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Unilateral hearing loss in children: phonology and vocabulary assessment

Perda auditiva unilateral em crianças: avaliação fonológica e do vocabulário

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ABSTRACT

Purpose: To analyze the phonological and vocabulary performance of children with unilateral hearing loss. **Methods:** Participants were twelve subjects with unilateral hearing loss of any degree and configuration, with deficit in any ear and without other associated impairments – six with conductive hearing loss due to congenital malformation of outer and/or middle ear, and six with congenital sensorineural hearing loss or acquired in the first year of life. Subjects' ages ranged from 3 years and 7 months to 7 years and 8 months. The phonology and vocabulary tasks of the "ABFW – Child Language Test" were applied. **Results:** Thirty-three percent of the children presented performances different than expected for their age groups regarding phonological (2 children) and lexical developments (2 children). On the phonology test, one child with sensorineural hearing loss presented phonological processes that were not expected for the age group (liquid simplification and fricative devoicing) and low indices of correct production in the phonetic inventory. One child with conductive hearing loss due to malformation presented stopping and liquid simplification, and borderline results in the analysis of the phonetic inventory (75%). On the vocabulary test, two children with sensorineural unilateral hearing loss presented mean of Usual Verbal Designations below the expected for their ages in different semantic fields. There were no differences between children with sensorineural and conductive hearing loss in the phonology and vocabulary tests. **Conclusion:** Children with unilateral hearing loss are considered at risk for language development. We emphasize the importance of language and auditory monitoring of these children, providing early and efficient interventions, thus preventing possible language disorders and learning difficulties.

Keywords: Hearing loss, Unilateral; Language development disorders; Child; Language; Vocabulary

RESUMO

Objetivo: Analisar o desempenho fonológico e do vocabulário de crianças com perda auditiva unilateral. **Métodos:** Participaram do estudo 12 crianças com perda auditiva unilateral, seis delas com perda condutiva por malformação congênita de orelha e seis com perda sensorioneural congênita ou adquirida no primeiro ano de vida, de qualquer grau, configuração, em qualquer ouvido e sem outro comprometimento associado, na faixa etária entre 3 anos e 7 meses e 7 anos e 8 meses. Foram aplicadas as provas de fonologia e vocabulário do "Teste de Linguagem Infantil – ABFW". **Resultados:** Trinta e três por cento das crianças apresentaram desempenho diferente do esperado para a faixa etária, no que concerne ao desenvolvimento fonológico (2 crianças) e lexical (2 crianças). Na prova de fonologia, 1 criança com perda sensorioneural apresentou processos produtivos não esperados para a faixa etária (simplificações das líquidas e ensurdecimento de fricativas) e baixos índices de acertos no inventário fonético. Uma criança com perda auditiva condutiva por malformação congênita de orelha apresentou plosivação de fricativas, simplificação de líquidas e resultado limítrofe, na análise do inventário fonético (75%). Na prova de vocabulário, 2 crianças com perda sensorioneural apresentaram médias percentuais de Designação Verbal Usual abaixo das esperadas para as idades, nos diversos campos conceituais. Não houve diferença entre os grupos sensorioneural e condutivo nas provas de fonologia e de vocabulário. **Conclusão:** Crianças com perda auditiva unilateral apresentam risco para o desenvolvimento de linguagem. Destaca-se a importância do acompanhamento de linguagem e audição neste grupo, uma vez que o monitoramento pode propiciar intervenções oportunas e eficazes, prevenindo possíveis alterações da linguagem e dificuldades escolares.

Descritores: Perda auditiva unilateral; Transtorno do desenvolvimento da linguagem; Criança; Linguagem; Vocabulário

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INTRODUCTION

There is little scientific evidence about the consequences of unilateral hearing loss (UHL) for children's oral language and learning development[1]. In UHL, the individual presents one ear with normal function and the other with hearing deficit of any degree, type and configuration. The hearing loss might be conductive, mixed or sensorineural, including the auditory neuropathy spectrum disorder.

The identification of children with UHL, since the implementation of the universal neonatal hearing screening (UNHS), has brought a new demand to Speech-Language Pathology and Audiology services[2]. Speech-language pathologists and audiologists must pay special attention to these children, who used to be diagnosed late until recently, in order to reduce or overcome any language or learning difficulty that may occur during their development[3]. In this sense, it was created the Children with UHL Follow-up Program at the CeAC – Child Hearing Center (CeAC/Derdic/PUC-SP), located in São Paulo, Brazil, which provides periodic follow-up for all infants and children diagnosed with unilateral hearing loss. This follow--up provides auditory monitoring; hearing aid adaptation, and the use of a frequency modulation (FM) system, if necessary; shared work with family and school; and referral to speech--language therapy, when recommended, at the healthcare service center closer to the child's residence address, in order to reduce the possible consequences of hearing loss.

According to the literature, UHL may cause deficits in auditory processing and, consequently, in language and communication development. These deficits may be related to the handicaps these children experience due to the absence of binaural hearing[4].

In the presence of environmental noise, children with UHL find more difficulties in understanding speech than those with normal hearing bilaterally, even when the good ear is turned to the direction of speech. Besides, difficulties with sound localization and distant speech recognition might interfere with language development[5]. Thus, UHL may be a risk factor for children's language development and academic achievement, since they might present difficulties in daily communication and hearing situations[6]. Studies have shown that 1/3 of children with permanent unilateral hearing loss present language and learning delays[7,8,9].

A study conducted at the Colorado Home Intervention Program[10] noticed that nearly 33% of its subjects presented language development below the expected for their age groups. The authors concluded that children with UHL present higher risk for socioemotional difficulties than children with normal hearing. Another study[11] that evaluated the linguistic abilities of children with UHL observed that they presented significantly lower results in the oral communication assessment than normal-hearing children subjects.

For the Joint Committee of Impaired Children[12], all children diagnosed with any type of hearing loss, including mild and unilateral losses, must have periodic follow-up, since they may present language disorders or delays.

With the aim to understand the needs of this population in our scenario, a research started in 2009 to investigate the impact of UHL on the development of children diagnosed in the healthcare service. The partial results have shown that nearly 30% of these children had oral language alterations, specially difficulties in the production of speech sounds[13].

Considering the lack of studies on this subject, this research had the aim to analyze the phonological performance and the lexical competence of children with sensorineural and conductive UHL due to congenital malformation of middle and/or outer ear.

METHODS

This cross-sectional descriptive research was approved by the Ethics Committee of the *Pontifícia Universidade Católica de São Paulo*, under protocol number 097/2008.

Participants of the study were selected among children diagnosed with permanent unilateral hearing loss who attended the Follow-up Program for Children with UHL at the institution between June and September 2013. To be included in the research, participants needed to have the Free and Informed Consent signed by their caregivers and to fulfill the following criteria: to have congenital sensorineural UHL or sensorineural UHL acquired in the first year of life, or conductive UHL due to congenital malformation of outer and/or middle ear, with any degree and configuration, with deficit in either ear. The exclusion criterion was to present other evident impairments that could cause language and/or speech development alterations, such as neurological and/or psychiatric disorders.

Twelve children participated in the study, and divided into two groups: Group 1, with sensorineural hearing loss (6 subjects), and Group 2, with conductive hearing loss due to malformation of outer/middle ear (6 subjects). Four subjects in Group 2 had already been referred to speech-language therapy, but, at the time the study was carried out, had not yet been enrolled in any service: subject 10, due to disfluency complaints; subjects 2 and 12, due to speech complaints; and subject 6, for writing complaints.

The predominant gender was female (66.4%), the predominant loss degree was moderate (50%), and the right ear was the most affected (66.7%). Fifty percent of the subjects presented conductive hearing loss due to congenital malformation, and 50% had sensorineural hearing loss. The mean age of diagnosis was 6 months of life (standard deviation of 6 months), and the mean age at the assessment was 5 years and 5 months (standard deviation of 17 months). Literature indicates that most cases of conductive hearing loss caused by congenital malformation of outer and middle ear are unilateral (70 to 85%)[14], which justifies the importance of including these cases in this study.

The summary of subjects' characterization is shown in Chart 1.

The degree of hearing loss was classified according to the criteria proposed by Northern and Downs[15].

Phonology and vocabulary were assessed using the ABFW – Child Language Test[16], according to test's manual for application and analysis. Word imitation and picture naming tasks were applied to verify the subjects' phonetic inventory and the use of phonological processes (ten processes observed during language development and four not frequently observed in normal development).

The vocabulary test followed the same sequence of nine semantic fields proposed: (1) clothing, (2) animals, (3) food, (4) means of transportation, (5) furniture and utensils, (6) occupation, (7) places, (8) shapes and colors, (9) toys and musical instruments.

The tests were applied individually, in only one session. The examiner sat in front of the subjects and used an iPad® tablet to record the answers. The equipment was positioned on the table so the microphone and camera were directed to the child's face, favoring the later observation of the articulatory production and phonetic transcription. After the application, the phonology tasks were phonetically transcribed on the specific protocol. In the analysis of the phonetic inventory, the most frequent types of occurrences were verified (omissions, substitutions, distortions and correct production). In the phonological analysis, the phonological processes were considered productive when they appeared in more than 25% of their possibilities of occurrence[16].

For the vocabulary assessment, the Tables of Percentage of Answers – normality reference were used. The tables correspond to the parameters of the expected percentages for each age group and each semantic field, considering: 1) Usual Verbal Designation (UVD) – when subject named correctly the picture showed; 2) No Designation (ND) – when subject did not name the picture; 3) Substitution Process (SP) – when subject used other signification resources in the attempt to name the target word. The results of this test allowed observing the children's degree of semantic development.

Data obtained were submitted to statistical analysis on the SPSS 18 software. Descriptive (mean, standard deviation, median, minimum and maximum) and inferential (Mann-Whitney test) analyses were performed for the comparison between the groups of children with sensorineural and conductive UHL. The significance level adopted was 5%.

RESULTS

The analysis of phonological processes showed that only two subjects (subject 2, with sensorineural UHL, and subject 12, with conductive UHL) presented productive processes that were not expected for the age group. Subject 2 also presented a process not frequently observed during the development (Table 1).

In the phonetic inventory, the mean percentage of correct productions was over 90% for imitation and naming, in both onset position (phoneme in onset position in the first syllable of the word) and final position (phoneme in onset position in the last syllable of the word). One subject (subject 12) presented low indices of correct productions on the imitation task, and another (subject 2) presented reduced indices (but still within

Chart 1. Characterization of the sample

Type of hearing loss	Subjects	Gender	Age at diagnosis	Age at evaluation	Degree of hearing loss*	Affected ear	Etiology
Sensorineural	1	F	5m	4y10m	Profound	LE	Asymmetry of the IAC and lateral semicircular canals
	2	M	3m	3y7m	Severe	LE	Unknown
	3	F	4m	4y2m	Severe	LE	Hyperbilirubinemia and fetal distress
	4	M	12m	4y5m	Moderate	RE	Unknown
	5	F	9m	6y10m	Profound	RE	Meningitis
	6	F	1m	7y5m	Profound	RE	Genetic
Conductive/ malformation	7	F	11m	6y5m	Severe	RE	LE microtia, agenesis of the EC and malformation of the ME
	8	M	24m	7y8m	Moderate	LE	Atresia of the EC and LE microtia
	9	F	1m	5y4m	Moderate	RE	LE microtia and agenesis of the EC
	10	M	2m	7y2m	Moderate	RE	RE microtia and agenesis of the EC
	11	F	10days	4y5m	Moderate	RE	LE microtia and agenesis of the EC
	12	F	6m	4y6m	Moderate	RE	Agenesis of the EC and malformation of the ME

*Degree of the hearing loss in the affected year

Subtitle: y = year; m = month; M = male; F = female; IAC = internal acoustic canal, EC = ear canal, ME = middle ear; LE = left ear, RE = right ear

Table 1. Percentage of occurrence of phonological processes for each subject on the imitation and naming tasks

	PP	SR*	CH*	St*	BV*	BP*	VF*	PF*	SL*	CS*	FCS*	SV**	FV**	SD**	FD**
Subject	Task														
1	Im									25					11.1
	Nam						11.1								
2	Im	1.9				28.5	5.8	83.3	**25**	91.6	42.8		7.6	23.5	**33.3**
	Nam			4.3				20	**45.4**	62.5	20		14.2	21.4	**55.5**
3	Im	3.8	1.9	4.5						41.6					
	Nam					18.1				12.5					
4	Im			4.5				16.6	12.5	25	42.8			7.6	
	Nam	2.2						20	18.1	12.5	20				
5	Im											34			
	Nam									12.5					
6	Im														
	Nam														
7	Im														
	Nam														
8	Im														
	Nam									12.5					
9	Im											3.4			11.1
	Nam														22.2
10	Im														
	Nam									12.5					11.1
11	Im							16.6		8.3					
	Nam									12.5					
12	Im	1.9	15.3	**50**			11.7		**87.5**	91.6	85.7			11.7	
	Nam	2.2	4.4	**52.1**		9	11.1		**54.5**	25	40				11.1

*Phonological processes observed during development

**Phonological processes not frequently observed during development

Subtitle: PP = phonological processes; SR = syllable reduction; CH = consonant harmony; St = stopping; BV = backing to a velar sound; BP = backing to a palatal sound; VF = velar fronting; PF = palatal fronting; SL = simplification of liquids; CS = cluster simplification; FCS = final consonant simplification; SV = stop voicing; FV = fricative voicing; SD = stop devoicing; FD = fricative devoicing; Im = imitation; Nam = naming

the expected), according to the parameters of the test (Figure 1).

In the comparison between the groups with sensorineural and conductive UHL, no differences were found in the mean percentage of correct productions in any of the tasks (imitation and naming, onset and final position) (Table 2).

In the vocabulary test, two subjects (subjects 3 and 6, both with sensorineural UHL) presented mean percentage of UVD below the expected for their ages. None of the subjects in the group with conductive hearing loss for congenital malformation of the ear presented performance below the expected for the age range, according to the parameters of the ABFW test (Table 3).

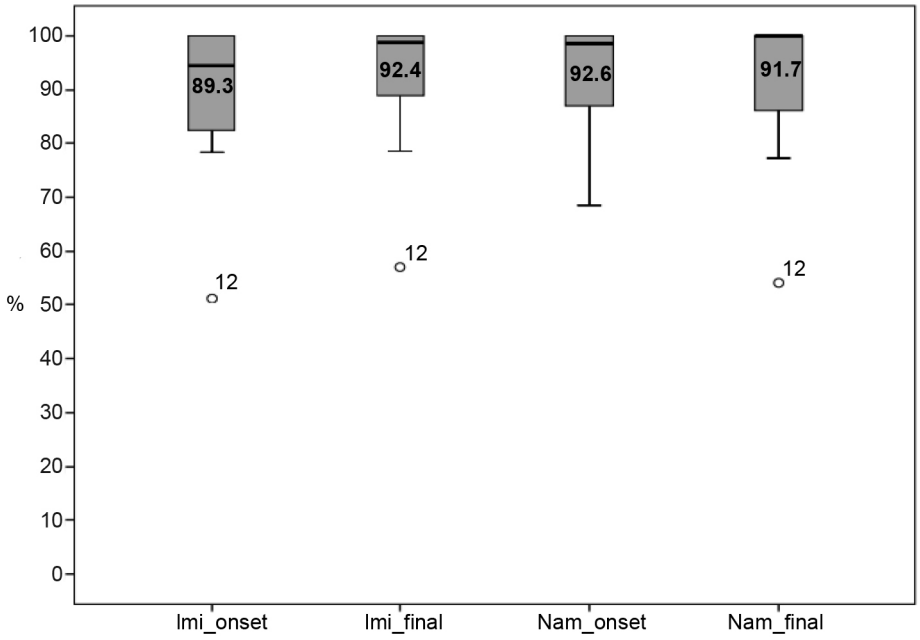
Considering all the participants, the semantic fields with higher means of UVD were animals, means of transportation, and toys and musical instruments, and the semantic fields with lower means of UVD and higher occurrence of SP were occupations and places. Overall, the mean percentage of UVD was 64.0% (±17.30), the mean percentage of PS was 30.5% (±14.04), and the mean percentage of ND was 5.4% (±4.37) (Table 4).

In the vocabulary test, there were no differences between groups for UVD, ND and SP in all the semantic fields and the total.

DISCUSSION

In the characterization of the subjects, it was noticed that 66.7% presented hearing loss in the right ear. Considering only the cases of conductive loss for congenital malformation of the ear, it was noticed that 85.7% presented congenital malformation in the right ear, which corroborates other studies that suggest there is predominance of malformation in the right ear, for unknown reasons[14,17].

In the analysis of phonological processes, two subjects – one with 3 years and 7 months and severe sensorineural



The values expressed in number correspond to the means; the black bold lines correspond to the medians
Subtitle: Imi = imitation; Nam = naming

Figure 1. Descriptive analysis of subjects' percentages of correct productions on the phonetic inventory based on the naming and imitation tasks, in onset and final position

Table 2. Comparison of the percentages of correct productions on the naming and imitation tasks between subjects with sensorineural and conductive UHL

Task	Position	Group	Median	U	Z	p-value
Imitation	Onset	Sensorineural	87.70	12.500	-0.944	0.345
		Conductive	100.0			
	Final	Sensorineural	96.30	12.500	-0.942	0.346
		Conductive	100			
Naming	Onset	Sensorineural	95.70	12.500	-0.942	0.346
		Conductive	100			
	Final	Sensorineural	94.50	15.000	-0.536	0.592
		Conductive	100			

Mann-Whitney test ($p<0.05$)
Subtitle: UHL = unilateral hearing loss

hearing loss in the left ear (subject 2), and the other with 4 years and 6 months and moderate conductive hearing loss/malformation in the right ear (subject 12) – presented phonological processes that are not expected for their age ranges (Table 1). These findings agree with a study that found the highest occurrence of these same processes in children with phonological disorders and history of otitis media, when compared with a group without history of otitis media[18]. Moreover, the results agree with other studies that concluded that liquid simplification is the phonological process with highest occurrence in the population[19], and that the devoicing processes are among the most frequent in individuals with phonological disorders[20].

In the vocabulary test, only two subjects (subjects 3 and 6) presented mean percentages of UVD below the expected for their ages, in the several semantic fields (Table 4). The semantic fields that presented higher means of UVD (animals, means of transportation, toys and instruments) are also indicated in literature[21,22] as very present in the vocabulary of younger children, which justifies the better performance of the subjects in these fields. The conceptual fields with lowest UVD and highest occurrence of SP were food, furniture and utensils, occupations, places, shapes and colors for subject 3, and food, places, shapes and colors for subject 6. These data corroborate a study[23] that found that these conceptual fields are the ones mostly presenting alterations, in general.

According to the literature, 1/3 of children with unilateral hearing loss present language and academic delays[7,8]. In this study, similar results were found, since four of the 12 analyzed subjects presented different performances than the expected

Table 3. Mean percentages of UVD, ND, and SP expected and obtained by the subjects

Subjects	Results	UVD	ND	SP
1*	Expected	44	17	38
	Obtained	54	10	36
2*	Expected	33	10	56
	Obtained	35	9	56
3*	Expected	44	17	38
	Obtained	36	12	51
4*	Expected	44	17	38
	Obtained	51	13	36
5*	Expected	72	9	19
	Obtained	80	0	20
6*	Expected	72	9	19
	Obtained	67	3	30
7**	Expected	72	9	19
	Obtained	84	0	16
8**	Expected	72	9	19
	Obtained	78	4	18
9**	Expected	61	11	28
	Obtained	82	0	18
10**	Expected	72	9	19
	Obtained	76	7	17
11**	Expected	44	17	38
	Obtained	51	4	46
12**	Expected	44	17	38
	Obtained	46	4	49

*Sensorineural hearing loss; **Conductive hearing loss/malformation

Subtitle: UVD = usual verbal designation; ND = no designation; SP = substitution process

for their ages regarding phonological (two) and lexical (two) development, which corresponded to 33.3% of the sample.

Results also indicated that the two children who presented performance below expected on the phonology test were not the same who presented the worst performance on the vocabulary test. Although some studies[24,25] show that vocabulary development is related to phonological working memory development since the beginning of language acquisition, some authors emphasize that the results obtained on vocabulary tests are not necessarily low in children with phonological alterations[26], as observed in this study.

The two subjects who presented the lowest performances on the vocabulary test and one who presented productive processes on the phonology test showed severe and profound levels of hearing loss. Moreover, they did not use hearing aids, thus they had less auditory access to information and more comprehension difficulties in noisy environments. It is still debatable in literature[8,12] whether the level of hearing loss in the affected ear interferes with language development in these cases. However, it is known that, for these children, the adaptation of hearing aids is not always recommended and, therefore, other accessibility equipments must be considered, such as the FM system.

There is also controversy regarding the correlation between performance and the affected ear in UHL. Some studies[27,28] have suggested that children with UHL in the right ear present more difficulty of speech and learning than the ones with hearing loss in the left ear. Other studies[29,30] did not find significant differences between these groups. In the present study, this trend was not observed, since the results that were not according to the standard parameters of the ABFW test were noticed both in subjects with hearing loss in the right (2) and the left ear (2).

This discrepancy of results can be certainly assigned to the complexity of the development process of language and auditory function. Although the alterations may be related to the nature of the hearing loss, there are numerous other factors that make it difficult to establish linear causal relationships between them.

The reduced number of subjects in each studied group was one of the limitations of this study. We emphasize the importance of new researches on the impact of unilateral hearing loss on language and learning development in childhood, so they can

Table 4. Descriptive analysis of the subjects' performance in each semantic field

Semantic field	Response	Mean	Standard deviation	Median	Minimum	Maximum
Clothing	UVD	64.17	18.32	70.00	30	90
	ND	0.83	2.88	.00	0	10
	SP	35.00	16.78	30.00	10	70
Animals	UVD	78.34	18.44	83.35	40	100
	ND	3.33	6.66	.00	0	20
	SP	18.33	16.35	13.30	0	53
Food	UVD	64.57	17.73	66.70	33	87
	ND	8.33	11.41	3.35	0	33
	SP	25.10	9.19	26.70	13	40
Means of transportation	UVD	72.7	13.99	72.70	55	91
	ND	0.76	2.62	.00	0	9
	SP	26.54	14.23	27.30	9	46
Furniture and utensils	UVD	70.66	17.70	76.10	39	91
	ND	4.33	4.13	4.30	0	13
	SP	24.99	14.61	21.70	9	48
Occupations	UVD	35.0	24.30	30.00	0	70
	ND	11.67	11.93	10.00	0	30
	SP	53.33	20.15	55.00	20	80
Places	UVD	37.49	26.23	41.65	0	75
	ND	5.55	6.49	4.15	0	17
	SP	56.93	27.49	50.0	8	100
Shapes and colors	UVD	66.67	27.74	65.00	10	100
	ND	9.17	13.11	5.00	0	40
	SP	24.17	21.51	15.00	0	60
Toys and musical instruments	UVD	72.73	21.21	77.25	46	100
	ND	6.07	9.76	.00	0	27
	SP	21.22	20.25	18.20	0	55
Total	UVD	64.03	17.39	62.00	38	86
	ND	5.41	4.37	5.13	0	13
	SP	30.56	14.04	31.62	15	54

Subtitle: UVD = usual verbal designation; ND = no designation; SP = substitution process

contribute to identify characteristics and factors in this group of children that represent higher risks for their development.

CONCLUSION

Most children with UHL were within the expected development for their age group. There were no differences between the groups with sensorineural and conductive UHL on the phonology and vocabulary tests.

Children with unilateral hearing loss presented risk for language development. In this study, 33.3% of the subjects performed below the expected for their age groups. we emphasize the importance of language and hearing follow up for all diagnosed cases, since this monitoring can provide timely and effective interventions in promoting development, as well as in the prevention and/or rehabilitation of possible language alterations and academic difficulties.

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