

Newborn hearing screening programs: integrative review on the effectiveness of early diagnosis of hearing loss

Programas de triagem auditiva neonatal: revisão integrativa sobre a efetividade no diagnóstico precoce da perda auditiva

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ABSTRACT

Purpose: To identify in the literature the effectiveness, efficiency, and impact of neonatal hearing screening (NHS) services in the early detection of hearing loss (HL) in newborns, considering different global socioeconomic contexts. **Research strategy:** The search was conducted in the BVS, SciELO, and PubMed databases, using descriptors and Boolean operators according to the PICO strategy. Two reviewers selected the studies in two phases: screening of titles/abstracts and full-text reading. **Selection criteria:** Included studies were those published between 2010 and 2024, in Portuguese, English, or Spanish, that evaluated or described NHS programs (NHSP). Exclusion criteria comprised studies that did not mention the diagnostic stage, especially those that did not report the mean age at diagnosis, as well as reviews, theses, dissertations, book chapters, and restricted-access articles. In total, 30 studies were included from 1,202 identified. Data extraction followed NHS guidelines and was systematized according to Donabedian's triad: structure, process, and outcome. Analysis was performed using Excel software, through percentage-based calculations. **Results:** A minority of NHSP presented an integrated database, and discrepancies were observed in screening protocols. Shortages of services, professionals, and equipment were evident. While some studies reported satisfactory coverage, high dropout rates were noted. Few studies addressed interventions. **Conclusion:** NHSP present structural, procedural, and outcome-related limitations, particularly in developing countries. Delayed completion was observed in all stages of NHS, reinforcing the need to strengthen public policies, invest in protocol standardization, expand coverage, and establish unified databases.

Keywords: Health services; Newborn; Hearing; Public health programs; Health care quality indicators

RESUMO

Objetivo: Identificar na literatura a eficácia, eficiência e impacto dos serviços de triagem auditiva neonatal (TAN) na detecção precoce da perda auditiva em recém-nascidos, considerando diferentes contextos socioeconômicos globais. **Estratégia de pesquisa:** A busca foi realizada nas bases BVS, SciELO e PubMed, usando descritores e operadores booleanos conforme estratégia PICO. Dois revisores selecionaram os estudos em duas etapas: leitura de títulos/resumos e leitura integral dos artigos. **Crerios de seleo:** Incluíram-se estudos publicados entre 2010 e 2024, em português, inglês e espanhol, que avaliaram ou descreveram programas de triagem auditiva neonatal (PTAN). Foram excluídos textos sem menção à etapa de diagnóstico, sobretudo os que não referiam a média de idade de sua ocorrência, além de revisões, teses, dissertações, capítulos de livros e artigos com acesso restrito. Ao todo, 30 estudos foram incluídos, de 1202 identificados. A extração seguiu as diretrizes da triagem auditiva neonatal e foi sistematizada conforme a Triade de Donabedian: estrutura, processo e resultado. A análise foi realizada por meio do *software* Excel, utilizando cálculos de porcentagem. **Resultados:** A minoria dos PTAN apresentou banco de dados unificado e houve divergência nos protocolos de triagem. Evidenciou-se a falta de serviços, profissionais e equipamentos. A cobertura foi satisfatória em parte dos estudos, mas houve elevada evasão. Poucos estudos abordaram intervenções. **Conclusão:** Os programas de triagem auditiva neonatal apresentam limitações em estrutura, processo e resultados, especialmente nos países em desenvolvimento. Houve conclusão tardia em todas as etapas da triagem, reforçando a necessidade de fortalecer políticas públicas, investir na padronização de protocolos, expansão da cobertura e em bancos de dados unificados.

Palavras-chave: Serviços de saúde; Recém-nascido; Audição; Programas de saúde pública; Indicadores de qualidade em assistência à saúde

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INTRODUCTION

Universal Newborn Hearing Screening (UNHS) is the first step in guaranteeing early intervention in hearing loss (HL) during childhood. Tests like Evoked Otoacoustic Emissions (EOAE) and Automated Auditory Brainstem Response (AABR) allow keeping track of possible hearing losses in children, used for subsequent diagnosis confirmation and intervention⁽¹⁾.

In Brazil, UNHS's guidelines suggest applying this procedure in two protocols: one for children with Risk Indicators for Hearing Loss (RIHL) and another for children without these indicators. Additionally, these guidelines postulate a determined time for applying each step of the UNHS, with screening tests being done within the first month since birth, diagnosis until the third month and intervention no later than the sixth month⁽²⁾.

However, literature shows that Newborn Hearing Screening Programs (NHSP) have some difficulties in regards to reaching the determined times for treatment, be it for high evasion levels^(3,4), due to a shortage of services that perform

Newborn Hearing Screening (NHS)⁽⁵⁻⁸⁾, or, still, for the insufficient number of phonoaudiology professionals and equipments needed to perform NHS⁽⁹⁾, among other reasons.

As a means of assuring that NHSP reach and improve their results, the guideline states that these programs should be evaluated based on quality indicators⁽²⁾. A myriad of studies intended on evaluating UNHS's services based on these indicators, aiming, through evaluation, finding out the main issues and obstacles aiming on overcoming them.⁽⁹⁻¹¹⁾ NHSP should promote complete access to a child's hearing health; screening tests are only the first step, and cases with negative results must lead to early diagnosis and intervention.⁽¹⁾

Studies show that audiological diagnosis tends to occur later than recommended.⁽¹²⁻¹⁴⁾ This shows the importance of highlighting studies related to early diagnosis issues. If it's not performed in children who fail UNHS' tests, the screening renders itself senseless, besides affecting the cost-effectiveness relation, whose initial investment for screening tests ends up lost⁽¹¹⁾.

OBJECTIVES

This study's goal is to identify how literature presents the effectiveness, efficiency, and impact of neonatal hearing screening services on the early detection of hearing loss in newborns (NB), discerning different socioeconomic global backgrounds, answering the question: "What evidence does literature provide on the effectiveness, efficiency, and impact of neonatal hearing screening services in the early detection of hearing loss in newborns?". It aims to show via scientific records the outcome of children's cases who failed the UNHS' tests, which could bring to light new strategies and solutions to reimagine and re-structure NHSP's so they can reach their goal.

RESEARCH METHODOLOGY

The investigation was elaborated based on an integrative literature review, a specific methodological approach that goes beyond merely describing evidence, allowing for the development of new discussions and insights on the topic

through integration and/or critique⁽¹⁵⁾ which, following the structure proposed by the authors of a previous review⁽¹⁶⁾, encompasses five steps for elaboration, four of which were applied in this study: problem assessment, literature search, data analysis and results' display.

The methodological structure, besides following the aforementioned four steps, also includes the guide *Centre for Reviews and Dissemination* (CRD), used in healthcare revisions⁽¹⁷⁾, a procedure commonly applied in systematic reviews which aims increasing robustness and reducing bias. This review is registered under protocol number CRD42024578022.

Literature research was based on the "PICO" acronym (Patient, Intervention, Comparison and Outcomes⁽¹⁸⁾), with "P" encompassing: newborns and infants; "I": newborn hearing screening and early audiological diagnosis in infants; "C": not applied; and "O": NHSP's services, effective or not. Based on the research problem, the acronyms were correlated and, from the answers, the headings to be used in the search strategy were obtained.

It was opted to utilize the databases PubMed, SciELO, and Virtual Health Library (VHL), which encompasses different databases such as LILACS, MEDLINE, MEDCARIB, PAHO-IRIS, WHOLIS, among others. Search strategies were adapted to each database, utilizing a combination of headings obtained from Descritores em Ciências da Saúde/ Medical Subject Headings - DeCS/MeSH, keywords and boolean operators (Figure 1)

SELECTION CRITERIA

The following insertion criteria were applied: scientific articles that evaluated or described NHS' services; complete scientific papers published from 2010 to 2024 (due to the temporal cutoff imposed by the legislation mandating NHS in Brazil, enacted in 2010) and written in portuguese, english or spanish. Texts that did not mention the diagnostic stage, particularly those that did not report the average age at which it occurred, as well as reviews, theses, dissertations, book chapters, and articles with restricted access were used as exclusion criteria. After this procedure, the research strategy was applied on the databases, gathering results through the fluxogram *Preferred Reporting Items for Systematic Reviews in Meta-Analyses* (PRISMA)⁽²⁰⁾, which is a flowchart describing the different revision's steps, mapping both included and excluded studies, as well as the reasons for said exclusion⁽²¹⁾. The eligibility of the identified studies was assessed independently and in a standardized manner by two reviewers in two stages.

The first step consisted in reading the articles' titles and summaries and, secondly, complete reading. By the end of this process, each selected scientific paper was compared by each author. Disparities were debated until the result was reached as Figure 1 shows. *Rayyan* reference manager was used to streamline the process.

Data were extracted via form (Appendix A) containing quality indicators for NHS services presented by the Multiprofessional Committee on Hearing Health and the Joint Committee on Infant Hearing^(1,22).

In order to validate the form, a pilot data collection was conducted by two researchers, who extracted data from a sample of the selected articles. Then, for each article in the sample, the data extracted by the researchers were then compared.

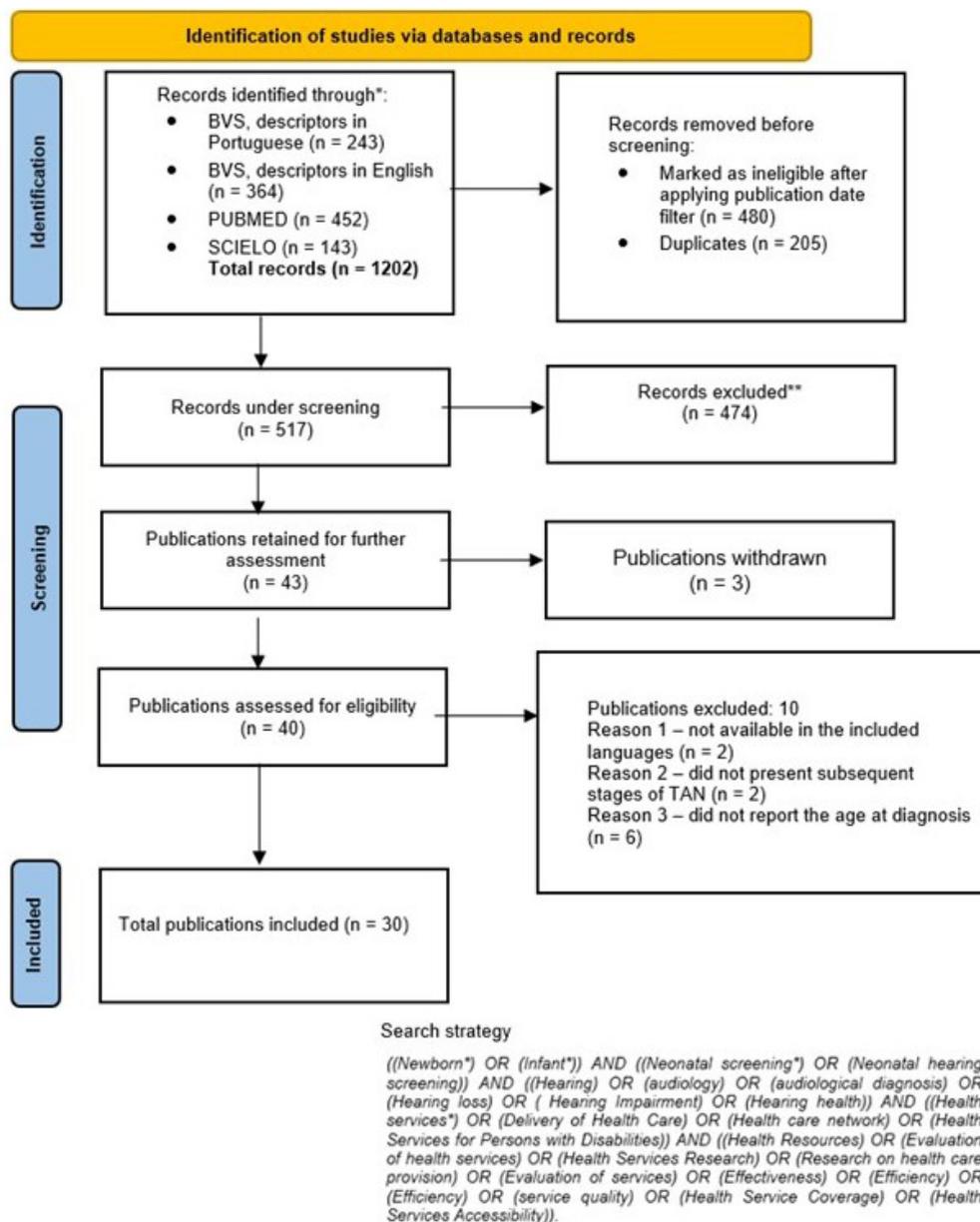


Figure 1. Literature search results and search strategy

This allowed for an analysis of whether there was homogeneity in the extraction and an ability assessment of the collected data to address the review objectives. As the extractions were similar, the examination proceeded, and only the lead author was responsible for completing the data extraction.

DATA ANALYSIS

After the data collection was completed, it was grouped into analytical categories based on Donabedian’s Triad⁽²³⁾, which serves as an approach to assess healthcare performance, consisting of structure, process, and outcome. Subsequently, data was compared so that conclusions could be drawn from each subgroup, with a description and discussion of patterns, differences, and similarities. Finally, the analysis stage reached an end with a synthesis of the findings.

Winding up the review, the results were presented, in which the evidence supports the conclusions, thereby contributing to a new understanding of the topic and aiming at practical and policy applicability regarding the organization and operation of NHS services, which allows scholar literature to identify strengths, problems, and their possible solutions, as well highlighting gaps that require further investigation.

RESULTS

The included scientific articles are presented in Chart 1, which shows that the studies were conducted in various parts of the world, nine of them being focused on Brazil’s NHSP, four from the United States of America (USA), two from South Korea, and two from South Africa. The remaining studies corresponded to one study each from Spain, England, Japan,

Chart 1. Selected papers' characteristics

| Title | Reference | Analyzed Region | Objectives | Methodology |
|--|-------------------------------------|--|---|---|
| Children's Hearing Health Panorama in the Unified Health System in the state of Sergipe | Duarte et al. ⁽²⁴⁾ | State of Sergipe, Brazil | Describe the panorama of pediatric hearing health within SUS in the state of Sergipe. | Quantitative, retrospective, cross-sectional, analytical study |
| Access to pediatric hearing healthcare in Rio Grande do Norte, Brazil | Dutra et al. ⁽¹⁴⁾ | State of Rio Grande do Norte, Brazil | Evaluate access to pediatric hearing health services and the factors influencing access. | Cross-sectional study with secondary data analysis |
| Newborn hearing screening programs: quality indicators and access to health services | Dutra et al. ⁽²⁵⁾ | State of Rio Grande do Norte, Brazil | Assess the quality indicators of neonatal hearing screening programs and analyze access to the Hearing Health Care Network. | Cross-sectional study using secondary data |
| Analysis of an outpatient pediatric hearing health program: from screening to referral for rehabilitation | Botasso et al. ⁽²⁶⁾ | Mogi Mirim, SP, Brazil | Analyze the stages of a hearing health program, from screening to referral for rehabilitation. | Cohort study, observational and retrospective |
| Audiological diagnostic process for infants following a failed newborn hearing screening | Galvão et al. ⁽²⁷⁾ | São Paulo, SP, Brazil | Examine the audiological diagnostic process in infants who failed newborn hearing screening. | Quantitative, descriptive, observational study |
| Newborn hearing screening in the process of auditory diagnosis and rehabilitation | Pagnossim et al. ⁽²⁸⁾ | Northern catarinense shore, Brazil | Describe the role of newborn hearing screening in the process of auditory diagnosis and rehabilitation. | Questionnaire application with descriptive and inferential statistical analysis |
| Early detection of neonatal hearing loss by otoacoustic emissions and auditory brainstem response over 10 years of experience | Escobar-Ipuz et al. ⁽²⁹⁾ | Hospital Virgen de la Luz, Cuenca, Spain | Present 10 years of experience using ABR as a complement to OAE in newborn hearing screening. | Retrospective data collection from medical records |
| Performance and characteristics of the Newborn Hearing Screening Programme in England: The first seven years | Wood et al. ⁽³⁰⁾ | England | Evaluate the performance of universal newborn hearing screening in England. | Retrospective analysis of population screening records |
| Newborn Hearing Screening and Follow-up: Are Children Receiving Recommended Services? | Gaffney et al. ⁽³¹⁾ | USA | Summarize the findings of hearing screening and follow-up research from the centers for disease control and prevention. | Analysis of totalled screening and diagnostic data |
| Analysis of Newborn Hearing Screening Results in South Korea after National Health Insurance Coverage: A Nationwide Population-Based Study | Choi et al. ⁽³²⁾ | South Korea | Analyze the situation and referral rates for NHS following health insurance coverage. | Analysis of national big data from the national health insurance service |
| Analysis of the effectiveness of coupon-mediated newborn hearing screening program through comparison of two government-funded pilot projects in South Korea | Park et al. ⁽³³⁾ | South Korea | Compare the outcomes of two government-funded pilot NHS programs. | Retrospective analysis of NHS database |
| Outcomes of regional-based newborn hearing screening for 35,461 newborns for 5 years in Akita, Japan | Sato et al. ⁽³⁴⁾ | Akita, Japan | Summarize the results of NHS in Akita Prefecture. | Analysis of NHS results data |
| Follow-Up Results of Newborns after Hearing Screening at a Training and Research Hospital in Turkey | Yılmaz et al. ⁽³⁵⁾ | Turkey | Present the follow-up results of newborns after newborn hearing screening. | Cross-sectional study with screening data analysis |
| Influence of the WIC Program on Loss to Follow-up for Newborn Hearing Screening | Hunter et al. ⁽³⁶⁾ | Hamilton e Butler, Ohio, USA | Test a targeted outpatient re-screening intervention to improve follow-up rates. | Controlled intervention study |
| Universal Neonatal Hearing Screening Program in Poland – 10-year summary | Greczka et al. ⁽³⁷⁾ | Poland | Summarize and discuss the results of the Neonatal Hearing Screening Program in Poland. | Retrospective analysis of program data |

Subtittle: SUS = United Healthcare System; NHS = Newborn Hearing Screening; NHSP = Newborn Hearing Screening Program; UNHS = Universal Newborn Hearing Screening; OAE = Otoacoustic Emissions; ABR = Auditory Brainstem Response

Chart 1. Continued...

| Title | Reference | Analyzed Region | Objectives | Methodology |
|--|--------------------------------------|---|---|---|
| Conductive Hearing Loss and Middle Ear Pathology in Young Infants Referred through a Newborn Universal Hearing Screening Program in Australia | Aithal et al. ⁽³⁸⁾ | Queensland, Australia | Assess the prevalence of conductive hearing loss and middle ear pathology in referred infants. | Retrospective review of medical records |
| Efficacy of a community-based infant hearing screening program utilizing existing clinic personnel in Western Cape, South Africa | Friderichs et al. ⁽³⁹⁾ | Western Cape, South Africa | Evaluate the first systematic community-based pediatric hearing screening program. | Cross-sectional study with assessment of coverage and follow-up rates |
| Newborn hearing screening in a developing country: Results of a pilot study in Abidjan, Côte d'Ivoire | Tanon-Anoh et al. ⁽⁴⁰⁾ | Abidjan, Ivory Coast | Investigate the feasibility of newborn hearing screening in infants. | Cross-sectional study using a two-step strategy |
| Delays in Diagnosis of Congenital Hearing Loss in Rural Children | Bush et al. ⁽⁴¹⁾ | Kentucky, USA | Examine the incidence of congenital hearing loss and the timing of diagnosis in a rural region. | Retrospective analysis of screening program data |
| Receipt and Timeliness of Newborn Hearing Screening and Diagnostic Services Among Babies Born in 2017 in 9 States | Deng et al. ⁽⁴²⁾ | 9 states from the USA | Examine the timing of key events in the early hearing detection and intervention process, from birth to diagnosis. | Retrospective and cross-sectional study |
| Assessing and monitoring the impact of the national newborn hearing screening program in Israel | Wasser et al. ⁽⁴³⁾ | Israel | Review NHSP coverage and evaluate its impact on the age at diagnosis and intervention. | Analysis of demographic data and interviews |
| From Neonatal Hearing Screening to Intervention: Results of the Dutch Program for Neonatal Hearing Screening in Well Babies | Uilenburg et al. ⁽⁴⁴⁾ | The Netherlands | Describe the structure and performance of NHS provided by health services for young people. | Analysis of monitoring report data |
| Limitations and drawbacks of the hospital-based universal neonatal hearing screening program: First report from the Arabian Peninsula and insights | Kolettchekkat et al. ⁽⁴⁵⁾ | Oman | Evaluate the effectiveness of the Newborn Hearing Screening Program in a tertiary hospital. | Retrospective review and interviews |
| National survey of paediatric audiological services for diagnosis and intervention in the South African private health care sector | Meyer et al. ⁽⁴⁶⁾ | South Africa | Describe the current status of diagnostic and intervention services in the private sector. | National-level survey by telephone and questionnaires |
| Hearing assessment after referral in universal newborn hearing screening | Galvão and Lewis ⁽⁴⁷⁾ | São Paulo, SP, Brazil | Study the audiological diagnostic process of infants who failed UNHS. | Medical record analysis and follow-up contact attempts |
| Universal newborn hearing screening program in a university hospital: analysis through the application of quality indicators | Avila et al. ⁽⁴⁸⁾ | Hospital das Clínicas de Porto Alegre, Brazil | Assess the Newborn Hearing Screening Program using quality indicators. | Retrospective analysis of records |
| Does newborn hearing screening anticipate diagnosis and intervention in children with hearing loss? | Rodrigues et al. ⁽¹²⁾ | Jundiaí, SP, Brazil | Identifying age at diagnosis and intervention in children with hearing loss. | Retrospective analysis of medical records |
| Quality indicators of the Early Detection Program for Permanent Hearing Loss at Padre Hurtado Hospital | Bravo et al. ⁽⁴⁹⁾ | Santiago, Chile | Report the results of the Early Hearing Loss Detection Program. | Analysis of newborn data |
| Initial results from the newborn hearing screening programme in Ireland | O'Connor et al. ⁽⁵⁰⁾ | Ireland | Review the results from the first year following program implementation. | Prospective collection of screening data |
| Newborn hearing screening in Eastern Saudi Arabia A tertiary hospital experience | Sulaiman ⁽⁵¹⁾ | Saudi Arabia | Evaluate the effectiveness of NHS in a renowned institution, focusing on identifying shortcomings in program practice and the prevalence of sensorineural hearing loss in Saudi Arabia. | Retrospective observational study with descriptive analysis |

Subtitle: SUS = United Healthcare System; NHS = Newborn Hearing Screening; NHSP = Newborn Hearing Screening Program; UNHS = Universal Newborn Hearing Screening; OAE = Otoacoustic Emissions; ABR = Auditory Brainstem Response

Turkey, Poland, Australia, Ivory Coast, Israel, the Netherlands, Oman, Chile, Ireland, and Saudi Arabia.

The results obtained for the first approach to health service evaluation of Donabedian’s Triad - the structure - are presented in Table 1. It was observed that only a minority of the studied NHS programs had a national database for UNHS, with service-specific databases being most common. Regarding screening protocols, it was found that there was no standardization, meaning that the NHSP used various screening formats. Finally, most studies showed that the NHS programs evaluated did not have sufficient professionals or equipment to meet their demand. It is important to note that a significant portion of the studies did not provide information related to structural aspects. It was observed that 10% of the studies did not report the existence of a service database or the NHS protocol used, while 33.33% did not mention the sufficiency of equipment and services in relation to the demand. In addition, 26.67% limited the analysis to a single service location, without assessing regional coverage, which compromises results’ notions. Regarding access to intervention, 56.67% did not provide data, 3.33% mentioned only the availability of Personal Sound Amplification Products (PSAP), and 40% reported access to both PSAPs and cochlear implants (CI).

The data regarding the second approach to health service evaluation - the process - are presented in Table 2. Regarding coverage, less than half of the studied NHSP presented UNHS coverage within the recommended range, and the fact that many studies do not present data on NHS coverage is noteworthy. The diagnostic referral rate reached the values recommended by the literature in little more than half of the studies.

Concerning intervention, the majority of studies (93.33%) did not mention the moment when phonoaudiological therapy was initiated with children identified with HL. It is important to highlight that a significant portion of the studies did not provide information regarding certain aspects of the process. In 26.67% of the articles, neither coverage rates nor diagnostic referral rates were reported, while 13.33% did not present data regarding attendance for diagnosis and dropout rates.

The last approach for evaluating health services - the outcome - is shown in Table 3. It is highlighted that the average age for the conclusion of the screening tests in the UNHS process should be up to 1 month after birth. Of the studies present in this literary review, half reached this mark, while 20% did not reach it and 30% did not report it. Regarding the average age for the conclusion of the diagnosis, only 30% reached the recommended standard, and for the average age of intervention, 13.33% concluded within the appropriate time, while 40% showed a delay in intervention and 46.67% did not present data on the start of the intervention.

Table 4 presents data regarding outcomes between developing and developed countries for comparison. The following countries were considered developed: Spain, England, the USA, South Korea, Japan, Australia, Israel, the Netherlands, Ireland, and Saudi Arabia. The developing countries consisted of: Brazil, Turkey, Poland, South Africa, Ivory Coast, Oman, and Chile. Significant differences were observed in the outcomes reported by developed countries compared to developing countries.

Table 5 presents the results from Brazil, organized in comparison with other developing countries. It’s noteworthy that Brazil has a poorer performance compared to other developing countries.

Table 1. Structure of the Newborn Hearing Screening Programs studied in the primary scientific articles

| Database | Protocol | Equipments and Personnel | Amount of Services | Access to Intervention | | | | | |
|---------------------------|----------|--------------------------|--------------------|------------------------|--------|----------------------|--------|---------------|--------|
| Not reported | 13.33% | Not available | 6.67% | Insufficient | 53.33% | Insufficient | 30% | Not available | 0% |
| National database | 26.67% | OAE | 30% | Sufficient | 13.33% | Sufficient | 10% | PSAP | 3.33% |
| Service-specific database | 40% | AABR | 13.33% | Not reported | 33.33% | Region not evaluated | 26.67% | PSAP + CI | 40% |
| Incomplete database | 10% | OAE+ AABR | 40% | | | Not reported | 33.33% | Not mentioned | 56.67% |
| Not mentioned | 10% | Not available | 10% | | | | | | |

Results obtained through percentage calculations in Excel software

Subtitle: OAE = Otoacoustic Emissions; AABR = Automated Auditory Brainstem Response; PSAP = Personal Sound Amplification Products; CI = Cochlear Implant

Table 2. Process of the Newborn Hearing Screening Programs studied in the primary scientific articles

| Coverage | Diagnosis referral | Diagnosis attendance | Phonoaudiological Therapy Onset | Dropout Rates | | | | | |
|---------------|--------------------|----------------------|---------------------------------|---------------|--------|----------------------------------|--------|---------------|--------|
| Under 95% | 33.33% | Over 4% | 16.67% | Under 90% | 60% | Late onset | 3.33% | Over 10% | 63.33% |
| Over 95% | 40% | Under 4% | 56.67% | Over 90% | 26.67% | Immediately post-diagnosis onset | 3.33% | Under 10% | 23.33% |
| Not mentioned | 26.67% | Not mentioned | 26.67% | Not mentioned | 13.33% | Not mentioned | 93.33% | Not mentioned | 13.33% |

Results obtained through percentage calculations in Excel software

Table 3. Outcomes of the Newborn Hearing Screening Programs studied in the primary articles

| Average age at screening completion | Average age at diagnosis conclusion | Average age at intervention onset | | | |
|-------------------------------------|-------------------------------------|-----------------------------------|-----|----------------|--------|
| Over 1 month | 20% | Over 3 months | 70% | Over 6 months | 40% |
| Under one month | 50% | Under 3 months | 30% | Under 6 months | 13.33% |
| Not mentioned | 30% | | | Not mentioned | 46.67% |

Results obtained through percentage calculations in Excel software

Table 4. Outcomes of the Newborn Hearing Screening Programs divided by developed and developing countries

| NHS results in developing countries | | | | | | | |
|-------------------------------------|--------|-------------------------------------|--------|-------------------------------------|-------|-----------------------------------|--------|
| Database | | Average age at screening completion | | Average age at diagnosis conclusion | | Average age at intervention onset | |
| Not available | 25% | Over 1 month | 18.75% | Over 3 months | 87.5% | Over 6 months | 62.5% |
| National database | 12.5% | Under 1 month | 31.25% | Under 3 months | 12.5% | Under 6 months | 0% |
| Service-specific database | 31.25% | Not mentioned | 50% | | | Not mentioned | 37.5% |
| Incomplete database | 12.5% | | | | | | |
| Not mentioned | 18.75% | | | | | | |
| NHS results in developed countries | | | | | | | |
| Not available | 0% | Over 1 month | 21.42% | Over 3 months | 50% | Over 6 months | 14.28% |
| National database | 42.85% | Under 1 month | 71.42% | Under 3 months | 50% | Under 6 months | 28.57% |
| Service-specific database | 50% | Not mentioned | 7.14% | | | Not mentioned | 57.14% |
| Incomplete database | 7.14% | | | | | | |
| Not mentioned | 0% | | | | | | |

Results obtained through percentage calculations in Excel software

Subtitle: NHS = Newborn Hearing Screening

Table 5. Outcomes of the Newborn Hearing Screening Programs in Brazil and other developing countries

| NHS Results - Brazil | | | | | |
|--|--------|-------------------------------------|--------|-----------------------------------|--------|
| Average age at screening completion | | Average age at diagnosis conclusion | | Average age at intervention onset | |
| Over 1 month | 22.22% | Over 3 months | 100% | Over 6 months | 66.66% |
| Under 1 month | 22.22% | Under 3 months | 0% | Under 6 months | 0% |
| Not mentioned | 55.55% | | | Not mentioned | 33.33% |
| NHS Results – Other developing countries | | | | | |
| Average age at screening completion | | Average age at diagnosis conclusion | | Average age at intervention onset | |
| Over 1 month | 14.28% | Over 3 months | 71.42% | Over 6 months | 57.14% |
| Under 1 month | 42.85% | Under 3 months | 28.57% | Under 6 months | 0% |
| Not mentioned | 42.85% | | | Not mentioned | 42.85% |

Results obtained through percentage calculations in Excel software

Subtitle: NHS = Newborn Hearing Screening

Source: Adapted from Page et al.⁽¹⁹⁾

DISCUSSION

Results' analysis regarding the first approach to health service evaluation of Donabedian's Triad - structure - (Table 1), it is worth noting that among the 30 selected articles, 26.67% of NHSP had a national database for UNHS data, 40% had a service-specific database, 13.33% had no records, 10% had a database but it was incomplete and 10% did not mention the existence of a database. This creates problems in the follow-up of these children and in the evaluation of NHSPs, as data on screening, diagnosis, and intervention are often lost and test results remain inaccessible to professionals, complexifying diagnostic processes and delaying early intervention for HL. Furthermore, a study⁽⁵²⁾ has shown that a unified database allows determining the prevalence and incidence of pediatric hearing loss, especially in Brazil, given that epidemiological studies on newborn hearing loss are still lacking, highlighting the importance of efforts to establish a unified database in the country.

It was found that the protocol used for UNHS varied among the studies, with 40% of the NHSPs employing otoacoustic emissions (OAE) combined with automated auditory brainstem response (AABR), which is considered the most appropriate protocol according to international organizations⁽⁵³⁾, while 30% of the programs used only the OAE test. Among these

30%, corresponding to nine studies, six were published from 2020 onward, indicating that these are recent analyses and ruling out the possibility that this significant proportion is represented solely by older studies, from a time when AABR was not yet a widely implemented test. Furthermore, none of the studies focused exclusively on the population without risk indicators for hearing loss (RIHL), which could justify the use of OAE alone. Scholar literature emphasizes the importance of NHSPs following a similar protocol to ensure standardization and efficiency in the screening, diagnosis, and intervention process for HL⁽⁵³⁾.

Another relevant finding regarding structure is that 13.33% of the NHSPs had sufficient equipment and professionals to meet the demand, while 53.33% lacked adequate resources to meet the needs of their regions, and 33.33% of the studies did not address this sufficiency or lack thereof, which hindered the evaluation of this item. Among the studies that analyzed more than one program, such as those covering a region or country, 30% reported that the facilities available to perform UNHS were insufficient to meet the demand; of these 30%, 26.67% evaluated only a single service, and in those cases, it was not verified whether it met the needs of a region or country. Also, 33.33% did not mention data regarding the amount of available services and only 10% reported having a sufficient number of locations to meet the demand.

The presented data demonstrates the need for further studies that take these structural aspects into account when evaluating NHSPs, given the impact that the lack of professionals, hearing screening and audiological diagnostic services, as well as equipment to perform such tests have on the coverage and completion time of the UNHS stages.

A study⁽⁹⁾ associated UNHS coverage with the number of phonoaudiologists in the Brazilian Unified Health System (SUS) and the availability of equipment across the country's federative units observed an increase in UNHS coverage in Brazil; however, it remains below the desired level. This increase was related to the growth in the number of phonoaudiologists in SUS, although their geographical distribution remains uneven.

Intervention-wise, 40% of the studies reported access to PSAPs and CIs, 3.33% reported access only to PSAPs, and 56.67% did not provide data on how the intervention was carried out. This percentage highlights the lack of data on intervention, which may suggest that this stage of hearing health services has not been studied frequently, also indicating the need for further research on this aspect, considering early intervention is the main goal of NHSPs and UNHS.

The data concerning the second approach to health service evaluation - the process - (Table 2) show that, regarding coverage, 33.33% of the NHSPs reported coverage below the recommended 95%, while 40% reached this target and 26.67% did not mention this information. This indicates that much of the data on coverage may have been lost due to the lack of databases on NHS, which prevented researchers from collecting this information.

Regarding coverage, among the ten studies (33.33%) that reported coverage below 95%, it was noted that seven of them were published after 2020, indicating that low coverage persists even in more recently evaluated NHS programs, suggesting that there is still much progress to be made for these programs to achieve coverage levels above 95%.

The referral rate for diagnostic evaluation was achieved by just over half of the NHSPs, while 16.67% did not reach it and 26.67% did not report it. Regarding the attendance rate for diagnosis, 60% did not meet the recommended level, which aligns with the dropout rate, as 63.33% of the NHSPs studied had shown dropout numbers above the recommended for the diagnostic stage (10%), revealing how significant the dropout rates were for the evaluated programs. Concerning the initiation of phonoaudiological therapy, the majority of studies (93.33%) did not report whether therapy began immediately after diagnosis, highlighting the need for research addressing this important intervention.

Literature reports challenges in the NHSP applications, the main ones being the lack of family knowledge regarding childhood hearing health^(4,53), the distance to service locations^(9,54), sociodemographic aspects of the population^(4,5), structural problems such as the lack of maternity wards performing NHS^(5,6), few specialized professionals, especially phonoaudiologists⁽⁹⁾ or inadequately trained professionals⁽⁵⁵⁾.

The last approach to health service evaluation - the outcome- (Table 3) highlights the average age at which screening tests are completed in the UNHS process, which should occur by the child's first month of life. Among the studies included in this review, 20% of the NHSPs did not meet this target, resulting in delays in the UNHS process, 50% reached the target, and 30% did not report when screening was completed.

Delays in screening tests point to structural and process-related issues, likely leading to subsequent delays in diagnosis and intervention.

Regarding audiological diagnosis, the recommended completion is by the newborn's third month of life; however, in 70% of the NHSPs evaluated by the studies, this stage was delayed, meaning that only 30% had an average age of diagnosis below three months. Concerning intervention, 46.67% of the studies did not report the completion time for this stage, and 40% of these cases did not reach the ideal six-month timeframe, with only 13.33% achieving intervention by the infants' sixth month of life.

These facts reflect problems across all approaches to health service evaluation in Donabedian's Triad: structure, process, and outcome. The Triad's author postulates that there is a causal link among these three approaches, forming a circle with no beginning, middle, or end; issues in any of the approaches within health services impact all the others, which is evident in the analysis of NHSPs: structural problems lead to delays in both process and outcome.

Data regarding the comparison of outcomes between developing and developed countries (Table 4) show that among the former, 50% of the studies did not report data on the age at completion of NHS, whereas in developed countries the percentage of studies was 7.14%, which is likely related to the absence or presence of unified NHS databases in these locations.

It was observed that, among developed countries, 100% had a NHS database, with 42.85% being unified and national, 50% service-specific as evaluated in the primary studies, and 7.14% service-specific with incomplete data. In developing countries, 56.25% had a database, of which 12.50% were unified and national, 31.25% service-specific, and 12.5% had incomplete data. The remaining 43.75% were divided into 25% that had no database and 18.75% that did not report the presence or absence of a database. This suggests a link between the lack of databases in developing countries and the absence of data regarding the age of completion of the NHS.

Regarding the average age at diagnosis completion, it was observed that among developed countries, 50% achieved diagnosis by three months of age, whereas in developing countries, only 12.5% of the NHSPs analyzed reached this mark. This data highlights that the challenges faced by developing countries in meeting the quality indicators of NHSPs are greater than those encountered in developed countries; however, even among developed countries, challenges remain that prevent timely diagnosis.

A study⁽⁵⁶⁾ reviewed literature on access to hearing health services in developing countries and emphasized that access is unequal compared to developed countries. Difficulties include the limited number of trained professionals in audiology, particularly for managing complex cases, although training efforts have been ongoing, along with the expansion of telehealth services, especially to provide access to rural areas. Consequently, the hearing health care infrastructure in developing countries has received increasing attention.

Concerning the age at intervention in developed countries, 57.14% of the studies did not provide information on the age at which intervention began, calling attention for the need for more research in these countries to address this stage. In studies involving developing countries, 62.5% reported that intervention occurred after six months of age, indicating the need for improvements to ensure that the final goal of NHSPs,

early intervention, is achieved. Additionally, in developing countries, 37.5% of the studies did not report information on the age at the beginning of the intervention process, emphasizing the importance of giving greater attention to this stage in future research, since early intervention is, ultimately, the primary purpose of NHSPs.

Considering that this review was conducted by Brazilian researchers, results from Brazil were organized for comparison with other developing countries (Table 5). In relation to data on the completion of NHS, it is notable that 55.55% of the Brazilian NHSP studies did not report the average age at which screening was completed, which is higher than the findings for other developing countries, highlighting the fact that the absence of a unified database in Brazil is a serious issue, and measures should be taken to establish such a database, preferably a national database that covers all stages of NHS. This would allow researchers to conduct more comprehensive studies and, primarily, enable professionals responsible for diagnosis and intervention to have easy access to test data from the screening stage onwards. Such access would expedite the intervention process and enrich data for cross-checking audiological diagnosis, allowing greater interaction among the stages of screening, diagnosis, and intervention.

Regarding the age at diagnosis completion, Brazilian studies showed that 100% of the NHSPs were performed after the recommended age, which is higher than what is observed in other developing countries and serves as a warning sign. In this context, intensified efforts must be made to ensure that the recommended age for NHS diagnosis is achieved. Concerning the beginning of intervention, 66.66% of Brazilian NHSPs were delayed in comparison to the recommended six months, which is close to the 57.14% found for other developing countries, yet still above.

The delay in intervention illustrates the interconnection between structure, process, and outcome, demonstrating that in Brazil there are significant structural problems within NHSPs that impact both their process and outcomes. Therefore, efforts are needed to ensure the quality of Brazilian NHSPs. New studies should continue evaluating these services, aiming on identifying problems and implementing solutions.

Additionally, it is essential to draw the attention of public authorities to encourage the expansion and effective implementation of these programs, providing greater investments so that more facilities can perform NHS in the country, as well as hiring more professionals - especially within SUS- to conduct NHS, and more equipment is made available for both testing and diagnosis. Commitment is required to make a unified national database real and to ensure that all services follow a standardized screening protocol, so that the structure of NHSPs achieves higher quality, positively impacting the process and results of Brazilian NHSPs.

CONCLUSION

Evidences available in scholar literature regarding the effectiveness, efficiency, and impact of newborn hearing screening services on the early detection of hearing loss in newborns shows that there are problems in structure, process, and outcome, resulting in 70% of NHSPs not achieving the recommended age for early diagnosis of hearing loss.

In terms of structure, the lack of professionals and equipment to carry out NHS and the absence of a nationally unified database stand out, which would ensure integration among the professionals involved from screening to intervention, providing greater efficiency to the service. In terms of process, high dropout rates and low coverage of NHSPs are notable, highlighting the need for measures to expand access to hearing health care and raise family awareness about NHS, so that attendance and coverage rates increase. Regarding NHSP outcomes, it is evident that improvements are needed to achieve the target timelines for screening, diagnosis, and intervention.

Worldwide, there are challenges to be overcome to ensure the quality of NHSPs, especially in developing countries such as Brazil, which has shown greater difficulties in achieving quality indicators compared to other developing countries.

In this context, it is of utmost importance to review and strengthen public policies, with investments aimed at expanding coverage, standardizing protocols, implementing national databases and encouraging the training and hiring of specialized professionals. Further studies are also needed to comprehensively evaluate all stages of NHS, particularly diagnosis and intervention, which are not frequently explored in scholarly literature. Only through such measures will it be possible to ensure the quality and effectiveness of NHSPs, guaranteeing that screening leads to timely diagnosis and early intervention, fulfilling its central purpose of promoting the auditory and communicative development of infants with hearing loss.

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Appendix A. Data Extraction Form

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| <p>Title:</p> <hr/> <p>Authors:</p> <p>Year of Publishing:</p> <p>Evaluated local:</p> <p>Publishing Language:</p> <p>Study's goals:</p> <p>Methodology:</p> <p>Results, elements to be extracted:</p> <p>Structure:</p> <p>Is there a database?</p> <p>Is a standard protocol followed for NHS?</p> <p>Were there enough equipment and professionals available for NHS ?</p> <p>In studies evaluating regions, was the number of facilities performing NHS enough?</p> <p>Access to intervention technologies: Personal Sound Amplification Products (PSAPs) and Cochlear Implants (CI).</p> <p>Process:</p> <p>NHS coverage rate?</p> <p>Referral rate for diagnostic evaluation?</p> <p>Attendance for diagnosis?</p> <p>Phonoaudiological therapy immediately after diagnosis completion?</p> <p>Dropout rates?</p> <p>Results:</p> <p>Average age at NHS completion?</p> <p>Average age at diagnosis completion?</p> <p>Average age at the start of the intervention?</p> <p>Conclusions:</p> |
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