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Original Article

Artigo Original

Health Vulnerability Index and newborn hearing screening: urban inequality

Índice de Vulnerabilidade à Saúde e triagem auditiva neonatal: diferenciais intraurbanos

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Keywords

Vulnerability
Socioeconomic Factors
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Neonatal Screening

ABSTRACT

Purpose: To analyze the intra-urban differentials related to the outcome of the Newborn Hearing Screening (NHS) of children living in Belo Horizonte tested in a reference service using the Health Vulnerability Index (HVI). **Methods:** cross-sectional study with children living in Belo Horizonte evaluated by a Newborn Hearing Screening Reference Service (NHSRS) between 2010 and 2011. The HVI of the census tract of each child was obtained by the georeferencing of their respective addresses. Multivariate analysis was conducted using the decision tree technique, considering a statistical model for each response. A thematic map of points representing the geographic distribution of the children evaluated by the NHS program was also developed. **Results:** The NHS failure rate for children living in areas with very high HVI, or without HVI data, was 1.5 times higher than that for children living in other census tracts. For children living in areas of low, medium, and high HVI, who underwent NHS after 30 days of life, the NHS failure rate was 2.1 times higher in children that presented Risk Indicator for Hearing Loss (RIHL) (17.2%) than in those who did not (8.1%). Uneven distribution was observed between areas for children that underwent the NHS and those who failed it. **Conclusion:** Significant intra-urban differentials were found in Belo Horizonte, indicating correlation between health vulnerability and NHS outcomes.

Descritores

Vulnerabilidade
Fatores Socioeconômicos
Políticas Públicas
Deficiência Auditiva
Triagem Neonatal

RESUMO

Objetivo: Analisar os diferenciais intraurbanos associados ao resultado da triagem auditiva neonatal (TAN) de crianças residentes em Belo Horizonte e avaliadas em um Serviço de Referência de TAN, tendo como referência o Índice de Vulnerabilidade à Saúde (IVS). **Método:** Estudo observacional com amostra de crianças residentes em Belo Horizonte e avaliadas por um Serviço de Referência de TAN, entre 2010 e 2011. O IVS do setor censitário de cada criança foi obtido por georreferenciamento de seu respectivo endereço. Foi elaborado modelo estatístico para as variáveis respostas: "resultado da TAN", "resultado no reteste", "absenteísmo no reteste" e realizada análise multivariada, utilizando-se a técnica de árvore de decisão. Foi elaborado mapa temático de pontos para representar a distribuição espacial das crianças avaliadas pelo Programa, segundo seu resultado na TAN. **Resultados:** A probabilidade de falhar na TAN para as crianças residentes em áreas de IVS muito elevado é 1,5 vez maior do que para as crianças residentes nas demais áreas. Para as crianças que residem em áreas de IVS baixo, médio e elevado e que fizeram a TAN após os 30 dias de vida, a probabilidade de falhar é 2,1 vezes maior nas crianças que apresentam indicador de risco para deficiência auditiva (17,2%), em relação às sem indicador de risco (8,1%). Observou-se também distribuição heterogênea de realização da TAN e de resultado da avaliação entre as regiões do município. **Conclusão:** Foram evidenciados importantes diferenciais intraurbanos no Município de Belo Horizonte, indicando associação entre a vulnerabilidade à saúde e o resultado da TAN.

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INTRODUCTION

Newborn Hearing Screening (NHS) is a hearing loss identification strategy that enables early intervention in neonates and, consequently, the development of oral language in children with hearing impairment[1,2]. Prevalence of hearing loss in newborns is high, ranging from 1.2 to 2.9:1000[3-6], reaching 9.8:1000 in children with Risk Indicators for Hearing Loss (RIHL)[6]. Newborn Hearing Screening Programs (NHSP) should assess the entire population of live births within their coverage areas in order to enable positive impact on the health condition of children with hearing impairment[7,8].

The effect of social inequalities on the health condition has been studied for several decades. Such studies aim to understand the relationship between epidemiological and socioeconomic indicators. Individuals and areas with unfavorable socioeconomic conditions almost invariably present poor health[9].

Inequality, when resulting from unfair distribution of resources, privileges or advantages, should be combated through the planning, organization, and implementation of health actions that aim to overcome this situation[10]. The wealth of a population - such as its Gross Domestic Product (GDP) - does not maintain a constant relationship with health indicators singly. Countries or regions with greater GDP do not necessarily present better health indicators. Nevertheless, differences in health status between groups are closely related to the degree of equity in income distribution[11]. The study of these relationships allows us to identify where and how interventions should be conducted with the aim of reducing inequalities[11]. These interventions on the social determinants of health, whether individual or macro, in addition to demanding a coordinated intersectoral action involving different levels of the public administration, should also be accompanied by more generalized, cross-sectional policies that seek to strengthen vulnerable communities[12].

One of the tools used for understanding the relationship between social determinants and health outcomes is geoprocessing - an important strategy for the development of effective health measures for the population[13]. The territorial logic underlying health-related issues is evident from the cultural and environmental conditions shared between neighboring areas[10]. This logic does not occur homogeneously among all elements, creating intra-urban differentials that require targeting health policies at different social groups[14]. In the so-called "layer model" described by Dahlgren and Whitehead in 1991, individuals are identified in the center of the model with their individual characteristics such as age, gender, and genetic factors. The inner layer represents the behaviors and lifestyles, which are under strong influence of social and community networks represented in the next layer. The middle layer illustrates factors related to living and working conditions, indicating that socially deprived individuals are at greater risk. The outer layer includes economic, cultural and environmental macro-determinants of society, which exert great influence on the other layers[11]. In this context, the use of strategies that consider the population's socioeconomic profile differentials allows better understanding of the relations between these factors and the health-disease process[15], and should support the organization of public health policies and the evaluation of health programs[16-18].

In 2009, the Municipal Secretary of Health of Belo Horizonte (SMSA-BH), in partnership with the Department of Health of Minas Gerais state (SES-MG), implemented the Municipal Program of Newborn Hearing Screening[19]. The strategy aims to cover 100% of the live births in the state capital, considering the principles of universality, integrality and equality, as well as the quality indicators of a NHSP proposed by the scientific community. Studies to assess and monitor this program are needed to identify flaws and detect opportunities for improvement that could foster management actions. Similarly, the identification of populations or areas with deprived health conditions allows actions and resources to be prioritized aiming at the promotion of equality.

The objective of the present study is to analyze the intra-urban differentials related to the NHS outcomes of children living in Belo Horizonte tested in a reference service using the HVI.

METHODS

The present study was approved by the Research Ethics Committee of the Federal University of Minas Gerais - FUMG under protocol number ETIC 0143.0.203.439-11.

This is an analytical, cross-sectional study with a sample of children living in Belo Horizonte evaluated by a Newborn Hearing Screening Reference Service (NHSRS) between January 2010 and February 2011.

The study setting was a hearing screening service integrated to a charity hospital associated with the National Health System (SUS). This is a reference hospital in obstetrics and gynecology in the municipality of Belo Horizonte and a high risk reference hospital in the metropolitan area and other cities in the state. The maternity ward comprises 134 beds and performs 850 deliveries per month on average. It is worth mentioning that the service selected for this study has an assessment capacity of 700 children/month, accounting for approximately 35% of the tests billed in Belo Horizonte.

The city of Belo Horizonte occupies an area of 331 km^2 and has a population of 2,258,096 inhabitants according to the 2010 Census conducted by the Brazilian Institute of Geography and Statistics (IBGE)[20]. The capital has the fifth largest GDP of the country and its Human Development Index (HDI) is considered high by the United Nations Development Program (UNDP); however, it presents large discrepancies between regions[21]. The primary health care network comprises 147 Basic Health Units (UBS) with defined coverage areas according to the following criteria: population access to health services, geographical barriers, urban road networks, and vulnerability to health of census tracts.

The research was developed in the context of the hearing care network and used the secondary database of the hearing screening service as its source. The data used are originated from routine treatment, which uses the measure of Transient-evoked Otoacoustic Emissions (TEOE) associated with the observation of child auditory response to sound stimuli. Otoacoustic emissions were

measured using Audx Pluss Bio-logic® or Accuscreen Madsen® equipment, which are checked and calibrated annually. A rattle with four bells and a large agogo bell were used for auditory behavior observation. Results were considered adequate for children with presence of blink reflex and transient otoacoustic emissions bilaterally. Any other responses were considered as abnormal results. The denominations "approved" (adequate results) and "failed" (altered results) were chosen.

The following inclusion criteria were considered for the selection of study participants: being a resident in Belo Horizonte and having undergone evaluation between January 2010 and February 2011. The following exclusion criteria were adopted: children without registered address or with lack of information on the study variables (age of child at the time of the NHS, record of the presence or absence of Risk Indicator for Hearing Loss (RIHL), and gender). Thus the sample of the present study was composed of 4442 children living in Belo Horizonte.

In the analysis of data, the Health Vulnerability Index (HVI) was analyzed as a single context variable. This index was developed by the Municipal Health Secretary of Belo Horizonte to guide the planning of health actions. This measure combines socioeconomic and environmental variables in an only indicator and allows the analysis of the characteristics of resident population groups in the census tracts of the municipality. For the creation of this index, 2560 of the 2564 census tracts of Belo Horizonte were classified considering sanitation components, housing, education, per capita income, and social and health factors. A score was defined for each component, and the census tracts were categorized as of low, medium, high, and very high risk of becoming ill and dying[22].

Data analysis was conducted in two phases: the first phase consisted in georeferencing the selected sample and the second included a multivariate analysis. Is worth mentioning that, for this study, "screening results", "retest results", and "retest absenteeism" were selected as response variables, whereas "HVI", "age of child at the time of the NHS", "RIHL", and "gender" were selected as explicative variables.

In the first phase, in order to identify the census tract and HVI corresponding to the children's residences, georeferencing of their addresses was conducted. Of the total of 4442 addresses, 2996 (67.4%) were automatically processed by the program MapInfo 10.0. The remainder of the data was georeferenced manually, and the census tracts were identified using the program Google Earth. It was not possible to manually find 260 addresses, corresponding to 5.9% of the available addresses. We chose to maintain these children in the survey and identify them as "without HVI data" considering that, in most cases, the addresses corresponded to slum areas, close to districts with very high HVI. Children from 1610 of the existing 2560 census tracts were georeferenced, corresponding to 62.9% of the geographical area of the municipality.

For the georeferencing procedures, we used the Geographic Information System (GIS) developed and managed by the Information Technology and Data Company of the Municipality of Belo Horizonte (Prodabel). The categorical variables were described by frequency distribution, whereas the continuous variable was described by analysis of central tendency and dispersion measures. The continuous variable "age of child at the time of the NHS" was categorized as "first 30 days of life" and "after the first 30 days of life," as recommended by the scientific community[2,7]. A thematic map of points representing the geographic distribution of the children evaluated by the NHS program was also developed according to the place of residence and the NHS results.

In the second phase, a multivariate analysis was conducted using the decision tree technique. This technique uses classification systems of the variables according to the correlation between them, by the algorithm Chi-Squared Automatic Interaction Detector (CHAID) - executed by the Answer Tree software. At each association of an explicative variable with the response (dependent) variable, a new branch (node) appears in the algorithm and the value of the statistical test and its respective *p* value are presented. Absence of branches means lack of statistical significance of the Chi-square test.

Three statistical models were constructed, one for each response variable analyzed. In all analyses, we chose to maintain the variable HVI on the first node of the models, even if there were no association with the dependent variable, because of the importance of its socioeconomic information. Significance level of 5% and confidence interval of 95% were adopted for all statistical analyses.

The study data were organized in an Excel® spreadsheet and processed and analyzed using PASW Statistics 18.0 and MapInfo 10.0.

RESULTS

Table 1 shows the main characteristics of the study sample. It is possible to observe that most of the children (92.6%) presented no risk indicator for hearing loss (RIHL) and that 64.3% of them underwent the newborn hearing screening (NHS) in the first 30 days of life.

Regarding the health vulnerability index (HVI), it can be seen that 46.6% of the children live in census tracts with high or very high risk. HVI identification was not possible in 5.9% of the cases.

With respect to the district of origin, the newborn hearing screening reference service (NHSRS) evaluated children living in all health districts of the municipality, although the proportion of children in the sample has varied from 16.9% (District *Norte*) to 4.6% (District *Centro-Sul*).

Of the children assessed, 4118 (92.7%) were approved and 324 (7.3%) failed the NHS and were referred for retesting. Age at the moment of the NHS ranged from three to 180 days (median of 25 days). Two hundred and thirty seventh (237) children attended the retesting phase, representing absenteeism of 25.6%. Of these, 150 were approved and 87 failed the retest and were referred to audiologic diagnostics. It was not possible to determine the number of children with confirmed hearing loss because the diagnostic phase was conducted in institutions other than those where the NHS was performed.

Table 1. General characteristics of sample included in the study (n=4442) - Belo Horizonte - 2010-2011

Characteristics	N	%
Gender		
Female	2147	48.3
Male	2277	51.5
Not informed	18	0.4
Risk Indicator for Hearing Loss		
RIHL absent	4116	92.6
RIHL present	326	7.4
Age at the time of the NHS		
First 30 days of life	2854	64.3
After 30 days of life	1588	35.7
District of origin		
District Barreiro	569	12.8
District Centro Sul	204	4.6
District Leste	437	9.8
District Nordeste	675	15.2
District Noroeste	518	11.7
District Norte	725	16.3
District Oeste	404	9.1
District Pampulha	228	5.1
District Venda Nova	682	15.4
Health Vulnerability Index		
Low	387	8.7
Medium	1724	38.8
High	1730	38.9
Very high	341	7.7
Not informed	260	5.9
NHS outcome		
Approved	4118	92.7
Failed	324	7.3
Total	4442	100

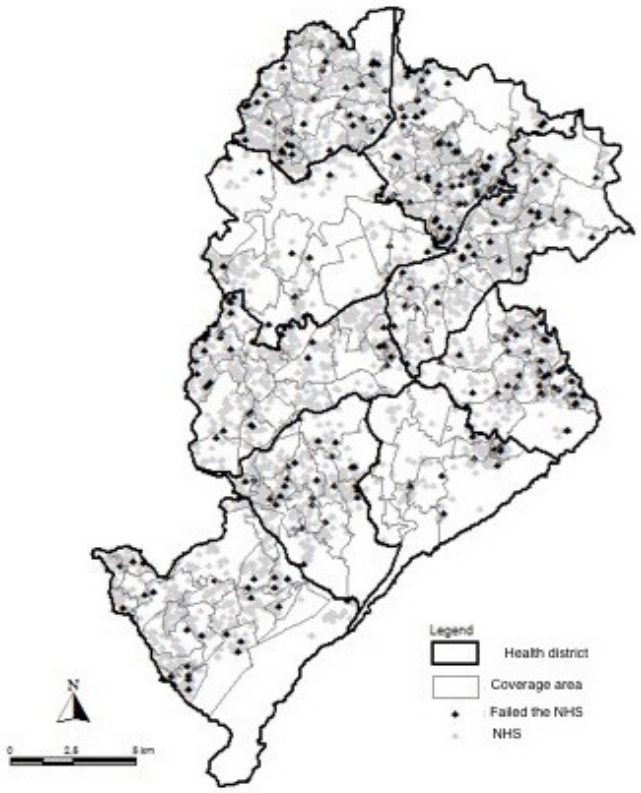

Figure 1. Spatial distribution map of the children assessed by the NHSRS according to address and NHS outcome, Belo Horizonte, 2010-2011

Figure 1 depicts the spatial location of children undergoing the NHS with the respective examination results. Uneven distribution was observed in relation to the different health districts of the municipality both for the children that underwent the NHS and for those who failed it.

Figure 2 presents the multivariate analysis by tree decision for the study of the correlation between the NHS outcome and the explicative variables "HVI", "RIHL", "age at the time of the NHS", and "gender". The NHS failure rate for children living in areas with very high HVI, or without HVI data, was 1.5 times higher than that for children living in other districts. For children living in areas of low, medium, and high HVI that underwent the NHS after 30 days of life, the NHS failure rate was 2.1 times higher in children that presented RIHL (17.2%) than in those who did not (8.1%). No correlation was observed between gender and the NHS results.

No association was found between the HVI, RIHL, age of child at the time of the NHS, and gender variables and retest absenteeism and result (Figure 3).

DISCUSSION

The analysis of this study reveals that the results of Newborn Hearing Screening (NHS) was inversely associated with the Health Vulnerability Index (HVI), with a higher failure rate proportion for children living in deprived health areas; however, the same was not observed in relation to absenteeism in the retesting phase and retest results.

The NHS failure rate for children living in areas with very high HVI or without data for this index (10.3%) was significantly higher than that for children living in districts with low, medium, or high risk (6.8%). No correlation with other variables was found for this health-deprived population, indicating that the HVI is associated with the NHS results regardless of the other variables assessed. It is worth noting that, in the group without data for the HVI, even after performance of manual georeferencing, the addresses corresponded to slum areas or

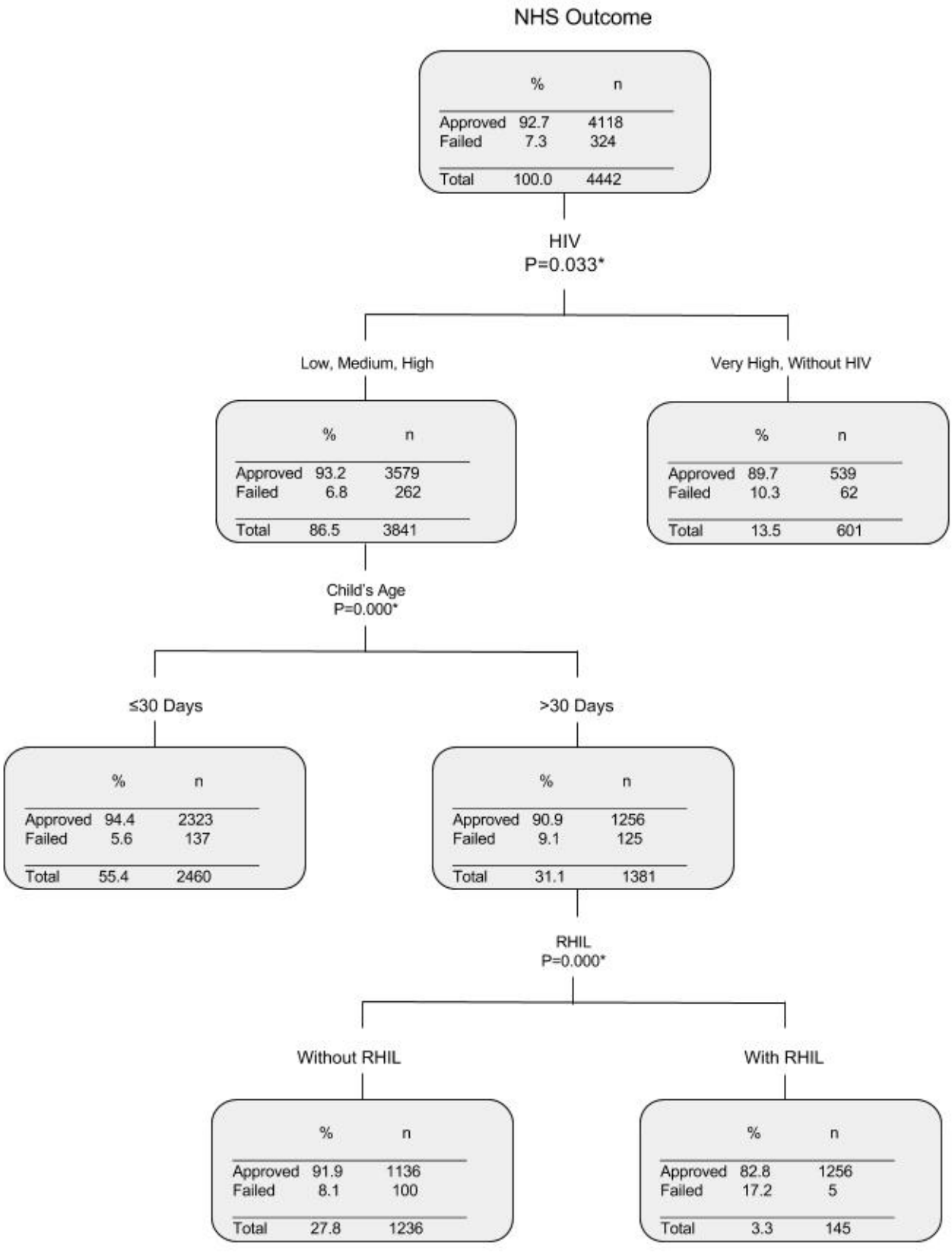

Figure 2. Multivariate analysis by tree decision: study of the correlation between the NHS outcome and the explicative variables, Belo Horizonte, 2010-2011

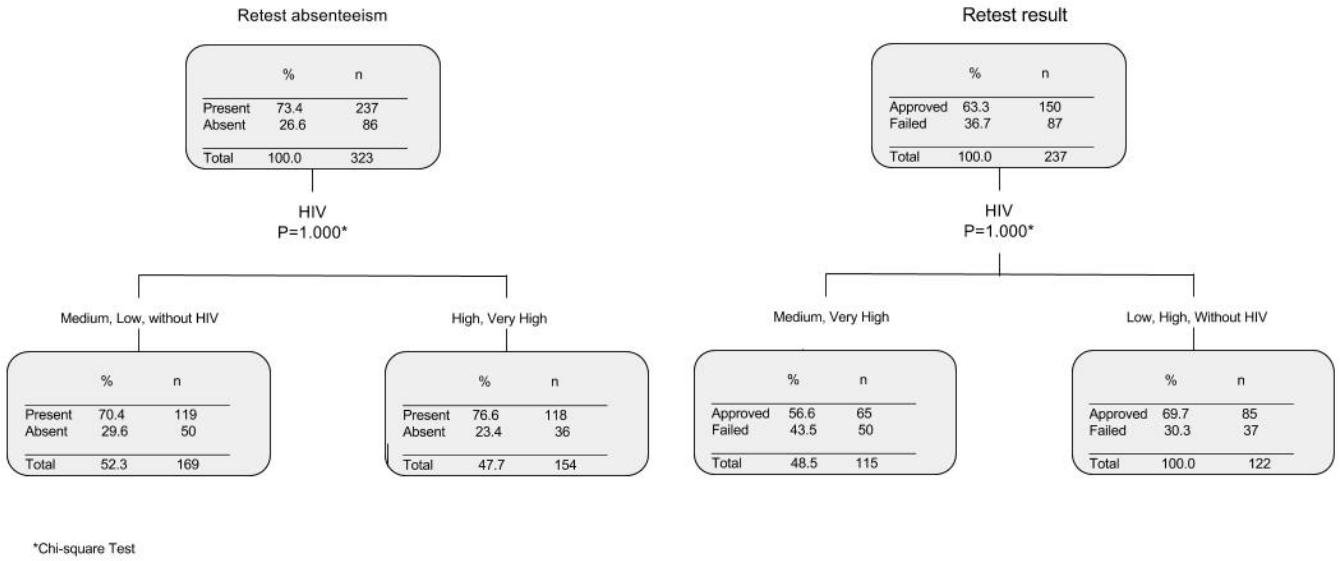

Figure 3. Multivariate analysis by tree decision: study of the correlation between the retest result and absenteeism and the explicative variables, Belo Horizonte, 2010-2011

were close to areas with very high HVI, which corroborates the result of the multivariate analysis.

Analysis of the health situation presents a geographical and territorial rationale. Human populations are distributed according to historical, environmental, cultural, social, and economic similarities in the same territory. Whereas disease is a manifestation of the individual, the health situation is a manifestation of the territory[10].

Approximately 50% of the children assessed by the NHSRS lived in areas of high and very high risk of becoming ill and dying. The lower number of exams conducted in the Districts *Centro Sul* (4.6%) and *Pampulha* (5.1%) may be explained by the fact that these regions present higher socioeconomic conditions and, consequently, access to and preference for private sector services. These data suggest that the population that depends on the National Health Service (SUS) has made greater use of this NHSRS than the other populations.

In this study, it was possible to note that altered results in the NHS were not associated only with determinants of individual health. Such information suggests that social macro-determinants of health, which are defined by socioeconomic, cultural, and environmental conditions, are associated singly with the children's results in the NHSRS. The consequences of social inequality and social determinants on health conditions have been studied by several authors[13,16-18,23]. The main challenge of these studies is to identify the hierarchy of determinations among social, economic, and political factors and their consequences on the health status of groups and individuals.

Correlation was observed between the NHS results and the child age at the time of examination, when considering the group of children living in areas of low, medium, or high HVI. In this group, the NHS failure rate is 5.6%, when the test is conducted with 30 days of life, and it rises to 9.1%, when the test is conducted outside the ideal time. It is known that the measure of otoacoustic emissions is strongly influenced by the clinical conditions of the nursing infant, such as conductive alterations and gastroesophageal reflux[24], as well as by internal noise - a condition more commonly found in agitated children. It is possible that older infants (after the neonatal period) are more likely to develop these clinical conditions and, therefore, more likely to fail the NHS. Such findings reiterate the importance of undergoing the NHS within the first 30 days of life, and suggest the need for further studies with appropriate designs to explain this outcome.

Considering the group of children living in census tracts with low, medium, or high HVI that underwent the NHS after 30 days of life, the NHS failure rate is higher for children who present RIHL (17.2%) than for those who do not (8.1%). These data suggest that once the vulnerability to health and social determinants are excluded, the biohazards begin to emerge as important factors associated with the NHS outcome.

The results of the retest were not associated with the variables investigated, showing homogeneity between the group of children who were approved in the NHS and the group of those who failed it. Similarly, no correlation was found between absenteeism in the retesting phase and the other variables. The proportion of children who attended the retest and those who did not was similar with respect to gender, age at the NHS, HVI, and RIHL. However, a study conducted in Nigeria reported lower attendance to retest in the group of children who underwent the NHS after 30 days of age[25]. In Campinas, Sao Paulo state, other factors were also associated with low attendance: non-first-born neonates, infants with mothers without a mate in the family, low frequency of prenatal care, and low education level[26]. Similar results were reported by a research conducted in Malaysia, where the lack of knowledge on hearing loss, no scheduling or scheduling on distant date, financial difficulties, and distance from hospital were associated with absenteeism at

the retesting phase[27]. In Recife, Pernambuco state, analysis of socioeconomic and demographic factors indicated that families that did not complete the NHS generally presented low education level and lived in rural areas[17]. Further studies are needed to understand the factors associated with family absenteeism at the retesting phase, as well as to support corrective actions both in care and management.

CONCLUSION

The study results show the existence of intra-urban differentials in the city of Belo Horizonte and the influence of social determinants of health in the outcome of the newborn hearing screening of children living in this municipality. Children living in districts with higher health vulnerability are more likely to fail the NHS than children living in areas with better conditions. Therefore, there is need for intersectoral action to reduce inequality, with greater investment of resources in census tracts with very high health vulnerability index. Further studies, associating other social determinants of the Municipal Program of Newborn Hearing Screening, become important to incorporate management knowledge and support the definition of strategic actions aimed at reducing social inequalities, reflecting positively on the program results and, consequently, on the quality of life of children with hearing loss.

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Author contributions

GCJ, AALF and SMAL participated in the study design, collection, analysis and interpretation of data, and writing of the manuscript; RCC and MCMA contributed to the collection and interpretation of data, and revision of the manuscript; CRLA was the study advisor, participated in the study design, collection, analysis and interpretation of data, and writing of the manuscript.