and the center of gravity alignment.

The head shaking–sensory organization test (HS–SOT) protocol is a key enhancement to the standard SOT that is appropriate for patients who perform within the normal range on the standard SOT, yet remain symptomatic. The HS–SOT identifies impairments in the patient's ability to effectively use vestibular inputs to maintain balance while simultaneously moving the head. Abnormal HS–SOT scores can further demonstrate the movement axes (horizontal, vertical, or roll) that present the maximum challenge to the patient in daily life [4].

In this study, we tried to find out the most sensitive and specific test for diagnosis of peripheral vestibular dysfunction in the children with sensorineural hearing loss (SNHL).

Aim of the work

The following were the aims of the study:

1. To assess normative data of SOT and HS test according to age, weight, and height of children in control group.
2. To detect any deviation from normal values of SOT and HS test in children with SNHL.
3. To correlate any vestibular dysfunction detected by vedionstagmography (VNG) and SOT with side, degree, and etiology of hearing loss.

PATIENTS AND METHODS

Ethical approval and consent was taken. This study was carried out in Audiology and Vestibular Units of Hearing and Speech Institute Giza, Egypt.

Patients

This study was conducted on 50 children divided into two groups: a study group (cases), which included 30 children with SNHL, either unilateral or bilateral, with any degree of hearing loss, aged 6–12 years, and height range of 110–160 cm. They were recruited from those attending the outpatients clinic. There was no restriction regarding dizziness (with or without complaint of vertigo).

A control group was recruited, which included 20 healthy children not complaining of dizziness or SNHL, aged 6–12 years, and height range of 110–160 cm. There were well matched to the cases with respect to age. Controls were recruited from among the relatives of study group or normal child in our clinic. The study was conducted from January 2014 to October 2017, with delaying of 2 years, as we starting by HS of VNG and re-examined the cases after updating of software for HS–SOT of posturography.

Inclusion criteria

School-age children measuring more than 76 cm in height were included.

Exclusion criteria

The following were the exclusion criteria:

1. No neuromotor disorder such as cerebral palsy.
2. No orthopedic dysfunction such as arthritis or lower limb problem.
3. Symptoms of uncorrected visual problems.
4. No medication affecting the central nervous system.

Methods

1. Every child in the study attended two separate sessions to complete all the tests.
2. The first session included the following:
   - (a) Full history taking.
   - (b) Otological evaluation.
   - (c) Full basic audiological evaluation.
3. The second session included the following:
   - (a) Office tests for vestibular evaluation.
   - (b) Videonystagmography.
   - (c) SOT.
   - (d) HS–SOT was done in horizontal, vertical, and roll directions.
   - (e) The last step was monothermal cool caloric test.

Between each two tests, 5 min of rest was offered to the child, and monothermal caloric test was the end, which was postponed to avoid child's frustration.

All participants in this study were subjected to the following:

1. Full history taking, including name; age; sex; prenatal, natal, and postnatal history, developmental history; and history of vertigo. Vertigo is difficult to be described or localize; therefore, we used parents' description about their observation regarding child's balance or history of delayed or defective walking.
2. Otological examination: it was done to clear wax or foreign body and also to take an idea about the size and direction of the external auditory canal for doing tympanometry, pure tone audiometry, and caloric test.
3. Basic audiological evaluation in the form of the following:
   - (a) Pure tone audiometry: it was done using two-channel audiometer (Interacoustics, model AC40, MN, NeuroComInternationalInc., Clackamas, U.S.A.). Air conduction thresholds were tested at the following frequencies: 0.25, 0.5, 1, 2, 4, and 8 KHz. Bone conduction thresholds were tested at the following frequencies: 0.5, 1, 2, and 4 kHz.
   - (b) Speech audiometry: this included speech reception threshold testing using Arabic spondee words and word discrimination score testing using Arabic Phonetically Balanced words.

i. Acoustic Immittance Testing: it was done using middle ear analyzer (Interacoustics model Az26). It included tympanometry and acoustic reflex threshold measurements.

(4) Office tests for vestibular evaluation:

Fukuda stepping test (FST): the children were asked to march in place 50 steps with their eyes closed with their hands extended in front of them. The test was considered positive if the child rotates 30° or more indicating an asymmetrical labyrinthine function.

(5) Videonystagmography: it was done using Micromedical VisualEyes (recording eye movements using digital video image technology).

Smooth pursuit: measure the ability to follow an object smoothly while maintaining a stable image on the fovea. Evaluation included at least three eye movements for frequencies of 0.1 Hz, six movements for frequencies of 0.2 HZ, and 12 movements for frequencies of 0.4 Hz of pendulum oscillation of the target. The parameter called gain was calculated, comparing the target velocity and eye velocity during smooth pursuit. The normal value of gain is ranged between 0.7 and 1.01.

Monothermal caloric test

The child was placed on a reclining chair with head elevated at an angle of 30 degrees to the horizontal. Headband camera was placed over the eyes of the child and results recorded on Micromedical VisualEyes software. Cool water at temperature of 30°C was irrigated into the child's external auditory canal. The cool water irrigation was done for 60 s in one ear and caloric responses were recorded simultaneously on the software. A gap of 5 min was given, and similar responses were recorded in the opposite ear. 'Monothermal caloric asymmetry' was depicted in the recording software as 'unilateral weakness.' This was based on the slow-phase velocity of the nystagmus generated by the cool water. Monothermal caloric asymmetry more than 22% was taken as evidence of canal paresis, according to Bush *et al.* [5].

The mono thermal caloric test was calculated as following:

$$\text{Mono thermal caloric test -----}$$
$$\text{Mon thermal caloric asymmetry}\left(\text{MCA}\right)\text{-}\rightarrow$$
$$\text{®}\ \text{MCA\%} = \left(\text{R} - \text{L}\right)/\left(\text{R} + \text{L}\right) \times 100$$

CDP was done using Neurocom, Version 4, Smart Balance Master.

Child's instructions and preparation of testing

On the day of testing, the participant was reassured that the testing began with easy tasks and slowly progressed into more difficult tasks and that the safety built was available in case one's balance was lost. The child was instructed to remain in the standing position on the force platform, keeping their arms loose along the body and their feet slightly apart and unmoving.

Sensory organization tests

Measurement of patient's height was done, which is a critical information for the computer to determine the relative position of center of gravity, to set the sway angles for the movement of the surface and surrounding, and in calculating the equilibrium score. The SOT protocol comprises the following six sensory conditions: (a) eyes open, fixed surface, and visual surround; (b) eyes closed and fixed surface; (c) eyes open, fixed surface, and sway referenced visual surround; (d) eyes open, sway referenced surface, and fixed visual surround; (e) eyes closed and sway referenced surface; and (f) eyes open, sway referenced surface, and visual surround.

Head shaking–sensory organization test

The HS–SOT consists of repeating SOT condition 2 (eyes closed and firm surface) and condition 5 (eyes closed and sway-referenced surface) while the child wears a head movement monitor and performs a continuous rhythmic head movement about a specified horizontal, vertical, or roll axis. The patient is instructed to maintain the frequency (approximately one turn per second) and amplitude (~30 degrees in each direction for the horizontal axis) of head movement so that the average velocity of the movement is maintained at or above a set minimum. For each condition, the patient is given one unscored practice trial, followed by up to five scored trials. A loss of more than 30% can be considered significant.

Results

This study included 50 children (29 males and 21 females). Their age range was 6–12 years. They were divided into two groups: the first was a control group, which consisted of 20 children (12 males and eight females). Their age range was 6–12 years, with mean and SD of 9.32 ± 1.92; weight range was 18–50 kg, with mean and SD of 24.55 ± 6.79; and height range was 112–163 cm, with mean and SD of 137.3 ± 15.24.

The second was the case group, which consisted of 30 children (17 males and 13 females). Their age range was 6–12 years with mean ± SD of 9.88 ± 2.21; weight range was 15–50 kg, with mean ± SD of 36.23 ± 10.69; and height range was 112–155 cm, with mean ± SD of 132.8 ± 12.93.

There was no statistically significant difference between the tested groups regarding age and height, whereas regarding weight, the case group had significantly higher weight than the control group.

Mean ± SD hearing threshold (hearing threshold calculated as average of all frequencies from 250 to 8 kHz each ear alone) in control group (all of them is normal hearing) in the right ear was 16.69 ± 5.09 and in the left ear was 16.22 ± 5.39. Mean ± SD hearing threshold in the case group in the right ear was of 52.02 ± 21.1 and in the left ear 55.17 ± 22.1, with no significant difference in the hearing threshold between right and left ears in the case group.

Comparison of Fukuda stepping between cases and controls showed significant difference in left deviation only in the cases.

Comparison of VNG tracking (smooth pursuit) between cases and controls showed no significant difference in VNG tracing between the groups.

Comparison between the groups regarding caloric test of right and left ears and caloric percentage showed no significant difference in monothermal cool caloric test between the groups.

Comparison between cases and controls in SOT for the six conditions and composite score showed no statistically significant difference between cases and controls in SOT, all conditions, as well as composite score.

Comparison of horizontal, vertical, and roll HS–SOT between cases and controls showed the cases had significantly lower values than controls regarding horizontal CD5, vertical CD5, and roll CD2 and CD5 (Table 1 and Fig. 1).

Correlation between horizontal, vertical, and roll HS in conditions 2 and 5 between the case done by using Pearson's correlation coefficient showed a significant positive correlation (Table 2).

χ^2 test was used for comparing control and cases groups at condition 2 in horizontal, vertical, and roll head shacking test according to cutoff point that appeared in receiver operating characteristic (ROC) curve and showed significant association and agreement.

Table 1: Mean±SD and *t* test for comparison of equilibrium score of horizontal, vertical, and roll head shaking-sensory organization test between control and study groups

	Groups	Mean	SD	*t* test	*P*
Horizontal					
CD 2	Control	80.79	9.99	1.755	0.086
	Study	75.63	9.94		
CD 5	Control	58.81	11.66	7.592	0.000
	Study	37.65	6.82		
Vertical					
CD 2	Control	76.61	8.49	1.563	0.125
	Study	72.32	9.98		
CD 5	Control	57.54	9.32	7.021	0.000
	Study	39.96	7.85		
Roll					
CD 2	Control	80.64	7.73	5.468	0.000
	Study	61.79	14.37		
CD 5	Control	50.93	10.80	5.571	0.000
	Study	35.76	7.50		

DISCUSSION

Balance disorders in children are relatively common but largely unrecognized. Dizziness is a lay term used to describe many different sensations, including unsteadiness, imbalance, clumsiness, lightheadedness, and vertigo. Young children are often unable to describe these different perceptions, and thus, any complaint of dizziness, instability, or vertigo should be considered in the broad context of the 'dizzy child' for diagnostic purposes [6].

In addition, Nakashima and Yanagita[7] and Narozny *et al.*[8] suggested that the clinical course of SNHL may be aggravated if the vestibular system is concomitantly involved. It may even result in delayed motor development in children [9].

The SOT of CDP is designed to measure the functional integration between different senses responsible for balance [10].

The HS–SOT protocol is more difficult than the standard SOT because the HS–SOT provides additional challenges to the sensory organization of balance. It can quantify problems in patients with subtle sensory control problems that perform within normal limits on the standard SOT [11].

Our study has been designed to assess normative data of SOT of CD posturography and HS–SOT in normal children (control group) and to detect any abnormality of HS–SOT in children with SNHL and also to correlate any vestibular dysfunction detected by office test (FST), VNG, and SOT with the side degree of hearing loss.

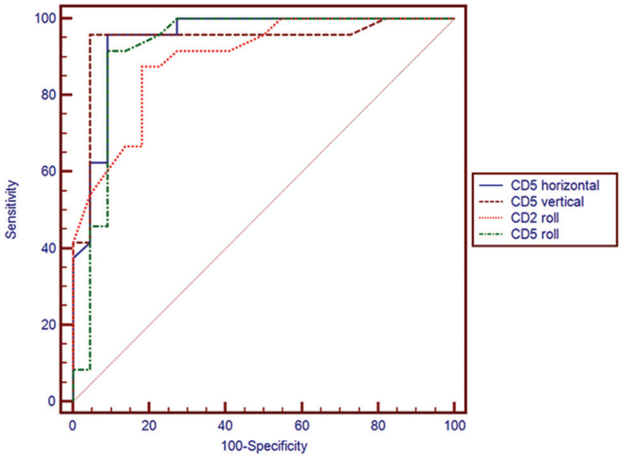

Figure 1: ROC curve for cutoffs detecting cases. ROC, receiver operating characteristic.

Table 2: Cuts off detecting cases in all axes of head shaking-sensory organization test CD2 and roll CD5

	Cut off point	AUC	Sensitivity	Specificity	PPV	NPV
CD5_horizontal	≤45	0.948	95.8	90.9	92	95.2
CD5_vertical	≤44.8	0.943	95.8	95.5	95.8	95.5
CD2_roll	≤73	0.897	87.5	81.8	84.0	85.7
CD5_roll	≤43.8	0.923	91.7	90.9	91.7	90.9

AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value.

In the present study, regarding FST, there was a statistically significant left deviation in the group of cases, indicating defective labyrinthine function mainly on the left side.

This is in agreement with Peitersen[12] and Bonanni and Newton[13] who suggested using the FST in combination with other clinical tests (e.g. electronystagmography, rotational chair, head thrust, and head-shaking tests) in the assessment of vestibular pathologies. However, Honaker *et al.*[14] examined 736 patients complaining of chronic balance disorder and concluded that the FST did not provide significant findings that would support using this test as a reliable screening tool of peripheral vestibular asymmetry in chronically dizzy patients. Moreover, Bonanni and Newton[13] concluded that the FST should not be used alone as a screening method.

In the current study, VNG test which is the gold standard in evaluation of the vestibular system was done and showed no statistically significant difference between study group and control group, reflecting normal oculomotor system (smooth pursuit test) and vestibule-ocular reflex.

This was similar to Schwab and Kontorinis[15] who found that around half of the children in their study showed a normal response in the caloric test; excessive excitability (on the left side) happened in only two patients, whereas the responses were either weak or non-existent within other participants.

Moreover, Pajor and Jozefowicz-Korczynska[16] noted abnormal ENG in 88% of patients (22 ears); in nearly all of them (20 ears), vestibular impairment was of peripheral type.

Similar results were obtained by Buchman *et al.*[17] who tested 22 children with age range of 2–16 years, and bithermal caloric irrigation, rotational chair testing, and CDP were performed. They found that 68% of the children had vestibular hypofunction. However, Cushing *et al.*[18] found that incidence of horizontal canal dysfunction on caloric testing was found in 50% of children with SNHL.

In the current study, results of the SOT in CDP among six conditions from CD1 to CD6 showed no significant difference between cases and control groups.

Similar results were obtained by Moussa *et al.*[10] who evaluated 20 patients with confirmed unilateral peripheral disorders, constituting the study group. They were age and sex matched to 20 normal patients. They showed the standard SOT conditions were not significantly different between the control and study groups. Similar results were obtained by Clendaniel [19], who reported that the SOT is relatively insensitive in detecting abnormality in patients with physiologically compensated unilateral vestibular weaknesses, despite the fact that they may still complain of subtle imbalance.

Moreover, Jafari and Malayeri[20] concluded that damaged vestibular system has significant influence on postural control in young adults with hearing loss (HI). Suarez *et al.* [1], Cushing *et al.* [18], and Jafari and Malayeri[20] found that people with HI depend on both visual and somatosensory information for effective postural control.

In the current study, results of HS–SOT showed significant difference between cases and control groups in condition 5 at horizontal, vertical, and roll axes and roll condition 2, which means these axes can diagnose vestibular dysfunction accurately in children with SNHL.

Same opinion was stated by Moussa *et al.*[10] who did their research for standardization of HS–SOT of CDP on 20 normal patients who were evaluated using both SOT and HS–SOT tests. Normal patients showed a tendency to increased sway with HS (decreased equilibrium scores) in HS–SOT C5 compared with HS–SOT C2 in the three axes of the test. This could be attributed to the increased challenge to maintain stance during condition 5. Clark *et al.*[21] reported that the sequences of pitch and roll motions used in HS–SOT were more disruptive to vestibular balance function than the horizontal head movements. Thus, Naval Aerospace Medical Research Laboratory researchers suggested their use to detect more subtle reductions of vestibular function in individuals whose high-performance flight duties require exceptional balance system capabilities.

Although this is in agreement with Mishra *et al.*[4] who evaluated 40 participants ranging in age from 20 to 79 years with no history of dizziness and with unilateral peripheral vestibular affection, completed conditions 2 and 5 of the SOT portion of CDP on EquiTest equipment, while maintaining head still as well as horizontal head movement velocity tasks only found that controlled horizontal head movement during the SOT led to highly significant reductions in the equilibrium score of the condition 5 in their unilateral peripheral vestibular patients, they had no significant effects on balance with normal somatosensory inputs (SOT condition 2).

In the current study, within the case group, a positive significant correlation was found among the three axes of HS–SOT (horizontal, vertical, and roll) in both CD2 and CD5, which means increase score of one axis in a certain condition (whether CD2 or CD5) is directly proportional with other axes at the same condition.

Despite the positive correlation between different positions, further tests were used to detect the most sensitive and specific position for diagnosing vestibular dysfunction, and the most sensitive ones were horizontal and vertical CD5 (95.8%) followed by roll CD5 (91.7%), whereas the most specific was vertical CD5 (95.5%) followed by roll CD2 and horizontal CD5 (90.9%).

However, Moussa *et al.*[10] showed slightly different results where the most sensitive SOT condition was HS–SOT CD5 in the vertical axis (100%) followed by HS–SOT C5 in the roll axis (95%) then HS–SOT C5 in the horizontal axis (80%). The sensitivity of HS–SOT C2 was less than HS–SOT C5 in the three axes of the test.

This agreed with Clark *et al*.[21] who found low sensitivity values for HS–SOT condition 2 and higher sensitivity values for HS–SOT condition 5. They suggested that the head-shake protocol is not challenging enough when used with condition 2.

Honaker *et al*.[14] examined 40 participants ranging in age from 20 to 79 years with no history of dizziness who completed conditions 2 and 5 of the SOT while maintaining head still as well as four horizontal head movement velocity tasks. They found that HS–SOT C5–15°/s condition (in the horizontal axis and the velocity of movement is 15) demonstrated superior performance for distinguishing between groups (sensitivity = 70%, specificity = 100%), whereas HS–SOT5–60°/s (in the horizontal axis and the velocity of movement is 60) had sensitivity of 70% and specificity of 60%. This research was done not to anticipate that knowledge of the sensitivity of the HS modification protocol will replace gold-standard procedures such as caloric irrigations as a tool for identifying peripheral vestibular system hypofunction; it may be used in combination with other clinical tests (e.g. electronystagmography or rotational chair) in the assessment of vestibular pathologies. It may also serve to alert physical therapists who routinely use posturography assessment and see balance disorder patients in whom the possibility of hypofunction is high and that the patient needs to be referred for more definitive testing. It is also possible that the addition of the HS protocol with increased sensitivity to peripheral asymmetry may serve as a better indicator of changes over time in the central compensation process because it attempts to link active peripheral vestibular stimulation with postural control.

Pointing to the curve (ROC) at this study, the test with highest ROC in our results was horizontal CD5 (0.95). This is in contrast to Honaker *et al*.[14] who stated that the HS–SOT C5–15°/s condition was identified as the superior condition for identifying peripheral vestibular asymmetry (area under the curve, 0.90).

In present study, association was done between different tests used in vestibular dysfunction diagnosis including FST, caloric test, and HS–SOT, but there was no significant association found between them.

Moussa *et al*.[10] showed different results as they found a significant reduction in the equilibrium scores of HS–SOT C5 in cases with positive Fukuda test in comparison with negative cases.

This reduction was statistically significant in the three tested axes reflecting the higher sensitivity of HS–SOT5 compared with HS–SOT2 and SOT in the diagnosis of peripheral vestibular disorders.

The possible explanation for postural instability following horizontal head-shake is likely owing to asymmetrical neural input within the velocity storage integrator and vestibular nuclei after stimulation of the semicircular canals mainly horizontal canals [13]. The head-shaking task produces enhanced vestibular asymmetry within the velocity storage integrator. So, after HS, post-headshake nystagmus and postural instability are clinically observed, and this may manifest via asymmetrical neural output via the vestibular-spinal reflex. Thus, we hypothesized that incorporation of HS–SOT may uncover unmasked postural control deficits resulting from vestibular lesions.

In this research, we found that HS–SOT test was very sensitive and specific test to differentiate between cases with SNHL and normal children at the same age, with horizontal and vertical HS–SOT CD5 having the highest sensitivity (by 95.8%) and horizontal and roll CD5 having the highest specificity (by 90%). This means that we can use this test as a highly recommended and one of the standardized investigations used in children with SNHL to diagnose them accurately whether they have vestibular dysfunction or not.

CONCLUSION

(1) The results of the current study sample showed that there were differences in balance skills between children with normal hearing and SNHL children with respect to FST, caloric test, and HS–SOT; otherwise, there were no differences between the two groups in smooth pursuit test, Dix-Hallpike test, and SOT).
(2) HS–SOT showed significant difference between two groups in horizontal, vertical, and roll axes of HS test especially in horizontal CD5, vertical CD5, roll CD2, and roll CD5. This means that these axes could diagnose vestibular peripheral dysfunction accurately in children with SNHL.
(3) The most sensitive conditions were CD5 in the horizontal and vertical followed by CD5 in the roll axis.
(4) There was a significant positive correlation in the case group among the three axes of HS–SOT (horizontal, vertical, and roll) for both CD2 and CD5.

Recommendation

HS posturography test can be considered a good enhancement to the standard SOT, being appropriate for patients who perform within the normal range on the standard test, yet remain symptomatic. It can objectively measure an individual's impairments with head movements and postural control.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Suarez H, Angeli S, Suarez A, Rosales B, Carrera X, Alonso R. Balance sensory organization in children with profound hearing loss and cochlear implants. International Journal of Pediatric Otorhinolaryngology 2007; 71:629–37.
2. Ronda JM. Results of computerized dynamic posturography‘spanish. Otolaryngiol J 2002; 53:252–255.

3. Rine RM, Cornwall G, Gan K, LoCascio C, O'Hare T, Robinson E, Rice M. Evidence of progressive delay of motor development in children with sensorineural hearing loss and concurrent vestibular dysfunction. Perceptual and motor skills. 2000; 90(3_suppl):1101–12.
4. Mishra A, Davis S, Shepard N. Head shake computerized dynamic posturography in peripheral vestibular lesions. Am J Audiol 2009; 18:53–59.
5. Bush ML, Bingcang CM, Chang ET, Fornwalt B, Rayle C, Gal TJ, Jones RO, Shinn JB. Hot or cold? Is monothermal caloric testing useful and cost-effective?. Annals of Otology, Rhinology & Laryngology 2013; 122:412–6.
6. Luxon L, Pagarkar W. The dizzy child. Chapter 46. In: Graham JM, Scadding GK, Bull PD, eds. *Pediatric ENT*. 1st ed. Germany: Springer- Verlag; 2008. 460–473.
7. Nakashima T, Yanagita N. Outcome of sudden deafness with and without vertigo. Laryngoscope 1993; 103:1145–1149.
8. Narozny W, Kuczkowski J, Kot J, Stankiewicz C, Sicko Z, Mikaszewski B. Prognostic factors in sudden sensorineural hearing loss: our experience and a review of the literature. Annals of Otology, Rhinology & Laryngology 2006;115:553–8.
9. Angeli S. Value of vestibular testing in young children with sensorineural hearing loss. Arch Otolaryngol Head Neck Surg 2003; 129:478–482.
10. Moussa AM, Kholi W. Head shake posturography in peripheral vestibular disorders. Mediterr J Otol 2008; 4:9–18.
11. Peters JF. Computerized dynamic posturography (CDP) and the assessment of balance with active head movements. J Korean Balance Soc 2007; 6:243–247.
12. Peitersen E. Vestibulospinal reflexes. X. Theoretical and clinical aspects of the stepping test. Arch Otolaryngol 1967; 85:192–198.
13. Bonanni M, Newton R. Test-retest reliability of the Fukuda stepping test. Physiother Res Int 1998; 3:58–68.
14. Honaker JA, Boismier TE, Shepard NP, *et al.* Fukuda stepping test: sensitivity and specificity. J Am Acad Audiol2009; 20:311–314.
15. Schwab B, Kontorinis G. Influencing factors on the vestibular function of deaf children and adolescents evaluation by means of dynamic posturography. Open Otorhinolaryngol J 2011; 5:1–9.
16. Pajor A, Jozefowicz-Korczynska M. Prognostic factors for vestibular impairment in sensorineural hearing loss. Eur Arch Otrhinolaryngol 2008; 265:403–407.
17. Buchman CA, Joy J, Hodges A, Telischi FF, Balkany TJ. Vestibular effects of cochlear implantation. The Laryngoscope 2004; 114(S103):1–22.
18. Cushing SL, Papsin BC, Rutka JA, James AL, Gordon KA. Evidence of vestibular and balance dysfunction in children with profound sensorineural hearing loss using cochlear implants. The Laryngoscope 2008; 118:1814–23.
19. Clendaniel R. Outcome measures for assessment of treatment of the dizzy and balance disorder patient. Otolaryngologic clincs of North America 2000; 33:519–533.
20. Jafari Z, Malayeri S. The effect of saccular function on static balance ability of profound hearing-impaired children. Int J Pediatr Otorhinolaryngol2011; 75:919–924.
21. Shepard N, Cole N, Bradshaw M, Hyder R, Parent R, McGrath BJ. Enhancing Sensitivity of the Sensory Organization Test (SOT) with the Head-shake (HS-SOT): Recommendations for Clinical Application. Clackamas, OR: NeuroCom International. Ore: Neurocom International, Inc; 1998.