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RESEARCH ARTICLE

Postural control during dual task in adolescent cochlear implant users under on/off-device conditions

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Abstract

Background and Aim: Vestibular system has several anatomical connections with cognitive regions of the brain. Vestibular disorders have negative effects on cognitive performance. Hearing-impaired patients, particularly cochlear implant users, have concomitant vestibular disorders. Previous studies have shown that attention assigned to postural control decreases while performing a cognitive task (dual task) in hearing-impaired children. Since the vestibular system and postural control performance develop around 15−16 years of age, the aim of this study was to compare postural control performance during dual task in adolescent boys with normal hearing and cochlear implant (CI) users with congenital hearing-impairment.

Methods: Postural control was assessed in twenty 16−19 year old cochlear implant boys and 40 normal hearing peers with force plate. The main outcomes were displacement in posterior-anterior and medial-lateral planes, and mean speed with and without cognitive task and under on/off-device conditions. Caloric test was performed for CI users in order to examine the peripheral vestibular system.

Results: Ninety-five percent of CI users showed caloric weakness. There were no significant differences in postural control parameters between groups. All performances deteriorated in the foam pad condition compared to the hard surface in all groups. Total mean velocity significantly increased during dual task in normal hearing group and in CI users with off-device.

Conclusion: Although CI users had apparent vestibular disorders, their postural control in both single and dual-task conditions was identical to the normal peers. These effects can be attributed to the vestibular compensation that takes place during growing.

Keywords: Balance; postural control; dual task; congenital hearing loss; cochlear implant

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Introduction

The development of the motor system has been demonstrated that is largely influenced by the coordination of posture and behaviors directed towards a specific goal. A postural control system that remains immature decelerates many stages of the motor system development and many functions are impossible to execute in the absence of an appropriate level of postural control [1]. The maintenance of the postural equilibrium requires the integration of visual, vestibular, and somatosensory information. Proprioceptive function matures in childhood at the age of 3 to 4 whereas visual and vestibular functions seem to mature at 15 to 16 years of age. The difference in ages is because of the difference between male and female adolescents [2,3].

Maturation of postural control milestones in children with hearing disorder is different from their normal hearing peers, probably because of the vestibular disorders associated with hearing deficits in many cases [4]. Balance and postural control disorders have been widely reported in children who received cochlear implant (CI). In addition to the association of vestibular disorders with hearing deficits, this problem is likely caused by the surgical intervention. Although the surgical procedures during cochlear implant are safe, balance disorders occur in 3.1 to 77% of cases [5] pre- or intraoperative [6]. The variability of the results may be caused by the different assessment methods. A recent meta-analysis report has demonstrated significant relative risk of vestibular damage during CI surgery [7].

In everyday life, postural stability interacts with cognitive functions such as memory, counting, and conscious thinking since there are several anatomical connections between cognitive system and balance and postural control structures [8,9]. Attention, as a cognitive process, plays a major role in this interaction. Difficult postural tasks such as walking require more attention than do easy or static tasks [10]. Children with CI needs increased resources of attention for maintaining postural stability due to the limitation of their sensory input. In dual tasks that require attention divides between postural control as the main task and a simultaneous cognitive activity, children with CI are not able to sufficiently devote their attention to both cognitive and sensory-motor tasks. While a growing body of knowledge is available on vestibular or cognitive deficits in hearing-impaired children, there is little information about interaction of their postural control and cognitive performance. Few studies that are available on dual tasks in patients with vestibular deficit have reported inconsistent findings from decreasing [8] or increasing postural instability [10] to no effect on postural control [11] as the difficulty of mental activity increases. Decreased allocation of attention to postural control during dual task has been reported in children with hearing loss [4]. Moreover, with increasing age dual task performance requires increased resources of attention and postural control seems to mature around 15−16 years of age. The ability to maintain postural stability during the performance of concurrent mental activity is not studied in adolescents with CI. Keeping in view of this, the aim of the present study was to determine postural control function in dual task condition in adolescents with congenital hearing loss that implanted in early childhood in comparison with their normal hearing counterparts. The postural control was assessed by using force plate with hard and soft surface. To investigate the effect of hearing on the performance of the participants with CI, all tasks were performed with the device switched on and off.

Methods

Participants

Twenty-three 16−19 years old cochlear implanted (CI) boys with congenital hearing loss who were implanted unilaterally before five years old were recruited. Three were reluctant to participate because of severe disequilibrium. The study involved 20 CI boys and 40 normal hearing (NH) peers with no history of motor and balance disorders. All parents gave written informed consent. The study was approved by Human Research Ethics Committee of Tehran University of Medical Sciences.

Procedure

Postural control was assessed in both groups with force plate (Bertec Series 9090, Columbus, USA) at sampling rate of 100 Hz. Both groups were assessed in four separate conditions including hard surface with and without cognitive task and soft surface (on a foam placed on the platform) with and without cognitive task. All conditions were administered for CI group with devices switched on and off. A total of 12 trials (four conditions) were performed for NH group and 24 trials (eight conditions) for CI groups. Each condition was repeated three times. Cognitive task was counting backward from 100 in steps of one. The participants were tested while standing barefoot on the force platform, facing forward, eyes open, feet together, and motionless. Each recording lasted 35 seconds with a short break between trials. In each condition, center of pressure (COP) parameters such as anterior-posterior (AP) and medial-lateral (ML) body sway, and total mean velocity (TMV) were recorded and averaged for three times repeating.

After postural control assessment, caloric test was performed for CI group by having them supine with the head inclined 30 degrees to the horizontal plane. Prior the test, the ear canal and tympanic membrane were checked by an otoscope. In order to make the subject comfortable and relaxed, the procedure was explained to him. Bithermal caloric test was employed and the eye movements were recorded using infra-red video goggles (Eye Dynamics, USA). Each ear canal was stimulated with cool (23°C) and warm (48°C) air for 45 seconds. There was three minutes interval between irrigations. The maximum slow phase velocities of caloric-induced nystagmus were calculated after each stimulation session. Unilateral weakness was determined by using Jongkees formula. The measure was considered abnormal when it was > 25%. Bilateral weakness was determined when all four irrigation responses were less than 8°/sec [12]. Caloric test was performed to clarify the status of the CI group vestibular function.

Data processing

Numerous variables comprising the COP plot were calculated including total sway area, total excursion, root mean square (RMS) distance, RMS of the velocity, the rectified peak to peak distance, and the mean velocity. These calculations were performed for directions in both the anterior- posterior and medial-lateral plane. In this study we used mean velocity and peak to peak distance in both the anterior- posterior and medial-lateral plane.

Statistical analysis

SPSS 22.0 software was used for statistical analysis. Data was expressed as mean of absolute values ± SD. Normality of data was assessed with Kolmogorov-Smirnov test before analysis. Repeated measurement analysis of variance (ANOVA) was used to determine effect of group on postural control parameters. For parameters with no normal distribution, we used Friedman test. We compared postural control parameters between conditions (dual vs single task, and hard vs soft surface) within each group with paired t-test for normally distributed data and Wilcoxon test for parameters with no normal distribution.

Results

Caloric test demonstrated bilateral weakness in 18 (90%), unilateral weakness in 1 (5%), and normal results in 1 (5%) participants in CI group. Group had no effect on COP parameters in four conditions ($F_{(2,77)} = 0.268$, $p > 0.05$ for body sway in AP direction; $F_{(2,77)} = 0.096$, $p > 0.05$ for body sway in ML direction; $F_{(2,77)} = 0.455$, $p > 0.05$ for TMV).

In all three groups, body sway in both AP and ML directions and TMV on soft surface was significantly deteriorated as compared to those measures on hard surface with both single and dual tasks (Fig. 1).

Task significantly increased TMV in NH group on both hard ($p = 0.036$) and soft surfaces ($p = 0.013$) and in CI group with device-off on soft surface ($p = 0.030$). Other COP parameters were not significantly affected by task within groups (Fig. 1).

Discussion

Our data showed in spite of abnormal caloric response in 95% of CI group, postural control in

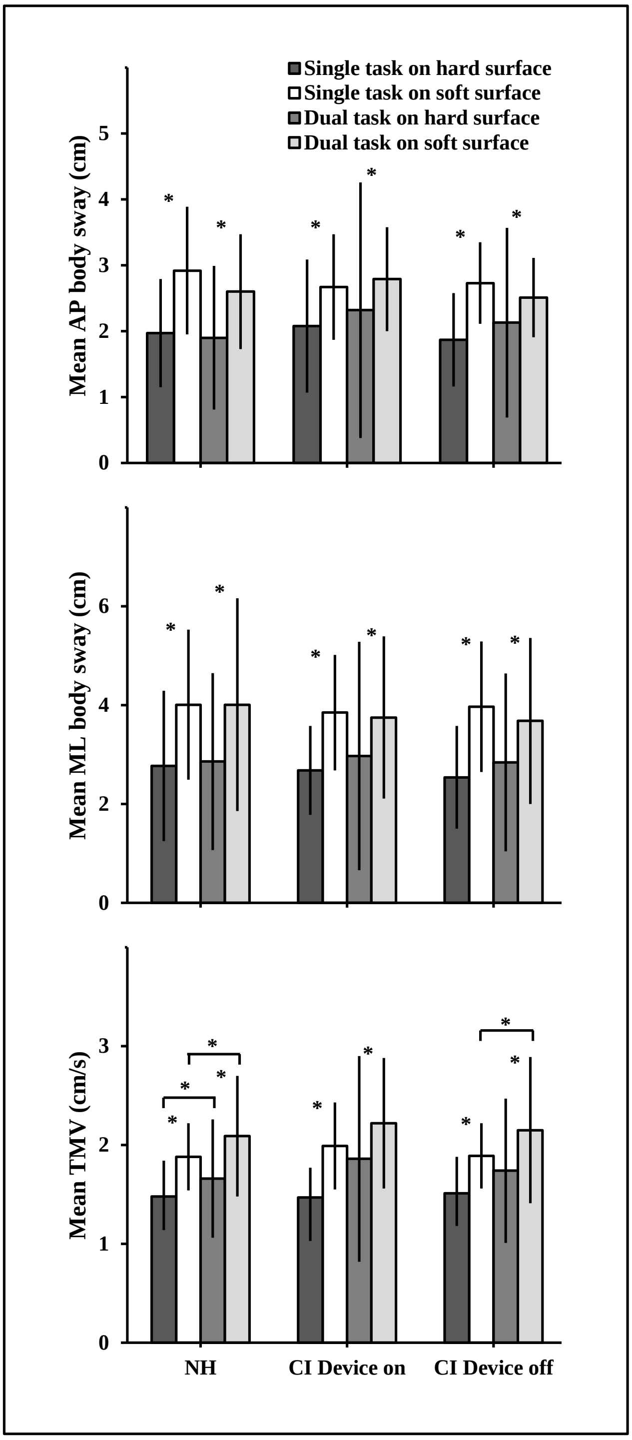

Fig. 1. Means and standard deviations of postural control parameters in normal hearing and cochlear-implanted adolescents in four test conditions. Asterisks indicate significant difference ($p < 0.05$). AP; anterior-posterior, ML; medial-lateral, TMV; total mean velocity, NH; normal hearing, CI; cochlear-implanted.

adolescents with CI was similar to their normal peers. Both NH and CI (device on and off) groups demonstrated deteriorated postural control function on soft surface in both single and dual task conditions. Mental activity increased postural TMV in NH and device-off CI groups.

Using computerized dynamic posturography, static posturography or Bruininks-Oseretsky test, previous studies have demonstrated declined postural control in children with CI compared to their normal hearing counterparts. Their finding was attributed to the vestibular dysfunction in children with hearing disorder [4,5,13-16]. In contrast with the findings in children with CI, studies on adults with CI have shown improved postural control in both static [17,18] and dynamic posturography [5] after implantation. It seems that central vestibular compensation is an effective mechanism that controls symptoms of vestibular loss in patients with CI [17]. Activity of the vestibular nuclei and cerebellum cause partial or complete restoration of the vestibular function. Restoration of the vestibular function after cochlear implantation occurs in interaction with other modalities during a long time [17] which may explain same results in our normal and CI groups. Moreover, other factors such as improvement of connections between systems, which involve in balance control from childhood to adolescence and adulthood and absence of other pathologies may justify our findings. Vestibular compensation after implantation can be considered as a positive effect of changes in the vestibular system. Although 18 patients had bilateral weakness and one patient had unilateral weakness, their postural control was identical to the normal group. This finding shows that the results of site-of-lesion tests solely cannot imply the extent of postural control ability in patients with CI. Postural stability is a multiple-system function and a cognitively-control task.

In our study, both CI and NH groups' postural control was better on hard surface compared to their performance on foam surface. With decreasing sensory information, postural control becomes more difficult and greater attention span is required. In this condition, standing on foam surface puts the somatosensory performance, as a system which is involved in balance and postural control, in challenge and leads to perturbation of the balance performance [10]. In such conditions, the visual input has a major contribution to maintaining of balance. The vestibular system contributes greatly when the eyes closed as well. We did not assess postural control with eyes closed.

Balance performance becomes more demanding and complicated in dual task condition in which attention devotes to two simultaneous postural control and cognitive activities than in conditions with no concurrent cognitive task. In our study, there was no significant difference between body sway in dual and single tasks in all participants; however, only NH subjects showed significantly larger TMV in dual task condition on both hard and soft surfaces. TMV is defined as a function of body sway and time spent during sway in AP and ML directions. It may vary despite of constant body sway since the spent time may increase or decrease. CI population is expected to show balance problem that is exacerbated in dual task conditions. Delich et al. has demonstrated that hearing-impaired children with CI or hearing aid showed poorer postural performance in dual task condition compared to the control group [4]. In our study, the NH adolescents have no history of balance dysfunction. During dual task condition, they could devote less time to their normal displacement in order to prevent increase of COP displacement that leads to TMV increase. However, CI group, particularly with device-off, could control COP parameters and simultaneous cognitive performance likely because of vestibular compensation and the effect of increasing age in comparison with children in other studies. We found that our cochlear implanted participants showed similar postural performance in all condition with CI device-on and off. Although several studies have demonstrated postural control improvement following activation of CI device in computerized dynamic posturography [5,19], elicited vestibular evoked myogenic potentials [20], and better overall performance on balance [21,22], our findings as well as several other studies [14,23] showed no difference in postural performance between device-on and off. Moreover, poorer postural control with device functioning was demonstrated in two studies [24,25]. There is a potential interaction between activation of the device and vestibular function. In addition to the possible risk of vestibular damage during surgery, the device electrical current may spread beyond cochlear nerve to the vestibular section. On the other hand, this electrical stimulation may deteriorate vestibular function due to the adverse effects of chronic electrical stimulation on vestibular labyrinth and nerve. However, electrical stimulation of the vestibular system seems to theoretically provide useful vestibular cues [21].

A limitation of this study is that the adolescents' postural control was not evaluated with eyes closed. Eliminating visual input leads to a challenging situation for postural control and is suggested to be considered for future studies.

Conclusion

Our finding has demonstrated approximately similar postural control performance in both normal hearing (NH) and cochlear Implant (CI) adolescents with device-on and off. This may be attributed to the overall maturity of both the balance system and the cognitive processes that take place after vestibular compensation in CI children, becomes similar to their NH peers in adolescence age. Vestibular compensation had occurred in a good manner because the CI group did not show any balance or postural control problem in spite of their vestibular loss. Standing on a soft surface put the somatosensory system in a challenging condition and deteriorate the balance performance. Thus, all participants' performance was better on the hard surface. Because of both groups' high ability in dividing attention between two concurrent tasks, there was no significant difference between groups except for total mean velocity.

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Conflict of interest

The authors declared no conflicts of interest.

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