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ORIGINAL ARTICLE

Epidemiology of mortality induced by acute respiratory infections in infants and children under the age of 5 years and its relationship with the Human Development Index in Asia: an updated ecological study

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Abstract

Aim Acute respiratory infection (ARI) is the most commonly reported disease in children. This study was conducted to investigate the epidemiology of mortality from ARI and its relationship with the Human Development Index (HDI) in children under the age of 5 years.

Subjects and methods The study data included the HDI, neonatal mortality rates, and the mortality of children under the age of 5 years due to ARIs retrieved from the World Bank. In this study, the bivariate correlation method was employed and a significance level of less than 0.05 was considered.

Results The mortality of children under the age of 5 years ($r = -0.784$, $p < 0.0001$) and neonatal death ($r = -0.792$, $p < 0.0001$) induced by ARIs was negatively correlated with the HDI. There was also a significant negative correlation between neonatal death caused by ARIs and gross national income (GNI) per capita per 1000 lives ($r = -0.453$, $p < 0.001$), mean years of schooling ($r = -0.645$, $p < 0.001$), life expectancy at birth ($r = -0.801$, $p < 0.001$), and expected years of schooling ($r = -0.736$, $p < 0.001$). A negative and significant correlation was also observed between the ARI-induced mortality of children under the age of 5 years and GNI per capita per 1000 lives ($r = -0.469$, $p < 0.001$), mean years of schooling ($r = -0.619$, $p < 0.001$), life expectancy at birth ($r = -0.771$, $p < 0.001$), and expected years of schooling ($r = -0.756$, $p < 0.01$).

Conclusion The components of the HDI are directly related to ARI deaths. Therefore, a careful analysis of these indicators in countries with a low HDI can be effective in promoting health and reducing ARI-related mortality in children.

Keywords Mortality · Acute respiratory infections · Children · Human Development Index

Introduction

The mortality rate of children under the age of 5 years is recognized as a major indicator of development and health in countries. In developing countries, more than 10 million children die before the age of 5 years old each year (Rajaratnam et al. 2010). Acute respiratory infections (ARIs), diarrhea, measles, malaria, and malnutrition are among the major causes of death in children under 5 years of age (Cunha 2000). ARI is the leading cause of death and hospitalization in children under the age of 5 years, especially in developing countries, so that some 1.3 million children aged under 5 years die from ARIs worldwide annually (Peng et al. 2009). The mortality of one-third of children aged under 5 years in developing countries can be attributed to ARIs (Ujunwa and Ezeonu 2014).

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According to the World Health Organization (WHO), respiratory infections account for 6% of the global burden of diseases, which is higher than that of diarrhea, cancer, human immunodeficiency virus (HIV) infection, ischemic heart disease, or malaria. Each year, more than 12 million children under the age of 5 years are admitted for ARIs (Tazinya et al. 2018).

In addition, 70% of mortality associated with respiratory infections occurs in Africa and Southeast Asia (Zhang et al. 2014).

Streptococcus pneumoniae and *Haemophilus influenzae* type b (Hib) are the major factors that contribute to the development of respiratory infections in children, accounting for more than 50% of ARI cases in developing countries (Shi et al. 2015).

The childhood vaccination program against these bacteria has resulted in a significant drop in mortality and morbidity associated with ARIs. Some of these factors are pertained to children (such as age, sex, and systemic diseases) (Biesbroek et al. 2014).

Regionally, South and Southeast Asia have some of the highest rates of ARI-associated mortality, with approximately 21% of all deaths in children under the age of 5 years attributable to respiratory infections (Black et al. 2010).

Environmental factors, family and socioeconomic status, and access to health and treatment systems are among the key factors in the growth of ARIs in children (Jackson et al. 2013).

Disparity in the impact of environmental conditions such as air pollution levels, economic and nutritional factors such as micronutrient deficiency, and cultural issues such as housing and type of consumed fuel, and difference in access to basic healthcare are some of the factors that explain the difference between the incidence and prevalence of respiratory infections in developing and developed countries (Jochem et al. 2016; Rudan et al. 2008).

The Human Development Index (HDI) is one of the factors that wield influence on the incidence and mortality of patients. Since 1990, the United Nations Development Programme (UNDP) has released a Human Development Report every year, which compares countries in diverse educational, health, economic, social, environmental, and political indicators, among other things. These indicators play a key role in determining the health of each country (Anand and Sen 1994).

Thus, although ARIs are largely curable and preventable, they continue to be the leading cause of morbidity and mortality worldwide, especially in developing countries, posing a serious health concern to people in these countries. Thus, the present study aims to explore the epidemiology of mortality associated with this disease and its relationship to the HDI.

Materials and methods

This is an ecological study that investigates the relationship between infant mortality in children under the age of 5 years due to respiratory infections and the HDI in Asian countries. The study data consisted of the HDI, neonatal mortality rate, and ARI-associated mortality of children under the age of 5 years retrieved from the World Bank (https://data.worldbank.org) (Mathers et al. 2009). The HDI data released by the World Bank provide the latest information on global development, including national, regional, and global estimates. In the Human Development Report, countries are divided into various groups, including very high human development, high human development, moderate human development, and low human development countries.

The value of the HDI is in the range from 0 to 1. It indicates the extent of a country's progress towards the highest possible value (i.e., 1). It also provides an opportunity for the comparison of countries. The HDI is a essence of human development measurements. It measures the average achievements of a country in terms of three dimensions of human development: a long and healthy life, education, and living standards (Anand and Sen 1994). The under-5 mortality rate refers to the probability of death in children from birth until the age of 5 years, which is expressed per 1000 live births, while the neonatal mortality rate is the probability of death during the first 28 days of life, which is also expressed per 1000 live births.

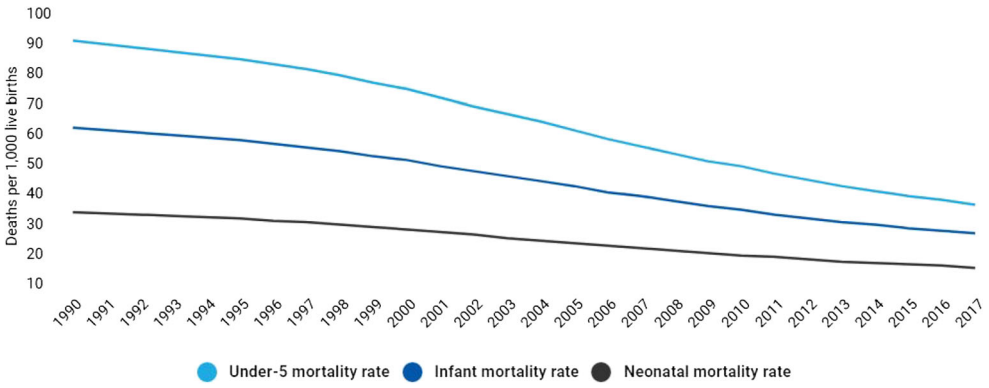

Fig. 1 Global under-5 mortality rate, infant mortality rate, and neonatal mortality rate since 1990–2017. Source: United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) 2018

Table 1 Neonatal death rate and under-5 death rate from acute respiratory infection in Asia

Country	Neonatal death rate due to acute respiratory infection (per 1000 live births)					Under-5 mortality rate due to acute respiratory infection (per 1000 live births)				
	2000	2005	2010	2015	2016	2000	2005	2010	2015	2016
Afghanistan	4.4	4.2	3.3	2.7	2.6	23.0	20.9	15.9	11.7	11.1
Armenia	1.8	1.1	0.74	0.45	0.42	6.0	3.5	2.2	1.4	1.3
Azerbaijan	2.0	1.5	1.1	0.9	0.9	14.5	8.8	5.9	3.9	3.8
Bahrain	0.0	0.06	0.0	0.02	0.02	0.18	0.42	0.57	0.14	0.14
Bangladesh	3.3	2.5	1.8	1.2	1.2	17.4	13.5	8.5	5.8	5.4
Bhutan	2.2	1.6	1.2	0.96	0.93	17.2	11.7	7.7	5.0	4.7
Brunei	0.08	0.08	0.09	0.08	0.03	0.5	0.5	0.5	0.3	0.2
Cambodia	2.6	1.7	1.2	0.9	0.8	24.2	13.7	7.9	5.2	5.0
China	3.1	1.5	0.6	0.3	0.2	7.6	3.5	2.04	1.3	1.2
Cyprus	0.0	0.0	0.0	0.0	0.0	0.18	0.09	0.03	0.02	0.03
Georgia	2.4	1.3	0.6	0.3	0.2	6.1	2.8	1.3	0.78	0.72
India	3.09	2.4	1.8	1.3	1.3	17.3	13.4	10.0	6.6	6.2
Indonesia	1.4	1.1	0.93	0.78	0.75	9.4	7.4	5.7	4.2	4.05
Iran, Islamic Republic of	0.98	0.78	0.6	0.4	0.4	5.8	3.7	2.6	2.0	1.9
Iraq	1.5	1.4	1.2	1.1	1.0	7.6	6.7	5.9	4.7	4.6
Israel	0.03	0.02	0.0	0.0	0.0	0.1	1.7	0.0	0.0	0.0
Japan	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.2	0.15	0.18
Jordan	0.7	0.5	0.4	0.3	0.3	3.1	2.2	1.8	1.5	1.5
Kazakhstan	1.0	0.8	0.5	0.3	0.3	7.8	5.0	2.9	1.6	1.5
Korea, Republic of	0.06	0.01	0.0	0.0	0.0	0.4	0.1	0.1	0.08	0.07
Kuwait	0.0	0.0	0.0	0.0	0.0	0.7	0.5	0.4	0.5	0.5
Kyrgyzstan	1.9	1.1	0.6	0.4	0.4	16.9	10.8	6.7	3.8	4.3
Lao People's Democratic Republic	0.0	0.0	0.0	0.0	0.0	0.7	0.5	0.4	0.5	0.5
Lebanon	0.58	0.37	0.17	0.13	0.12	2.0	1.2	0.63	0.48	0.47
Malaysia	0.13	0.0	0.0	0.0	0.0	0.88	0.53	0.47	0.46	0.46
Maldives	2.3	0.81	0.32	0.17	0.15	8.0	2.7	1.2	0.65	0.59
Mongolia	1.4	1.06	0.76	0.53	0.51	13.0	6.7	3.3	2.6	2.5
Myanmar	2.5	2.1	1.8	1.5	1.5	17.6	16.3	13.4	9.6	9.2
Nepal	3.2	2.4	1.75	1.2	1.2	15.8	12.1	8.5	5.5	5.2
Oman	0.1	0.0	0.0	0.0	0.0	1.7	0.9	0.6	0.6	0.6
Pakistan	4.5	3.7	3.3	2.9	2.8	21.5	19.1	15.0	11.8	11.5
Philippines	1.1	1.01	0.87	0.76	0.74	8.3	7.4	6.6	5.2	4.9
Qatar	0.0	0.0	0.0	0.0	0.0	0.68	0.48	0.4	0.39	0.39
Saudi Arabia	0.2	0.18	0.14	0.1	0.0	2.2	1.4	1.0	0.75	0.72
Singapore	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.18	0.25	0.28
Sri Lanka	0.6	0.47	0.42	0.46	0.47	3.2	2.1	1.7	1.6	1.7
Syrian Arab Republic	0.6	0.47	0.42	0.46	0.47	3.2	2.1	1.7	1.6	1.7
Tajikistan	2.0	1.6	1.4	1.2	1.2	21.0	13.5	9.07	7.8	7.5
Thailand	0.9	0.5	0.38	0.26	0.25	2.6	1.8	1.37	1.06	1.0
Timor-Leste	3.05	2.3	1.8	1.6	1.5	25.4	18.0	13.5	11.0	10.5
Turkey	0.2	0.2	0.1	0.0	0.0	2.6	1.4	0.82	0.52	0.48
Turkmenistan	1.8	1.6	1.5	1.3	1.3	17.3	14.5	10.9	8.7	8.5
United Arab Emirates	0.03	0.03	0.03	0.03	0.03	0.6	0.4	0.4	0.3	0.3
Uzbekistan	1.7	1.3	1.0	0.78	0.73	12.1	8.5	5.1	3.5	3.3
Viet Nam	1.42	1.1	0.9	0.8	0.8	5.2	3.8	3.03	2.7	2.6
Yemen	2.8	2.4	1.9	1.9	1.9	21.2	15.02	10.5	8.4	9.1

The United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) is determined to gather all available national data on child mortality, including data from vital registration systems, population censuses, household surveys, and sample registration systems. To estimate the under-5 mortality trend series for each country, a statistical model in fitting with the data points is designed. The model meets quality standards established by the UN IGME. It is then used to predict a trend line, which is extrapolated to a common reference year (2016) for the estimates presented here. Infant mortality rates are based on either a statistical model or transformation of under-5 mortality rates in accordance with model life tables. Neonatal mortality rates are developed by a statistical model that employs national available data and estimated under-5 mortality rates as the input.

Statistical analysis

In this study, the bivariate correlation method was utilized to analyze data extracted from the correlation between ARI-

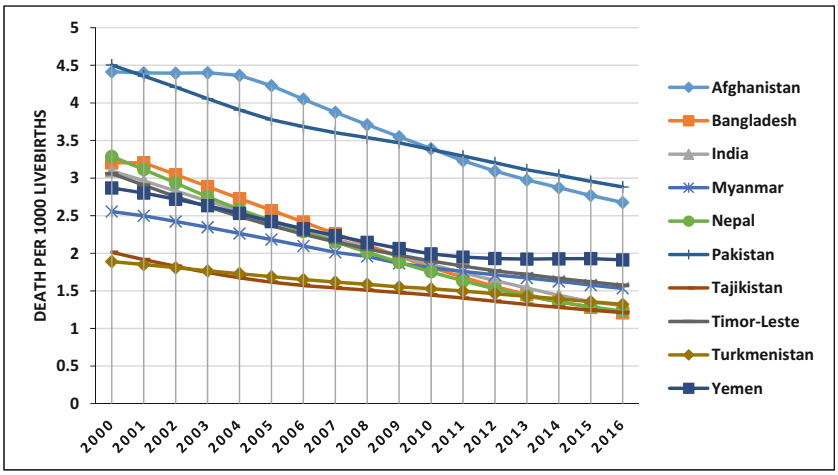

Fig. 2 Trend of the neonatal death rate from acute respiratory infection (per 1000 live births) in Asian countries during the period 2000–2016

related mortality rates and the HDI at a significance level of $p < 0.05$. The analyses were performed using Stata 14 software.

Ethical considerations

Since the data analyzed in this study were from the World Bank and data on ARIs are estimated for each country, there is no specific ethical consideration.

Results

There has been remarkable progress in child survival over the past few decades, with millions of children facing a higher chance of survival compared to 1990; 1 in 26 children died before the age of 5 years in 2017, compared to 1 in 11 in 1990. Moreover, advancement in controlling child mortality has been accelerated in the 2000–2017 period compared to the 1990s, with the annual reduction rate of the under-5 mortality rate increasing from 1.9% in 1990–2000 to 4.0% in 2000–2017. Despite the global progress in reducing child mortality over the past few decades, an estimated 5.4 million children under the age of 5 years died in 2017—approximately half of the deaths were recorded in sub-Saharan Africa (Fig. 1).

According to the data, in the Asian countries, the infant death rate and ARI-associated mortality of children under the age of 5 years has been decreasing since 2000. The results exhibited that, in most Asian countries, the ARI-related mortality of newborns decreased to 0 or less than 1 in 1000 live births in 2016. The results also suggest that infant mortality rates linked to respiratory infections have soared from 2000 to 2016 in ten countries, including Pakistan (2.8 per 1000), Afghanistan (2.6 per 1000), Yemen (9.1 In 1000), Myanmar (1.5 in 1000), Timor-Leste (1.5 in 1000), India (1.3 in 1000), Turkmenistan (1.3 in 1000), Bangladesh (1.2 in 1000), Nepal (1.2 per 1000), and Tajikistan (1.2 per 1000). Nonetheless, it was still more than 1 per 1000 live births in 2016 (Table 1, Fig. 2). The study of mortality in children under the age of 5 years suggested that ARI-associated deaths had developed a decreasing trend from 2000 to 2016. The highest death rates in 2016 were reported in Pakistan (11.5 per 1000), Afghanistan (11.1 per 1000), Timor-Leste (10.5 per 1000), Myanmar (9.2 per 1000), Yemen (9.1 in 1000), Tajikistan (7.5 in 1000), India (6.2 in 1000), Bangladesh (5.4 in 1000), and Nepal (5.2 in 1000), (Table 1, Fig. 3).

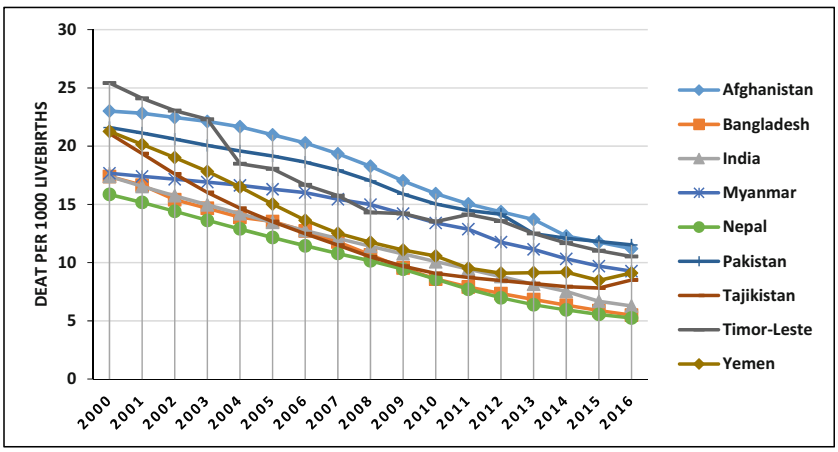

Fig. 3 Trend of the under-5 death rate from acute respiratory infection (per 1000 live births) in Asian countries during the period 2000–2016

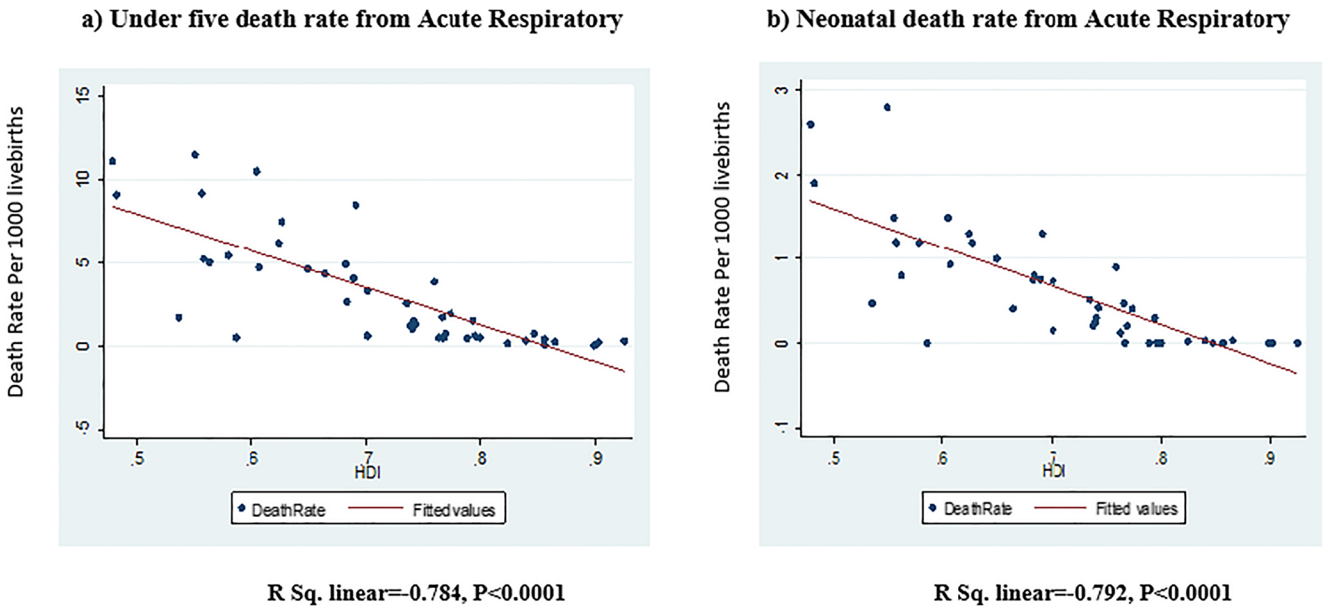

Fig. 4 Correlation between the Human Development Index (HDI) and death rate from acute respiratory infection. **a** Children under 5 years old. **b** Neonatal death in Asia in 2016

The results revealed that the mortality of children under 5 years of age ($r = -0.784$, $p < 0.0001$) and neonatal death ($r = -0.792$, $p < 0.0001$) due to respiratory infections was negatively correlated with the HDI (Fig. 4).

The study of the components of the HDI and ARI-related mortality in children and infants exhibited that there was a significant negative correlation between ARI-linked neonatal mortality and gross national income (GNI) per capita ($r = -0.453$, $p < 0.001$), mean years of schooling ($r = 0.645$, $p < 0.001$), life expectancy at birth ($r = -0.801$, $p < 0.001$), and expected years of schooling ($r = -0.736$, $p < 0.001$). Also, the results manifested a significant negative correlation between the death of children under 5 years of age due to respiratory infections and GNI ($r = -0.469$, $p < 0.001$), mean years of schooling ($r = -0.619$, $p < 0.001$), life expectancy at birth ($r = -0.771$, $p < 0.001$), and expected years of schooling ($r = -0.756$, $p < 0.01$) (Table 2).

The results of the regression analysis revealed that there was a significant statistical relationship between neonatal mortality due to respiratory infections and life expectancy at birth ($B = -0.05$, $p < 0.05$) and expected years of schooling ($B = -0.12$, $p < 0.05$). The analysis also manifested a statistically significant relationship between mortality due to respiratory infections in children under 5 years of age and life expectancy at birth ($B = -0.3$, $p < 0.05$), while this relationship was not significant in other factors (GNI, mean years of schooling, and expected years of schooling) (Table 3).

Discussion

According to the results of the study, ARI-related mortality declined between 2000 and 2016, with the highest mortality rate reported in Pakistan (11.5 per 1000 live births) in 2016. The results revealed a significant negative correlation between the under-5 mortality rate ($r = -0.784$, $p < 0.0001$) and neonatal mortality ($r = -0.792$, $p < 0.0001$) due to respiratory infections and the HDI. The analysis of the HDI components results suggested that life expectancy at birth, education, and GNI in countries is associated with ARI-related mortality in infants and children under 5 years of age.

Table 2 Pearson correlation between the Human Development Index (HDI) components and the dependent variable

HDI components	Under-5 mortality rate due to acute respiratory infection		Neonatal death rate due to acute respiratory infection	
	r	*p*-Value	r	*p*-Value
GNI per capita per 1000 lives	− 0.453	$p < 0.001$	− 0.469	$p < 0.001$
Mean years of schooling	− 0.645	$p < 0.001$	− 0.619	$p < 0.001$
Life expectancy at birth	− 0.801	$p < 0.001$	− 0.771	$p < 0.001$
Expected years of schooling	− 0.736	$p < 0.001$	− 0.756	$p < 0.001$

Dependent variables: under-5 death rate and neonatal death rate due to acute respiratory infection

Table 3 Effect of the Human Development Index (HDI) components on death rate from acute respiratory infection in 2016

HDI components	Neonatal death rate due to acute respiratory infection			Under-5 death rate due to acute respiratory infection		
	B	95% CI	*p*-Value	B	95% CI	*p*-Value
GNI per capita per 1000 lives	− 1.4	(− 7.4, 4.6)	*	− 2.06	(− 8.1, 5.2)	*
Mean years of schooling	− 0.01	(− 0.07, 0.04)	*	− 0.14	(− 0.4, 0.1)	*
Life expectancy at birth	− 0.05	(− 0.09, − 0.01)	**	− 0.3	(− 0.5, 0.1)	**
Expected years of schooling	− 0.12	(− 0.2, − 0.01)	**	− 0.3	(− 0.8, 0.1)	*

CI, confidence interval; GNI, gross national income

*$p > 0.05$

**$p < 0.05$

In the United States, about 100,000 ARI-related deaths were reported in children under the age of 1 year old in the 1980s. Five countries, Brazil (40%), Mexico (19%), Peru (14%), Bolivia (7%), and Haiti (5%), account for 85% of these cases. The Pan American Health Organization (PAHO) estimates that ARI-associated mortality varies from 2% to 16%. Meanwhile, in countries such as Canada and the United States, the percentage of deaths linked to ARI in this age group is only 2% (Casteleijn and Finney-Brown 2010). Childhood respiratory infections are caused by a set of risk factors associated with the host, environment, and infectious agents, and the difficulty of diagnosis in developing countries. However, according to existing evidence, many studies have identified *S. pneumoniae* and *H. influenzae* as the major pathogens associated with childhood infections (Berman 1991; Selwyn 1990). Multiple approaches that involve the use of simple, inexpensive, and accessible methods, such as vaccination, nutritional, social, and environmental factors, identification of people in need of care, early detection, and timely prescription of antibiotics can help reduce respiratory system infections (WHO 2014).

Previous studies have shown that childhood acute lower respiratory infection is associated with poverty, malnutrition, indoor air pollution, living in crowded areas, and access to medical care (Ali et al. 2001; Rudan et al. 2008). It is also influenced by all parameters affecting the safety status and exposure to pathogens or lung-irritant agents (Mizgerd 2006).

Death rates caused by infectious diseases and respiratory infections are higher in countries with lower HDI. In these countries, lower employment opportunities hamper access to healthcare and, in most cases, patients refer to hospitals when their disease is at the acute and untreatable stages. In various studies, the association of the HDI and its dimensions with the health of communities has been confirmed. In societies with low HDI, insufficient socioeconomic support is tied to a variety of adverse health outcomes (Anand and Sen 1994). The results of assessing maternal caring behaviors during childhood disease have exhibited that the total household income, the number of symptoms, and mother's education wield influence on the mother's healthcare-seeking behavior in improving and reducing the mortality rate of children (Razi et al. 2005; Sreeramareddy et al. 2006). The ARI-related mortality rate of children in developing countries is 30 times higher than that of the developed world (Chretien et al. 1984). A growing body of studies has shown that the mortality rate of children with respiratory infections and lower socioeconomic status is lower in developing countries (Rudan et al. 2013; Sonego et al. 2015).

Other studies have introduced different measures of social status, including income, house ownership, and education, to predict respiratory infections in different countries (Crighton et al. 2007; Emch et al. 2010). Socioeconomic status may affect respiratory infections by increasing exposure to pathogens in crowded neighborhoods or diminishing immunity to stress or malnutrition (Cohen 1999).

Several studies in developing countries have confirmed the relationship between maternal education and ARIs in children (Murray et al. 2012; Savitha et al. 2007). In households where mothers have a lower level of education, the rate of births and household dimension are higher. Moreover, studies have shown that a factor influencing respiratory infections and mortality is household size. It has been shown that a greater household size is associated with higher risk of respiratory infections (Bruden et al. 2015; Bulkow et al. 2002). The prevalence of respiratory infections indicates the incidence of malnutrition in children under the age of 5 years. Studies suggest that ARI is more common in children with acute malnutrition (Cunha 2000). Children with moderate or severe respiratory infections have higher mortality rates.

In addition, in 2-year-old children, malnutrition is associated with a significant increase in ARI incidence (Nantanda et al. 2008). In countries with low HDI, solid fuel is used to reduce cooking costs. Furnaces produce a huge amount of particles and gases, which usually escalates contamination and provokes respiratory infections in children. Studies have shown that, in developing countries, exposure to indoor air pollution (due to the use of fossil fuels) can exacerbate respiratory infections and increase child mortality (Fonseca et al. 1997; Murray et al. 2012). Studies have shown that children

with low birth weight (below 2500 g), who have a shorter life expectancy, are more likely to be exposed to respiratory infections, and the death rate related to respiratory infections is higher in these infants. Therefore, in countries where life expectancy is high, the probability of death and mortality due to respiratory diseases is lower (Cilla et al. 2006).

Low birth weight is strongly associated with respiratory disease in children. On the other hand, exclusive breastfeeding diminishes the incidence of lower respiratory tract infection compared to partially breastfed and non-breastfed infants. Therefore, in countries with low HDI, higher prevalence of low birth weight and lack of exclusive breastfeeding can increase the prevalence of respiratory infections (Dagvadorj et al. 2016).

Conclusion

According to the results of the study, the Human Development Index (HDI) is directly related to the mortality due to respiratory infections. Hence, greater attention should be paid to indicators such as level of education, income, and life expectancy to reduce child mortality.

Maternal education and awareness of the importance of care in children with respiratory infections, low birth weight, and increased life expectancy at birth, together with greater care in countries with low HDI levels, can reduce respiratory infections in children.

In countries with low HDI, further planning to strengthen HDI components can help promote health and reduce child mortality due to respiratory infections.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to report.

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