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Prevalence of childhood hearing impairment of different severities in urban and rural areas: a nationwide population-based study in Taiwan

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ABSTRACT

Objective Childhood hearing impairment (CHI) is a major developmental disability, but data at the national level are limited, especially those on different severities. We conducted a study to fill this data gap.

Design A nationwide study on the basis of a reporting system.

Setting To provide services to disabled citizens, the Taiwanese government maintains a registry of certified cases. Using data from this registry, we estimated prevalence rates of CHI of different severities from 2004 to 2010 and made comparisons between urban and rural areas.

Participants Taiwanese citizens ≤17 years old.

Primary outcome measures To qualify for CHI disability benefits, a child must have an unaided pure-tone better ear hearing level at 0.5, 1 and 2 kHz with an average ≥55 decibels (dB), confirmed by an otolaryngologist. The severity was classified by pure-tone better ear hearing level as mild (55–69 dB), moderate (70–89 dB) and severe (≥90 dB).

Results The registered cases under 17 years old decreased annually from 4075 in 2004 to 3533 in 2010, but changes in the prevalence rate were small, ranging from 7.62/10 000 in 2004 to 7.91/10 000 in 2006. The prevalence rates of mild CHI increased in all areas over time, but not those of moderate or severe CHI. Rural areas had higher overall prevalence rates than urban areas in all years, with rate ratios (RRs) between 1.01 and 1.09. By severity, rural areas had higher prevalence rates of mild (RRs between 1.08 and 1.25) and moderate (RRs between 1.06 and 1.21) CHI but had lower prevalence rates of severe CHI (RRs between 0.92 and 0.99).

Conclusion While rural areas had higher overall prevalence rates of CHI than urban areas, the RRs decreased with CHI severity. Further studies that identify factors affecting the rural–urban difference might help the prevention of CHI.

Strengths and limitations of this study

- ► Data on the same population were collected over a 7-year period, which allows the assessment of time trends.
- ► The study number of cases was large, over 3533 cases in 2010 alone.
- ► We have information on severity, which is rarely reported by large-scale studies.
- ► This study used administrative data, which do not cover cases who are not detected or who have never received services from the administration.
- ► Data on individual cases were not provided by the registry, which hindered more detailed analyses.

born with or acquire HI during childhood. Compared with infants born in resource-rich countries, infants born in resource-poor countries have a nearly twofold risk.[2–4] The costs of the education support to children with better ear hearing level (BEHL) >50 dB was estimated as $3.9 billion.[5] Compared with normal children, patients with childhood HI (CHI) have difficulties in language development, speech production and cognition, which in turn affect their academic performance, vocational attainment and socioemotional competence.[2 6 7]

The World Health Assembly affirmed the importance of interventions in control preventable HI[8] and recommended population-based epidemiological studies to determine the prevalence rate and causes of HI in all nations for targeting of preventive efforts.[2] The reported prevalence rates of CHI varied widely around the world.[9–13] Most studies focus on either rural or urban populations, even though comparing the difference between the two is important. The urban–rural differences might be attributable to differences in cultural perceptions regarding the impact of HI, diagnosis and treatment,[14] but efforts are needed to investigate the differences further.

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INTRODUCTION

Hearing impairment (HI) is a global problem, and the WHO estimated that 360 million people (including 32 million children) have disabling HI.[1] Most patients live in low-income and middle-income countries, and 25% are

In 1980, the Taiwanese government constructed a system to certify disabled residents and to provide them with various services. The central government keeps a registry of certified cases,[15] presenting a rare opportunity for studying CHI at the national level. The objectives of this study were to estimate the prevalence rates of CHI of different severities and to evaluate the differences between urban and rural areas.

METHODS

The disability registry system in Taiwan

In Taiwan, the Disabled Welfare Act was promulgated in 1980.[16] Accordingly, the local governments began to certify seven types of patients with disabilities, including 'hearing impairment or balance disability.' When the Act was revised to become the People with Disabilities Rights Protection Act in 1997,[17] the 'hearing impairment or balance disability' category was divided into two: HI and 'balance disability.'

Individuals can make applications for certification through their local government in the residential area.[18–20] These local governments report certified cases to the central government. The registry of cases was first maintained by the Ministry of the Interior and then by the Ministry of Health and Welfare after the reorganisation of the government in 2013.[19] Because the registry identifies cases by the unique National Identification Numbers, each case is identified as one entity only.

Case definition of CHI

When a child is suspected of having HI, parents or guardians can apply for certification. To qualify for disability benefits, a child must have an unaided pure-tone BEHL at 0.5, 1 and 2 kHz (pure-tone average [PTA]) with an average ≥55 decibels (dB) and confirmation by an otolaryngologist accredited by the government.[18 19] Different hearing tests are used to check for hearing disability in children less than 5 years of age. Neonatal HI is identified by the otoacoustic emissions screening with referral for diagnostic auditory brainstem response assessment. Visual reinforcement audiometry and play audiometry are used to test HI in older babies and young children. In cases with suspected malingering or difficulties in testing, an auditory brainstem response is applied.

According to the Taiwanese government,[19] the severity of HI is defined as 'mild' with PTA ≥55 dB BEHL and <70 dB BEHL, 'moderate' with PTA ≥70 dB BEHL and <90 dB BEHL and 'severe' with PTA ≥90 dB BEHL. In order to continue to receive the disability benefits, a registered case needs to be re-evaluated every 3 years by an otolaryngologist accredited by the government.

Data collection

Using the nationwide registry data of HI, we conducted a study that included all children (≤17 years old) with Taiwanese citizenship. Each year, the government publishes a Statistical Yearbook.[15] We obtained the data

from the central government, but they are available since 2004 only. Furthermore, with the reorganisation of administrative regions in 2011, one of the rural regions was merged into an urban region. While the impact of the reorganisation on the classification was small, it made the population subdivisions incomparable before and after the reorganisation. Therefore, we only analysed the data until 2010. To calculate the prevalence rates, we obtained the total number of individuals in each age group from the Monthly Bulletin of Interior Statistics.[21] The numbers were used as the denominators in estimating prevalence rates because the case ascertainment of the registry is through reporting by caregivers, and all eligible children are under continuous watch of the caregivers and will be reported when they become cases.

According to the Directorate-General of Budget, Accounting and Statistics, we defined an 'urban area' as a city or county with >50% of the population living in metropolitan regions.[22] In Taiwan, there are 7 cities and 18 counties, of which 7 cities and 5 counties were categorised as urban areas, and the remaining 13 counties were categorised as rural areas.

Statistical analysis

We estimated the prevalence rate of CHI in a rural or urban area by dividing the number of cases by the number of individuals each year and evaluated the trend over time. According to the yearbooks,[15] we categorised the age into five groups (<3 years, 3–5 years, 6–11 years, 12–14 years, and 15–17 years). We calculated the overall prevalence rates, as well as the prevalence rates by severity, and evaluated the trends over time.

To evaluate the differences between urban and rural areas, we estimated the prevalence rate ratio (RR) by dividing the prevalence rate of rural areas by that of urban areas. A 95% CI was calculated for each RR to evaluate its statistical significance.

We used the χ^2 test for trend to evaluate trends of changes in the prevalence rates over time and across age groups. To evaluate trends of changes in prevalence RRs over time and across age groups, we used linear regressions. In addition, we used analysis of variance for repeated measures to evaluate trends of changes in the prevalence RRs among three different severity groups.

We conducted the analyses using SAS V.9.1 and performed all statistical tests at the significance level of 0.05.

Patient and public involvement

This study was based on secondary data analysis, and there was no patient or public involvement.

RESULTS

The trend of the overall prevalence rate by area

From 2004 to 2010, the registered cases under 17 years old decreased from 4075 to 3533, with a decreasing time trend. However, the changes in prevalence rates were

small, ranging from 7.62/10 000 in 2004 to 7.91/10 000 in 2006, without a remarkable time trend, mainly because of the decreasing number of newborns each year. The prevalence rates in rural areas fluctuated between 7.70/10 000 and 8.18/10 000, without remarkable time trends (table 1). The prevalence rates in urban areas also fluctuated, between 7.50/10 000 and 7.85/10 000, without remarkable time trends (table 2). Rural areas had higher overall prevalence rates in all years, and the rural-to-urban prevalence RRs ranged from 1.01 to 1.09 (with P<0.05 in 2008 and 2009), without remarkable time trends (table 3).

The trends of prevalence rates by age

In rural areas, the prevalence rates in age groups <3 years, 3–5 years, 6–11 years, 12–14 years, and 15–17 years was 2.31–4.90/10 000, 5.91–7.75/10 000, 7.61–8.39/10 000, 8.97–9.73/10 000, and 9.71–12.00/10 000, respectively (table 1). In each year, prevalence rates increased with age (P<0.01 for all χ^2 tests for trend). Over time, the prevalence rates increased in age groups <3 years (P<0.01, increased by 71.0% from 2004 to 2010) and 3–5 years (P<0. 05, increased by 23.6%) but decreased in the age group 15–17 years (P<0.01, decreased by 19.1%).

In urban areas, the prevalence rates in age groups <3 years, 3–5 years, 6–11 years, 12–14 years and 15–17 years was 2.24–4.01/10 000, 5.90–6.82/10 000, 7.37–7.84/10 000, 8.18–9.25/10 000 and 9.21–11.17/10 000, respectively (table 2). In each year, prevalence rates increased with age (P<0.01 in all years). The prevalence rates increased in the age group <3 years over time (P<0.01, increased by 79.0%) but decreased in age groups 12–14 years and 15–17 years (P<0.05 for both, decreased by 8.3% and 17.6%, respectively).

The trends of prevalence rates by severity and area

For mild CHI, the overall prevalence rates increased over time in both rural and urban areas (P<0.05 for both) (table 4). For moderate CHI, overall prevalence rates decreased over time in urban areas (P<0.01), but no remarkable trends were observed in rural areas. For severe CHI, the changes in overall prevalence rates were small in both rural and urban areas and without any remarkable time trends.

Rural areas had higher overall prevalence rates of mild CHI in all years, and the differences reached statistical significance in all years except 2005 and 2007. Rural areas also had higher prevalence rates of moderate CHI in all years, but the difference reached statistical significance in 2008 only. For severe CHI, prevalence rates in urban areas were slightly higher in all years, but none of the differences reached statistical significance (table 4). The changes in rural-to-urban RR were small in all severity groups and without any remarkable time trends. Nevertheless, the mean of rural-to-urban RR in mild, moderate and severe CHI was 1.15, 1.10 and 0.96, respectively, indicating a decreasing trend (P<0.01). The rural-to-urban

Table 1 The prevalence rate (per 10000 children) of hearing impairment in rural areas by age in Taiwan

Year	<3years N	Prev.*	(95% CI)	3–5years N	Prev.	(95% CI)	6–11years N	Prev.	(95% CI)	12–14years N	Prev.	(95% CI)	15–17years N	Prev.	(95% CI)	0–17years N	Prev.	(95% CI)
2004	50	2.31	(1.75 to 3.05)	159	6.27	(5.37 to 7.32)	438	8.05	(7.33 to 8.84)	256	9.13	(8.08 to 10.32)	343	12.00	(10.80 to 13.34)	1246	7.88	(7.46 to 8.33)
2005	49	2.43	(1.84 to 3.22)	150	6.16	(5.25 to 7.23)	403	7.61	(6.90 to 8.39)	270	9.73	(8.63 to 10.96)	315	10.87	(9.74 to 12.14)	1187	7.70	(7.28 to 8.15)
2006	70	3.68	(2.91 to 4.65)	154	6.99	(5.97 to 8.19)	420	8.04	(7.30 to 8.84)	259	9.31	(8.25 to 10.52)	301	10.68	(9.54 to 11.96)	1204	8.06	(7.62 to 8.53)
2007	89	4.90	(3.99 to 6.03)	122	5.91	(4.95 to 7.05)	422	8.39	(7.63 to 9.23)	251	9.05	(8.00 to 10.24)	277	9.77	(8.69 to 10.99)	1161	8.00	(7.55 to 8.47)
2008	68	3.90	(3.08 to 4.95)	143	7.43	(6.31 to 8.75)	389	8.10	(7.33 to 8.94)	248	8.99	(7.94 to 10.18)	284	10.10	(8.99 to 11.35)	1132	8.06	(7.61 to 8.54)
2009	68	4.06	(3.20 to 5.15)	132	7.21	(6.08 to 8.55)	378	8.34	(7.54 to 9.22)	255	9.23	(8.16 to 10.43)	282	9.98	(8.89 to 11.22)	1115	8.18	(7.72 to 8.68)
2010	61	3.95	(3.07 to 5.07)	135	7.75	(6.55 to 9.17)	353	8.07	(7.27 to 8.96)	234	8.97	(7.90 to 10.20)	274	9.71	(8.63 to 10.93)	1057	8.07	(7.60 to 8.58)

*Prev,,the prevalence, estimated by dividing the number of cases by the population in each age group in each year.

Table 2 The prevalence rate (per 10000 children) of hearing impairment in urban areas by age in Taiwan

Year	<3 years			3–5 years			6–11 years			12–14 years			15–17 years			0–17 years		
	N	Prev.*	(95% CI)	N	Prev.	(95% CI)	N	Prev.	(95% CI)	N	Prev.	(95% CI)	N	Prev.	(95% CI)	N	Prev.	(95% CI)
2004	104	2.24	(1.85 to 2.71)	364	6.14	(5.54 to 6.81)	989	7.37	(6.92 to 7.84)	621	8.96	(8.29 to 9.70)	751	11.17	(10.40 to 12.00)	2829	7.51	(7.24 to 7.80)
2005	111	2.52	(2.10 to 3.04)	334	5.90	(5.30 to 6.56)	1013	7.71	(7.25 to 8.20)	610	8.88	(8.20 to 9.61)	767	11.05	(10.29 to 11.86)	2835	7.66	(7.38 to 7.95)
2006	140	3.26	(2.76 to 3.85)	326	6.38	(5.73 to 7.12)	998	7.65	(7.19 to 8.14)	639	9.25	(8.56 to 10.00)	734	10.80	(10.04 to 11.61)	2837	7.85	(7.57 to 8.14)
2007	138	3.24	(2.75 to 3.83)	325	6.69	(6.00 to 7.46)	957	7.62	(7.15 to 8.12)	629	9.05	(8.37 to 9.78)	709	10.30	(9.57 to 11.09)	2758	7.77	(7.48 to 8.06)
2008	132	3.10	(2.62 to 3.68)	315	6.82	(6.11 to 7.62)	907	7.54	(7.07 to 8.05)	600	8.66	(8.00 to 9.38)	643	9.43	(8.73 to 10.19)	2597	7.50	(7.21 to 7.79)
2009	147	3.50	(2.98 to 4.12)	283	6.28	(5.59 to 7.05)	889	7.84	(7.34 to 8.37)	567	8.18	(7.53 to 8.88)	652	9.52	(8.82 to 10.28)	2538	7.50	(7.22 to 7.80)
2010	159	4.01	(3.43 to 4.68)	293	6.55	(5.84 to 7.35)	853	7.74	(7.24 to 8.28)	536	8.22	(7.55 to 8.95)	635	9.21	(8.52 to 9.96)	2476	7.53	(7.24 to 7.84)

*Prev., the prevalence, estimated by dividing the number of cases by the population in each age group in each year.

Table 3 The rural-to-urban prevalence rate ratio of hearing impairment by age in Taiwan

Year	<3 years		3–5 years		6–11 years		12–14 years		15–17 years		0–17 years	
	Rate ratio	(95% CI)	Rate ratio	(95% CI)	Rate ratio	(95% CI)	Rate ratio	(95% CI)	Rate ratio	(95% CI)	Rate ratio	(95% CI)
2004	1.03	(0.74 to 1.45)	1.02	(0.85 to 1.23)	1.09	(0.98 to 1.22)	1.02	(0.88 to 1.18)	1.07	(0.95 to 1.22)	1.05	(0.98 to 1.12)
2005	0.96	(0.69 to 1.35)	1.05	(0.86 to 1.27)	0.99	(0.88 to 1.11)	1.10	(0.95 to 1.26)	0.98	(0.86 to 1.12)	1.01	(0.94 to 1.08)
2006	1.13	(0.85 to 1.50)	1.10	(0.90 to 1.33)	1.05	(0.94 to 1.18)	1.01	(0.87 to 1.16)	0.99	(0.87 to 1.13)	1.03	(0.96 to 1.10)
2007	1.51	(1.16 to 1.97)*	0.88	(0.72 to 1.09)	1.10	(0.98 to 1.23)	1.00	(0.86 to 1.16)	0.95	(0.83 to 1.09)	1.03	(0.96 to 1.10)
2008	1.26	(0.94 to 1.69)	1.09	(0.89 to 1.33)	1.07	(0.95 to 1.21)	1.04	(0.89 to 1.20)	1.07	(0.93 to 1.23)	1.08	(1.00 to 1.15)*
2009	1.16	(0.87 to 1.55)	1.15	(0.93 to 1.41)	1.06	(0.94 to 1.20)	1.13	(0.97 to 1.31)	1.05	(0.91 to 1.21)	1.09	(1.02 to 1.17)*
2010	0.98	(0.73 to 1.32)	1.18	(0.96 to 1.45)	1.04	(0.92 to 1.18)	1.09	(0.94 to 1.27)	1.05	(0.92 to 1.21)	1.07	(1.00 to 1.15)

*P<0.05.

Table 4 The overall rural-to-urban prevalence rate ratio of hearing impairment by severity in Taiwan

	Mild				Moderate				Severe			
	Prev.†		Rate		Prev.		Rate		Prev.		Rate	
Year	Rural	Urban	ratio	(95% CI)	Rural	Urban	ratio	(95% CI)	Rural	Urban	ratio	(95% CI)
2004	2.44	2.13	1.15	(1.01 to 1.29)*	2.03	1.92	1.06	(0.93 to 1.21)	3.42	3.47	0.99	(0.89 to 1.09)
2005	2.49	2.28	1.09	(0.97 to 1.23)	1.95	1.85	1.06	(0.92 to 1.21)	3.26	3.53	0.92	(0.83 to 1.02)
2006	2.69	2.38	1.13	(1.00 to 1.27)*	1.97	1.84	1.07	(0.93 to 1.23)	3.41	3.62	0.94	(0.85 to 1.04)
2007	2.59	2.41	1.08	(0.95 to 1.22)	2.09	1.86	1.12	(0.98 to 1.29)	3.31	3.50	0.95	(0.85 to 1.05)
2008	2.64	2.32	1.14	(1.01 to 1.29)*	2.12	1.76	1.21	(1.05 to 1.39)*	3.30	3.42	0.96	(0.87 to 1.07)
2009	2.93	2.35	1.25	(1.10 to 1.40)*	1.98	1.74	1.14	(0.99 to 1.31)	3.27	3.41	0.96	(0.86 to 1.07)
2010	2.95	2.45	1.21	(1.07 to 1.36)*	1.76	1.64	1.07	(0.92 to 1.25)	3.37	3.45	0.98	(0.87 to 1.09)

*P<0.05.
†Prev., the prevalence per 10 000 children, estimated by dividing the number of cases by the population in each age group in each year.

RR decreased with severity in all years except for 2007 and 2008.

DISCUSSION

Prevalence data on CHI between urban and rural areas from large-scale studies are limited, and the reported prevalence rates range widely. We conducted a search of literature in the PubMed database and identified 16 studies on the prevalence rate of low-frequency CHI, which defined HI by dB hearing level (HL) values and included rural and/or urban participants, and 11 of them used cutoffs ≥30 dB (table 5).[2 9–11 13 20 23–32] The variation in reported prevalence rates may mainly be attributable to differences in case definition, age range, and case-finding methods.[33] Factors such as genetic makeup, healthcare accessibility, and socioeconomic status may also have contributions.[11–13] The differences make comparisons among studies difficult. For example, the case definition of severe CHI in our study was ≥90 dB BEHL, and the 3.4/10 000 prevalence rate in the rural areas in 2010 was lower than those reported by a study in Saudi Arabia (3.9/10 000)[9] and a study in India (35.2/10 000)[10] adopting similar criteria. However, the age ranges used were different, making the comparison difficult. The above limitations highlight the need for standardisation to enhance the quality and comparability of study results. For example, the WHO recommends disabling HI in children be defined as a permanent unaided BEHL >30 dB taken as the average BEHL for frequencies 0.5, 1, 2 and 4 kHz; while we were unable to adopt the standards because the lack of data on individual cases, of the 11 previous studies identified from the systematic literature review, none adopted the WHO standards, even though most of them had data on individual cases. Standardisation can allow direct future comparisons of studies as well as establishing normative baseline data to illuminate potential intervention strategies.[12]

Our major finding of a higher prevalence rate of CHI in rural areas was consistent with the results of previous studies in other countries.[20 24] In 2009, the rural–to-urban prevalence RR was 0.96 (not statistically significant) in severe cases and 1.14 (not statistically significant) in moderate cases, but it was 1.25 (statistically significant) in mild cases, making the overall RR (1.09) statistically significant. In a study in Tanzania, in which 802 primary school children were examined using pure tone audiometry and HI was defined as a low-frequency PTA threshold of >5 dB HL in the frequencies of 0.5, 1 and 2 kHz,[24] the prevalence rate of CHI was 1102.4/10 000 among rural children, while it was only 755.6/10 000 among urban children (P<0.05). Similarly, in a survey in Nepal, school children with a diagnosis of otitis media with effusion (aged from 4–13 years) underwent audiometric assessment, and the prevalence rate of HI, defined as a middle-frequency PTA threshold of >25 dB HL in the frequencies of 0.5, 1, 2 and 4 kHz, was higher among rural children (2700.0/10 000 vs 400.0/10 000, P<0.05).[20]

Some studies comparing CHI between urban and rural areas reported findings that are different from our observations. A study in China examined 6626 residents with an age range from 1 month to 90 years using the WHO definitions of HI and found no differences between urban and rural areas (19.7% vs 15.7% reduction in dB HL, P>0.05).[34] However, the report did not have separate data on CHI specifically, and therefore it is difficult to draw a conclusion on the difference in CHI. A study in Tanzania examined 854 school children from one urban district and one rural district by screening audiometry (air conduction) and found that the prevalence of bilateral HI was higher in the urban district (10.5% vs 4.7%).[35] However, they did not include sensory HI, and therefore it is difficult to compare their data with our findings directly.

Some studies have investigated the possible aetiological factors of the high prevalence rate of CHI in rural populations. A study on 335 school children between 6 and 19 years of age in an impoverished area of Peru identified the following risk factors for CHI: neonatal jaundice, seizure, hospitalisation, recurrent otitis media, past otorrhea, family history of HI at <35 years, tympanic membrane

Table 5 The prevalence rate (per 10 000 children) of low-frequency hearing impairment (≥30 dB hearing level [HL] in the better ear) defined by dB values in different studies

Study (year)	Country	Case-finding method	Case number (area)	Age (year)	Case definition	Prevalence
Seely et al (1995)[23]	West Africa	Two-stage screening	2015 (rural)	15	Average of 0.5, 1 and 2 kHz	
					>40 dB HL in the better ear	297.8
					>60 dB HL in the better ear	129.0
					>80 dB HL in the better ear	99.3
Minja and Machemba (1996)[24]	Tanzania	Two-stage screening	127 (rural)	5–20	Average of 0.5, 1 and 2 kHz	
					>40 dB HL in the better ear	0.0
			675 (urban)	5–19	Average of 0.5, 1 and 2 kHz	
					>40 dB HL in the better ear	163.0
Morioka et al (1996)[25]	China	Population registry survey	282 (rural)	7–17	Average of 0.5, 1 and 2 kHz	
					≥35 dB HL in the better ear	496.5
Jacob et al (1997)[10]	India	Population registry survey	284 (rural)	6–10	Average of 0.5, 1, 2 and 4 kHz	
					>40 dB HL in the better ear	1091.5
					>65 dB HL in the better ear	70.4
					>90 dB HL in the better ear	35.2
Kaewboonchoo et al (1998)[11]	China	Population registry survey	442 (urban)	6–19	Average of 0.5, 1 and 2 kHz	
					≥35 dB HL in the better ear	113.1
Olusanya et al (2000)[27]	Nigeria	Two-stage screening	359 (urban)	4.5–10.9	Average of 0.5, 1, 2 and 4 kHz	
					>40 dB HL in the better ear	55.7
Czechowicz et al (2010)[2]	Peru	Population registry survey	335 (rural)	6–19	Average of 0.5, 1, 2 and 4 kHz	
					>40 dB HL in the better ear	238.8
					>55 dB HL in the better ear	119.4
					>70 dB HL in the better ear	29.9
Schmitz et al (2010)[29]	Nepal	Population registry survey	3646 (rural)	15–23	Average of 0.5, 1, 2 and 4 kHz	
					≥30 dB HL in the better ear	151.3
					>40 dB HL in the better ear	71.5
					>60 dB HL in the better ear	38.5
					>80 dB HL in the better ear	33.0

Table 5 Continued

Study (year)	Country	Case-finding method	Case number (area)	Age (year)	Case definition	Prevalence
Bagshaw et al (2011)[20]	Nepal	Population registry survey (with a diagnosis of otitis media with effusion)	70 (rural)	4–13	Average of 0.5, 1, 2 and 4 kHz	
					>40 dB HL in the better ear	1000.0
			51 (urban)	4–13	Average of 0.5, 1, 2 and 4 kHz	
					>40 dB HL in the better ear	0.0
Gondim et al (2012)[30]	Brazil	Population registry survey	90 (urban)	4–19	Average of 1, 2 and 4 kHz	
					>30 dB HL in the better ear	111.1
Al-Rowaily et al (2012)[9]	Saudi Arabia	Two-stage screening	2574 (urban)	4–8	Average of 1, 2 and 4 kHz	
					>40 dB HL in the better ear	73.8
					>90 dB HL in the better ear	3.9
Our study	Taiwan	National registry (reporting)	1 309 068 (rural) 3 286 699 (urban)	0–17	Averaged of 0.5, 1 and 2 kHz	
					≥55 dB HL in the better ear	8.1
					≥70 dB HL in the better ear	5.1
					≥90 dB HL in the better ear	3.4
					≥55 dB HL in the better ear	7.5
					≥70 dB HL in the better ear	5.1
					≥90 dB HL in the better ear	3.5

abnormality, cerumen impaction, and eustachian tube dysfunction.[2] This study proposed that untreated middle ear disease in the context of limited access to paediatric care may be a major risk factor for rural CHI. In a rural primary school in south India, hearing assessments were performed on 284 students (from 6 to 10 years old), and middle ear disease was found to be the predominant cause of CHI.[10] An investigation of HI in 75 Yemeni children (0.6–15 years) with chronic suppurative otitis media found that middle ear disease predominantly caused an HI of 26–60 dB HL.[36] According to these findings, middle ear disease appears to be major cause of CHI in rural areas, mainly leading to HI in the range of 26–60 dB HL. In our study, we found that mild CHI (55–69 dB BEHL) was more prevalent in the rural areas in all years, with most of the rural-to-urban RRs reaching statistical significance, while the prevalence rates of CHI in the other two higher severity categories (≥70 dB HL) were similar between rural and urban areas. Therefore, we speculate that a higher prevalence of untreated middle ear disease in rural areas contributed, at least in part, to the rural–urban differences observed in our study.

In each year, the prevalence rates of CHI in both rural and urban areas increased with age. This finding was also noted in the Metropolitan Atlanta Developmental Disabilities Surveillance Program in the USA,[37] which found that the prevalence rate of CHI >40 dB HL increased steadily from 6.7/10 000 among 3-year-old children to 13.8/10 000 for 10-year-old children. Likewise, a study in the UK found that the prevalence rate of CHI >40 dB HL rose from 9.1/10 000 among 3-year-old children to 16.5/10 000 among children 9–16 years old.[38] Because HI was rarely fatal and a substantial proportion of serious cases were not curable,[33] it is reasonable that age appears to be a main determinant of the prevalence rate of CHI. In addition, both newly acquired HI and the progress of impairment severity might also contribute to the increasing trend in the prevalence of CHI associated with age.

We found that the prevalence rates of CHI in the age group <3 years significantly increased over time. In urban areas, the rates increased significantly by 79% from 2004 to 2010, and they increased significantly by 71% in rural areas. We speculated that one of the main causes of this

was the implementation of the newborn hearing screening (NHS) programme in Taiwan. As early diagnosis and early intervention of congenital HI have been demonstrated effective in reducing its negative impacts on a child's development, the Health Promotion Administration of Taiwan began the promotion of NHS using otoacoustic emission and automated auditory brainstem response in 2003.[39] We believe that through increasing the awareness of parents and professionals and promoting easier access to NHS, the registration of CHI cases has increased. According to Taiwan's official reports, the participation rate of NHS has increased from 4.0% in 2002 to 71.1% in 2010, and 97.8% of the baby-delivering institutions offered NHS services in 2013.[40] Another possible cause is that Taiwan Health Promotion Administration has also implemented the Hearing Screening Plan for Pre-School Age Children in communities and kindergartens. In 2013, for example, 138 197 children were thus screened, yielding a screening rate of 81.6%, much higher than the 30.3% rate in 2002.[40]

In contrast with previous studies, our study has some unique features. While most previous studies were cross-sectional surveys, we have data on the same population over time. In most previous large-scale studies, data collection was just a one-time effort, but our study included 7 years' worth of data, which allows for the assessment of time trends. In addition, our study has a very large number of cases, over 3533 cases in 2010 alone, and therefore we can generate reliable statistical estimates. We also have specific information on severity, which is rarely reported by large-scale studies.

However, our study also has some limitations. We used 'administrative prevalence' data, which did not cover cases that were not detected or never received services from the administration. Also, data on individual cases provided by the registry were limited, which hindered the study of the aetiology of the differences between rural and urban areas. Investigations to clarify the aetiology of the difference should be performed, which would help prevention and health education to reduce the risk of CHI. Furthermore, we used city/county as the unit for observation, but there may be both urban and rural townships within a county. Therefore, using township as the unit of study may lead to more precise classification. Unfortunately, such data were unavailable from the Taiwan government. Nonetheless, this limitation tends to underestimate the difference in CHI prevalence between rural and urban areas, instead of overestimating it, and since we observed a statistically significant difference, its effect is unlikely to change our conclusions.

In conclusion, we found that the prevalence of CHI had remained similar from 2004 to 2010 in Taiwan. During this period, rural areas generally had higher prevalence rates than urban areas. This difference was attributable to the higher prevalence rates of mild CHI (55–69 dB BEHL). The rural-to-urban prevalence RRs generally decreased with severity. In addition, we found that the prevalence rate in the age group <3 years had increased remarkably in both rural and urban areas, which might be attributable to the implementation of the NHS programme. We hope these findings can cast some light on the prevention and control of CHI.

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