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Universal neonatal hearing screening program in Shanghai, China: An inter-regional and international comparison

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ABSTRACT

Objective: By comparing the Universal Neonatal Hearing Screening (UNHS) program as implemented in Shanghai and other regions in China and countries around the world, this study makes an assessment of the Shanghai model and summarizes the experiences implementing the UNHS program, so as to provide a valuable reference for other countries or regions to carry out UNHS more effectively. Since Shanghai is one of the most developed regions in China, we also examined the relationship between economic development and the UNHS starting year and coverage rate.

Methods: The study conducted a systematic review of published studies in Chinese and English on the program status of neonatal hearing screening to compare and analyze the implementation of the UNHS program in 20 cities or provinces in China and 24 regions or countries around the world. The literature search in Chinese was conducted in the three most authoritative publication databases, CNKI (China National Knowledge Infrastructure), WANFANGDATA, and CQVIP (http://www.cqvip.com/). We searched all publications in those databases with the keywords "neonatal hearing screening" (in Chinese) between 2005 and 2014. English literature was searched using the same keywords (in English). The publication database included Medline and Web of Science, and the search time period was 2000–2014.

Results: Shanghai was one of the first regions in China to implement UNHS, and its coverage rate was among the top regions by international comparison. The starting time of the UNHS program had no relationship with the Gross Domestic Product (GDP) per capita in the same year. Economic level serves as a threshold for carrying out UNHS but is not a linear contributor to the exact starting time of such a program. The screening coverage rate generally showed a rising trend with the increasing GDP per capita in China, but it had no relationship with the area's GDP per capita in selected regions and countries around the world. The system design of UNHS is the key factor influencing screening coverage. Policy makers, program administrators, and cost-sharing structures are important factors that influence the coverage rates of UNHS.

Conclusion: When to carry out a UNHS program is determined by the willingness and preference of the local government, which is influenced by the area's social, political and cultural conditions. Mandatory hearing screening and minimal-cost to no-cost intervention are two pillars for a good coverage rate of UNHS. In terms of system design, decision-making, implementation, funding and the concrete implementation plan are all important factors affecting the implementation of the UNHS.

1. Introduction

The incidence of permanent hearing impairment in newborn infants ranges between 1‰ and 5.5‰ across regions and countries [1–5]. Hearing loss may have significant adverse effects on the development of speech, language capabilities and social-emotional

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development, as well as lead to worse educational and occupational performance in adulthood [6–8]. Regular infant physical examinations cannot detect hearing loss, so neonatal hearing screening (NHS) is necessary [9]. Many studies have illustrated the validity and reliability of universal neonatal hearing screening (UNHS) programs in the early detection of newborn hearing impairment [10–13]. More importantly, newborns with hearing loss that is detected early can receive intervention before 6 months of age, which is critical in allowing them to develop linguistic, cognitive and logical abilities on par with normal infants [6,7].

Because of their feasibility and effectiveness, UNHS programs have been implemented in many countries all over the world; coverage rate is one of the most important indicators to evaluate the impact of these programs [14]. In 1993, the National Institutes of Health in the U.S. suggested that all neonates should have hearing screening before hospital discharge [15]. The coverage rate of neonatal hearing screening was over 95% in 2012 in the U.S [16]. In 1996, regulations on UNHS were adopted in Russia, and the latest coverage rate of the UNHS program in Russia was 73% in 2009 [17]. The Joint Committee on Infant Hearing (JCIH) issued the Principles and Guidelines for Early Hearing Detection and Intervention (EHDI) Programs in 2000, which suggested maximizing competence in linguistics and communication of infants with hearing loss through national UNHS programs [6]. EHDI programs have been conducted in nearly all European Union countries through legislation or on a voluntary basis [15].

Since 2000, the central government of China has developed various regulations, national plans, guidelines and technical criteria for a UNHS program [15]. However, implementation of the program was at the discretion of provincial or local governments, which vary significantly in their economic development and the available resources to implement these programs. Shanghai is one of the most developed cities in China, with a population of 23.03 million in 2010. As the commercial and financial center of China, Shanghai had a total Gross Domestic Product (GDP) of $249.2 billion in 2010, which ranked it first among all Chinese cities. GDP measures a region or a country's total economic activity in the broadest scope, and GDP per capita often reflects the level of economic development in the region or country [18]. Shanghai was among the first two cities in China to adopt the UNHS program, beginning in 2002 to cover all neonates born in the city. Gradually over the past decade, the Shanghai city government established a “Shanghai Early Hearing Detection and Intervention (EHDI) Model,” including the UNHS, comprehensive intervention and education. Although a literature search turned up 1465 publications on neonatal hearing screening in China, most of them approached the topic from a clinical perspective and very few of these publications focused on policy evaluation. Among this limited number of papers, very little research has been done to evaluate Shanghai's EHDI model.

1.1. Introduction of the Shanghai model

The Shanghai EHDI program consists of three stages (Fig. 1): The first stage is to detect and diagnose the neonates who have a hearing loss problem; at the second stage, the infants with confirmed hearing impairment receive early intervention and rehabilitation; at the third stage, the program will assist children with hearing loss to return to normal living conditions with special education.

At the screening stage, hospitals and hearing diagnostic centers work together to implement a two-stage screening protocol [10,11]. Hospitals are responsible for the first stage test of Otoacoustic Emission (OAE) in all neonates during their first 3–5 days of life before they are discharged from hospitals. Those who fail the OAE test are recommended to have a second test of OAE in the same hospitals within 42 days of birth. Those who fail two tests are then referred to the hearing diagnostic center to have a more accurate test (Auditory Brainstem Response, ABR). The quality of screenings is controlled by the Neonatal Hearing Screening Management Center. At the second stage, medical intervention and linguistic training rehabilitation are provided so that the children will be ready for admission to primary school at age 6 [10,11]. At the third stage, education, the students with hearing impairment can study in normal schools only if they pass a rehabilitation assessment at level 3, meaning with their hearing aids (catching over 70% of the words). Students who fail the rehabilitation assessment at level 3 can only be enrolled in special education schools.

The objective of this research is to compare the Shanghai UNHS program with those in other regions of China and other countries. The comparison can provide a valuable reference for other countries and regions who seek to implement UNHS. We also aimed to examine the relationship between economic development, the starting time of the UNHS program and its coverage rate, which reflects the impact of UNHS.

2. Materials and methods

Studies on the program status of neonatal hearing screening in

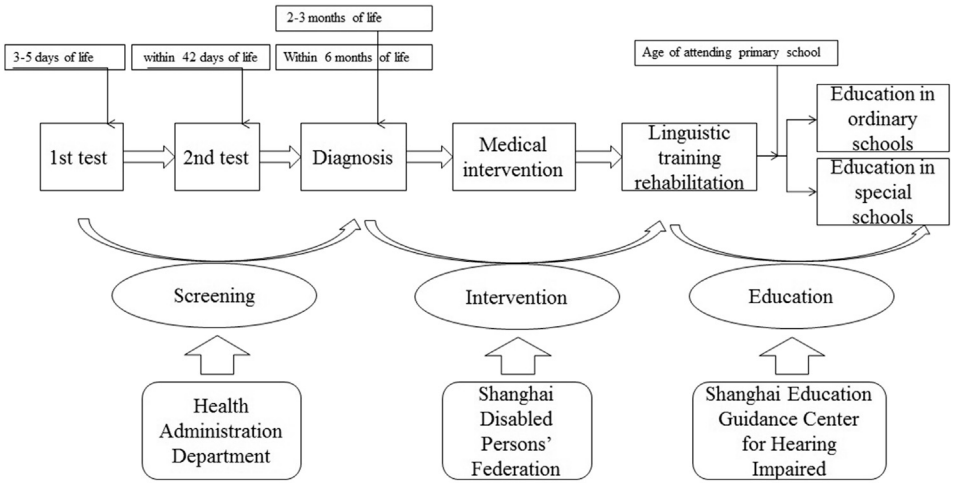

Fig. 1. Flow chart of Shanghai EHDI pattern.

different regions of China or other countries were systematically reviewed in Chinese and English. The systematic review of the literature in Chinese was conducted in the three most authoritative publication databases, CNKI (China National Knowledge Infrastructure), WANFANGDATA, and CQVIP (http://www.cqvip.com/). We searched all publications in those databases with the keyword "neonatal hearing screening" (in Chinese) between 2005 and 2014, which turned up 1465 articles. The beginning year was chosen because the first national guide for neonatal hearing screening in China was enacted by the Ministry of Health in December 2004. English literature was searched using the same keyword (in English). The publication database included Medline and Web of Science, and the search time period was 2000–2014. The reason for choosing 2000 as the beginning year is because the JCIH declared their Position Statement of Principles of EDHI in the same year [19].

In the literature review, the following exclusion criteria were applied: studies with screening populations below 5000; studies conducted in only 1–2 screening institutions or small areas which were not representative of the regional population.

The inclusion criteria for the review of the 1465 Chinese articles were: reviews or prospect reports of the NHS programs conducted in a region with the minimum level being a city in China; principles or guidelines of the NHS programs that have been issued by applicable local government agencies.

We applied similar inclusion and exclusion criteria when extracting available information from articles about other countries' NHS programs: reviews or prospect reports of the NHS programs conducted in a country or at least a region; reports related to the NHS released by the World Health Organization, societies of audiology or otolaryngology or applicable government agencies.

With the set inclusion criteria and exclusion criteria, 59 out of 1465 Chinese articles and 124 out of 480 English studies met the criteria. From those articles, we collected information on the NHS programs in 20 cities and provinces in China and 24 countries and regions around the world.

To assess the relationship between the NHS program and economic development, we also used two GDP measurements: the GDP per capita of the regions or countries in the same year when the NHS was implemented and the GDP per capita in 2010, as most of the regional screening rates were available. The GDPs of regions in China were extracted from the Statistical Bulletin of National Economic and Social Development. The GDPs of other countries or regions were collected from the International Monetary Fund (IMF).

3. Results

3.1. Relationship between implementation of the UNHS program and the GDP per capita

3.1.1. Starting time and GDP per capita in China and selected countries and regions

From the literature review, we found information on 14 cities in China and 17 countries about the starting time of the UNHS. We identified all these regions' GDP per capita in 2010 and in the same year when they started the UNHS. The results of the starting time and the GDP per capita are described below.

In China, the Ministry of Health announced the formal "Neonatal Screening Regulation" in 2009, which required that UNHS programs should be implemented in all regions of China starting June 1, 2009. Some developed cities in China had initiated a UNHS program long before 2009. For example, Shanghai and Zhuhai were the first two cities in China to start such a program, both in 2002 [20]. Though the GDP per capita of some cities like Beijing, Tianjin and Dalian were higher than that of Shanghai, these cities started their UNHS programs slightly later than Shanghai [21–23]. The starting times of the UNHS programs in each city and the GDP per capita in 2010 of each city are shown below (Fig. 2). The starting year had a negative relationship with economic development and the coefficient of correlation was significant (CC = −0.580, $p < 0.05$); the GDP in 2010 explained 33.7% of the variations in the starting time ($R^2 = 0.337$). Therefore, given their current economic development, the more-developed regions in China were likely to implement UNHS earlier.

However, the GDP per capita in the starting year of UNHS varied dramatically across cities in China. The range of the GDP per capita was $6,948, and the standard deviation was $1828. Suqian had the lowest GDP per capita when it started its UNHS program in 2004

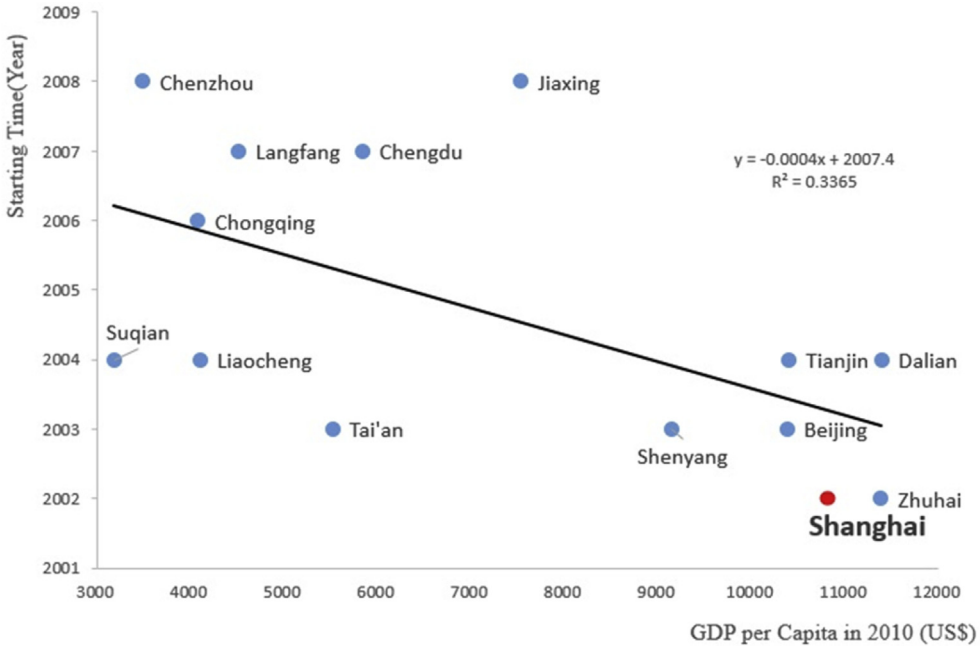

Fig. 2. Starting time of UNHS programs and GDP per capita 2010 in China.

(GDP per capita that year was $778). The highest was Jiaxing. When it began to carry out UNHS in 2008, the GDP per capita reached $7726 in the same year. We plotted the UNHS starting year against the GDP per capita in that year (Fig. 3). As shown in the figure, at the same level of GDP per capita, the starting year of UNHS in different cities varied significantly, and the coefficient of correlation between starting time and GDP per capita in the same year was not significant (CC = 0.196, $p > 0.05$). Therefore, there was no relationship between the starting time of UNHS with the GDP per capita in the same year. In other words, given a city, the starting year of UNHS was not certain given a fixed level of GDP per capita in that city. However, nearly 80% of the areas in China began to undertake UNHS when their GDPs per capita exceeded $1500. In other words, GDP per capita serves as a threshold for starting UNHS but is not a linear contributor to the exact starting time of UNHS programs.

Figs. 2 and 3 suggest that given their economic development at the time, more advanced cities in China were more likely to start UNHS earlier. However, once the cities reached a certain threshold of GDP per capita, the starting time was not significantly related to local economic development per se. Other factors, such as the willingness of the local government, may have served as determinants of the exact starting time.

Worldwide, the starting times of the UNHS programs of each country and their GDP per capita in 2010 are shown below (Fig. 4). It seems as if there was a negative relationship between starting time and the GDP per capita. However, the hypothesis test for coefficient of correlation had no significance (CC = −0.415, $p > 0.05$), and the scattered spots are dispersed greatly. Four outliers, Germany, the U.S., Russia and Austria, might make the relationship insignificant. For example, one outlier is Germany, which had over $40,000 per capita GDP in 2010 but made UNHS mandatory on January 1, 2009 [15]. If treated as an independent region and compared with countries with similar economic development, Shanghai was the second region to start UNHS, coming in only after Russia, which has a more centrally planned healthcare system inherited from the Soviet Union era [24]. The starting time of the Shanghai UNHS program was about the same as other more developed countries, such as Singapore and the Netherlands.

The gap of GDP per capita at the UNHS starting year varied significantly across countries (Fig. 5). The range of GDP per capita was $39,453, and the standard deviation was $13,493. The lowest GDP per capita at the starting level was India, which began to carry out UNHS in 2006 when its GDP per capita was only $822. The highest GDP per capita at the beginning of a UNHS program was in Germany, which began to carry out UNHS in 2009 when its GDP per capita was $40, 275.

As shown in Fig. 5, similar to the results in China, there was also no relationship between the starting time of UNHS and GDP per capita in the same year worldwide (CC = −0.199, $p > 0.05$). The threshold of GDP per capita to start UNHS programs was $2500 in the same year.

3.1.2. *Coverage rates of the UNHS program and the GDP per capita in China and other countries*

Coverage rate is one of the most important indicators reflecting the impact of UNHS. We examined the relationship between the UNHS coverage rate and the GDP per capita in China and other selected countries. The coverage rate of the UNHS program in 2010 and GDP per capita in the same year in cities in China were plotted in Fig. 6. From the figure, it can be seen that the screening coverage rate generally showed a rising trend with increasing GDP per capita, and this relationship has statistical significance (CC = 0.678, $p < 0.05$). However, as the coverage rate has a ceiling of 100%, the coverage rate did not continue to grow when the GDP per capita arrived at a certain level. Since Chongqing adopted a random screening method in newborn hearing screening instead of universal screening, as in other cities of China, the coverage rate was significantly lower there than that in other cities in China [25].

The latest coverage rates of the UNHS programs of each country and the 2010 GDP per capita of those countries and Shanghai are shown below (Fig. 7). As shown in the figure, the coverage rate had no relationship to the area's GDP per capita, since many countries approached the 100% coverage rate regardless of their GDP per capita. The UNHS program coverage rate of Shanghai in 2012 was 97.3%, which is among the highest in the world. This rate was about the same as that in some developed countries like the U.K [15]. The

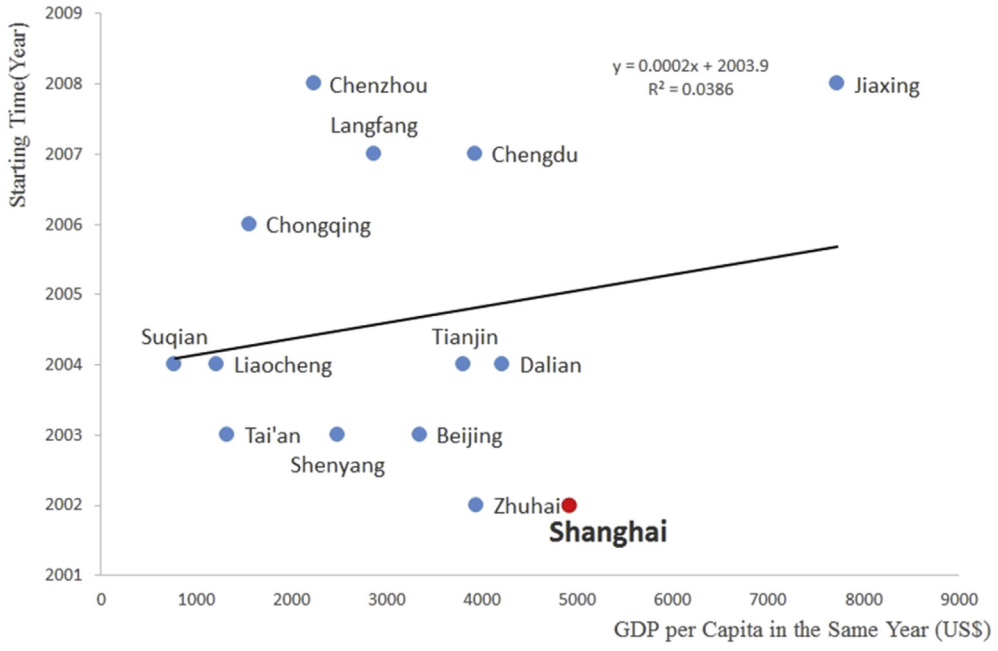

Fig. 3. Starting time of UNHS programs and GDP per capita the same year in China.

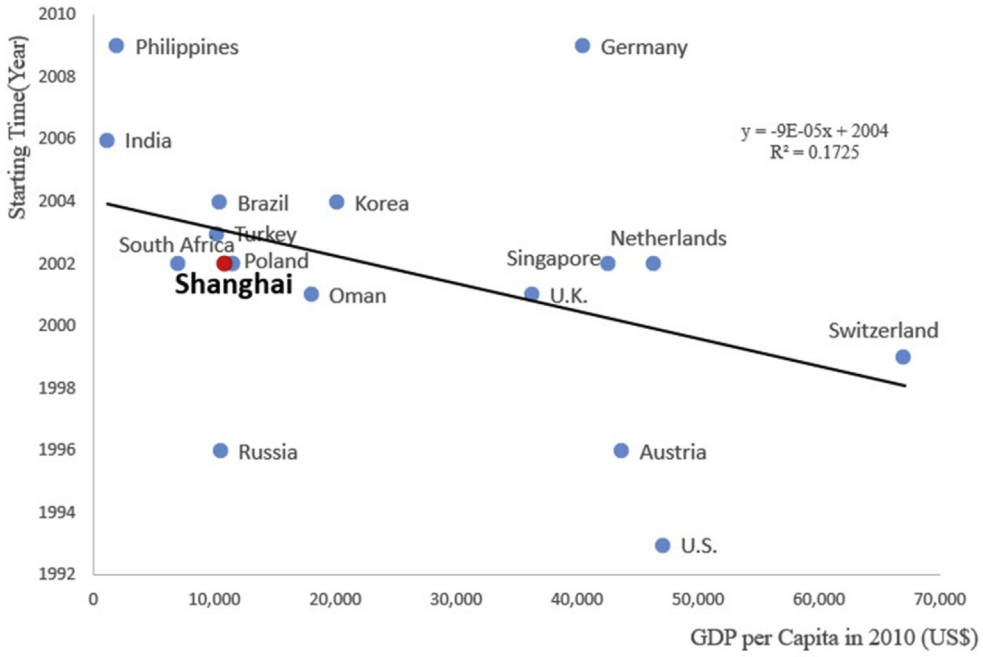

Fig. 4. Starting time of UNHS programs and GDP per capita around the world.

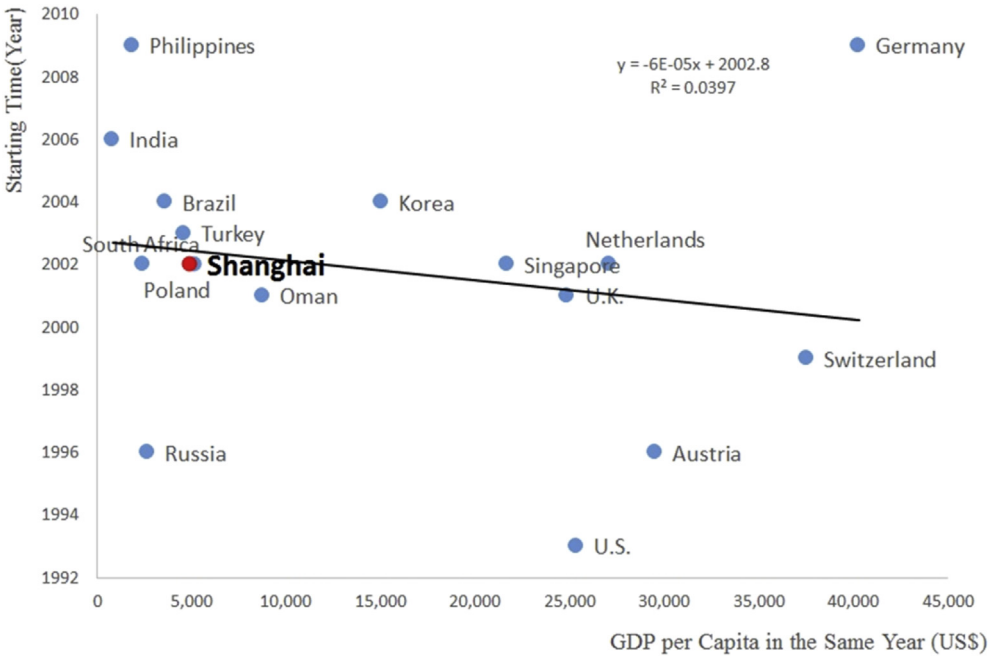

Fig. 5. Starting time of the UNHS and the GDP per capita in the same year around the world.

GDP per capita of Turkey, Brazil and Shanghai in 2010 was about the same, but the coverage rate of the UNHS program in Shanghai was much higher than that in Turkey and Brazil [15,28].

3.2. Comparison of the screening models of the UNHS program in Shanghai with the models in other regions or countries

The UNHS program is a systematic project, which demands at least three levels of system design: the decision-making system, the implementation system and the funding source system. The decision-making system is the original motivating power that drives promotion of UNHS. The members in the decision-making system promote a definite goal and develop policies, guidelines and the legal documents that are required to implement the UNHS program so that it has a political or legal basis. The implementation system is a specific institution that is in charge of organizing and implementing the UNHS program. It is mainly responsible for developing the concrete operational processes and technical details and coordinating the allocation of human resources and financial resources to make the program able to be carried out smoothly in accordance with the set processes. Moreover, it's also responsible for the surveillance and administration of the implementation

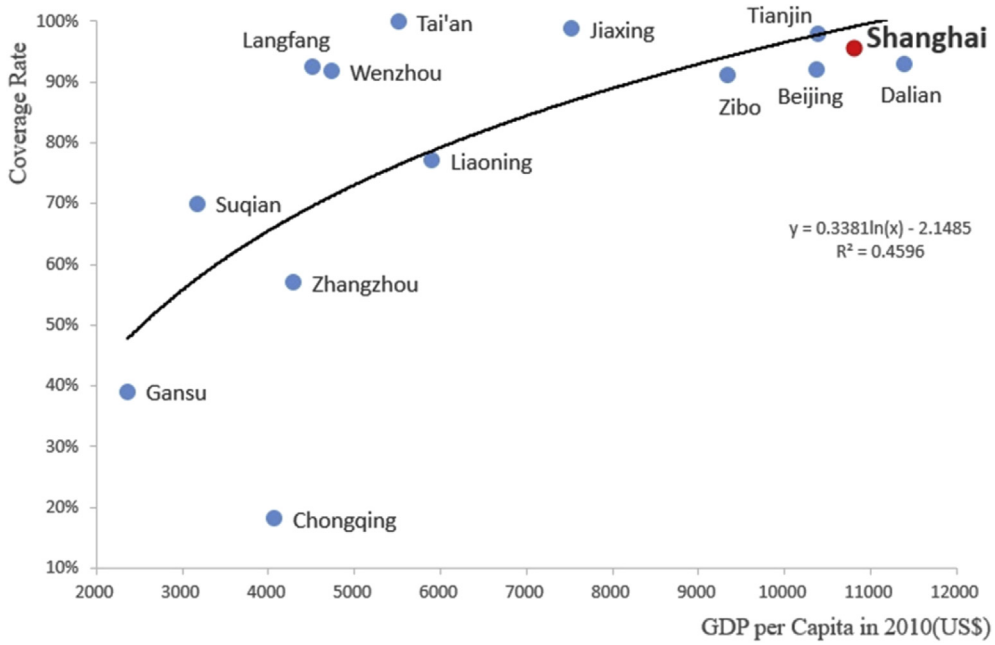

Fig. 6. Coverage rate of UNHS programs and GDP per capita in China.

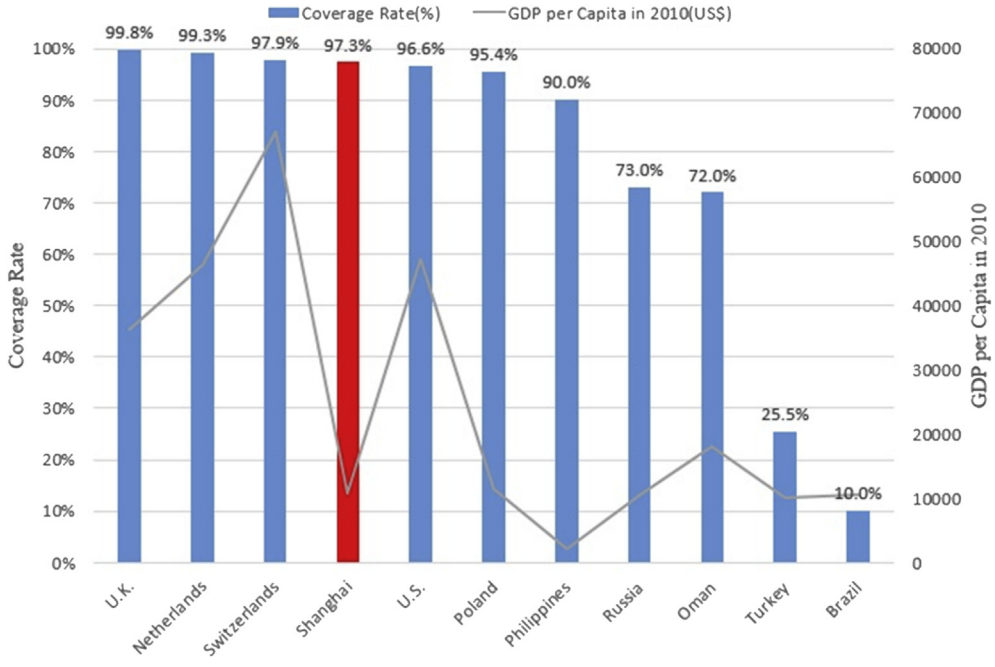

Fig. 7. Coverage rate of UNHS programs and GDP per capita around the world.

process and the effectiveness of the program. Finally, the funding source system decides which parties cover the cost in different stages of the program to ensure that it has sufficient funding to be rolled out smoothly. The integration of these three sub-systems constitutes a screening system or model for the UNHS program in a country or a region. Although there is not an optimal model for UNHS throughout the world, the choice of the UNHS model will influence the cost and the effectiveness of the UNHS program. This study conducted a systematic comparison of the UNHS systems in various countries and regions with the focus on Shanghai, China.

3.2.1. Who makes the policies or guidelines for UNHS programs?

In China, the program's driving force came from all levels of government. At the national level, China's Federation of the Disabled, the Ministry of Health and other ministries jointly issued a document in 1999 that included UNHS in routine examinations for maternal and child health care for the first time [29]. China's Ministry of Health developed the "Technique Specifications for NHS" in 2004 [30] and then issued the "Neonatal Screening Regulations" in 2009, which defined UNHS as an essential item in neonatal screening. The UNHS program was carried out nationwide

[31]. Based on differences in the implementation of UNHS, the 20 cites in China that are covered in this review can be divided into three categories. Cities in the first group made a specific guideline for a UNHS program at the municipal level, such as Shanghai, Beijing, Hangzhou, Zibo and Tianjin. The second group of cities (numbering 13) did not develop any operational documents at the city level, but followed the provincial guidelines (Chengdu, Sanming, Zhangzhou, Chenzhou, Tai'an, Liaocheng, Jiaxing, Wenzhou, Gansu, Dalian, Shenyang, Suqian and Zhuhai). The third group of cities, such as Chongqing and Tonghua, did not develop operational guidelines either at the city level or adopt those at the provincial level. As a consequence of these different implementation styles, the various UNHS system models achieved different coverage rates, as seen in Fig. 6. All the first group cities' screening coverage rates were more than 90%. Four out of seven cities in the second group achieved a screening coverage rate over 90%. Chongqing belongs to the third group, and its screening coverage was the lowest (18%).

In reviewing 17 countries worldwide, their UNHS systems can be divided into two groups: government-initiated and professional-organization-initiated. In the government-initiated countries, UNHS could be either mandatory or non-mandatory. The 10 mandatory government-initiated countries in this review include Brazil [32], Switzerland [27], Nigeria [33], the United Kingdom [34], Poland [35], Belgium [36], the Philippines [15], Germany [15], the United States [37] and Russia [15]. The five non-mandatory government-initiated countries include Canada [38], the Netherlands [39], India [15], Oman [40] and South Africa [13]. In these countries, UNHS programs were launched only as government programs, and there were no laws or regulations to make them mandatory. Two countries' UNHS program were initiated by professional organizations, namely in Austria and Ireland. In these two countries, the UNHS programs were promoted by the Austrian ENT society [41] and the National Audiological Review Group [42], respectively. Given the available data on screening coverage rates, 5 out of 7 of the mandatory countries' screening coverage rates achieved more than 90%, while 50% of the non-mandatory countries' screening coverage rates achieved more than 90%.

3.2.2. Who implements the UNHS programs?

We reviewed 20 cities in China to find information on their administrative bodies for the UNHS program. Ten cities had a definite responsible subject that was in charge of the implementation of the UNHS program. These cities were Shanghai, Beijing [21], Chengdu [43], Shenyang [44], Dalian [23], Tai'an [45], Liaocheng [46], Zibo [47], Tianjin [22] and Hangzhou [48]. Another 10 cities do not have a definite subject responsible for UNHS, such as Sanming, Zhangzhou, Zhuhai, Chenzhou, Tonghua, Suqian, Jiaxing, Wenzhou, Gansu and Chongqing. It can be seen from Fig. 6 that 100% of the cities with a definite responsible subject achieved screening coverage rates over 90%, but only 33% of the cities without a responsible subject achieved comparable levels of coverage.

Worldwide, we reviewed 16 countries' responsible subjects for the UNHS program. Nine countries have a definite responsible subject with clear authority for implementing UNHS. Among these countries, some of the subjects are agencies subordinate to the government's health department, such as in Oman [40], the United Kingdom [49], the United States [37], Netherlands [26] and Belgium [50], while some other responsible subjects are industry associations, such as in France [51], Ireland [42], Switzerland [27] and South Korea [15]. A second group of countries do not have a definite subject responsible for UNHS, such as Canada [52], Brazil [32], Poland [35], South Africa [53], Singapore [54], Italy [55] and Russia [15]. It can be seen from Fig. 7 that 80% of the countries with a definite subject of responsibility achieved a screening rate over 90%, while only 33% of the countries without a definite subject of responsibility achieved that.

3.2.3. Who covers the cost of UNHS programs?

In China, we reviewed the cost coverage in 20 cities. In 15 cities, individuals were responsible for the cost, such as in Chongqing, Tianjin, Zhuhai, etc. In the remaining five cities, the government or insurance took care of the cost of the UNHS program. Among these five cities, three cities' government agencies provided free UNHS, such as Beijing [19], Dalian [23] and Tai'an [45]. However, in Shanghai, the cost of screening was covered by birth insurance, while the cost was covered by health insurance in Tonghua [56]. In the 14 cities with data on their screening coverage rates, all cities with government coverage or insurance coverage had screening rates over 90%, while only 50% of the cities with individual cost sharing had a screening coverage rate over 90%.

Worldwide, we reviewed 14 countries with regard to the funding source. There are four models of UNHS funding. In the first, the cost is covered by the government, health insurance, or charity. Nine countries adopted this model, including Canada [38], France [51], Germany [15], Poland [57], Britain [49], the Netherlands [26], Belgium [58], the Philippines [15] and South Korea [15]. The second model has the cost covered by the government, insurance and the individual, such as in Brazil [32]. The difference between the first and the second model is that in the first model, the individual does not share any cost. The third model is that individuals are responsible for all UNHS costs, such as in Switzerland [27], Singapore [59] and Nigeria [60]. The fourth model has no unified cost undertaker across the country, such as in the United States [15]. In some states of the U.S., UNHS is covered by health insurance, while in other states the cost is borne by individuals. It can be seen from Fig. 7 that the screening coverage rates were all over 90% in Poland, Britain, the Netherlands and the Philippines, which adopted the first model. The screening coverage rate was only 10% in Brazil, which adopted the second model. Although the Swiss adopted the third model, which shares the cost with individuals, its screening coverage reached 97.9%. Therefore, different cost sharing models can achieve different screening coverage rates across countries.

4. Discussion

4.1. Willingness and preference of the government is the decisive factor in the starting time of UNHS

To carry out UNHS, resources such as personnel, equipment and funds are all needed. Therefore, to carry out UNHS, a country or a region needs a certain level of economic resources. However, there is no significant relationship between the starting time of UNHS and the local GDP per capita; the level of economic development is not the only decisive factor in the initiation of UNHS. Whether a country or a region tries to carry out UNHS or not is more subject to social, political and cultural factors such as the severity of hearing impairment in the region, the importance of this health issue compared with the population's other health problems, the region's cultural background, and the efficiency of the region's government in performing public service functions. These factors ultimately influence the decision of the government to implement UNHS. For example, if a country or region has a high prevalence of infectious diseases, UNHS may not be a priority to be implemented. Even if the national government makes it mandatory, UNHS may not be sustainable due to the lack of local governments' and societal support, such as in South Africa [53] and Nigeria [60]. Therefore, economic development is the foundational requisite for being able to implement UNHS, while social needs are the driving force for actually doing so.

4.2. The system design of UNHS is the key factor influencing screening coverage

Although economic development and social structure vary across regions and countries, system design plays similar roles in all UNHS programs. If the UNHS is mandatory and local governments make specific implementation plans, the coverage rate of UNHS can be better. If there is a designated agency responsible for the UNHS program, the implementation of the program can be more effective. If the screening is free to individuals, the effectiveness of the UNHS can be improved. An exception occurs when the region or country reaches a high level of economic development such that the screening cost is trivial. In such circumstances, cost will not affect coverage rates, such as in Switzerland [27]. Countries and regions without UNHS can benefit from these experiences based upon the studied countries and regions in China.

4.3. The implementation plan for UNHS should be adjusted based on the local health care system

Compared with the system design for screening, the implementation plan should be more flexible based on local economic development, political structure and cultural background. For example, since the U.K. has a well-established family doctor system and the length of stay for women after delivery is reduced, neonates are screened in the hospital and in the family as well by family doctors to ensure a higher screening coverage rate [35,61]. Hessian, Germany, has established an information network covering 78 maternity hospitals to coordinate their screening. To achieve information sharing and efficient cooperation between participating hospitals, the screening results are transmitted directly to various agencies responsible for screening and reminder messages are sent to the families of the newborns [13]. In Hangzhou, China, since many newborns are from domestic migrant families who may not have stable residences, additional screenings can be conducted in maternity hospitals near the residence [62]. In Shanghai, in addition to routine screening of newborn hearing in the hospital, the maternal and child health care system provides supplementary screening for those who missed the hearing screening in the hospital, thereby ensuring full coverage of newborns [11]. For example, infants are required to have immunization and regular physical examination in the community health centers, where those who missed the hearing screening in the delivery hospital can receive supplementary hearing screening. For those who tested positive for hearing loss in the first test, delivery hospitals sent the relevant information to the community health centers to ensure further examinations. The flexible design of the UNHS implementation plan based on local health care systems helps China to achieve better coverage.

Due to the limitation of research time and data resources, it is difficult to launch a comprehensive investigation of UNHS in all countries around the world and all cities in China. Since this study is a systematic review of the existing literature, only the regions or countries reported in the literature were studied.

5. Conclusion

The UNHS is a reliable and effective public health program with a core objective of identifying children with hearing loss problems as soon as possible after birth and to implement interventions for them as soon as possible.

When to carry out the program is determined by many factors, such as the local and national political structure, local health care systems and human resources. Looking back, we saw that Shanghai implemented a comprehensive screening system and achieved high coverage rates compared with other regions in China. Mandatory hearing screening and minimal-cost to no-cost intervention were two of the main reasons for the city's good coverage rate. In regions and countries without a UNHS or with a UNHS but having lower coverage rates, more system design optimization based on their existing local health care systems should be implemented. More research is needed to compare the effectiveness of the interventions in China and other developed or developing countries.

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Competing interests

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ijporl.2016.08.022.

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