Balance and gait evaluation: comparative study between deaf and hearing students

Avaliação do equilíbrio corporal e da marcha: estudo comparativo entre surdos e ouvintes em idade escolar

Evaluación del equilibrio corporal y de la marcha: estudio comparativo entre sordos y oyentes en edad escolar

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ABSTRACT

Objective: To evaluate the body balance and gait of deaf and hearing students and to compare data between groups, considering the gender and the age of the sample.

Methods: This cross-sectional study evaluated 44 deaf students and 44 hearing ones aged seven to 17 years-old. The evaluation of balance and gait characteristics was performed using the Tinetti Balance and Mobility Scale and the gait velocity with the test Timed Up and Go. For data analysis, two statistical approaches were applied: the Student's t-test to evaluate balance and the chi-square or Fisher's exact test to evaluate gait.

Results: The results from the balance evaluation did not show significant differences between groups, genders or age groups; however, the deaf scholars had worse performance on clinic balance in all categories. In the evaluation of gait characteristics, there were significant differences between groups ($p<0.001$), genders ($p<0.001$), and age groups: 7–10 years-old ($p=0.022$) and 11–17 years-old ($p<0.001$). With respect to gait speed, results showed significant differences between groups only for female students ($p=0.027$) aged 7–10 years-old ($p<0.001$).

Conclusions: Deaf students presented changes in gait and higher risk of falls compared with the hearing ones.

Key-words: child; postural balance; gait; hearing loss, sensorineural; deafness.

RESUMO

Objetivo: Avaliar o equilíbrio corporal e a marcha de escolares surdos e ouvintes e comparar os dados entre os grupos, considerando o sexo e a faixa etária da amostra.

Métodos: Estudo de corte transversal que avaliou 44 escolares surdos e 44 ouvintes, na faixa etária de sete a 17 anos. A avaliação do equilíbrio e das características da marcha foi realizada por meio da *Escala de Equilíbrio e Mobilidade de Tinetti,* e a velocidade da marcha, pelo teste *Timed Up and Go*. Para a análise dos dados foram utilizadas duas abordagens estatísticas: para o equilíbrio (teste *t* de Student) e para a marcha (teste do qui-quadrado ou exato de Fisher).

Resultados: A avaliação do equilíbrio não demonstrou diferenças significativas entre os grupos, os sexos e as faixas etárias, apesar de os escolares surdos apresentarem menor desempenho clínico nas categorias avaliadas. Na avaliação das características da marcha, os resultados apontaram diferenças significativas entre os grupos ($p<0{,}001$), os sexos ($p<0{,}001$) e todas as faixas etárias: 7-10 anos ($p=0{,}022$) e 11–17 anos ($p<0{,}001$). Com relação à velocidade da marcha, os resultados demonstraram diferenças entre os grupos apenas para o

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sexo feminino (p=0,027) e na faixa etária entre 7–10 anos anos (p<0,001).

Conclusões: Escolares surdos apresentaram alterações na marcha e maior risco para quedas quando comparados aos ouvintes.

Palavras-chave: criança; equilíbrio postural; marcha; perda auditiva neurossensorial; surdez.

RESUMEN

Objetivo: Evaluar el equilibrio corporal y la marcha de escolares sordos y oyentes y comparar los datos entre los grupos, considerando el género y la franja de edad de la muestra.

Métodos: Estudio de cohorte transversal, que evaluó a 44 escolares sordos y 44 oyentes de ambos los géneros, en la franja de edad de siete a 17 años. La evaluación del equilibrio y de las características de la marcha fue realizada por medio de la *Escala de Equilibrio y Movilidad de Tinetti* y la velocidad de la marcha, por la prueba *Timed Up and Go*. Para el análisis de los datos, se utilizaron dos acercamientos estadísticos: para el equilibrio (prueba t de Student) y para la marcha (prueba del chi cuadrado o exacto de Fisher).

Resultados: La evaluación del equilibrio no demostró diferencias significativas entre los grupos, los géneros y las franjas de edad, a pesar de que los estudiantes sordos presentan menor desempeño clínico en las categorías evaluadas. En la evaluación de las características de la marcha, los resultados apuntaron diferencias significativas entre los grupos (p<0,001), géneros (p<0,001) y todas las franjas de edad: siete y diez años (p=0,022) y 11 a 17 años (p<0,001). Respecto a la velocidad de la marcha, los resultados demostraron diferencias entre los grupos solamente para el género femenino (p=0,027) y en la franja de edad entre siete a diez años (p<0,001).

Conclusiones: Escolares sordos presentaron alteraciones en la marcha y mayor riesgo para caídas, cuando comparados a los oyentes, aunque no demuestren diferencias significativas en el equilibrio corporal.

Palabras clave: niño; equilibrio postural; marcha; pérdida auditiva neurosensorial; sordera.

Introduction

The vestibular system is an organ that detects the sensations of physical balance and plays an important role in the spatial relationship between the human body and the space it occupies[1]. In order to achieve satisfactory balance, sensory systems must be perfectly integrated and in tune[2,3].

The vestibulocochlear system is located in the inner ear and has twin functions, with the cochlea responsible for hearing and the vestibule for balance[4]. However, in truth, the ability to hear is a secondary characteristic, since the primary responsibility of the auditory organ is to maintain balance[5]. People's ability to balance their bodies can be affected if the vestibular system has some type of disorder, as is the case with some people who have sensorineural hearing loss[6].

Since the vestibular system and the cochlea are very close together anatomically and can be affected by the same harmful agents, it is reasonable to assume that many deaf children may also have vestibular problems in conjunction with their sensorineural hearing loss[7-9]. Furthermore, studies have demonstrated that vestibular system hypoactivity is a common finding during otoneurological assessments of children with sensorineural hearing loss, which may cause vestibular disorders[10,11].

Vestibular dysfunctions are not as rare in childhood as is commonly believed and they can affect acquisition of motor abilities or interfere with vestibular system sensory integration. Children with vestibular dysfunctions may report feeling unbalanced, may have problems with walking and may exhibit manifestations such as falling over, dizziness, vertigo and bumping into things, making it harder for them to acquire the abilities that are typical of their age group, such as riding a bicycle, skipping and even using the equipment at children's playgrounds[12].

In view of the above, it appears that children with sensorineural hearing loss suffer from an inadequacy of the sensory information provided by the vestibular system, as a result of inner ear damage. This can predispose them to problems with balance and difficulties with motor coordination and make it hard for them to perform tasks and functions that depend on balance, such as walking.

Despite this evidence, there is little published data on balance among deaf schoolchildren when compared with hearing children and even less on gait, which is the reason why this study was conducted. The objective was to evaluate balance and gait in deaf and hearing schoolchildren aged between 7 and 17 years and to compare the two groups, broken down by sex and age.

Methods

This was a cross-sectional study conducted from February to July of 2009. Prior to calculating the sample size for this study, information was obtained from the administration at the *Centro de Reabilitação e Educação Especial Rotary* school for children and adolescents with special needs and used to identify the number of deaf schoolchildren enrolled in the target age group who met the inclusion and exclusion criteria.

It was found that it would only be possible to pair 44 schoolchildren for sex and age because one or other sex predominated at certain ages, thereby limiting the available sample size. An equal number of schoolchildren with normal hearing were selected and paired with the deaf schoolchildren. Therefore, 88 volunteers took part in the study, 44 schoolchildren with sensorineural hearing loss and 44 with normal hearing, all aged from 7 to 17.

The schoolchildren were selected by convenience and paired for sex and age by lots drawn by their teachers, who were blind to the study objectives. Lots were drawn in the classroom in the presence of the schoolchildren and the researchers.

The deaf schoolchildren were recruited at the *Centro de Reabilitação e Educação Especial Rotary* and the children with normal hearing were recruited at the *Escola Duque de Caxias*, both belonging to the Pernambuco State education department and both located in the same neighborhood of the city of Caruaru, PE, Brazil.

The schoolchildren were separated into two groups: Group H (children with normal hearing) and Group D (deaf children). The inclusion criteria for both groups were enrolment at one of the two participating schools; age within the target range and; a free and informed consent form duly signed by a parent or guardian. Additional inclusion criteria for the deaf children were fluency in Brazilian sign language (LIBRAS) and a medical report containing a clinical diagnosis of sensorineural hearing loss.

Group H contained 44 schoolchildren with normal hearing, 22 boys and 22 girls, including two members of each sex for each age. Exclusion criteria for this group were: neurological, physical, auditory, visual or mental deficiencies or a discrepancy in leg length greater than 2cm, tested by measurement of true and apparent leg length.

Group D contained 44 deaf schoolchildren and once more there were 22 boys and 22 girls, with two members of each sex per age. The exclusion criteria for this group were: neurological, physical, auditory, visual or mental deficiencies or a discrepancy in leg length greater than 2cm, tested by measurement of true and apparent leg length in advance by the researchers.

The data used to assess inclusion and exclusion criteria were obtained during interviews with the children's parents and from their school records, which were provided by the schools' administrations.

Prior to assessing balance and gait, the procedures involved were described to the participants by the researchers. Volunteers with normal hearing received the explanation orally and one of the researchers, who is a LIBRAS interpreter, explained the procedures to the deaf volunteers in sign language.

Both groups of schoolchildren were assessed by researchers who are physiotherapists, using Tinetti's balance and mobility scale[13] and the timed "*Up and Go*" test[14].

Tinetti's balance and mobility scale[13] is a combination of two scales, one assessing balance and the other gait characteristics. The balance scale includes nine items, which cover components of static and dynamic balance and assess balance in isolation by observation of the following maneuvers: balance while sitting, standing, attempting to stand up, balance standing up, balance when "nudged", with eyes closed, turning through 360° and sitting back down again. The gait scale contains seven tests, assessing initiation of gait, step length and height, step symmetry and step continuity, path (direction), trunk position and stance (position of ankles). The full scale sums 28 points, 16 for balance and 12 for gait. The results make it possible to evaluate volunteers' performance taking balance and gait in conjunction and provide an assessment of mobility and falling risk. People who score below 19 are at high risk of falls; those scoring 19 to 24 are at moderate risk and people scoring over 24 are not at risk of falling[15].

Gait velocity was assessed using the timed "Up and Go" test[14]. A digital stopwatch was used to measure the time taken (in seconds) for each subject to stand up from a sitting position on a chair with no arms, walk 3m to another chair, go round it, come back to the first chair and then sit on down it once more, without aid from another person. This test was performed with subjects unshod.

Volunteers who are able to complete the distance and sit down again within ten seconds are classified as able to walk independently. Those who are unable to complete the test in ten seconds are classed as having walking dependencies.

Two different statistical treatments were employed. The results of the Tinetti balance and mobility scale were analyzed using Student's t test. The timed "Up and Go" test results were analyzed using the chi-square test or Fisher's exact test, to a significance level of $p<0.05$. The Statistical Package for the Social Sciences (SPSS), version 11.5, was used for statistical analyses.

Table 1 - Means and standard deviations of balance and gait test scores and overall Tinetti balance and mobility scores for a sample of deaf schoolchildren and schoolchildren with normal hearing

	n	Mean	SD	*p*-value
Balance scale				
Deaf children	44	13.6	1.0	0.47*
Children with normal hearing	44	14.8	0.9	
Gait scale				
Deaf children	44	9.9	1.3	<0.001*
Children with normal hearing	44	11.8	0.5	
Full scale				
Deaf children	44	23.6	1.9	<0.001*
Children with normal hearing	44	26.7	1.15	

*Student's *t* test; SD: standard deviation.

This study was assessed and approved by the Research Ethics Committee at the *Associação Caruaruense de Ensino Superior* (ASCES) under protocol number 068/08, in accordance with National Health Council resolution 196/96.

Results

This study investigated the balance and gait of 44 deaf schoolchildren and 44 schoolchildren with normal hearing. Mean age was 12±3.2 years in both groups. The Tinetti scale results for balance and gait indicate that the deaf schoolchildren had similar performance to the children with normal hearing in the balance component. In contrast, the two groups differed in terms of gait characteristics (Table 1).

Balance scores did not differ significantly between sexes, but the deaf schoolchildren had lower mean scores for

Table 2 - Means and standard deviations of balance and gait test scores and overall Tinetti balance and mobility scores for a sample of deaf schoolchildren and schoolchildren with normal hearing, broken down by sex

	Balance Scale		*p*-value	Gait Scale		*p*-value	Full Scale		*p*-value
	Mean	SD		Mean	SD		Mean	SD	
Males									
Deaf children	13.5	0.9	0.691*	9.5	1.1	<0.001	23.0	1.7	0.025
Children with normal hearing	14.6	0.9		11.9	0.5		26.5	1.2	
Females									
Deaf children	13.7	1.1	0.469*	10.3	1.3	<0.001	24.1	1.9	0.056
Children with normal hearing	15.0	0.9		11.8	0.5		26.9	0.9	

SD: standard deviation

Table 3 - Means and standard deviations of balance and gait test scores and overall Tinetti balance and mobility scores for a sample of deaf schoolchildren and schoolchildren with normal hearing, broken down by age group

	Balance Scale			Gait Scale			Full Scale		
	Mean	SD	*p*-value	Mean	SD	*p*-value	Mean	SD	*p*-value
7 to 10 years									
Deaf children	13.4	0.9	0.403*	9.8	1.2	0.022	23.4	1.4	0.254
Children with normal hearing	14.6	1.0		11.8	0.7		26.3	1.3	
11 to 14 years									
Deaf children	13.3	0.9	0.549*	9.7	1.3	<0.001	23.0	1.9	0.002
Children with normal hearing	15.0	0.8		11.9	0.3		26.9	0.9	
15 to 17 years									
Deaf children	14.2	1.1	0.296*	10.4	1.3	<0.001	24.6	2.0	0.002
Children with normal hearing	14.9	0.8		11.9	0.3		26.8	0.9	

SD: standard deviation

performance in the balance tests than the group of children with normal hearing (Table 2).

When balance scores were broken down by age group (7-10, 11-14 and 15-17), the greatest difference between mean scores for deaf and hearing children was in the 11 to 14 age group (Table 3), but the results were not statistically significant for any of the age groups.

Deaf schoolchildren had significantly worse performance on the Tinetti balance and mobility scale than children with normal hearing (Table 1). When the Tinetti balance and mobility scale gait scores were broken down by sex, male schoolchildren with normal hearing had a statistically higher mean score than deaf male schoolchildren. The same was true of the girls (Table 2). When gait scores from the Tinetti balance and mobility scale were broken down by age group, the deaf schoolchildren scored lower, with significant differences between means for all three age groups (Table 3).

The results for total score on the Tinetti balance and mobility scale, which reflects the sample's performance for balance and gait and also indicates their risk of falling, were significantly different between groups (Table 1). When the total Tinetti balance and mobility scale scores were broken down by sex, it was found that schoolchildren of both sexes with normal hearing scored better than their deaf peers. However, only the boys exhibited significant differences and had a moderate risk of falling (Table 2). When broken down by age group, the overall Tinetti balance and mobility scores showed that children with normal hearing had better performance than deaf children from 11 years of age onwards. Deaf schoolchildren aged 11 to 14 had a moderate risk of falling (Table 3).

The results of the gait velocity assessment, based on performance in the timed "Up and Go" test, classified 17 deaf schoolchildren (38.6%) and 10 children with normal hearing (22.7%) as having walking dependencies. Although a greater number of deaf schoolchildren had walking dependencies, there were no significant differences between groups (p=0.10). Comparing groups broken down by sex in terms of gait velocity showed that males in both groups were similar, but there were significant differences between the females (Table 4). When gait velocity was broken down by age, there were only significant differences between groups for children aged seven to ten.

An important finding that can be observed in the performance of the group of deaf children in the timed "Up and Go" test relates to the variable age. The younger the age group of the deaf schoolchildren, the greater their degree of walking dependency, and, as age increased, walking dependency decreased (Table 5).

Table 4 - Classification of deaf and hearing schoolchildren according to timed "Up and Go" gait velocity test, broken down by sex

Gender	Timed "Up and Go" Test				
	Walking dependencies		Independent walking		*p*-value
	n	%	n	%	
Male					
Deaf children	6	27.3	16	72.7	1.000
Children with normal hearing	6	27.3	16	72.7	
Female					
Deaf children	11	50.0	11	50.0	0.027
Children with normal hearing	04	18.2	18	81.8	

Table 5 - Classification of deaf and hearing schoolchildren according to timed "Up and Go" gait velocity test, broken down by age group

Age group	Timed "Up and Go" Test				
	Walking dependencies		Independent walking		p-value
	n	%	n	%	
7 to 10 years					
Deaf children	11	68.8	5	31.2	<0.001
Children with normal hearing	1	6.3	15	93.7	
11 to 14 years					
Deaf children	4	25.0	12	75.0	0.5
Children with normal hearing	3	18.8	13	81.2	
15 to 17 years					
Deaf children	2	16.7	10	83.3	0,097
Children with normal hearing	6	50.0	6	50.0	

Discussion

Mauerberg-de-Castro[16] states that sensorineural hearing loss does not only affect the hearing and, as a result, speech, but also affects the sensory pathways responsible for maintaining balance in humans. However, the results of this study relating to balance in deaf schoolchildren contradict that statement. In this study, deaf schoolchildren's performance in balance tests was mildly different from that of children with normal hearing, from a clinical point of view. However, this difference was not statistically significant and was not maintained when groups were compared on the basis of sex and age group, in common with findings reported by Gayle and Pohlman[17]. They investigated dynamic and static balance in 40 schoolchildren with a mean age of ten years (20 children with hearing loss and 20 children with normal hearing) and concluded that when age and sex were taken into account there were no differences between the two groups in terms of balance.

Potter and Silverman[18] explain that deaf children can learn to compensate for possible vestibular system deficiencies using other organs and systems responsible for maintaining balance, through adaptive mechanisms. This could explain the findings of this study relating to the two groups' performance in the balance tests. It should be pointed out that the volunteers' vestibular function was not assessed.

In contrast, some studies have employed different methods from those used here and have demonstrated significant differences in balance between deaf and hearing schoolchildren, as in Sousa *et al*[19] and Sousa *et al*[20].

Although the deaf schoolchildren studied here did not have significantly compromised balance when balance was assessed in isolation, but they did perform worse in the gait tests. The schoolchildren assessed had significant differences in gait performance for both sexes and in all age groups. The most obvious anomalies were in step height and behavior of the trunk. When gait was analyzed it was found that a majority of the deaf children tended to exhibit trunk flexion, in line with what was observed by Mauerberg-de-Castro[16]. She conducted a qualitative analysis of the locomotion of 20 deaf children of both sexes after filming them and concluded that the deaf children exhibited trunk flexion during locomotion, in addition to short and irregular steps.

In addition to the adaptations to trunk position, a large proportion of the deaf schoolchildren studied here did not lift their feet off the floor when walking (swing phase), i.e. they did not complete the phases of walking that are considered normal (heel-toe index). The deaf children dragged their feet along the floor when walking and took short steps during the tests, thereby maintaining double support continuously (stance phase). Perry and Burnfield[21] believe that people with vestibular deficiencies need greater security when walking, which is provided by an increased proportion of double support when walking, in order to improve maintenance of balance.

Despite the similarity in performance in balance tests between deaf children and children with normal hearing observed in this study, the full results of the Tinetti balance and mobility scale suggest that mobility function, which includes balance and gait, is compromised among the deaf children, increasing their falling risk. This may in turn explain the findings from the gait velocity tests.

The results of the gait velocity tests demonstrated that the deaf group had poorer performance than the group with normal hearing. However, only the differences for both sexes in the seven to ten years age group and the females at all ages were significant. Studies have shown that people with vestibular dysfunction walk with short steps, using a wide support base, turn en bloc and avoid sudden movements[22,23] to avoid provoking undesirable symptoms such as dizziness and vertigo caused by their vestibular dysfunction. Furthermore, ability is compromised in the balance position and gait velocity is reduced in patients with vestibular dysfunction[24,25].

This being so, one factor that might explain the gait differences among the deaf schoolchildren may be identifiable in the findings of a study conducted by Gonçalves *et al*[26]. These authors assessed vestibular system activity in 42 deaf children aged four to seven years and pointed out that the reduction in vestibular function can vary from 49 to 95% in caloric and rotational tests. Other studies have also reported that vestibular system hypoactivity is a common finding in otoneurological examinations of children with sensorineural hearing loss[27,28], which may explain why the deaf schoolchildren in this study had poor performance in the gait tests.

On the basis of these data, it is believed that all children with clinical diagnoses of sensorineural hearing loss should undergo vestibular tests, irrespective of age or sex and even in the absence of vertigo or dizziness[29].

One of the most important contributions of this study is to publish data on the gait characteristics of deaf children and a comparison with their peers with normal hearing, since there is a shortage of published data on the subject. It should be borne in mind that the study population did not undergo vestibular system function assessment, which limits the extent to which conclusions can be drawn about compromise to the vestibular system.

Balance is essential for the stages of child neuromotor development, since it is a part of every interaction between the child and its environment during daily activities and particularly during childhood games. This means that children with sensorineural hearing loss can suffer neuromotor developmental delays and problems with certain motor abilities, may complain of discomfort during games that are typical of their age and, most importantly, may have difficulties keeping up with other children of the same age and sex and interacting with their peers.

These findings emphasize the need to develop prevention programs and appropriate therapeutic measures, in the school environment, in order to correct and/or improve motor performance, gait and, as a consequence, the quality of life of deaf schoolchildren, thereby preventing falls and more serious morbidities in this population. Physiotherapy can have a positive impact on childhood vestibular dysfunction, whether provided at school, in institutions who treat these populations or by multidisciplinary teams, which emphasizes the importance of physiotherapists in the school environment and of monitoring the neuromotor development of deaf schoolchildren[30].

It can be concluded that schoolage deaf children did not have significant differences in balance when compared with their peers with normal hearing, despite having poorer clinical performance in all categories evaluated. Their difficulties were most pronounced during dynamic activities, such as walking.

With relation to the deaf schoolchildren's gait, it was observed that there were certain abnormalities, particularly related to step length, trunk movement and gait velocity, and that there could be an increased falling risk in this population. These abnormalities may be linked with vestibular system disorders, possibly caused by damage to the inner ear.

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