
Prevalence of Asthma in Children in worldwide and Korea

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Abstract

Objectives: Asthma in children has been worldwide disease and lots of research has been conducted for etiology, prevalence and prevention strategy. Most prevalence studies were limited to the specific area, countries, time or some period so that they could only give snap shot of target study population in a given time. The purpose of this study was to review the temporal trend of the prevalence of asthma in children in worldwide and Korea.

Methods: Articles related to the prevalence of asthma or asthmatic symptoms in children, written in English or Korean, were systematically searched using web searching engine. Then, the prevalence rates were described by countries with study design and criteria of asthma diagnosis while in Korea residence area of target population was used instead of country.

Results: The prevalence rates were varied by the diagnostic criteria of asthma. So, the prevalence of parent reported asthma or wheezing symptoms were higher than that of physician diagnostic asthma (PDA). The prevalence of asthma worldwide has continually increased since 1970 to the late 1990 or 2000. It was 5%, 8.3±6.5%, 13.8±11.1%, 11.4±8.3% in 1970', 1980', 1990', after 2000', respectively. After 2000', the trend of the prevalence of asthma seemed to be equilibrium or slightly increased but it is unclear because of variation of data. In Korean, PDA has not changed dramatically but small fluctuation over the decades. The PDA asthma was 8.9 ± 2.8%, 6.0 ± 2.9%, and 8.9 ± 2.7% in 1980, 1990 and 2000, respectively.

Conclusion: The prevalence rate of asthma worldwide has increased over decades but the increasing rate became unclear after 2000' while it was steadily continued over decades since 1980'.

keywords: Asthma, Children, Diagnosis. Factor, Prevalence, Symptom, Wheeze

Introduction

Asthma in children has been a concern in worldwide and Korea from the viewpoint of public health because of its prevalence. Asthma is a persistent respiratory disease marked by bronchoconstriction, airway hyper responsiveness, airway inflammation, and edema. Acute asthma symptoms include bronchospasm, coughing, wheezing, and mucus production, inducing airway obstruction and decreased airflow and oxygen exchange [1].

Asthma affects all ages and is one of the major factors causing non-attendance and preventing regular physical activities for school-aged children. In the US, asthma with pneumonia and injuries are the main causes of hospitalization in children < 18 years of age [2]. The burden of asthma on children

and families is substantial. The school absence rate in children with asthma is three times higher than that of non-asthmatic children [3].

There are few reports about the prevalence trends in many countries before the 1990s. The results of temporal trends in the prevalence of asthma in European and Asian countries are inconsistent. Therefore, it is necessary to understand the trend of the change of the prevalence of childhood asthma in western, Asian countries and Korea. So, the purpose of this study was to review the prevalence of asthma or asthmatic symptoms in children in worldwide and Korea.

Methods

Articles related to the prevalence of asthma or

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asthmatic symptoms in children, written in English or Korean, were systematically searched. Articles were searched in database from Pubmed (<http://www.ncbi.nlm.nih.gov/pubmed>) and KERIS (<http://www.riss.kr>). The keywords used in searching papers were childhood asthma, prevalence, and trends and other papers in references in searched papers, published from 1988 to 2015 (in Korea, from 1980 to 2015), were also reviewed. After searching related papers, some papers such as irrelevant papers, review papers and papers using same data with previous paper were excluded. As a result, total of thirty-nine papers, twenty-seven of foreign countries and twelve of Korean asthma prevalence papers, were reviewed and summarized. Prevalence rates were described by countries with the references, study design, population, research methodology of each paper, criteria of asthma. In case of Korea, area of population residence instead of country was described.

Results

Changes in the prevalence of asthma in worldwide

The prevalence of asthma in children had increased since 1970, but it showed slight increasing rate before the late 1990 or 2000 but inconsistent trend after that period in USA, developed European countries, and Australia [4-31]. The trends of the prevalence of asthma in children in each country were below (Table 1).

In USA, the prevalence of asthma in children had increased until 1990, but it showed decreasing trend after the late 1990 [4-6]. Akinbammi LJ and Schoendorf KC reported that between 1980 and 1996, the prevalence of asthma increased from 3.7% to 6.9% among children aged from birth to seven years [4]. Carter et al. reported the prevalence of physician-diagnosed current asthma increased from 1995 to 2003 (3.0% to 6.2%) [5]. Weitzman et al. reported that the estimated prevalence of childhood asthma increased from 3.1% in 1981 to 4.3% in 1988 and increases occurred among white children (2.7% to 4.1%) especially [6].

In Australia, the prevalence of asthma in children had increased until 1990, but it showed decreasing trend after 2000 [7, 8]. Downs SH et al. reported

the prevalence of wheeze increased by 5.1% and asthma diagnosis by 8.1% between 1992 and 1997 [7]. Robertson CF et al studied a questionnaire-base survey to determine the change in prevalence of asthma in Melbourne schoolchildren. There was a 26% reduction in the 12-month period prevalence of reported wheeze, from 27.2% in 1993 to 20.0% in 2002 [8].

In England, the prevalence of asthma in children had been studied since 1970 and it showed increased trend until early 2000 after 1970 [9-14]. Burr ML et al. reported that the prevalence of a history of wheeze at any time had increased from 17.0% to 22.3%, while that of a history of asthma at any time had increased from 5.5% to 12.0% in 1973 and 1988 in South Wales [9]. The prevalence of wheeze rose from 10.4% in 1964 to 19.8% in 1989, and the reported diagnosis of asthma rose from 4.1% to 10.2%, in Aberdeen, Scotland [10]. Kwong et al. investigated trends in asthma diagnosis and symptom morbidity between an eight-year time period in a paired prevalence study in Sheffield. There was significant increase between the two surveys in the prevalence of asthma ever (19.9% and 29.7%), current asthma (10.3% and 13.0%), and wheeze ever (30.3% and 35.8%) [11]. Anderson et al. reported an increase in lifetime asthma in 12- to 14-year-olds from 20.6% (1995) to 25.9% (2002) [12]. Shamsain M assessed time trends in symptoms of asthma among children in the north-east of England. There was an increase in the prevalence of current wheeze from 21.8% and 18.0% in 1995/1996 to 21.4% and 23.2% in 2001/2002 in girls and boys respectively [13]. Burr et al. reported an increase in reported asthma in 12-year-olds from 5.5% in 1973 to 12.0% in 1988, and 27.3% in 2003 [14].

In Germany, many studies were performed about the change of the prevalence following the environmental change after unification of western and eastern Germany [15-17]. Mutius EV et al. studied the change of the prevalence of asthma in children in eastern Germany following the exposure to western lifestyle after unification. But there was no significant increase in the prevalence of asthma in children [15]. Frye C et al. tested the hypothesis that prevalence of bronchial hyperresponsiveness (BHR) increased in East German children after reunification. Two consecutive cross-sectional

surveys of schoolchildren aged 8-14 years from three communities in East Germany were carried out in 1992-1993 and 1995-1996. The prevalence of BHR increased from 6.4% in 1992-1993 to 11.6% in 1995-1996 but no changes were found for asthma [16]. Zollner IK et al. investigated time trends in the prevalence of asthma and allergic sensitization among school children in Germany between 1992 and 2001. Over the 9-year study period, there was no increase in the prevalence of current wheezing and asthma [17].

In Italy, the prevalence of asthma in children increased between 1970 and 1990 but it stabilized after the late 1990. Ronchetti R et al. reported the prevalence of asthma in children in Rome have been changed 5.0%, 11.6%, and 11.0% [18]. The prevalence of asthma in children became stable or decreased after the late 1990. Braun-Fahrlander C et al. reported the prevalence of asthma remained constant 7.8% (1992-1993), 7.6% (1995-1997), 7.4% (1995-1997) in Switzerland [19]. In Norway, Selnes A et al. reported the prevalence of asthma was 9.3%, 13.2% and 13.8% in 1985, 1995 and 2000, respectively [20].

In Asia, the prevalence of asthma in children were various in each country for their situation [21-24]. Many countries are belonged to same geographic region as Asia but each country is located in different socioeconomic situation. That is, Japan, Hong Kong, Singapore, and Korea are similar to developed countries in western society but China and Indonesia are under developing. And some countries are still undeveloped. Wong GWK et al. indicated the lack of standardized methodologies and objective measurements and they compared the results of the Phase III ISAAC (the International Study of Asthma and Allergies in Childhood) study (2002) with the Phase I ISAAC study (1994-95) which used the identical and validated core questionnaires in Hong Kong. In the results, the prevalence rates of physicians' diagnosis of asthma were similar in the two surveys (11.2% and 10.2%), but the prevalence rates of wheeze in the past year have decreased from 12.4% in 1994-95 to 8.7% in 2002 [21]. Wang XS et al. studied the change of the prevalence of asthma using data from two ISAAC surveys seven years apart. In the study, the prevalence of wheeze in past year decreased from 16.6% in 1994 to 10.2% in

2001, and the prevalence of physician diagnosed asthma decreased from 18.5% to 16.3% in the 6-7 year age group [22]. Lee YL et al. compared the prevalence of asthma in Taiwanese middle-school students in 1995-96 and 2001. Lifetime prevalence of physician diagnosed asthma increased from 4.54% to 6.05% during the period [23]. Lee HB et al. studied the patterns of childhood asthma prevalence in six Asian countries from the data of ISAAC Phase I and III. The childhood asthma prevalence in China, Hong Kong, and Singapore decreased and it increased slightly in Thailand and the Philippines. The childhood asthma prevalence decreased from 5.9% to 5.3% in China, from 10.1% to 6.1% in Hong Kong, and from 12.0% to 11.0% in Singapore. Otherwise, the childhood asthma prevalence increased from 12.2% to 13.8% in Thailand and from 9.6% to 13.0% in Philippines [24].

Changes in the prevalence of asthma in Korea

The surveys for the prevalence of asthma in children in Korea were carried out without the standardized questionnaire or methods until 1995 like other countries. In general, the prevalence of asthma in children in Korea increased rapidly until the mid-1980, increased slightly after 1990, and stabilized or decreased after 2000 [32-43].

The prevalence of asthma was determined based on outpatients in the pediatric department of the national medical center in 1981-1982. The subjects were 2,074 children under 15 years old. The questionnaires were filled by parents assisted by nurse and physician. The prevalence of asthma was 5.7% [32]. Kim HS et al. studied the prevalence of asthma in children for the 832 elementary and middle school students in 1987 in Seoul.

Table 1. Worldwide childhood asthma prevalence

Country	Reference	Study design, population	Methodology	Criterion	Prevalence (%)
USA	Weitzman et al. (1992) [6]	Analyses of data from national health survey, 0-17 years, 15,224 in 1981, 17,110 in 1988	Questionnaire by parents	Parents reported asthma	3.1 (1981), 4.3 (1988)
	Akinbami and Schoendorf (2002) [4]	Analyses of five data sources from the National Center for Health Statistics, 0-17 years, from 1980 to 2000	Questionnaire survey	PDA	3.7 (1980), 6.9 (1996)
	Carter et al. (2005) [5]	Cross-sectional study, 2330 in 1995, 2397 in 2003 in Seattle	Questionnaire survey	PDA Wheeze	3.0 (1995), 6.2 (2003) 12.0 (1995), 6.2 (2003)
Canada	Dell et al. (2014) [26]			Lifetime Asthma	15.5 (2006)
		Cross sectional study (Phase 1), 5-9 years, 481 children in 2006	Questionnaire survey	Current Asthma	11.3 (2006)
				Lifetime Wheeze Current Wheeze	29.2 (2006) 14.2 (2006)
Brazil	Feitosa et al. (2011) [27]	Cross-sectional study, 0-7 years, 416 among 869 children in 2006	ISAAC questionnaire	SA Wheeze	22.84 (2006) 30.29 (2006)
	Downs et al. (2001) [7]	Cross sectional study, 769, 8-10 years in 1982, 850/1016 8-11 years in 1992/1997	Questionnaire by parents	PDA Wheeze ever	12.9 (1982), 30.5 19(92), 38.6 (1997) 23.9 (1982), 36.9 (1992), 42.3 (1997)
Australia	Robertson et al. (2004) [8]	Consecutive cross-sectional study, 6-7 years, 2843/2968 school children in 1993/2002	ISAAC questionnaire filled in by the parents	PDA	28.6 (1993), 25.5 (2002)

					Wheeze ever	40.7 (1993), 37.1 (2002)
	Vuillermin et al. (2007) [30]	Cross-sectional study, 4-13 years, 7813 student in 2005	ISAAC questionnaire filled in by the parents		Wheeze	20.2 (2005)
	Burr et al. (1989) [9]	Cross-sectional study: 15 years apart. 12 years schoolchildren 817 in 1973, 965 in 1988, South Wales	Questionnaire by parents		Asthma ever Wheeze ever	5.5 (1973), 12.0 (1988) 17.0 (1973), 22.3 (1988)
	Ninan and Russell (1992) [10]	Primary school children (8-13), 2510 in 1964, 3403 in 1989, Aberdeen, Scotland	Wheeze Self-reported by parents		Wheeze SA	10.4 (1964), 19.8 (1989) 4.1 (1964), 10.2 (1989)
UK	Kwong et al. (2001) [11]	Cross-sectional study: 8 years apart. 8-9 years schoolchildren 4580 in 1991, 5011 in 1999, Sheffield	ISAAC questionnaire filled in by the parents		PDA Wheeze ever	19.9 (1991), 29.7 (1999) 30.3 (1991), 35.8 (1999)
	Anderson et al. (2004) [12]	As part of ISAAC, 12-14 year old, 15,083 in 1995, 15,755 in 2002	ISAAC questionnaire		Lifetime asthma	20.6 (1995), 25.9 (2002)
	Shamssain et al. (2007) [13]	Two cross-sectional study 6 year apart, 13-14 year old, 3000/2195 in 1995/2001	ISAAC core questionnaire		Wheeze (Male) Wheeze (Female)	18.0 (1995), 23.2 (2001) 21.8 (1995), 21.4 (2001)
	Burr et al. (2006) [14]	Consecutive cross-sectional study, 12 year old, 817/965/1148 in 1973/1988/2003	Questionnaire survey		Asthma ever	5.5 (1973), 12.0 (1988), 27.3 (2003)
	Mutius et al. (1998) [15]	Consecutive cross-sectional study, 1854/2334 school children in 1974/92/98	Questionnaire by parents		PDA Wheeze	6.9 (1991), 6.8(1995) 25.9 (1991), 19.4 (1995)
	Frye et al. (2001) [16]	Consecutive cross-sectional study, 8-14 years, 530/790 school children in 1992/95	Questionnaire by parents		PDA Wheezing	8.0 (1992), 6.2 (1995) 21.6 (1992), 20.3 (1995)
Germany	Zollner et al. (2005) [17]	Six serial cross sectional survey, 9-11 years, 6762 school children	ISAAC questionnaire filled in by the parents		PDA Wheeze ever	aOR, 1.00 (0.95-1.06) aOR, 0.95 (0.93-0.98)

Italy	Ronchetti et al. (2001) [18]	Primary school children (6-14 year), 2259/1229/1139 in 1974/1992/1998	Self-reported by parents	PDA SA	5.0 (1974), 11.6 (1992), 11.0 (1998) 1.6 (1974), 4.0 (1992), 3.7 (1998)
Switzerland	Braun-Fahrlander et al. (2004) [19]	Consecutive cross-sectional study, 13-14 years, 1324/1668/1250 school children in 1992/1995/1999	ISAAC questionnaire filled in by the parents	PDA Wheeze ever	7.8 (1992), 7.6 (1995), 7.4 (1999) 19.9 (1992), 19.5 (1995), 22.5 (1999)
Norway	Selnes et al. (2005) [20]	Three cross-sectional studies, 9-11 years, 1794/1432/3853 in 1985/95/00	Questionnaire ISAAC questionnaire	SA (Male) SA (Female)	8.9 (1985), 10.0 (1995), 12.7 (2000) 4.4 (1985), 7.6 (1995), 7.6 (2000)
Georgia	Adamia et al. (2015) [25]	Cross-section method, 2-8 / 9-17 years, 860/590 children in 2010	Questionnaire	SA (2-8 years) SA (9-17 years)	7.2 (2010) 13.7 (2010)
Iran	Zamanfar et al. (2016) [31]	Cross-sectional study, 11-14 years, 3000 children in 2012	ISAAC questionnaire	PDA SA	12.2 (2012) 30.5 (2015)
Lebanon	Salameh et al. (2015) [29]	Cross-sectional study, 12-19 years, 717 schoolchildren in 2012	ISAAC questionnaire	SA	4.5 (2012)
Taiwan	Lee et al. (2005) [23]	Cross sectional study, middle school students, 44,104 in 1995 and 11,048 in 2001	Questionnaire by parents	PDA SA	4.54 (1995), 6.05 (2001) 9.5 (1995), 11.8 (2001)
China	Hong et al. (2013) [28]	Cross-sectional study, 5-15 years, 481 children in 2009	ISAAC questionnaire	PDA	7.2 (2009)
Hong Kong	Wong et al. (2004) [21]	ISAAC study protocol, schoolchildren aged 13-14 years, 4667 in 1994, 3321 in 2002	ISAAC written questionnaire	PDA Wheeze ever	11.2 (1994), 10.2 (2002) 19.5 (1994), 16.2 (2002)
Singapore	Wang et al. (2004) [22]	ISAAC study protocol, 6-7 years, 2030 in 1994, 5305 in 2002	ISAAC core questions	PDA Wheeze	18.5 (1994), 16.3 (2002) 16.6 (1994), 10.2 (2002)

PDA : Physician-diagnosed asthma

SA : Self reported asthma, mostly done by parents with Questionnaire-determined asthma

aOR : Adjusted Odd ratio

Table 2. Korea childhood asthma prevalence

Area (year)	Reference	Study design, population	Methodology	Criterion	Prevalence (%)
Seoul (1981-1982)	Lee HR et al. (1983) [32]	2,074 children aged under 15 years, outpatients of pediatrics department of NMC	Questionnaire filled in by parents	PDA	5.7
Seoul (1987)	Kim HS et al. (1989) [33]	832 school children, 6-17 years from elementary and middle school	Questionnaire filled in by parents	PDA	10.8
Seoul (1988)	Ahn YM and Choi EY (1990) [34]	Cross-sectional study, 661 children from one primary school, all grades	Questionnaire	Asthma	10.4
Seoul (1989)	Shin TS et al. (1990) [35]	Cross-sectional study, 4,149 children from three primary schools, all grades	Questionnaire filled in by parents	PDA	10.1
Seoul/Chongju	Kim YY et al. (1996) [36]	Cross-sectional study, 3,219 7-19 years	Modified ATS questionnaire and methacholine bronchial provocation test	Asthma symptoms	5.2 (Seoul), 4.1 (Chongju), 4.6 (Total)
Seongnam, Kyunggi-Do	Son BK et al. (1997) [37]	Cross-sectional study, 2850 elementary schoolchildren	Questionnaire filled in by parents	Asthma	10.3
Nationwide (9 cities, 1995)	Lee SI et al. (2001) [38]	Cross-sectional study, 27,405 6-12 years and 15,481 12-15 years	ISAAC questionnaire	PDA Wheeze ever	7.7 (6-12), 2.7 (12-15) 15.9 (6-12), 13.4 (12-15)
Nationwide (9 cities, 1995/2000)	Hong SJ et al. (2004) [39]	Cross-sectional study, 15,481/15,894 12-15 years in 1995/2000 from 34 middle schools	ISAAC questionnaire	PDA Wheeze ever	2.7 (1995), 5.3 (2000) 13.9 (1995), 12.8 (2000)
Nationwide (9 cities, 1995/2000)	Hong SJ et al. (2008) [40]	Cross-sectional study, 25,117/27,831 6-12 years in 1995/2000 from 34 elementary schools	ISAAC questionnaire	PDA Wheeze ever	7.7 (1995), 9.1 (2000) 17.0 (1995), 13.0 (2000)
Ilsan, Kyunggi-Do (2005)	Son KY et al. (2007) [41]	Cross-sectional study, 2,745 children from three primary schools, all grades	ISAAC questionnaire by parents	PDA Wheeze ever	12.4 18.2
Seoul, Kangneung, Ulsan (2006)	Kim BS et al. (2007) [42]	Cross-sectional study, 1,499 students from 4 high-schools	ISAAC questionnaire	PDA Wheeze ever	7.0 16.0
Nationwide (15 cities, 2006)	Jee HM et al. (2009) [43]	Cross-sectional study, 37,365 6-13 years from 438 elementary schools	ISAAC questionnaire (completed by parents)	PDA Wheeze ever	10.5 7.8

Asthma symptoms questionnaire were filled by parents, and it was found that it was 10.8% [33]. Ahn YM and Choi EY performed skin prick tests and questionnaire survey in 6-12 years old 661 schoolchildren at an elementary school. The prevalence of asthma was reported to be 10.4% [34]. Shin TS et al. researched the incidence of allergic disease in elementary schoolchildren in Seoul by questionnaires in 1989. The study was done on 4,149 of 5,000 students and the prevalence of asthma in children was 10.1% [35]. Kim YY et al. indicated the limitations of a questionnaire survey such as the lack of objectivity and poor predictability and studied the prevalence of asthma based on questionnaires and methacholine bronchial provocation test. They performed modified ATS (American Thoracic Society) respiratory questionnaires among 3,219 subjects aged 7-19 years in Seoul and Chungju. Methacholine bronchial provocation tests were also performed among those who had asthma symptoms according to the questionnaire. The criteria of asthma were presence of both asthma symptoms and nonspecific bronchial hyperresponsiveness. In the results, the prevalence of asthma were 5.2% and 4.1% in Seoul and Chungju respectively [36]. Son BK et al. performed questionnaire survey and pulmonary function test among 2,850 schoolchildren in Seongnam. The prevalence of asthma was 10.3% [37]. Lee SI et al. estimated the national prevalence of childhood asthma and determined potential risk factors.

Stratified random samples of 42,886 were selected from 34 elementary and 34 middle schools nationwide (Seoul, Suwon, Chungju, Jeonju, Changwon, Chunchon, Jeju, and Ulsan). The Korean-translated modified version of the ISAAC questionnaire was used in this cross-sectional survey. In the results, 12-month prevalence of the symptoms of asthma was 8.7% and risk factors were passive smoking and obesity [38]. Hong SJ et al. compared findings from nationwide cross-sectional surveys in 1995 and 2000 on populations of middle-school children using the Korean version of the ISAAC questionnaire. The lifetime prevalence of wheeze did not change from 1995 (13.9%) to 2000 (12.8%). The lifetime prevalence of asthma diagnosis, however, increased

significantly, from 2.7% in 1995 to 5.3% in 2000 [39]. Also, Hong SJ et al. reported the change of the prevalence of asthma among elementary schoolchildren (6-12 years). The prevalence of wheeze ever decreased from 17.0% in 1995 to 13.0% in 2000 and the prevalence of physician diagnosed asthma increased from 7.7% in 1995 to 9.13% in 2000 [40]. Son KY et al determined the prevalence of asthma among elementary schoolchildren in Ilsan. A cross-sectional study was performed among 2,745 students using ISAAC questionnaire. The prevalence of physician diagnosed asthma was 12.4% and wheeze ever was 18.2% [41]. Kim BS et al. investigated the prevalence of asthma using ISAAC questionnaire in high school students. Subjects were 1,499 and the lifetime prevalence of asthma diagnosis was 7.0% and wheeze ever was 16.0% [42]. Jee HM et al. evaluated the prevalence and changing patterns of morbidity of allergic diseases. ISAAC questionnaires were completed by the parents of 37,365 children in 2006. In the results, the prevalence of wheeze ever was 10.5% and asthma diagnosis was 7.8% [43].

The prevalence rates of asthma defined with various types of criteria such as PDA, SA (Self reported asthma), wheeze, wheeze ever and asthma ever are summarized in Figure 1.

The prevalence rates were varied greatly by the asthma criteria. As anticipated, wheeze ever symptom showed high prevalence rate. If PDA was assumed to be more objective and strict definition of asthma, it seemed to be increased since 1970' till late 1990' but after 2000, it seemed to be slightly decreased or seemed to be kept flat. Other asthma criteria like SA, wheeze, wheeze ever also showed same trend though the numerical values were different each other. Figure 2 only draws the line within the data suggested by the same author within a journal. So, the lines between two or three data in figure 2 are the trend of asthma during corresponding period researched by the same author in the same research.

As seen in Figure 2, we could see clearly increasing trend of asthma of all kinds of asthma types till 1990'. After 2000, some data shows increasing pattern but other data shows flat or slightly decreasing trend. The prevalence rate of

Korea PDA or Korea wheeze ever was located in lower part of the figure 2 which meant that the prevalence rate in Korea was relatively low compared to the other data (see also Table 1 and 2).

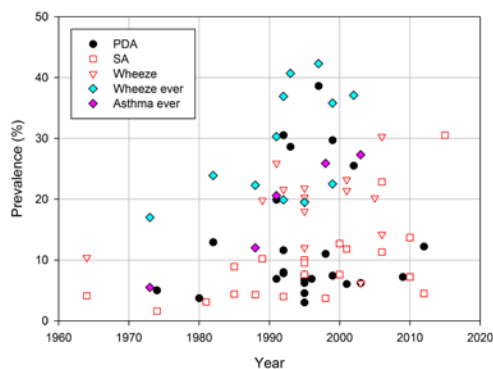


Figure 1. Temporal changes in prevalence rates of PDA, SA, Wheeze, Wheeze ever, and Asthma ever (%).

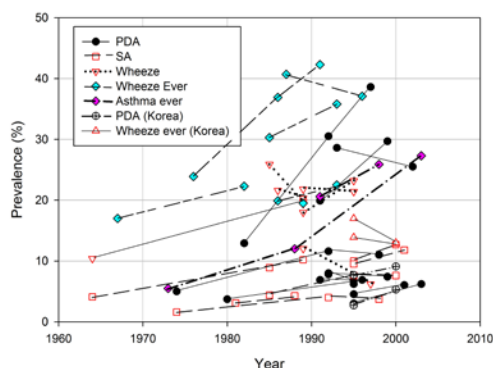


Figure 2. Comparison of prevalence rates of PDA, SA, Wheeze, Wheeze ever, Asthma ever in worldwide and in Korea done by the same author. Each line compares the data researched by the same author so that the data could be compared with reliability.

Discussion

Asthma is a chronic respiratory disease characterized by bronchoconstriction, airway hyperresponsiveness, airway inflammation, and edema. Asthma acute exacerbations include bronchospasm, coughing, and wheezing leading to airway obstruction and decreased airflow. These attacks may be mild or life threatening [44]. But

there is no agreed definition of asthma applied to all cases. The symptoms are most important characters in diagnosis of asthma, so this is why questionnaire were used as basic tool in survey of the prevalence of asthma. Recently, reliability issues on estimating prevalence of atopic disease including asthma in children was reported that overestimation or underestimation of atopic disorders could be possible and much consideration should be given to compare different database [45].

So it was suggested to use the standardized questionnaire of International Study of Asthma and Allergies in Childhood (ISAAC) which was possible to compare the asthma prevalence between countries or regions [46]. As seen in Table 1 and Figure 2, Prevalence rates varied widely according to the target population (i.e. area) as well as research periods. So there are difficulties to compare the asthma prevalence before the ISAAC study. But some researcher compared two and more periods of time within the same target population with the same criteria. In that case, we can assume the prevalence rates suggested with in a journal has the same criteria and seems to be good to compare with high reliability. For example, Akinbami and Schoendorf (2002) suggested the prevalence rates of PDA were 3.7% in 1980 and 6.9% in 1996 in the same Seattle population. So, this data shows clear increase in prevalence rate with reliability.”

It is inevitable to consider variation in prevalence rate due to the study design and participated population, diagnostic criteria and technique, use of data (primary data or secondary data) as well as the result obtained from one cross sectional study or the results from consecutive cross sectional study. Among the worldwide data as shown in Table 1, Twenty out of total twenty-seven papers (74 %) compared at least two periods while seven (26 %) only studied one period. On the contrary, in Korea most papers (nine out of twelve papers, 75%) published so far presented one snap shot prevalence rate rather than comparison of prevalence rate within a study.

But the prevalence of asthma in children had showed increasing trend before 2000, it showed decreasing or stabilized status after 2000 in developed countries in western and Asian areas generally. As seen in figure 2, overall trends seem to increase after 1980 till 2010’ but unclear after

that period. In spite of increasing trend, large variation of prevalence rate was found after 1980' between the asthma criteria as well as within the same asthma criteria. For example, SA increased from 1960' to the late 2000' with increasing variation in recent years. This large variation is also partly due to the increasing number of papers published as well as within and between asthma criteria.

The occurrence of asthma is affected by many factors which are categorized in genetic and environmental factors. The reason why the prevalence of asthma in children had increased since 1970 but decreased after the late 1990 or 2000 was unclear. It has been suggested that the environment plays an important role in respiratory disease. Both physical environment and socioeconomic factor could affect the asthma prevalence. For examples of physical environment factors, allergens, such as allergens from house dust mite, cat, cockroach, has been studied as risk factors for the childhood asthma. Also, air pollutants such as particulate, NO₂, ozone, environmental tobacco smoke (ETS) and volatile organic compounds(VOCs) were suggested sufficiently to trigger or exacerbate asthma, and increase rates of hospitalization for asthma. Also, better health care system worldwide could attribute to reduce the prevalence rate but there were very limited papers mentioning this effect. Gender difference in asthma prevalence has been reported that higher prevalence in males in children before puberty and in females in adolescence and adulthood [47]. The reason is unclear but these differences might be attributed to biological differences between genders as well as sociocultural and environmental differences [47]. Even though this study compared the trend of asthma prevalence rate worldwide including western countries, Asian countries as well as Korea over the several decades, validity and reliability of each paper was not investigated. Also, further investigation beyond simple comparison of asthma prevalence rate is needed though we tried to compare the prevalence rate by asthma diagnostic criteria over the decades and tried to explain large variation of the prevalence rate.

Conclusion

The prevalence of asthma worldwide has increased since 1970 till late 1990 or 2000 but the trend of the prevalence of asthma has recently reached an equilibrium or shown an inconsistent trend. In Korea, the prevalence rate of asthma was relatively flat after 1980' till 2000. The PDA asthma in Korea was 8.9 ± 2.8 %, 6.0 ± 2.9 %, and 8.9 ± 2.7 % in 1980, 1990 and 2000, respectively.

Acknowledgements

This study was partially supported by the China Medical Board (CMB) and the BK21 Plus Project.

References

1. Smith K et al. Evaluation of Risk Factors and Health Outcomes among Persons with Asthma. *J Asthma* 2009;46:234-237
2. Health, United States, 2005. Hyattsville, MD: National Center for Health Statistics, December 8, 2005:63. (Accessed March 23, 2010, at [http://www.cdc.gov/nchs/data/05.pdf](http://www.cdc.gov/nchs/data/hus/05.pdf).) (page 345)
3. Fowler MG et al. School functioning of US children with asthma. *Pediatrics* 1992;90:939-944
4. Akinbami LJ et al. Trends in Childhood Asthma: Prevalence, Health Care Utilization, and Mortality. *Pediatrics* 2002;110:315-322
5. Carter, Edward R, Debley, Jason S, Redding, Gregory J. Changes in asthma prevalence and impact on health and function in Seattle middle-school children: 1995 vs 2003. *Ann Allergy Asthma Immunol* 2005;94(6): 634-639
6. Weitzman M et al. Recent Trends in the Prevalence and Severity of Childhood Asthma. *JAMA* 1992;268:2673-2677
7. Downs SH et al. Continued increase in the prevalence of asthma and atopy. *Arch Dis Child* 2001;84:20-23
8. Robertson CF et al. Asthma prevalence in Melbourne schoolchildren: have we reached the peak? *MJA* 2004;180:273-276
9. Burr ML et al. Changes in asthma prevalence: two surveys 15 years apart. *Arch Dis Child*

- 1989;64:1452-1456
10. Ninan TK and Russell G. Respiratory symptoms and atopy in Aberdeen schoolchildren: evidence from two surveys 25 years apart. *BMJ* 1992;304:873-875
 11. Kwong GN et al. Increasing prevalence of asthma diagnosis and symptoms in children is confined to mild symptoms. *Thorax* 2001;56:312-314
 12. Anderson HR et al. Trends in prevalence of symptoms of asthma, hay fever, and eczema in 12-14 year olds in the British Isles, 1995-2002: questionnaire survey. *BMJ* 2004;328:1052-1053
 13. Shamssain M. Trends in the prevalence and severity of asthma, rhinitis and atopic eczema in 6- to 7- and 13- to 14-yr-old children from the north-east of England. *Pediatr Allergy Immunol* 2007;18:149-153
 14. Burr ML et al. Asthma prevalence in 1973, 1988 and 2003. *Thorax* 2006;61:296-299
 15. Mutius EV et al. Increasing prevalence of hay fever and atopy among children in Leipzig, East Germany. *Lancet* 1998;351:862-866
 16. Frye C et al. Increasing prevalence of bronchial hyperresponsiveness in three selected areas in East Germany. *Eur Respir J* 2001;18:451-458
 17. Zollner IK et al. No increase in the prevalence of asthma, allergies, and atopic sensitisation among children in Germany: 1992-2001. *Thorax* 2005;60:545-548
 18. Ronchetti R et al. Is the increase in childhood asthma coming to an end? Findings from three surveys of schoolchildren in Rome, Italy. *Eur Respir J* 2001;17:881-886
 19. Braun-Fahrlander C et al. No further increase in asthma, hay fever and atopic sensitisation in adolescents living in Switzerland. *Eur Respir J* 2004;23:407-413
 20. Selnes A et al. Diverging prevalence trends of atopic disorders in Norwegian children. Results from three cross-sectional studies. *Allergy* 2005;60:894-899
 21. Wong GWK et al. Declining asthma prevalence in Hong Kong Chinese schoolchildren. *Clin Exp Allergy* 2004; 34:1550-1555
 22. Wang XS et al. The prevalence of asthma and allergies in Singapore; data from two ISAAC surveys seven years apart. *Arch Dis Child* 2004;89:423-426.
 23. Lee YL et al. Changing prevalence of asthma in Taiwanese adolescents: two surveys 6 years apart. *Pediatr Allergy Immunol* 2005; 16: 157-164
 24. Lee HB et al. New patterns of childhood asthma prevalence in six Asian countries: comparison of ISAAC phases I and III. *Pediatr Allergy Respir Dis* 2008;18:70-77
 25. Adamia N et al. Allergic Diseases and Asthma in Adolescents, *Georgian Med News*. 2015;243:58-62.
 26. Dell SD et al. Presence of other allergic disease modifies the effect of early childhood traffic-related air pollution exposure on asthma prevalence. *Environ Int*. 2014;65:83-92.
 27. Feitosa CA et al. Behavior problems and prevalence of asthma symptoms among Brazilian children. *J Psychosom Res*. 2011;71(3):160-165.
 28. Hong H et al. A hospital-based survey on the prevalence of bronchial asthma in patients with allergic rhinitis in southern China. *Am J Rhinol Allergy*. 2013;27(6):502-505.
 29. Salameh P et al. Asthma, indoor and outdoor air pollution: A pilot study in Lebanese school teenagers *Rev Mal Respir*. 2015;32(7):692-704.
 30. Vuillermin PJ et al. Asthma among school children in the Barwon region of Victoria. *Med J Aust*. 2007;187(4):221-4.
 31. Zamanfar D et al. The Prevalence of Allergic Rhinitis, Eczema and Asthma in Students of Guidance Schools in Mazandaran Province, Iran. *J Med Sci*. 2016;4(4):619-623.
 32. Lee HR et al. Survey on allergic disease in children. *J of Korean Med Assoc* 1983;26(3):254-262
 33. Kim HS et al. The effect of infantile eczema on the development of allergic diseases. *Korean J Pediatrics* 1989;32(6):834-838
 34. Ahn YM et al. The result of skin prick tests with 9 common aeroallergen in Korea and RAST reactivity to *D. farina* in a community school children. *Allergy (Korean)* 1990;10(3):213-225
 35. Shin TS et al. A survey of the distribution of allergic diseases in primary schoolchildren. *Allergy (Korean)* 1990;10(3):201-212

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36. Kim YY et al. Prevalence of childhood asthma in Korea based on questionnaires and methacholine bronchial provocation test. *Allergy (Korean)* 1996;16(2):175-184
37. Son BK et al. Prevalence of allergic disease and asthma related conditions in primary school-Aged children and comparison of pulmonary function test between normal and children with condition related with asthma. *Korean Academy Pediatric Allergy and Respiratory J* 1997;7(2):198-206
38. Lee SI et al. Prevalences of symptoms of asthma and other allergic diseases in Korean Children: A nationwide questionnaire survey. *J Korean Med Sci* 2001;16:155-164
39. Hong SJ et al. Self-reported prevalence and risk factors of asthma among Korean adolescents: 5-year follow-up study, 1995-2000. *Clin Exp Allergy* 2004;34:1556-1562
40. Hong SJ et al. The prevalences of asthma and allergic diseases in Korean children. *Pediatr Allergy Respir Dis (Korean)* 2008;18:15-25
41. Son KY et al. Prevalence of allergic diseases among primary School children in Ilsan, Gyeonggi and changes of symptoms after environmental control in 2005. *Pediatr Allergy Respir Dis(Korean)* 2007;17:384-393
42. Kim BS et al. Prevalence of allergic diseases in high school students in Korea. *Korean J Asthma Allergy Clin Immunol* 2007;27:168-175
43. Jee HM et al. Prevalence of asthma, rhinitis and eczema in Korean children using the international study of asthma and allergies in childhood (ISAAC) questionnaires. *Pediatr Allergy Respir Dis(Korean)* 2009;19:165-172
44. Tang E et al. Epidemiology of asthma and allergic disease. In: Adkinson Jr NF, Yunginger JW, Busse WW. *Middleton's allergy: principles and practice*. 6th edition. Philadelphia: Mosby, 2003:1127-1144
45. Pols DHJ et al. Reliably estimating prevalences of atopic children: an epidemiological study in an extensive and representative primary care database, 2017. *Primary Care Respiratory Medicine* 2017;23:1-6
46. Asher MI et al. International study of asthma and allergies in childhood (ISAAC): rationale and methods. *Eur Respir J* 1995;8:483-491
47. Arathimos R et al. Sex discordance in asthma and wheeze prevalence in two longitudinal cohorts. *PLoS ONE* 2017;12(4): e0176293.