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Systematic Review

Revisão Sistemática

Frequency Modulation System and speech perception in the classroom: a systematic literature review

Sistema de Frequência Modulada e percepção da fala em sala de aula: revisão sistemática da literatura

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Keywords

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Hearing Aids
Cochlear Implantation
Self-Help Devices
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ABSTRACT

Purpose: This review aimed at presenting the benefits regarding the speech perception in noise shown by children who wear hearing aid devices and/or cochlear implants with the Frequency Modulation (FM) System at school. **Research strategy:** A bibliographic survey was conducted in an electronic database with standardized search until the year 2012, and a manual search was performed by using specific keywords. **Selection criteria:** For the selection and evaluation of the scientific studies chosen in the search, criteria were established covering the following aspects: type of study, participants, adopted intervention, and evaluation of results. **Data analysis:** The FM system was verified to improve speech perception and speech threshold in noise in all studies. **Results:** Regarding the performance as to type, the best results were obtained when children used the personal FM system, followed by the table and the sound field systems. **Conclusion:** After extensive review of national and international literature, it was concluded that the studies indicate the need for further research concerning mainly the impact of the FM system on the school performance of children who have sensory devices coupled to the FM system. Findings in the literature with relation to the publications focused on speech perception in noise did not relate educational and auditory aspects.

Descritores

Perda Auditiva
Auxiliares de Audição
Implante Coclear
Equipamentos de Autoajuda
Ruído
Criança
Docentes
Aprendizagem

RESUMO

Objetivo: Esta revisão teve como objetivo apresentar os benefícios, em relação à percepção de fala no ruído, que crianças usuárias de aparelho de amplificação sonora individual e/ou implante coclear demonstram com o Sistema de Frequência Modulada (FM) na escola. **Estratégia de pesquisa:** Foi realizado levantamento bibliográfico conduzido em base eletrônica de dados com busca padronizada até o ano de 2012 e busca manual, utilizando palavras-chave específicas. **Critérios de seleção:** Para a seleção e avaliação dos estudos científicos levantados na busca, foram estabelecidos critérios contemplando os aspectos: tipo de estudo, participantes, intervenção adotada e avaliação dos resultados. **Análise dos dados:** Foi possível verificar que o Sistema de FM melhora a percepção de fala e o limiar de fala no ruído, sendo esses resultados encontrados em todos os estudos. **Resultados:** Em relação ao desempenho quanto ao tipo, os melhores resultados foram obtidos quando as crianças utilizavam o Sistema de FM pessoal, seguido pelo de mesa e o campo livre. **Conclusão:** Após a extensa revisão da literatura nacional e internacional, foi possível concluir que os estudos indicam a necessidade de pesquisas voltadas principalmente ao impacto do Sistema de FM no desempenho escolar de crianças usuárias de dispositivos sensoriais acoplados ao Sistema de FM. O que foi encontrado na literatura específica quanto às publicações voltadas à questão da percepção de fala no ruído não relacionaram os aspectos educacionais e auditivos.

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INTRODUCTION

Recent progress in the treatment of children with hearing impairment has enabled the access to the auditory perception of speech sounds for individuals with sensorineural hearing loss, thus providing valuable benefits for communication and quality of life of these people.

Such progress can mostly be seen in sensory devices applied to hearing impairment. Among them, hearing aid devices and cochlear implant (CI) stand out, as well as the Frequency Modulation (FM) systems.

With early diagnosis and the activation of the National Policy of Hearing Health Care[1], implemented in September 2004, many children with hearing impairment gained free access to sensory devices such as the hearing aids and the CI; so, they could go to school and use these devices, which favors the learning process in the school context[2]. Currently, we are living in a new historical moment, with the implementation of the program "*Viver sem Limites*"[3], which is organized in four principles: access to education, social inclusion, health care, and accessibility of people with disabilities in a vulnerable situation, as well as to promote initiatives with the Union, state, and city. According to the National Policy on Special Education[4], the integration between education and school refers to the process of educating — teaching the child both with and without impairment, in the same group, part or full time at school.

When the child has a disability, it is important to ensure access to education. The FM system is seen as an alternative among all support resources used by students with hearing impairment, aiming at assisting the integration between education and school. For some authors, the FM system is the most important and essential educational tool that has ever been developed for people with hearing impairment; regardless of type (personal, self-contained, and free-field), it is the most effective means that favors signal-to-noise ratio, especially in an education environment[5-7].

The benefit regarding speech perception in the school environment of children with hearing impairment wearing sensory devices (hearing aid and CI) together with the FM system is important in school and in studies of the Audiology field.

The current hearing health reality in public services provides better conditions for the development of the auditory function and language among children who received an early diagnosis of hearing impairment; therefore, they have more access to specialized treatment. However, even if these children show good functional performance in terms of hearing and oral language, during their development and when attending school they are faced with many obstacles, such as noise in the classroom, distance between the teacher and the child (speaker-listener), and reverberation in the classroom. These adverse conditions are mostly owed to the large number of students in the same classroom and classrooms with little or no acoustic treatment; besides, teachers in general have little or no prior knowledge regarding hearing impairment. It is estimated that guidance on management and necessary conditions to value the use of sensory devices is also scarce.

These adverse conditions lead to difficulties acquiring academic content, and, in more severe cases, the educational performance is totally harmed.

In this sense, the FM system is an electronic device used for the accessibility of people with hearing impairment, especially in the educational setting. It enables children with hearing impairment who wear sensory devices to perceive the voice of the teacher in the classroom, regardless of distance and noise that is usually generated in classrooms. Therefore, it is considered to be an assistive instrument that is part of the treatment for hearing impairment. This resource is used in school, regardless of age; however, it is potentially addressed to children.

In Brazil, sensory devices (hearing aid and CI) are already made available by the Unified Health System (SUS), and the use of the FM system was an important step toward the academic accessibility of children with hearing impairment since it was included in Recommendation n. 1,274, from June 25, 2013, in the table of Procedures, Medications, Orthoses, Prostheses and Special Materials of SUS[8].

OBJECTIVE

As the essential principle of a study based on evidence, the question of this study's investigation was: does the child with hearing impairment who wears sensory devices (hearing aid and CI) have benefits regarding speech perception in school environment when using the FM system in the classroom?

RESEARCH STRATEGY

The search strategy used in the literature review was oriented by the combination of nine descriptors indexed in the Health Sciences Descriptors (DeCS), in Portuguese and in English; besides, keywords that are not considered to be health sciences descriptors were also used, however, they were used to help the bibliographic survey in the databases. All of the descriptors were used in groups with, at least, two keywords (Chart 1).

The scientific databases chosen for the study were the following: LILACS, MEDLINE, SciELO, *Cochrane Library*, PubMed, EMBASE, *Institute for Scientific Information* (ISI), and *Science Direct*. The manual search was also conducted, with the objective of finding bibliographic references when they were not present in the electronic bases.

SELECTION CRITERIA

This study considered publications produced from 2000 to 2012, and the last search was made in the electronic databases in October 2012.

The selection of articles followed the inclusion criteria based on the agreement of the limits of the topics and the objectives of this study. The adopted criteria were as follows:

- participants: children wearing sensory devices (hearing aids and/or CI) who attended elementary school and high school;

- intervention: studies were selected in case the intervention had been performed by standardized tests, aiming at assessing speech perception of the child wearing hearing aid devices and/or CI together with the FM system;
- measured outcomes: according to categories of interest — results are expressed as percentage of hits in tests of perception and speech intelligibility, by the classification of scales related to the development of hearing skills and description of academic status;
- period: published in the past 12 years (2000–2012);
- language: studies in Portuguese, English, and Spanish; and
- types of study: published in indexed journals with level of evidence 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, and 4, according to the classification from the *Oxford Centre for Evidence-Based Medicine*[9] (Table 1).

DATA ANALYSIS

Studies were selected in three stages, and this process was oriented by the aforementioned criteria. First, three reviewers analyzed all of the studies identified by the combination of the descriptors in all of the proposed databases, by verifying the study title and selecting the ones that presented the predetermined eligibility criteria.

In that stage, it was possible to conduct a manual search of the articles that were not in the electronic databases (first

Chart 1. Searching strategies to consult the databases

Searching strategy – descriptors in Portuguese	Searching strategy – descriptors in English
"Perda Auditiva" and "Criança" and "Aparelhos Auditivos" and "Educação"	"Hearing Loss" and "Child" and "Hearing Aids" and "Education"
"Perda Auditiva" and "Criança" and "Implante Coclear" and "Educação"	"Hearing Loss" and "Child" and "Cochlear Implant" and " Education"
"Criança" and "Aparelhos Auditivos" and "Educação" and "Tecnologia Assistiva"	"Child" and "Hearing Aids" and "Education" and "Assistive Technology"
"Criança" and "Implante Coclear" and "Educação" and "Tecnologia Assistiva"	"Child" and "Cochlear Implant" and "Education" and "Assistive Technology"
"Perda Auditiva" and "Criança" and "Aparelhos Auditivos" and "Educação" and "Ruído"	"Hearing Loss" and "Child" and "Hearing Aids" and "Education" and "Noise"
"Perda Auditiva" and "Criança" and "Implante Coclear" and "Educação" and "Ruído"	"Hearing Loss" and "Child" and "Cochlear Implant" and "Education" and "Noise"
"Criança" and "Amplificação FM"	"Child" and "FM Amplification"
"Criança" and "Amplificação FM" and "Aparelhos Auditivos"	"Child" and "FM Amplification" and "Hearing Aids"
"Criança" and "Amplificação FM" and "Implante Coclear"	"Child" and "FM Amplification" and "Cochlear Implants"
"Criança" and "Sistema FM"	"Child" and "FM System"
"Criança" and "Sistema FM" and "Aparelhos Auditivos"	"Child" and "FM System" and "Hearing Aids"
"Criança" and "Sistema FM" and "Implante Coclear"	"Child" and "FM System" and "Cochlear Implant"
"Perda Auditiva" and "Aparelhos Auditivos" and "Educação" and "Reabilitação de Deficientes Auditivos"	"Hearing Loss" and "Hearing Aids" and "Education" and "Rehabilitation of Hearing Impaired"
"Perda Auditiva" and "Implante Coclear" and "Educação" and "Reabilitação de Deficientes Auditivos"	"Hearing Loss" and "Cochlear Implant" and "Education" and "Rehabilitation of Hearing Impaired"
"Perda Auditiva" and "Aparelhos Auditivos" and "Educação" and "Pessoas com Deficiência Auditiva"	"Hearing Loss" and "Hearing Aids" and "Education" and "Hearing Impaired Persons"
"Perda Auditiva" and "Implante Coclear" and "Educação" and "Pessoas com Deficiência Auditiva"	"Hearing Loss" and "Cochlear Implant" and "Education" and "Hearing Impaired Persons"
"Perda Auditiva" and "Criança" and "Aparelhos Auditivos" and "Educação" and "Docentes"	"Hearing Loss" and " Child" and "Hearing Aids" and "Education" and "Faculty"
"Perda Auditiva" and "Criança" and "Implante Coclear" and "Educação" and "Docentes"	"Hearing Loss" and "Child" and "Cochlear Implant" and "Education" and "Faculty"

Table 1. Levels of scientific evidence according to the classification from the *Oxford Centre for Evidence-Based Medicine*

Levels of evidence	Treatment/prevention - etiology
1A	Systematic review (with homogeneity) of controlled and randomized clinical trials
1B	Controlled and randomized clinical trials with narrow confidence interval
1C	Therapeutic results such as "it is all or nothing"
2A	Systematic review (with homogeneity) of cohort studies
2B	Cohort study (including randomized clinical trials with lower quality)
2C	Observation of therapeutic results (*outcomes research*)/ecological study
3A	Systematic review (with homogeneity) of case-control studies
3B	Case-control study
4	Case reports (including cohort or case-control of lower quality)
5	Opinion without critical evaluation or based on basic subjects (physiological study or study with animals)

stage). Afterwards, in the stage of text selection, abstracts were analyzed regarding the information available about the use of any assessment instrument on the speech perception of children enrolled in the elementary school and high school with the FM system. The full texts were analyzed when the title or the abstract left doubts (second stage). The main data from each selected paper were collected in detail in a standard file used for this study. Articles were fully read (third stage).

The descriptive analysis of the selected publications was performed according to the objectives of the review.

RESULTS

In total, 2,241 papers were identified in all of the electronic databases and in manual searches (Table 2). When these texts were preselected, based on the titles and the abstracts of all of the studies located in the electronic search, 2,233 were excluded; therefore, eight papers were fully read (Table 3).

In Figure 1, it is possible to see a summary of the survey conducted in the electronic databases and in the manual search.

Finally, eight papers met the inclusion criteria. From the articles included in the review, seven studies were classified as being cross-sectional, 2B level of evidence, and one was characterized as a systematic review, classified as level 2A, according to the *Oxford Centre for Evidence-Based Medicine* classification[9] (Table 1).

The systematic review was described in Chart 2 as to the name of authors, title, name of the journal, year of publication, objective of the study, study method and participants, levels of scientific evidence in each study, results, and conclusion.

Table 2. Number of articles identified in the databases and in the manual search

	PubMed	SciELO	Cochrane Library	LILACS	MEDLINE	Science Direct	EMBASE	Institute for Scientific Information	Manual Search	Total
Hearing Loss X Child X Hearing Aids X Education	187	0	0	2	26	177	158	21	–	571
Hearing Loss X Child X Cochlear Implant X Education	190	0	1	2	19	230	93	43	–	578
Child X Hearing Aids X Education X Assistive Technology	11	0	0	0	2	5	8	2	–	28
Child X Cochlear Implant X Education X Assistive Technology	1	0	0	0	0	3	2	1	–	7
Hearing Loss X Child X Hearing Aids X Education X Noise	12	0	0	0	3	56	12	0	–	83
Hearing Loss X Child X Cochlear Implant X Education X Noise	12	0	0	0	1	92	6	2	–	113
Child X FM Amplification	6	1	0	0	2	14	10	8	–	41
Child X FM Amplification X Hearing Aids	0	1	0	0	0	12	9	5	–	27
Child X FM Amplification X Cochlear Implant	0	0	0	0	0	7	4	2	–	13
Child X FM System	1	3	0	0	5	47	0	0	–	56
Child X FM System X Hearing Aids	6	0	0	0	5	28	27	8	–	74
Child X FM System X Cochlear Implant	4	0	0	0	0	32	15	5	–	56
Hearing Loss X Hearing Aids X Education X Rehabilitation of Hearing Impaired	99	1	2	2	18	67	17	5	–	211
Hearing Loss X Cochlear Implant X Education X Rehabilitation of Hearing Impaired	0	0	0	0	0	3	7	3	–	13
Hearing Loss X Hearing Aids X Education X Hearing Impaired Persons	48	0	1	1	12	24	18	1	–	105
Hearing Loss X Cochlear Implant X Education X Hearing Impaired Persons	33	0	0	0	1	34	8	2	–	78
Hearing Loss X Child X Hearing Aids X Education X Faculty	13	0	0	0	1	42	10	0	–	66
Hearing Loss X Child X Cochlear Implant X Education X Faculty	12	0	0	0	0	79	4	0	–	94
Manual Search	0	0	0	0	0	0	0	0	27	26
Total	635	6	4	7	95	952	408	108	26	2.241

Table 3. Reasons to exclude the papers found in each analyzed database and number of papers selected for reading

	PubMed (n=635)	Science Direct (n=952)	LILACS (n=7)	MEDLINE (n=95)	SciELO (n=6)	Cochrane Library (n=4)	EMBASE (n=408)	Institute for Scientific Information (n=108)	Manual search (n=26)	Total
Repeated ones	91	224	1	30	1	0	177	35	0	559
Theme	457	310	6	51	5	4	146	65	9	1.053
Language	0	0	0	6	0	0	12	5	0	23
Literature review	7	3	0	5	0	0	41	3	10	69
Comment	1	0	0	1	0	0	0	0	0	2
Incomplete abstracts	58	407	0	0	0	0	32	0	0	497
Age	12	3	0	0	0	0	0	0	2	17
Case study	4	5	0	2	0	0	0	0	1	12
Recommendation	0	0	0	0	0	0	0	0	1	1
Selected for reading	5	0	0	0	0	0	0	0	3	8

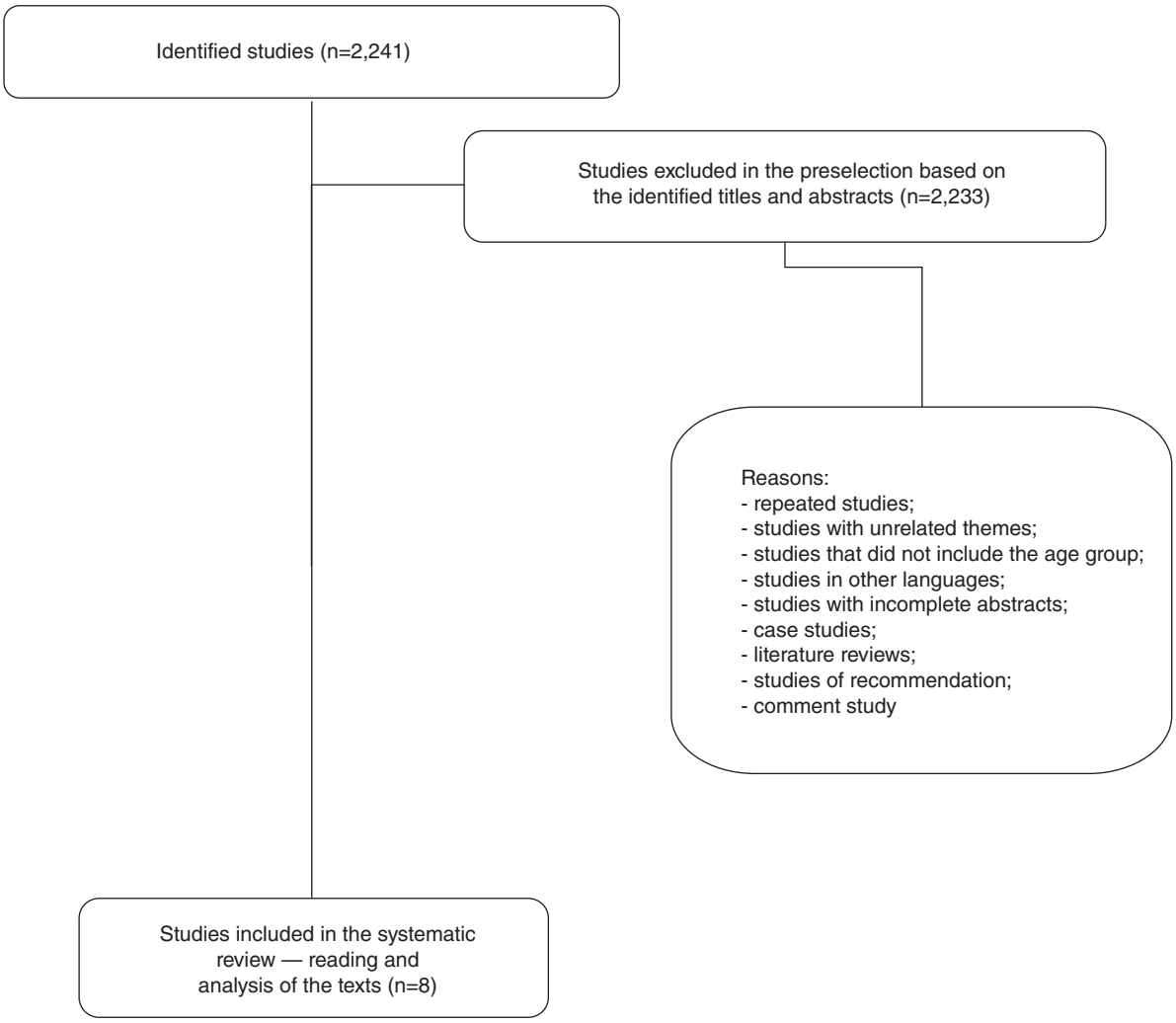

Figure 1. Exclusion criteria of the identified studies

Chart 2. Summary file of the studies included in the systematic review

Author/title/ journal/year	Study location	Objective	Methods/participants	Levels of evidence	Results	Conclusion
Davies et al.[10]. Speech-in-noise perception of children using cochlear implants and FM Systems. The Australian and New Zealand J Audiol. 2001;23(1):52-62.	New Zealand/ Australia	To investigate speech perception in noise among children wearing CI and FM	Cross-sectional study; Fourteen children aged between 7 and 17 years wearing CI and FM	2B	Significant benefit has been observed with FM for the conditions of S/N 0 and 3 dB. There was interaction between the age of the child and the benefit of FM: older children benefitted more from it. Younger children had varied results. A small 3 dB increase in the level of noise had a negative effect on speech perception, and the use of an FM system helped to control these effects for most children	The use of FM provided significant improvement for children in terms of speech perception in noise
Iglehart[11]. Speech perception by students with cochlear implants using sound-field systems in classrooms. Am J Audiol. 2004;13:62-72.	United States	To investigate if free-field FM in the classroom improves speech perception; To verify the effectiveness of the FM system in free field when compared to the desktop FM system , analyzing the performance in acoustically poor and ideal classrooms; To verify if the FM system in free field minimizes noise and reverberation in an acoustically poor classroom	Cross-sectional study Fourteen children (10 boys and 4 girls); Severe to deep bilateral loss; They wear the CI, however, they do not wear the hearing aid device in the contralateral ear; Age of the participants: 6 years and 4 months to 16 years and 1 month	2B	Ideal acoustic room: the speech perception results with each model were: 40% hits without the FM system in free field; 50% hits with the FM system in free field close to the wall, and 45% hits with the desktop FM; Acoustically poor room: 10% hits without the FM system in free field, 23% hits with the FM system in free field close to the wall, and 38% hits with the desktop FM system; Both types of the FM system provided significant benefit for students with CI in relation to the nonuse of the device. This benefit was obtained in the two analyzed environments (acoustically poor and ideal); There was no significant difference in speech perception when using the desktop FM system and the free-field system close to the wall when in the ideal room. In the acoustically poor room, the desktop FM system presented more benefits	The two amplification systems were beneficial to the speech perception of children wearing CI, regarding the nonuse of these devices both in an ideal and in a poor environment. In an ideal room, both systems were similar, and only for the poor environment, the desktop FM system was the most effective one in terms of speech perception due to the proximity of the microphone and the CI
Anderson and Goldstein[12]. Speech perception benefits of FM and infrared devices to children with hearing aids in a typical classroom. Lang Speech Hear Serv Sch. 2004;35:169-84.	United States	To investigate speech perception among children wearing hearing aid devices exposed to noise and reverberation in the classroom; To investigate the three types of amplification technology (free-field system by infrared, desktop FM system, personal FM system) among the same children; To investigate the participants and relatives regarding their favorite technology	Cross-sectional study; Eight children wearing hearing aid devices; Age of the participants: between 9 and 12 years	2B	Participants presented better speech recognition with the three types of amplification system. In a room with noise and reverberation, eight participants aged between 9 and 12 years did not present differences in the results of the free-field FM system by infrared and without hearing aid devices. The benefit of speech perception was clear when the desktop FM system and the personal FM system were used. Participants preferred to use the desktop FM system and the personal FM system in a room with reverberation and noise	According to the authors, children with hearing impairment need to wear the FM system in the classroom, which allows the access to verbal instruction
Anderson et al.[13]. Benefit of S/N enhancing devices to speech perception of children listening in a typical classroom with hearing aids or a cochlear implant. J Educ Audiol. 2005;12:16-30.	United States	To investigate the speech perception skills of children wearing hearing aid devices and/or CI when exposed in classroom with noise and reverberation; To investigate the S/N ratio with the three types of infrared wall technology; desktop FM system and personal FM system among children wearing hearing aid devices or CI; To investigate which is the preference between the three amplification systems; To relate the three previous objectives to different levels of hearing loss (mild to severe); To relate the results obtained in the acoustically ideal and nonideal classroom	Cross-sectional study; Twenty-eight children with mild to severe loss; Three experimental groups: (1) 8 children wearing hearing aid devices: 9–12 years old; (2) 9 children wearing hearing aid devices: 8–14 years old; (3) 11 children: 8 years and 11 months old to 12 years and 11 months old. Of these 11 children, 6 had CI	2B	Group 1: Only hearing aid: 82.4% hits; Infrared: 83.1% hits; Desktop FM system: 93.5% hits; Personal FM system: 94.4% hits. Group 2: Only hearing aid: 87.3% hits; Infrared: 88% hits; Desktop FM system: 92.4% hits; Personal FM system: 92.6% hits. Group 3: Only hearing aid: 77.0% hits; Infrared: 70% hits; Desktop FM system: 87.6% hits; Personal FM system: 91.8% hits. Word recognition: 1) No significant differences were found with the infrared compared to the use of hearing aid devices and CI alone; 2) There was no difference between the benefits coming from desktop and the personal FM system; From the 28, 11 had higher score of speech perception with the free-field FM system when compared to the isolated use of hearing aid devices or CI. The personal FM system had the highest score among the 28 participants	In a normally noisy and reverberating classroom, the isolated use of sensory devices (AASI or IC) is not sufficient, so another device is required (personal FM system).

Continue...

Chart 2. Continuation

Author/title/ journal/year	Study location	Objective	Methods/participants	Levels of evidence	Results	Conclusion
Schafer and Thibodeau.[14]. Speech recognition in noise in children with cochlear implants while listening in bilateral, bimodal, and FM- System arrangements. Am J Audiol. 2006;15:114-26.	United States	To assess the improvement in speech perception in noise provided by the three types of stimulation: bilateral, bimodal, and monaural with the FM system	Cross-sectional study; Twenty-two children were assessed: 12 of them wore sequentially implanted bilateral CI (3 male and 9 female participants) and 10 wore unilateral CI with adaptation of the contralateral hearing aid device (2 male and 8 female participants). Age of the participants: 3–12 years old. All of the children wore the CI before the age of 5 and use the oral language to communicate	2B	Three of the 22 children were able to complete the six testing conditions; The average of speech and noise thresholds without FM was 0 in the S/N ratio, while with the FM system thresholds of up to -15 were reached; the lowest values were up to -5 for the following condition: CI + hearing aid or CI with FM, IC + hearing aid or CI with FM, in which results were better; The average score was similar for both conditions and groups, only with CI and CI + hearing aid device or CI; There was no difference in the thresholds of the S/N ratio for monaural and binaural stimulation, nor regarding bilateral and bimodal stimulation; Speech perception in FM conditions was much better than the same conditions without the FM system in more than 20 dB.	The FM system enables improvements in the S/N ratios of up to 20 dB; Statistically significant differences were detected between the conditions with an FM system, and better when worn in both sides or in the first implanted side
Schafer and Kleineck[15]. Improvements in speech recognition using cochlear implants and three types of FM Systems: a meta-analytic approach. J Educ Audiol. 2009;15:4-14. *	United States	To compare speech recognition in noise among CI users with three types of FM system: traditional free-field, desktop FM and personal FM coupled by DAI	Age of the participants: >18 and <18 years (excluded from this analysis); Intrasubject evaluation — repeated measures (with and without FM system, more than one condition with FM); Randomized listening conditions; Várias listas randomizadas; More than one participant; Speech perception evaluation in noise; Fixed use of the S/R ratio of +5 to +20 dB; Monaural use of CI	2A	Nine cross-sectional studies were analyzed; the minimum age of the children was 4 years, and the maximum age was 18 years. Global results suggest that the three types of FM system significantly improve speech recognition in noise, both for children and adults, regarding the performance without FM. When the three types were compared, the traditional free field did not present benefits in comparison to CI for speech recognition in noise. The desktop FM system and the personal FM system significantly improve the performance in noise, in comparison to CI alone. The personal FM system provides more benefits than other types of FM systems	The authors suggest the indication of the personal FM system coupled by DAI for CI users because this model presents more benefits for speech perception in noise than the other two types of FM system
Jacob et al.[16]. *FM Listening Evaluation for Children*: adaptação para a Língua Portuguesa. Rev Bras Ed Esp. 2009;16(3):359-74.	Brazil	To translate and adapt the questionnaire FM Listening Evaluation for Children to Portuguese and to assess its reliability	Cross-sectional study; Translation to Portuguese, linguistic adaptation and revision of grammatical and idiomatic equivalence, as well as cultural adaptation; The questionnaire was used with 12 professors and 1 speech language pathologist of 12 children aged from 7–13 years old, with hearing impairment, wearing hearing aid devices, and adapted for the FM system	2B	The translation and the adaptation of the questionnaire resulted in the new inventory: *Avaliação do Sistema FM,* presenting significant differences between the results of noise and auditory path and silence; Distance and auditory path and silence; Auditory path and noise, distance and silence; Silence and noise and auditory path; There was significant difference without and with the FM system; the latter always showed lower score; In the intraresearcher comparison, it was possible to see significant difference between: total score with FM; auditory path without FM and noise with FM; there was no correlation with age	The questionnaire *Avaliação do Sistema FM* was considered to be a reliable instrument to verify the follow-up of the benefits from the FM system
Jacob et al. [17]. Sistema de frequência modulada em crianças com deficiência auditiva: avaliação de resultados. Rev Soc Bras Fonoaudiol. 2012;17(4):417-21.	Brazil	To assess the speech perception of children with hearing impairment wearing hearing aid devices and FM system in situations of noise in free field and in the classroom	Cross-sectional study; Thirteen children with hearing impairment aged between 7 and 17 years old; HINT was applied with the hearing aid device and with the FM System; The questionnaire *Avaliação do Sistema FM*, was answered by the children's teachers to perform an individual evaluation of the children's performance in different hearing situations only wearing the hearing aid device and with the hearing aid device and the FM system	2B	There were differences for all of the situations with and without a FM system in the HINT. The same was true for the results of the questionnaire; without the FM, the score was always lower than with the FM, regardless of the condition	The use of subjective methods, like the questionnaire, is essential to determine the efficacy of the indication of auxiliary devices for the person with hearing impairment. The effectiveness of the FM system can be observed by the "FM advantage," which is the minimal mean difference of 10 dB found in the speech perception evaluations with and without FM in the different noise situations

*Systematic review and meta-analysis

Caption: CI = cochlear implant; FM = frequency modulation; S/N = signal/noise; DAI = direct audio input; HINT = Hearing in Noise Test

SUMMARY OF FINDINGS

On the basis of the analysis of the studies, it was possible to identify the reasons for the exclusion of articles; they were not fully analyzed for being repeated, or for presenting non-related themes, for not including the studied age group, for being in another language, among others. Out of the eight studies that were selected for the systematic review, three included only the population wearing CI: studies number 1, 2, and 6. Study number 1 investigated speech perception in noise among children wearing CI together with the FM system, and study number 2 investigated speech perception, noise, and reverberation with a single FM system (free field) in two situations that were acoustically different in the school environment (ideal and poor acoustics). In study number 6, through a systematic review and a meta-analysis, the authors verified if the three types of FM system provide better speech recognition in noise than the CI alone.

The analysis of the selected articles showed that study number 3 investigated speech perception, noise, and reverberation only among children wearing hearing aid devices, by using three types of technology (infrared, desktop FM, and personal FM).

Two other articles analyzed both users of hearing aid devices and CI. Study number 4 investigated speech perception among users of CI and/or hearing aid devices exposed in acoustically poor and ideal rooms, using three types of technology from the FM system (infrared, desktop FM, and personal FM). Study number 5 assessed the improvement in speech perception in noise provided by the three types of stimulation (bilateral, bimodal, and monaural) among users of hearing aid devices and/or CI together with the FM system. Studies number 7 and 8 only assessed children wearing hearing aid devices.

Regarding the evaluations performed in the studies in relation to speech perception in noise, it was possible to observe that six of them evaluated speech perception in noise (studies number 1, 3, 5, 6, 7, and 8) and two of them compared the speech perception in acoustically different environments: one that was acoustically poor and the other that was acoustically ideal (studies number 2 and 4).

From the articles that were fully analyzed, studies number 1, 5, 7, and 8 only assessed the performance with the personal FM system, and the other studies analyzed the following three types of FM: free field, desktop FM, and personal FM, comparing their results.

The analysis of the papers regarding the type and level of evidence of each of them showed that only study number 6 was considered to be a systematic review and a meta-analysis with 2A level of evidence, and the rest of the studies were considered to be cohort, with 2B level of evidence, according to the classification from the *Oxford Centre for Evidence-Based Medicine*[9] (Table 1).

CONCLUSION

It was possible to verify that the FM system improves speech perception and speech threshold in noise, and these results were found in all of the papers. Concerning the performance with relation to the type of FM system, the best results were obtained when children were wearing personal FM system, followed by desktop FM system and free field.

After a national and an international literature review, it was possible to conclude that studies indicate the need for analyses addressed to the impact of FM system on school performance of children who wear sensory devices together with the FM system because the findings in the eight papers analyzed in this study were addressed to the matter of speech perception in noise.

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