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Risk Factors Associated With Hospital Readmission in Pediatric Asthma

Hoi Sing Chung, PhD, BSN, RN^{a,*}, Donna K. Hathaway, PhD, FAAN^b,
Dukhee B. Lew, MD^{c,d}

^aLoewenberg School of Nursing, The University of Memphis, Memphis, TN

^bCollege of Nursing, University of Tennessee Health Science Center, Memphis, TN

^cDepartment of Pediatrics, College of Medicine, University of Tennessee Health Science Center, Memphis, TN

^dAllergy and Immunology, LeBonheur Children's Hospital, Memphis, TN

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Asthma is a leading cause of hospitalization among children, and about 15–50% of pediatric patients are readmitted after an index admission. The purpose of this integrative review is to explore contemporary scientific findings on the association between pediatric asthma readmission and various demographic, environmental, psychosocial and clinical risk factors. An electronic database search resulted in a sample of 29 studies. African American, public or no insurers, previous admission and complex chronic comorbidity were identified as risk factors associated with pediatric asthma readmission. However, more interdisciplinary and well-designed investigations are warranted to further explicate the spectrum of environmental and psychosocial correlates. Published by Elsevier Inc.

ASTHMA IS A leading cause of hospitalization among children (Bloomberg, Trinkaus, Fisher, Musick, & Strunk, 2003; Nelson & Zorc, 2013) and together with infections contributes one-third to one-half of all hospitalizations for children 1–9 years of age (Bloomberg et al., 2003; Nelson & Zorc, 2013). Previous studies demonstrated that upwards of 40% of pediatric asthma hospitalizations are repeat hospitalizations (i.e., the child had been hospitalized for asthma previously). Moreover, hospitalizations accounts for nearly one-third of national pediatric asthma costs (Kenyon et al., 2014). Therefore, the reduction of repeat hospitalizations could significantly reduce costs of health care in addition to improving patient outcomes (Kenyon et al., 2014).

Over the past two decades, the specific issue of readmissions has drawn the attention of investigators in England, Canada, and New Zealand, as well as the United States (refer to Table 1). These studies have examined readmission over various time periods ranging from 7 days to 4 years. However, in clinical practice, it is difficult to assimilate these findings and determine which hospitalized

children with asthma are at risk of experiencing a subsequent asthma readmission. Delineating risk factors for asthma readmission in a manner directly applicable for clinical practice could help health care providers target discharge transition and chronic care improvement efforts to high-risk populations.

In studies examining readmission among pediatric asthma populations, one focus has been on identifying population characteristics and other risk factors associated with hospital readmissions and/or emergency department (ED) re-visits. Variables typically considered by these studies as risk factors associated with susceptibility for readmission have included age at first admission, sex, race/ethnicity, acute severity of asthma, chronic asthma severity, previous admissions, socioeconomic status, parental knowledge, and drug management (Bloomberg et al., 2003). With the rapidly accumulating research evidence, a systematic literature review of studies examining risk factors related to hospital readmission in pediatric asthma could provide the foundation necessary to develop interventions directly applicable to practice. This systematic review explores the current empirical literature with the specific aim of integrating research findings related to identification of risk factors

* Corresponding author: Hoi Sing Chung, PhD, BSN, RN.
E-mail address: hschung@memphis.edu.

Table 1 Samples of study reports included in the integrative review.

Citation/Population	Defined readmission	Setting	Design	Variables/Confounding factors	Results/Findings
Newman et al. (2014)/n = 758, 1–16 years, USA	Hospital readmission within 12 months	Cincinnati Children's Hospital Medical Center, an urban tertiary care hospital between August 2010 and October 2011	A population-based prospective observational cohort study	Traffic-related air pollution (TRAP) exposure, covariate including race, controller medication, tobacco smoke exposure, the presence of cracks or holes in walls and bedroom carpet, caregiver psychological distress, allergy-specific IgE for ragweed, white oak, animal dander of cat, dog and mouse, American cockroach, as well as 2 types of dust mite	Multivariate analysis • TRAP exposure 3.0 [1.1–8.1] only for Caucasian - o TRAP exposure 1.1 [0.6–1.8] for African American
Topal et al. (2014)/n = 1177, 6 month–17 years, Turkey	Hospital readmission in 7 days	Pediatric emergency department (ED) and allergy and asthma departments at 3 teaching and research hospitals including Gazi University Faculty of Medicine, Gulhane Military Medical Academy, and the Medical School, Diskapi Education and Research Hospital	Prospective study	Age, sex, exposure to cigarettes, breast feeding for less than 6 months, regular follow-up by allergy specialist, historical severity of asthma, level of control, preventive treatment, time of last attack, number of attacks in previous year, number of attacks requiring systemic steroids, number of attacks requiring hospitalization, short-acting β_2 -agonists within 6 hours before admission, severity of attack at admission, signs of physical exam such as retractions and oxygen saturation, treatment given at hospital, drug prescribed when discharge to home, instructional plan provided at discharge	Multivariate analysis • short-acting β_2-agonists within 6 hours before admission 2.43 [1.73–3.43] • No prescribed high dose inhaled steroids 2.02 [1.37–3.00] • Accessory respiratory muscle retraction at admission 1.76 [1.12–2.77] • No written instructional plan 1.55 [1.08–2.23]
Howrylak et al. (2014)/n = 774, 1–16 years; USA	Hospital readmission in 12 months	Cincinnati Children's Hospital Medical Center (CCHMC) (urban, tertiary care, pediatric stand-alone hospital)	Prospective observational cohort	Caregivers reported any tobacco exposure at home, in a secondary residence, or in the car. Measured serum and saliva cotinine levels with mass spectrometry	Multivariate analysis - o Caregiver report of any tobacco exposure 1.18 [0.79–1.89] • Detectable serum or salivary cotinine (1.59 [1.02–2.48] and 2.35 [1.22–4.55], respectively).

Beck et al. (2014)/n = 774, 1–16 years; USA	Hospital readmission in 12 months	Cincinnati Children's Hospital Medical Center (CCHMC) (urban, tertiary care, pediatric stand-alone hospital)	Prospective observational cohort	Race/Ethnicity Confounding factors: child race, socioeconomic status (measured by lower income and caregiver educational attainment), and hardship (caregivers looking for work, having no one to borrow money from, not owning a car or home, and being single/never married)	Multivariate analysis • African American children vs. White children 1.98 [1.42–2.77] • After adjusted with both SES and hardships 1.44, [1.07–1.96]
Moncrief, Beck, Simmons, Huang, and Kahn (2014)/ n = 526, 1–16 years, USA	Emergency room (ER) revisit or hospital readmission) within 12 months	Cincinnati Children's Hospital Medical Center (CCHMC) (urban, tertiary care, pediatric stand-alone hospital)	Prospective observational cohort	Single parent households Confounding factors: four psychosocial variables (household income, caregiver risk of psychological distress, ratio of in-home children to adults, and regular attendance at childcare or a secondary home)	Multivariate analysis • Single parent households vs. married parents 1.44 [1.00–2.07], $p < 0.05$ • After adjusted with household income, 1.02, [0.66–1.58]
Kenyon et al. (2014)/n = 44204, > = 2 years, USA	Hospital readmission within 7, 15, 30, 60, 180, and 365 days	Administrative database of Pediatric Health Information System (PHIS) from 42 free- standing children's hospitals affiliated with Children's Hospital Association	Longitudinal, retrospective cohort analysis	Age at index admission (2–4, 5–11, 12–18, and > 18 years), race/ethnicity (non-Hispanic Black, non-Hispanic White, Hispanic, Other), sex, and primary insurance at index admission (public, private, self-pay/no-charge, other type of insurance), comorbid conditions or pediatric complex chronic conditions (CCC) include pediatric cardiovascular, congenital/ genetic defect, gastrointestinal, hematologic, malignancy, metabolic, neuromuscular, renal, and respiratory diagnoses. Use of magnesium for enhanced bronchodilation, severity of illness (mild,	Multivariate analysis • Prior year asthma admission at all time points (OR 2.0–3.6) • Age 12–18 years at all time points (1.1–4.7) • Presence of a CCC at all time points (1.5–2.6) • Black race/ethnicity at 60 days and beyond (1.3–1.8) • Public insurer at 60 days and beyond (1.2–1.3)

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Table 1 (continued)

Citation/Population	Defined readmission	Setting	Design	Variables/Confounding factors	Results/Findings
Visitsunthorn, Lilitwat, Jirapongsananuruk, and Vichyanond (2013)/ n = 76, 0–14 years, Thailand	Hospital readmission in 1–12 months	Department of Pediatrics, Siriraj Hospital, Mahidol University, Bangkok, Thailand	Retrospective case–control study	moderate, severe, and extremely severe), use of intensive care unit services during admission, length of hospital stay, and discharge disposition (to home with or without nursing, or post-discharge care facility), and asthma admission in the year prior to index admission Age, sex, housing, socioeconomic status, length of stay in hospital, Siriraj Asthma Score before admission, parental history of allergic disease, co-morbid diseases (allergic rhinitis and sinusitis), level of asthma control, pediatric intensive care unit (PICU) admission, antibiotics or methylprednisolone usage at the first admission, skin prick test results, influenza vaccine injection, continuity of outpatient unit (OPD) visits, and steroid compliance along with environmental data (presence of household smoking contact and pets)	Bivariate analysis • A parental history of allergic disease (OR [95% CI]: 3.17 [1.10–9.10]), • A history of intensive care unit (ICU) admission (29.62 [3.35–262.18]), • Partially controlled asthma (4.83 [1.24–18.88]), uncontrolled asthma (29 [2.25–373.77]) • Methylprednisolone usage during the 1st admission (8.33 [2.46–28.19]) # A history of influenza vaccination (0.24 [0.16–0.36])
Auger, Kahn, Davis, Beck, and Simmons (2013)/n = 601, 1 to 16 years, USA	Asthma readmission events were prospectively collected via billing data and followed for a minimum of 1 year	A single pediatric facility that captures >85% of all pediatric asthma admissions in an 8-county area, Ann Arbor, Michigan, USA	A prospective observation cohort study	Medical home quality measured by a Likert-based validated survey of Parent's Perception of Primary Care (P3C) including 6 subscale scores assessing continuity, access, contextual knowledge, comprehensiveness,	Multivariate analysis • Patients with low medical home access (score < 75) had a significantly increased risk of readmission compared those with the highest level of access (adjusted hazard

Beck, Simmons, Huang, and Kahn (2012)/n = 601, 1–16 years, USA	Readmission or emergency department revisit within 12 months	A prospective cohort of children hospitalized with asthma in 2008 and 2009 in Cincinnati, Ohio	Secondary analysis of a prospective observational cohort study	communication, and coordination. Access measured items including case of travel to the primary care provider (PCP) and availability of routine care, sick care and evening/ weekend advice Geographic socioeconomic measures by 10 socioeconomic census tract variables including poverty, ownership (home and car), housing (vacancy, value, and crowding), marriage, and education	ratio 1.56 [1.06–2.32], $p < 0.001$). o Overall P3C score and the other P3C subscales were not associated with readmission within one year.
Li, To, and Guttman (2012)/n = 801, 2–17 years, Canada	Hospital readmissions within 1 year	Multiple linked health administrative datasets available at the Institute for Clinical Evaluative Sciences including National Ambulatory Care Reporting System, Canadian Institute for Health Information Discharge Abstract Database, Ontario Health Insurance Plan claims database and Ontario Asthma Surveillance Information System in Ontario, Canada	Population-based retrospective cohort study	ED follow-up care, sex, age, neighborhood income quintile, Canadian triage assessment score, asthma admission prior 2 year, asthma ED revisit prior 2 year, hospital type	Bivariate and multivariate analysis • Pediatric asthma children at medium and high geographic risk stratum had higher readmission or ER reutilization in one year with hazard ratio [95% CI] 1.30 [0.90–1.88] and 1.83 [1.37–2.44], respectively. • Caregivers of children at highest geographic risk were 5 times as likely to report more than 2 financial hardships ($p < 0.001$) and 3 times as likely to report psychological distress ($p = 0.001$). Multivariate analysis • Canadian Triage Assessment Score: less urgent or non-urgent as reference, urgent 1.72 [1.35–2.18], resuscitation or emergent 2.68 [2.09–3.43] • Asthma admission prior 2 yr 2.87 [2.43–3.39] • Asthma ED visit prior 2 yr 1.85 [1.57–2.19] • Community with available pediatrician 1.24 [1.04–1.49] # Age: 2–5 yr as reference, 6–9 yr 0.56 [0.46–0.67], 10–13 yr 0.51 [0.41–0.65], 14–17 yr 0.42 [0.32–0.57]

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Table 1 (continued)

Citation/Population	Defined readmission	Setting	Design	Variables/Confounding factors	Results/Findings
Delmas, Marguet, Raheison, Nicolau, and Fuhrman. (2011)/87598, 2–44 years, France	Readmission rates at 7 days and 1 year estimated using the Kaplan–Meier method	Nationwide hospital recorded in metropolitan France between 2002 and 2005	Population-based retrospective cohort study	Age, sex	- o Follow up ED visit 1.06 [0.92–1.23] Bivariate analysis • Age: 2–4 yr as reference, 5–9 yr 0.81 [0.73–0.89], 10–14 yr 0.87 [0.78–0.98], 15–19 yr, 0.69 [0.59–0.81] • Female: 1.11 [1.04–1.12] • Female: age 10–14 yr 1.31 [1.07–1.60] and age 15–20 yr 1.54 [1.13–2.10]
Liu and Pearlman, (2009)/n = 2919, 0 to 19 years, USA	Hazard ratios of hospital readmission within 4 years from 2001 to 2005 estimated	Rhode Island Hospital Discharge Data from 2001 to 2005	Longitudinal retrospective study	Race/Ethnicity, sex, age, insurance payer, shares zip code with a hospital, season of index admission, year of index admission, LOC for index admission, percent of census tract living below poverty level, percent of census tract living in crowded conditions, percent of census tract minority population	Multivariate analysis • Public insurance: 1.40 [1.11–1.78] • Higher proportion of minority residents: 1.33 [1.02–1.74] - o Higher proportion of neighborhood poverty and higher proportion of crowded housing conditions not associated with higher readmission rates.
Lasmar, Camargos, Goulart, and Sakurai (2006)/n = 202, 0–15 years, Brazil	Hospital readmission within 18 months	Campos Sales Pediatric Pulmonology Outpatient Clinic, Belo Horizonte, Brazil from October 1994 to December 1995	Retrospective study with chart review	Age, sex, body weight at birth, educational level of mother, family income, severity of asthma symptoms, pulmonary function level	Bivariate analysis • Age: ≤ 12 mo 3.14 [1.42–7.02], 12–24 mo 3.52 [1.22–10.38] • ED visit > 2/mo 2.13 [1.10–4.18] • Lower mother's educational level 2.55 [1.26–5.20] • Moderate and severe persistent level 6.28 [2.92–13.48] • Asthma attack >4/mo 2.19 [1.03–4.71]
Reznik, Hailpern, and Ozuah (2006)/n = 152, 0 to 21 years, USA	Hospital readmission within 30 days of the index admission	Children's Hospital at Montefiore (CHAM), Bronx, New York from January 1998 and December 2004	Matched case–control study	Age, gender, race, and medical insurance, history of asthma-related ED visits and admissions to hospital in past 12 months, prior history of ICU admission for asthma, premature birth,	Multivariate analysis • Previous hospital admission in 12 mo 1.89 [1.10–3.25]

Alshehri, Almegamesi, and Alfrayh (2005)/ n = 28, age not available (70% younger than 4 years), Saudi Arabia	Hospital readmission within 2 months	Aseer Central Hospital, southwestern Saudi Arabia from August 1998 to December 2002	Longitudinal retrospective case-control study	prescription of inhaled corticosteroids (ICS) before index admission, exposures to environmental triggers such as roaches and tobacco smoke, oxygen saturation level at ED, LOS in days, therapeutic management of asthma including subcutaneous injection of epinephrine or IV magnesium sulfate, and number and frequency of aerosolized beta-agonist treatments, oxygen requirement during index admission, and receipt of a pulmonary consultation, last recorded oxygen saturation level in medical chart before discharge, presence of wheezing, and prescription of ICS Gender, race, route of admission, i.e. emergency room or outpatient clinic, months of admission, number of previous admissions for asthma, history of other atopic disorders, neonatal intensive care unit admission, bronchopulmonary dysplasia (chronic pulmonary diseases of infancy that was followed by ventilator and oxygen therapy), congenital lung anomalies, tracheoesophageal fistula, recurrent aspiration, family history of asthma, exposure to smoke, duration of asthma symptoms before admission (in days) and severity of asthma attack, admission to intensive care, prescribed nebulized β agonist, intravenous treatment with, steroids, theophylline and antibiotics in addition, patients' progressive notes were examined for radiographic changes in the chest x-rays, length of hospital stay (in days), prescribed β agonists, oral steroids and	Multivariate analysis • Prior history of asthma admission 2.21 [1.08–9.10], • Neonatal intensive care graduate 4.44, [1.67–9.34], • Bronchopulmonary dysplasia 3.06 [2.01–7.95], • Recurrent aspiration 1.96 [1.08–4.27], • Moderate to severe clinical assessment 1.12 [1.01–2.94] • Intensive care admission 1.96 [1.08–4.63] # Duration of asthma symptoms more than five days 0.15 [0.03–0.42] # Positive x-ray findings 0.04 [0.011–0.230] # Mechanical ventilation 0.010 [0.002–0.130] # Intravenous steroids 0.104 [0.016–0.321]
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Citation/Population	Defined readmission	Setting	Design	Variables/Confounding factors	Results/Findings
				prophylactic inhaled steroids, follow up arrangement and whether or not there was a copy of a written action plan in the records. Patients with co-morbid and chronic diseases such as immunodeficiency disorders, morbid obesity, congenital heart defects, fibrosis and cerebral palsy were excluded	
Kocevar et al. (2004)/n = 9,635, 0–14 years, Nordic Countries (Denmark, Sweden, Norway, and Finland)	Hospital readmission within 1998/1999	Public national databases from Denmark, Sweden, Norway, and Finland in 1999 and 1998/1999	Longitudinal retrospective analysis	Age	Multivariate analysis • Age 0–2 yrs 8.5 times higher readmission rates (Relative hazard of readmission not available) • 3–5 yrs 2.8 times higher readmission rates • 6–14 yrs as reference
Wallace, Denk, and Kruse (2004)/n = 21016, 1–14 years, USA	Hospital readmission within 180 days of discharge	Hospitalization records extracted from New Jersey Hospital Discharge Files between 1994 and 2000 and linked by patient identifiers using a probabilistic matching algorithm. Additional records used from 2001 for readmission	Longitudinal retrospective analysis	Age, sex, race/ethnicity	No regression analysis • African American had 16–29% readmission rates compared to Caucasian at 7–11% from three different age groups • Hispanic had 17–21% readmission rates • Age 10–14 yrs had 29% higher readmission rate only in African American girls
Chen, Dales, et al. (2003)/n = 86863, 0–20 years, Canada	Asthma readmission calculated during the 3 year study period	Data for a first admission for asthma as 1 of first 5 diagnoses in Canada between April 1, 1994 and March 31, 1997	Longitudinal retrospective analysis	Age, sex, length of stay	Multivariate analysis • Age <1 yr 2.36 [2.15–2.59] and 1.54 [1.42–1.66] for boy and girl; 1–4 yr 1.54 [1.41–1.69] and 1.15 [1.08–1.22] for boy and girl; 10–14 yr 1.15 [1.06–1.24] for girl; 15–19 yr as reference • Female 1.47 [1.34–1.60] for 10–14 yr; 1.35 [1.22–1.49] for 15–19 yr # Female 0.86 [0.81–0.93] for < 1 yr

Bloomberg et al. (2003)/n = 8761, 0–20 years, USA	Hospital readmission 1 day to 10 years after index admission	Two universities affiliated children's hospitals in St. Louis, USA	Longitudinal retrospective analysis	Age, sex, race/ethnicity, residence, payor status, length of stay, and month of admission, allergic and infectious factors, prior admission	Multivariate analysis • Medicaid or self-pay and African American race 1.28 [1.03–1.58] commercial insurance or White/other race as reference # White/Other race 0.83 [0.73–0.94] African American as reference
Chen, Bloomberg, Fisher, and Strunk (2003)/n = 115, 4–18 years, USA	Hospital readmission during a 1-year follow-up period	St Louis Children's Hospital (SLCH) in St. Louis, USA between June and December 1999	Longitudinal prospective study/questionnaire study	Family impacts (greater family strain and family conflict greater financial strain), caretaker characteristics (greater personal strain, beliefs about not being able to manage one's child's asthma, lower sense of mastery, being less emotionally bothered by asthma)	Bivariate analysis • Lifetime history of admission 5.36 [1.90–15.14], • Parents with less bothered emotionally by child's asthma 1.64 [1.00–2.70] # Parents with mastery respect to child's illness 0.68 [0.46–1.00]
Wever-Hess, Hermans, Kouwenberg, Duiverman, and Wever (2001)/n = 100, 0–4 years, Netherlands	Hospital readmission within 1 year	Outpatient department of the Juliana Children's Hospital in The Hague, Netherlands	Longitudinal prospective cohort study	Age, antibodies against inhalant allergens, number of readmissions	Bivariate analysis • Positive antibodies against inhalant allergens, determined by radioallergosorbent test (RAST) 1.54 [1.22–1.95] in the age group 2–4 years
Minkovitz, Andrews, and Serwint (1999)/n = 119, 0–14 years, USA	Hospital readmission within 1 year after the index admission	Urban pediatric primary care clinic, Harriet Lane Primary Care Clinic (HLPC) at John Hopkins Children's Center, Baltimore, MD	Nested case-control study of a cohort of children hospitalized for asthma	Sex, prescribed albuterol, prescribed cromolyn, inhaled corticosteroids as controller, other chronic conditions, pulmonary consultation	No regression analysis • Female 63% vs. 29%, $p < 0.001$ • Other chronic conditions 69% vs. 49%, $p = 0.049$ • Prescribed albuterol sulfate 89% vs. 69%, $p = 0.02$ • Cromolyn sodium 49% vs. 21%, $p = 0.003$ • Inhaled corticosteroids 17% vs. 5%, $p = 0.03$ • Pulmonary consultation during index admission 23% vs. 4%, $p = 0.001$ and year after discharge 37% vs. 12%, $p = 0.002$
Raymond, Henry, Higginbotham, and Coory (1998)/n = 121, 1–7 years, Australia	Hospital readmission over 1 year period	Pediatric ward of 28 beds in a medium sized general Mt Druitt Hospital, Sydney	Retrospective study	Negative perceived consequences of treatment with inhaled therapy	Multivariate analysis # Decreased negative perceived consequences

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Table 1 (continued)

Citation/Population	Defined readmission	Setting	Design	Variables/Confounding factors	Results/Findings
Chabra, Chavez, Adams, and Taylor (1998)/n = 6844, 1–12 years, USA	Hospital readmission within a year	California hospital discharge data in 1994 for asthma hospitalizations among 1 to 12-year-old Medicaid patients	Retrospective cohort study	Race/Ethnicity, history of hospital stays of at least 5 days duration	of treatment with inhaled therapy 0.31 [0.12–0.83] Multivariate analysis • African American children 1.93 [1.49–2.49] • Latino children 1.34 [1.04–1.72] • Hospital stays of at least 5 days duration 1.35 [1.05–1.74]
Farber (1998)/n = 277, 0–15 years, USA	Hospital readmission within 12 months of index hospital admission	Kaiser Foundation Hospital (KFH), Hayward, California, USA between September 30, 1991 and June 30, 1993	Retrospective study	Age, history of hospital admission	Bivariate analysis • Aged < 5 years 4.36 [2.02–9.41] • Previous hospital admission 2.34 [1.19–4.60]
To, Dick, Feldman, and Hernandez (1996)/n = 28646, 0–17 years, Canada	6 months probability of readmission after index admission	Hospital discharge data from the Canadian Institute for Health Information between 1989 and 1992	Retrospective cohort study	Age	Bivariate analysis • Age from 0- to 4-year olds 1.38 [1.30–1.46] for asthma; 5.02 [4.16–6.05] for asthma-related causes
Schaubel, Johansen, Mao, Dutta, and Manfreda (1996)/16429, 0–4 years, Canada	At least 30 months after index admission	Computerized hospital admission/separation records and physician claims obtained from a provincial health organization to produce a person-oriented database between 1984 and 1989 in Manitoba, Canada	Population based study (longitudinal retrospective cohort study)	Number of admission, sex, age	Non regression analysis • One previous hospitalization 42% • Two previous hospitalization 59% • Three previous hospitalization 76%
Senthilselvan (1995)/sample size not available, 0–14 years, Canada	The ratio between the number of readmissions and all admissions defined as the readmission rate for each calendar year from 1980 to 1989.	Hospital admissions data for asthma obtained from the Saskatchewan Health Department for all 134 hospitals in the province between 1980 and 1989	Longitudinal retrospective study	Sex, age (0–4, 5–9, and 10–14 years)	Bivariate analysis • Girls aged 10–14 years 1.6 [1.3–1.9]
Mitchell, Bland, and Thompson (1994)/n = 1034, 0–14 years, New Zealand	Readmission for a maximum of 33 months	Children's wards of Auckland Hospital, a teaching hospital, New Zealand	Observational (retrospective) longitudinal study	Sex, age, ethnicity, number of previous admissions, inpatient intravenous treatment, inpatient treatment with theophylline, respiratory and pulse rate, medical team, prescribed prophylactic treatment, type of follow up, and the use of action	Multivariate analysis • Female sex 1.23 [1.03–1.46] • Age < 5 years old 1.71 [1.41–2.08] • One previous admission 1.32 [1.03–1.70] • Two previous admissions 1.68 [1.24–2.26]

plans.	• Three previous admissions 2.00 [1.47–2.71]
	• Four or more previous admissions 2.80 [2.23–3.51]
	• Inpatient intravenous treatment 1.29 [1.08–1.55]
	# Inpatient treatment with theophylline 0.51 [0.28–0.92]
Note: •, # and ° represent positive, negative and no association. Data shown as adjusted odds ratio (AOR) or odds ratio (OR) or hazard ratio (HR) [95% confidential intervals (CI)].	

associated with hospital readmission. Additionally, implications for nursing practice will be described, gaps in the extant literature identified, and potential avenues for future research presented.

Design

The design of this study primarily followed the guidelines and framework published by the Center for Reviews and Dissemination (2009) for integrative reviews. The primary purpose of this review is to explore the association between pediatric asthma readmission and various risk factors including demographic, environmental, psychosocial and clinical factors. All risk factors discussed in the review represent these five classes.

Methods

Search Criteria

The inclusion criteria for target studies were: (a) stated purpose was primarily to examine readmission for pediatric asthma; (b) the target population was children aged 0–18; (c) published in English. Exclusion criteria were: (a) case reports, meta-analyses, or systemic review articles that did not adopt a research design; (b) abstracts, dissertations, manuscripts, or conference proceedings that were not published in peer reviewed journals; (3) theoretical, expert opinion, editorial, or any articles that did not report empirical findings; (4) samples included participants greater than 18 years of age, and younger participants were not independently reported and analyzed. Eligible articles were retrieved in May 2014 from four electronic databases: PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Ovid/MEDLINE, and ScienceDirect. No date limits were set. The following Medical Subject Headings (MeSH) terms, CINAHL headings, thesaurus terms, and keywords were used: readmission, rehospitalization, asthma, pediatric and children. Additional eligible articles were identified by manually checking the reference lists of included studies.

Search Outcome

The initial search strategy identified 1565 articles across the four databases. After title and abstract review, 1513 articles were ruled out as not meeting inclusion/exclusion criteria or as duplicates articles. Most studies were deleted because they were not designed ‘primarily’ to explore the risk factors associated with readmission of pediatric asthma, and these data could not be determined from the published report. In addition, there is a collection of articles associated

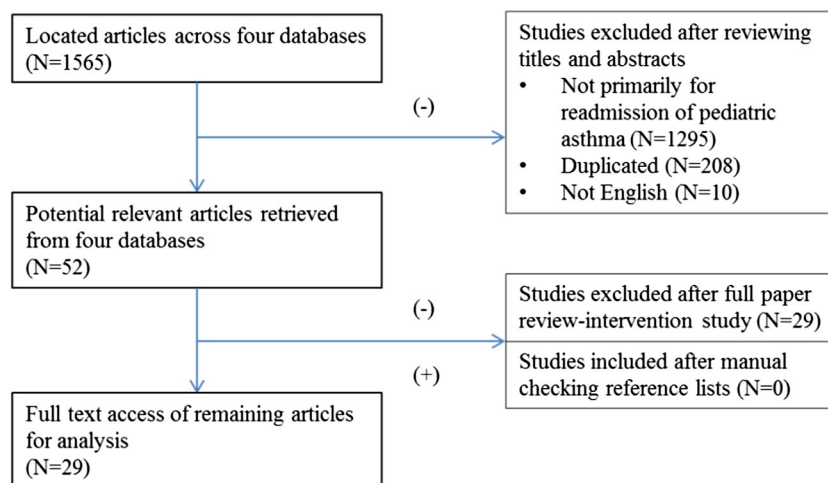


Figure 1 Selection process of included studies.

with interventions or strategies to reduce hospital readmission of pediatric asthma not included into this review. The full-texts of the remaining 29 articles were accessed online or through the printed publications or by online transmission from the interlibrary system at the University of Memphis library. After manually checking the references of all the selected papers, no additional articles were identified that met review inclusion criteria. Thus, a total of 29 studies were included in this review. Our review work was done from November 2013 to May 2014. The process for selection of eligible publications is detailed in [Figure 1](#).

Results

Study Characteristics¹

Publication Years and Recruited Sample

Twelve out of 29 (41%) of the reviewed articles were published in the past five years (2009–2014). Fifteen of 29 (51.7%) reviewed papers were conducted in USA, and 5 (17%) were from Canada. There were also a portion of studies conducted from France, Nordic Countries, Netherlands, Turkey, Australia, and New Zealand, as well as other non-western countries including Thailand, Saudi Arabia, and Brazil.

The developmental stage of children in selected studies included all pediatric age group from infants, toddlers, preschoolers, to adolescents. Early studies predominately included infants, and a few also recruited toddlers. One study included patients from 2 to 44 years old; however, the pediatric population could be extracted and was therefore included in this review ([Delmas et al., 2011](#)). Similarly, four additional studies also recruited young adults up to 21 years old with the extractable pediatric data ([Bloomberg et al., 2003](#); [Chen, Dales et al., 2003](#); [Liu & Pearlman, 2009](#); [Reznik et al. 2006](#)).

The number of subjects in each study varied greatly. The smallest sample was of 28 children who were in a longitudinal retrospective case–control study, whereas the

largest sample ($n = 44,204$) was conducted by [Kenyon et al. \(2014\)](#) in USA.

Definitions of Hospital Readmission and Index Admission

Selected studies defined hospital readmissions or rehospitalizations as covering a span of time that ranged from 7 days to 10 years. Most studies utilized a definitional framework that identified an index or first hospitalization, admission diagnosis, time frame from discharge to readmission and data source. Index admission was defined by a contract work for Centers for Medicare & Medicaid Services (CMS) as “any eligible admission to an acute care hospital assessed in a measure for the outcomes” ([Centers for Medicare & Medicaid Services, 2011](#)).

Risk Factors Related to Readmission of Pediatric Asthma

Age at Index Admission

Among the studies considering age at index admission, eight studies conducted between 1994 and 2012 found positive associations between younger age and higher readmission rate. Those studies examined readmission by 28 days, 6, 12 and 18 months after discharge of the index admission ([Chen, Dales, et al., 2003](#); [Delmas et al., 2011](#); [Farber, 1998](#); [Kocevar et al., 2004](#); [Lasmar et al., 2006](#); [Li et al., 2012](#); [Mitchell et al., 1994](#); [To et al., 1996](#)).

[Mitchell et al. \(1994\)](#) found age younger than 5 years caused 71% higher readmission rates within 1 year after index admission. A Canadian group also found 38% higher risk of readmission for asthma in children younger than 5 years old ([To et al., 1996](#)). In addition, [To et al. \(1996\)](#) found the estimated risk of readmission for any asthma-related causes among the same age group was fivefold that of the older children. Similar results were also reported in [Farber \(1998\)](#) that found age younger than 5 years old had 3.36 times higher readmission rates compared with the group

older than 5 years old. Furthermore, a Canadian study (Chen, Dales, et al., 2003) found the highest readmission rates occurred in children younger than 1 year old and from 1 to 4 years old during the 3-year study period. Similarly, in a longitudinal population study conducted in Nordic countries (Kocevar et al., 2004), children younger than 5 years old had 2.8–8.5 times higher readmission rates compared with school children from 6 to 14 years old. Similarly, in a Brazil study (Lasmar et al., 2006), asthma patients aged less than 12 months and from 12 to 24 months had 2.14 or 2.52 folds higher readmission rates, respectively compared with and older age group (Lasmar et al., 2006). Higher readmission or emergency department (ED) revisit rates were found for the age group younger than 5 years old.

Using patients 2–4 years as a reference, a French study (Delmas et al., 2011) found pediatric asthma children aged from 5 to 9, 10 to 14, and 15 to 19 years had 19%, 13% and 31% lower readmission rates respectively. A similar pattern was also observed in a Canadian study (Li et al., 2012) which found that pediatric asthmatic patients aged 6–9, 10–13, and 14–17 years had 44%, 49% and 58% lower readmission rates respectively when compared with patients aged from 2 to 5 years. Interestingly, Wallace et al. (2004) found that African American 10–14 year old children had higher readmission rates (20% and 29% in boys and girls) compared with 1–4 and 5–9 years old (16% and 15–20% for boys and girls). However, this pattern was not shown for Caucasian or Hispanic children. Moreover, a recent study found that adolescents who ranged in age from 12 to 18 years had 370%, 220%, 100%, 60%, 30% and 10% higher readmission by 7, 15, 30, 60, 180 and 365 days following an index asthma admission (Kenyon et al., 2014).

Gender

Mitchell et al. (1994) found female gender as a risk factor contributing to 23% higher hospital readmission rates within 1 year after index admission in a sample aged from 0 to 14 years. Similar results were shown by Minkovitz et al. (1999) who found that a large proportion of those readmitted were female (63%) as compared to a single admission (29%) in a nested case control study. In contrast, Senthilselvan (1995) found that Canadian girls aged from 10 to 14 years had 60% higher hospital readmission rates for asthma than boys, whereas in children of 0–4 and 5–9 years, no significant differences in readmission rates between boys and girls. Furthermore, Chen, Dales, et al. (2003) considered how the association of gender with readmission might differ for various age groups. This Canadian study found the rate of readmission to be higher in males under 1 year old and similar for both genders at 1 to 9 years old; whereas it was markedly higher in females 10 to 19 years of age. The higher readmission rates for female adolescents were further confirmed by two other studies (Delmas et al., 2011; Wallace et al., 2004). Wallace et al. (2004) found a distinctively higher readmission rate (29% vs. 20%) for African American girls ranging from 10 to 14 years old within 180 days after

index admission while readmission rates were roughly uniform in other age groups (1–4 and 5–9 years old). In general, females had relatively higher readmission rates compared with male asthmatic patients, which was most apparent in French study that found 10–14 and 15–20 age groups had 31% and 54% higher readmission rates (Delmas et al., 2011).

Race/Ethnicity

Chabra et al. (1998) first reported that African American and Latino pediatric patients had 93% and 34% higher readmission rates than Caucasians in a population of Medicaid-insured asthma children. African Americans were also reported to have a 20% higher readmission rate than Caucasians in a 10-year longitudinal study (Bloomberg et al., 2003) which was confirmed in a later study which found 30 to 80% higher readmission rates at 60, 180 and 365 days after index admission (Kenyon et al., 2014). In addition, Wallace et al. (2004) found that African Americans and Hispanics had higher readmission rates at different age groups and both genders compared to Caucasians within 180 days after index admission. In a study by Beck et al. (2014), African Americans were 98% more likely to be readmitted compared to Caucasians. Furthermore, as compared to Caucasians, African American caregivers were significantly more likely to report lower income and educational attainment, difficulty finding work, having no one to borrow money from, not owning a car or home, and being single/never married. Socioeconomic status and hardship explained 49% of the observed racial disparity in readmission.

Smoking/Detectable Cotinine

Despite the known harmful effect and sequelae associated with second hand exposure to smoke, only one recently published study explored the relationship between tobacco/smoke exposure (reported versus biomarker) and rates of readmission for children hospitalized for asthma. Detectable serum or salivary cotinine was associated with 59% and 135% higher readmission respectively, whereas caregiver report of any tobacco exposure was not associated with asthma related hospital readmission (Howrylak et al., 2014).

Other Environmental Factors

In a Netherland study (Wever-Hess et al., 2001), patients with antibodies against inhalant allergens, determined by radioallergosorbent test (RAST), had a 54% higher risk of readmission 1 year following index admission. More recently, Newman et al. (2014) found that high traffic-related air pollution (TRAP) exposure had two fold higher readmission rates only in Caucasian children, whereas TRAP exposure was not associated with increased readmission in African American children.

Public Insurance

In a 10-year longitudinal study by Bloomberg et al. (2003), African American children with Medicaid or no insurance

were found to be at a 28% higher risk of asthma readmission than African American children with commercial insurance. Subsequently, [Liu and Pearlman \(2009\)](#) found that the readmission rate of pediatric asthma children insured by Medicaid was 40% higher than children with private insurance in a fully adjusted model. More recently, [Kenyon et al. \(2014\)](#) confirmed this findings in a study of 44,204 US children which found that 20–30% higher readmission rates were associated with public insurance at time intervals delineated by 60, 180 and 365 days after index asthma admission.

Other Psychosocial Risk Factors

In addition to public insurance, other potential psychosocial risk factors associated with higher asthma readmission have been examined including perception of asthma inhaled steroid treatment, family conflict, negative family, social, and financial impact; negative personal impact and confidence; neighborhood-level poverty, racial/ethnic minority residents and crowded housing conditions; geographic risk stratum; poor access to medical home; and single parent households as well as mother's educational level ([Auger et al., 2013](#); [Chen, Bloomberg, et al., 2003](#); [Lasmar et al., 2006](#); [Liu & Pearlman, 2009](#); [Moncrief et al., 2014](#)).

In an Australia study by [Raymond et al. \(1998\)](#), a decrease of one standard deviation in the negative perceived consequence of inhaled steroid treatment resulted in a 69% decrease in readmission. In a Brazilian study ([Lasmar et al., 2006](#)), lower mother's educational level had a 155% higher readmission rate compared to a higher educational group. [Chen, Dales, et al. \(2003\)](#) found that both family level relationship factors and individual caretaker characteristics were associated with life-time hospitalization, however, all neighborhood- and family-level relationship factors did not predict future hospitalization after controlling other variables. Two individual-level characteristics of caretakers, including parents reporting low levels of mastery and lower emotional burden of asthma, were associated with the likelihood of future readmission at rates of 32% and 64%, respectively.

Similarly, [Liu and Pearlman \(2009\)](#) found that all three neighborhood-level variables including neighborhood-level poverty, racial/ethnic minority residents, and crowded housing conditions were related to higher hospital readmission rates in unadjusted survival curves. However, [Liu and Pearlman \(2009\)](#) only found residence in an area with a high proportion of minority residents to be associated with 33% higher risk of readmission rates after controlling other covariables, whereas, the higher proportion of crowded housing conditions and neighborhood-level poverty were not associated with higher readmission rates. More recently, [Beck et al. \(2012\)](#) found that residence in medium and high geographic risk strata was associated with 30% to 80% higher risk of ED revisit and hospital readmission, which was attributed to financial hardship. Moreover, poor access to a medical home was found to significantly increase risk of hospital readmission by 56% compared with those with

highest level of access after adjusting for covariates ([Auger et al., 2013](#)). However, a total score of medical home quality represented by Parent's Perception of Primary Care (P3C) and other five subscale scores such as continuity, contextual knowledge, comprehensiveness, communication, and coordination were not associated with readmission. In addition, [Moncrief et al. \(2014\)](#) recently explored the relationship between single parent households and ER reutilization and hospital readmission. Patients in single parent households were significantly (44%) more likely to reutilize ED or be readmitted within 12 months than those in married parent households. When adjusted for income, the relationship between single parent households and readmission became non-significant. It could be concluded that higher ER reutilization and hospital readmission rates by single parent household were primarily related to household income among four assessed psychological variables, including household income, caregiver risk of psychological distress, ratio of in-home children to adults, and regular attendance at childcare or a secondary home.

Previous Asthma Admission

Previous asthma admission has been widely studied as a strong independent risk factor for subsequent readmission since an early study by [Mitchell et al. \(1994\)](#) who found that the number of previous hospital admissions has been shown to indicate higher hospital readmission. This was subsequently supported by [Schaubel et al. \(1996\)](#). [Mitchell et al. \(1994\)](#) also found that the number of previous asthma admissions was associated with a 32%, 68%, 100%, and 180% higher readmission rate following one to four or more previous hospital admissions, respectively. A Canadian study ([Schaubel et al., 1996](#)), estimated the probability of hospital readmission for asthma to be 42%, 59%, and 76% among children with one, two, and three previous hospitalizations, respectively. [Chen, Bloomberg, et al. \(2003\)](#), in collaboration with Bloomberg, also found that lifetime history of admission was strongly associated with a 4.36 fold higher readmission rate during a 1 year follow-up period. Furthermore, several studies have found asthma-related admissions within the prior year to be predictive of readmission ([Alshehri et al., 2005](#); [Farber, 1998](#); [Kenyon et al., 2014](#); [Li et al., 2012](#); [Reznik et al., 2006](#)). [Farber \(1998\)](#) found that a history of prior asthma hospital admission had 134% higher readmission rates within 12 months of the index admission. In [Alshehri et al. \(2005\)](#), previous history of asthma admission had a 121% higher readmission rate for a Saudi Arabia pediatric sample. [Reznik et al. \(2006\)](#) demonstrated that previous hospital admission in 12 months had 89% higher readmission rates in their matched case control study.

In addition, prior admissions to ED, previous ICU admissions and NICU graduates were also linked to higher hospital readmission in studies by [Alshehri et al. \(2005\)](#), [Lasmar et al. \(2006\)](#), and [Visitsunthorn et al. \(2013\)](#). In a

Table 2 Risk factors associated with time intervals after index asthma admission.

Category	Early readmission				Late readmission		
	7 days	15 days	30 days	60 days	180 days	365 days	> 1 year
Demographic factors	• Age 12–18 years • Female at 10–20 years	• Age 12–18 years	• Age 12–18 years	• Age 12–18 years • African American children	• Age 0–4 years • Age 12–18 years • African American children • Hispanic	• Age 0–5 years • Age 12–18 years • African American children • Hispanic children • Female at 10–20 years • Female • TRAP exposure for Caucasian • Detectable serum or salivary cotinine • Positive antibodies against inhalant allergens at 2–4 years	• Age 0–5 years • Female at 10–19 years • African American children • Female • Male < 1 year
Environmental factors	NA	NA	NA	NA	NA	• Public or no insurer • Single parent households • Low medical home access • Medium and high geographic risk stratum • Community with available Pediatrician • Caretakers with less bothered emotionally by child's asthma • Negative perceived consequences of treatment with inhaled therapy • Lack of mastery respect to child's asthma	NA
Psychosocial factors	NA	NA	NA	• Public or no insurer	• Public or no insurer	• Public or no insurer • Single parent households • Low medical home access • Medium and high geographic risk stratum • Community with available Pediatrician • Caretakers with less bothered emotionally by child's asthma • Negative perceived consequences of treatment with inhaled therapy • Lack of mastery respect to child's asthma	• Public or no insurer • Low medical home access • Higher proportion of minority residents • Low mother's education
Clinical factors	• Prior year asthma admission • Complex chronic conditions	• Prior year asthma admission • Complex chronic conditions	• Prior year asthma admission • Complex chronic conditions	• Prior year asthma admission • Neonatal intensive care graduates	• Prior year asthma admission • Complex chronic conditions	• Prior asthma admission • Prior ED visit • Complex chronic conditions • History of intensive	• Number of prior asthma admission • Severity of asthma • Inpatient intravenous

(continued on next page)

Table 2 (continued)

Category	Early readmission					Late readmission			
	7 days	15 days	30 days	60 days	180 days	365 days	> 1 year		
	• Short-acting β_2 agonists within 6 hours before admission • No prescribed high dose inhaled steroids • Accessory respiratory muscle retraction at admission • No written instructional plan			• Complex chronic conditions • Severity of asthma • Intravenous steroids • Positive x-ray findings • Mechanical ventilation • Duration of asthma more than five days			• care unit (ICU) admission • Severity of asthma • Hospital stay at least 5 days • Parental history of allergic disease • Methylprednisolone usage during index admission • Prescribed albuterol sulfate • Cromolyn sodium • Inhaled corticosteroids • Pulmonary consultation • Lack of influenza vaccination	• Inpatient treatment with theophylline	

Note: •, and # represent positive and negative association.

small Saudi Arabia sample [Alshehri et al. \(2005\)](#) found that a history of neonatal intensive care and intensive care admission had a 344% and 96% higher readmission rate, respectively, within 2 months after index admission. In a Brazilian study [Lasmar et al. \(2006\)](#) found that greater than 2 ED visits had a 113% higher readmission rates compared. In [Visitsunthorn et al. \(2013\)](#), a history of ICU admission was shown to be associated with a 29 fold higher readmission rate within 1 year after index admission in 20 out of 76 readmitted population. In addition, prior asthma admissions or ED visits within 2 years were associated with 187% and 85% higher readmission rates respectively when compared to those without prior admissions or ED visits ([Li et al., 2012](#)). More recently, [Kenyon et al. \(2014\)](#) found that prior year asthma admission was associated with 100% to 260% higher readmission by 7 days to 365 days after index admission respectively; which was predictive of both early (7, 15, 30, and 60 days) and late readmission (180 and 365 days) after index admission.

Acute and Chronic Severity of Asthma

There were four previous studies which reported that severity of asthma symptoms was associated with higher hospital readmission from 28 days to 18 months after index asthma admission ([Alshehri et al., 2005](#); [Lasmar et al., 2006](#); [Li et al., 2012](#); [Visitsunthorn et al., 2013](#)). In a small Saudi Arabia study [Alshehri et al. \(2005\)](#) found that moderate to severe clinical assessment had a 12% higher readmission rate within 2 months after index admission. In another Brazilian study ([Lasmar et al., 2006](#)), moderate and severe persistent asthma was found to have a 5.28 fold higher readmission rate compared to mild or intermittent asthma. In addition, a 119% higher readmission rate was found for patients who experienced greater than 4 asthma attacks per month, compared to a group of mild sufferers ([Lasmar et al., 2006](#)). When compared with the less urgent or non-urgent cases, the urgent or emergent/resuscitation cases had 72% or 168% higher readmission rates demonstrated by Canadian Triage Assessment Score ([Li et al., 2012](#)). A Thai study by [Visitsunthorn et al. \(2013\)](#) recruited 20 out of 76 asthmatic children readmitted as recurrent asthma attack 1 month to 1 year after index admission. Bivariate regression analysis demonstrated higher readmission rates associated with asthma control level.

Complex Chronic Comorbidity

Three studies have examined the association of complex chronic comorbidity with hospital readmission ([Alshehri et al., 2005](#); [Kenyon et al., 2014](#); [Minkovitz et al., 1999](#)). These complex chronic comorbidities include pediatric cardiovascular, congenital/genetic defect, gastrointestinal, hematologic, malignancy, metabolic, neuromuscular, renal, and respiratory diagnoses. Early in 1999, Minkovitz et al. found that a larger proportion of children with multiple admissions had other chronic conditions (69% vs. 49%). [Alshehri et al. \(2005\)](#) found that bronchopulmonary

dysplasia and recurrent aspiration had a 206% and 96% higher readmission rate respectively within 2 months after index admission. Kenyon et al.'s recent large epidemiological study (2014) reported that these complex chronic comorbidities were associated with a 50% to 160% higher readmission rate at time intervals ranging from 7 days to 365 days after index admission; including early hospital asthma readmission (7, 15, 30, and 60 days) as well as late readmission (180 and 365 days).

Other Clinical Risk Factors

In addition to the above risk factors, atopic status, initial length of stay, inpatient intravenous treatment, and pulmonary function and consultation have been examined in a limited number of studies as potential risk factors associated with hospital readmission in pediatric asthma (Chabra et al., 1998; Delmas et al., 2011; Minkovitz et al., 1999; Mitchell et al., 1994; Visitsunthorn et al., 2013; Wever-Hess et al., 2001).

Mitchell et al. (1994) found that intravenous treatment had 29% higher readmission within 1 year after index admission. Subsequently, Chabra et al. (1998) found that at least 5 days of hospital stay was associated with a 35% higher readmission rate within 1 year after index admission. In another nested case control study (Minkovitz et al., 1999), a larger proportion of children with multiple admissions were found to have been prescribed albuterol sulfate (89% vs. 69%), cromolyn sodium (49% vs. 21%) and inhaled corticosteroids (17% vs. 5%) as usual home medications. In addition, children with multiple admissions were more likely to receive a pulmonary consultation during index admission (23% vs. 4%) and in the year after discharge (37% vs. 12%). Interestingly, inpatient treatment of theophylline was associated with reduced readmission rate by 51%.

There are some inexplicable reports. For instance, Alshehri et al. (2005) described that intravenous steroids as well as mechanical ventilation were associated with a 90% and 99% decrease in readmission rates, respectively. Parental history of allergic disease and methylprednisolone usage were shown to be associated with higher readmission rates by bivariate analysis by Visitsunthorn et al. (2013), whereas a history of influenza vaccination had a 76% decreased readmission rate 1 to 12 months following index admission. Most recently, a Turkish study (Topal et al., 2014) found the use of short acting β_2 agonist within 6 hours before admission increased risk of readmission at 7 days after discharge by 143%. In addition, presence of retraction on physical exam was also associated with a 76% higher readmission rate. In contrast, high dose inhaled steroids prescribed and a written instructional plan were found to reduce the risk of short term readmission at 102% and 55% respectively, 7 days after discharge of index admission (Topal et al., 2014). Additional studies will be required to confirm the findings of these individual studies prior to considering incorporation of their findings into clinical practice.

Risk Factors Associated With Time Intervals

Because time intervals following the index asthma admission is important in terms of understanding relevant risk factors associated with asthma readmission, all demographic, environmental, psychosocial, and clinical risk factors are summarized and categorized into Table 2 with early (7, 15, 30, and 60 days) and late (180, 365 days and beyond) asthma readmission. As for early readmissions, demographic risk factors include age 12 to 18 years, being African American children and female, and ranging in age from 10 to 20 years. Clinical risk factors include prior asthma admission, complex chronic conditions, severity of asthma, short-acting β_2 agonists within 6 hours before admission, accessory respiratory muscle retraction at admission, and no prescribed high dose of inhaled corticosteroids or written instructional plan. Environmental and psychosocial factors associated with early readmission have not been fully investigated except for public insurer at 60 days after index admission.

Late readmission, especially 365 days or 1 year after index admission, was found to be severely impacted by demographic, environmental, psychosocial, and clinical factors. Both age 0–5 years and 12–18 years were found to be associated with later readmission in pediatric asthma. In addition, African American and Hispanic children were also found related to higher later readmission. Although limited information are available in the aspect of environmental risk factors, detectable serum and salivary cotinine, positive antibodies against inhalant allergens at 2–4 years, and TRAP exposure in Caucasians have been studied as potential risk factors and found to be related to higher readmission 1 year after index admission. Furthermore, several potential psychosocial risk factors have been found to be related to late readmission, including public insurer, single parent households, lower medical home access, medium and high geographic risk stratum, community with available pediatrician, caretakers who are less bothered emotionally by child's asthma, lack of mastery respect to child's asthma as well as negatively perceived consequences of treatment with inhaled therapy. In addition, prior asthma admission including ED and ICU history, complex chronic conditions, severity of asthma, hospital stay at least 5 days, parental history of allergic disease, prescribed albuterol, cromolyn, and inhaled corticosteroids as well as pulmonary consultation and lack of influenza vaccination have been linked to late readmission in pediatric asthma in terms of clinical aspect.

Discussion

Demographic Risk Factors

The contradictory results from different studies indicate that age younger than 5 years and adolescents are two important age groups at risk for higher readmission after index discharge. Eight studies (Chen, Dales, et al., 2003; Delmas et al., 2011; Farber, 1998; Kocevar et al., 2004; Lasmar et al., 2006; Li

et al., 2012; Mitchell et al., 1994; To et al., 1996; Wever-Hess et al., 2001) found that higher rates of asthma readmission occur in younger compared to older children. However, most studies included children aged younger than 2 years old, whose higher risk of readmission could be related to an overlapping diagnosis of bronchiolitis or other respiratory illness characterized by wheezing. In support of this hypothesis, a recent study from 42 children's hospitals and 44,204 subjects, (Kenyon et al., 2014) found that the asthma readmission rate from 7 days to 1 year after index hospital admission occurred most often in adolescents aged from 12 to 18 years. It could be postulated that the higher rates of readmission at this age are attributed to controller non-adherence and a great proportion of "difficult to control" asthma found in adolescents (Fleming, Wilson, & Bush, 2007). In addition, other demographic factors including gender and race/ethnic might interact with age induced risks on asthma readmission in pediatric population.

Findings reported by Mitchell et al. (1994) and Minkovitz et al. (1999), provided initial evidence that female adolescence is a risk factor for asthma readmission. Several studies confirm this (Chen, Dales, et al., 2003; Delmas et al., 2011; Senthilselvan, 1995; Wallace et al., 2004), and Wallace's findings (2004) suggest that the inclusion of African Americans in the female cohort might have influenced this finding. In their discussion of age- and sex-differences related to asthma readmission, Chen, Dales, et al. (2003) offer some additional insights that may help explain the phenomenon of higher asthma readmission in female adolescences. These investigators speculate that the hormonal changes, increased use of cosmetic products, and increased cigarette smoking that often occur among adolescent girls may contribute to the upsurge in asthma related problems and readmissions.

Racial discrepancies in relation to pediatric asthma readmission have been consistently found in several studies (Beck et al., 2014; Bloomberg et al., 2003; Kenyon et al., 2014; Wallace et al., 2004). Being African Americans or Hispanics in particular is considered a risk factor associated with high readmissions in pediatric asthma. Although the mechanisms for this have not been elucidated, it should be noted that of the 98% higher asthma readmission rate observed for African Americans children by Beck et al. (2014), hardships alone and socioeconomic status and hardship jointly were able to explain 41% and 49% of the variance. Residual disparities might be related to socioeconomic conditions surrounding access to healthcare and environmental factors associated with poor living conditions such as pollution, tobacco exposure and housing quality. Kenyon's work (2014) indicated that the increased risk for readmission experienced by African American children extends to 60 days and beyond, as these children continue to experience difficulty in preventing longer term asthma exacerbations. Although inpatient asthma care in most hospitals closely adheres to the Joint Commission recommendations for use of inpatient bronchodilators and systemic

steroids (Morse et al., 2011), well-orchestrated transitions from inpatient to outpatient care and timely, effective outpatient and community care are also important to prevent longer term readmission. It is likely that because African American pediatric asthma patients have not been found able to equally access outpatient and community care (Bryant-Stephens, 2009), this compromised transition of care may partially explain the significantly higher readmission rate for both the African American and Hispanic population. In addition, an asthma-related genetic link has also been postulated to drive racial disparities in asthma (Kumar et al., 2012). Personalized management of asthma may benefit from complementing genetics with a focus on financial or social hardships that could guide hospital- and community-based resources to those with the most of gain (Hacker & Walker, 2013). Targeted interventions could thereby help achieve greater child health equity.

Environmental Risk Factors

Exposure to tobacco smoke is a well-known risk factor for individuals with asthma. Although parents and caretakers are instructed to help their children avoid exposure to tobacco smoke, and they may attempt to do this, such exposure is often difficult to control. However, because most children, and particularly young children do not smoke, and caretakers report controlling exposure; testing for exposure to tobacco smoke is rarely performed on children. Therefore, a discrepancy may exist between caregiver reports of children's exposure to secondhand smoke and measurements of serum and salivary cotinine levels. This discrepancy may reflect a bias toward underreporting or could indicate significant hidden secondhand smoke exposure from factors unique to a low-income population, such as multiunit housing. A similar discrepancy has been noted in situations in which social desirability to underreport tobacco exposure might be heightened, such as evaluating prenatal secondhand smoke exposure and maternal smoking (Himes, Stroud, Scheidweiler, Niaura, & Huestis, 2013; Spanier, Kahn, Xu, Hornung, & Lanphear, 2011). The ability to measure serum and salivary cotinine levels presents the possibility of an objective measure or biomarker that can be obtained when a child is seen in the emergency department or in the hospital that could be used to predict future hospital readmissions. Furthermore, such a measure for exposure to tobacco smoke could be used to target specific interventions including parental counseling and contact of the primary care providers used in the inpatient setting and outpatient clinics (Howrylak et al., 2014).

Although African American children had a higher asthma readmission rate, the association between TRAP exposure and hospital readmission was significant only for Caucasian children (Newman et al., 2014). A post hoc analysis demonstrated that African American children had significantly higher possibilities on housing risks, environmental factors, and neighborhood poverty. These associations are

similar to a previous report (Beck et al., 2012), which may have obscured the association between TRAP and readmission in these children.

Psychosocial Risk Factors

Consistent with two previous studies (Bloomberg et al., 2003; Liu & Pearlman, 2009), Kenyon et al. (2014) recently found that public insurance is associated with higher readmission rates within 60 to 365 days after index discharge. This may be explained by the likelihood that outpatient and community care are not equally accessible or effective for children of all demographic backgrounds.

In the U.S., public health insurance is provided for income-eligible children. The high degree of overlap of racial and socioeconomic status makes it difficult to determine if it is bi-factors or a factor that produces disparities in health status and health outcomes (LaVeist, 2005). In addition, the mechanisms contributing to the disparities in pediatric readmission linked with race/ethnicity and public insurance are also complicated, and have been attributed to the complex interactions among biological, psychological, and environmental risk factors (Strunk, Ford, & Taggart, 2002).

Chen, Bloomberg, et al. (2003) suggest that less caretaker confidence in providing home asthma care may be associated with feeling more overwhelmed and thus with a higher likelihood of child hospitalizations. This suggests that caretaker mastery in handling a chronic illness forms an important component of a child's readmission patterns, especially in the case of pediatric asthma readmission. On the other hand, caretakers being emotionally bothered may be associated with higher asthma related vigilance, earlier action taken for asthma symptoms, and a lower likelihood of the child requiring hospital care for severe symptoms. This preventive health behavior may be beneficial for caretakers caring for children with asthma although emotional concern may contribute to poorer caretaker quality of life. In addition, multiple caretakers and miscommunication among the caretakers are among the serious risk factors in our patient population at Le Bonheur Children's Hospital in Memphis, TN.

More recently, Beck et al. (2012) demonstrated the association between geographic risk and ED revisit and hospital readmission pediatric asthmatic patients, highlighting a clinical population that may benefit from further assessment and interventions. Once such geographic risk index data are integrated into evolving electronic health records, it would facilitate both individual as well as community based interventions and preventive approaches. Moreover, poor access to medical home among six aspects of medical home quality was the only measure associated with higher hospital readmission by Auger et al. (2013). Access may be especially important in asthma because children who are able to be seen or receive advice early during an exacerbation may avoid hospitalization.

Although single parents face substantial parenting demands and life stressors including potentially less time, emotional and material resources to commit to chronic asthma care Victorino and Gauthier (2009) and Moncrief et al. (2014) found that much of the effect of single parent household on readmission was attributable to reported household income. Lower household income has been shown to translate to fewer financial resources available for quality housing, transportation to appointments or other expenses related to chronic asthma care. Lower income may also be a proxy for related environmental exposures including allergens, tobacco smoke and air pollution, as well as access to healthcare, health beliefs and literacy (Beck et al., 2012; Halfon & Newacheck, 1993; Kattan et al., 1997). Therefore, parents and their children with asthma may benefit from home health care services or medication home delivery programs. Further research is necessary to identify appropriate and targeted interventions on single parent family in clinical and community settings.

Clinical Risk Factors

Over the past several decades, research has identified many clinical risk factors contributing to readmission for asthma including prior asthma admission, history of ED and ICU admission, complex chronic comorbidities, severity of asthma, long hospital stays at least 5 days, prescribed methylprednisolone, albuterol, cromolyn and inhaled corticosteroids, pulmonary consultation as well as lack of influenza vaccination.

Previous asthma admission or number of previous asthma admission(s) is well established as a strong independent risk factor for readmission by the studies of Mitchell et al. (1994), Schaubel et al. (1996), and Bloomberg et al. (2003) as well as Farber (1998), Alshehri et al. (2005), Reznik et al. (2006), and Kenyon et al. (2014). In addition, Prior admissions to ED, previous ICU admissions and NICU graduates were also linked to higher hospital readmission in the studies by Chabra et al. (1998), Alshehri et al. (2005) and Visitsunthorn et al. (2013). These findings likely reflect a number of unmeasured factors including higher disease severity, lower access to care, and substandard disease control (Reznik et al., 2006).

An early longitudinal study by Rasmussen et al. (2002) also identified frequency of respiratory symptoms and airway hyper-responsiveness as posing a high risk for multiple asthma admissions. More recently, other cross sectional studies have demonstrated severity of asthma symptoms to be associated with higher hospital readmission from 28 days to 18 months after index asthma admission (Alshehri et al., 2005; Lasmar et al., 2006; Li et al., 2012; Visitsunthorn et al., 2013).

A few studies indicate that a diagnosis of complex chronic comorbidity is associated with higher hospital readmission by contributing to an elevated odds of readmission in pediatric asthma patients (Alshehri et al., 2005; Kenyon

et al., 2014; Minkovitz et al., 1999). A targeted discharge with planned outpatient and community interventions are essential for reducing the expected higher readmission in this population.

In addition to the above clinical/hospitalized risk factors, atopic status, initial length of stay, inpatient intravenous treatment, and pulmonary function as well as pulmonary consultation have been found to be potential risk factors associated with hospital readmission in pediatric asthma in a limited number of studies (Chabra et al., 1998; Delmas et al., 2011; Minkovitz et al., 1999; Mitchell et al., 1994; Visitsunthorn et al., 2013; Wever-Hess et al., 2001). More clinical studies will be needed to validate their predictive roles in pediatric asthma readmission.

Limitations¹

The inclusion and exclusion criteria adopted for this systematic review may pose some limitations to our findings. First, the choice of terms defining risk factor and readmission may have excluded some relevant studies. Secondly, all reviewed articles have no time limitations and includes studies from 1994 to 2014. During this time frame there has been some changes in the beliefs and emphasis in clinical practice related to the environmental impact on asthma diagnosis and treatment. Over the years represented by the studies included in this review, diagnosis and treatment of asthma was guided by different expert panel reports (EPR) from EPR1 to EPR3. Finally, the studies included in this review were conducted across the globe from the USA to non-western countries, representing different study population and healthcare systems in international settings which often differ greatly.

While the diversity of the studies included in this review in regards to definition of risk factor and readmission, time frame of selected studies, and location of studies poses some degree of limitations it also lends some additional insights regarding our extant literature.

Conclusions

This review includes a large number of studies that have examined risk factors associated with hospital readmission for pediatric asthma using various research designs. There have been several risk factors associated with increased hospital readmission in pediatric asthma population that have repeatedly emerged in these studies under the categories of demographic, environmental, psychosocial and clinical factors linked with asthma. Although demographic and clinical risk factors have been widely investigated in the past several decades, environmental and psychosocial impacts are beginning to draw more attention and presents the potential

for more targeted interventions to improve outcomes related to pediatric asthma readmission. In addition, it appears that the time intervals after an index asthma admission is a critical consideration as risk factors that differentiate early and late readmissions linked to the acute hospital stay versus the long term community-, family- and self-care quality.

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