

The impact of childhood asthma on academic performance: A matched population-based cohort study

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Abstract

Background: There is inconclusive evidence of the effect of asthma on the academic performance of young people. This study aims to compare scholastic performance and high school completion of young people hospitalized with asthma compared to matched peers not hospitalized with asthma.

Method: A population-based matched case-comparison cohort study of young people aged ≤ 18 years hospitalized for asthma during 2005–2018 in New South Wales, Australia using linked birth, health, education and mortality records. The comparison cohort was matched on age, gender and residential postcode. Generalized linear mixed-modelling examined risk of school performance below the national minimum standard (NMS) and generalized linear regression examined risk of not completing high school for young people hospitalized with asthma compared to matched peers.

Results: Young males hospitalized with asthma had a 13% and 15% higher risk of not achieving the NMS for numeracy (95%CI 1.04–1.22) and reading (95%CI 1.07–1.23), respectively, compared to peers. Young males hospitalized with asthma had a 51% (95%CI 1.22–1.86) higher risk of not completing year 10, and around a 20% higher risk of not completing year 11 (ARR: 1.25; 95%CI 1.15–1.36) or year 12 (ARR: 1.27; 95%CI 1.17–1.39) compared to peers. Young females hospitalized with asthma showed no difference in achieving numeracy or reading NMSs, but did have a 21% higher risk of not completing year 11 (95%CI 1.09–1.36) and a 33% higher risk of not completing year 12 (95%CI 1.19–1.49) compared to peers.

Conclusions: Educational attainment is worse for young people hospitalized with asthma compared to matched peers. Early intervention and strategies for better management of asthma symptoms may enhance academic performance for students.

KEYWORDS

academic performance, asthma, high school completion, young people

1 | INTRODUCTION

Asthma is one of the most common chronic health conditions amongst young people in high-income countries.[1,2] In Australia, around 12% of males and 8% of females aged ≤ 14 years (approximately 460,000 young people) are reported to have asthma.[3] If

not adequately controlled, asthma can have a wide ranging impact on the lives of young people, including on their health, sleep, academic performance, social interactions and overall quality of life. [4,5] Asthma in children can result in frequent unscheduled medical visits that not only result in significant healthcare burden but may also impact school attendance and academic performance.[6]

There is inconclusive evidence of the effect of asthma on school performance amongst young people.[4] Previous research found that young people with asthma either performed worse on school-based assessments[7–11] or experienced little to no difference in their school performance[12–14] compared to peers without asthma. Compared to students with no or controlled asthma, young people with uncontrolled asthma were either found to perform poorly academically[5,15] or showed no discernible difference in their performance.[16] One study of twins showed no difference in performance on school assessments at 15–16 years for the twin with asthma compared to the twin without asthma.[17] The influence of asthma on adolescents completing high school has been little studied.[18]

Differences in study findings on the impact of asthma on school performance are likely to stem from a variety of factors. The use of subjective (eg caregiver- or teacher-reported) versus objective (eg standardized school assessment) measures of academic performance, differences in comparison populations, ability to control for potential moderating factors (such as parental education, socioeconomic status, school absenteeism and comorbid health conditions), inability to consider young people across a range of ages, and method of diagnosis (eg self- or caregiver-reported versus physician-diagnosed asthma).[4,14]

Effective management of asthma involves regular monitoring of symptoms,[19] adherence to recommended treatment regimens, and adherence to an asthma management plan.[20] Poor adherence to asthma management strategies can lead to inadequately controlled asthma.[20] Inadequately controlled asthma has been associated with emergency department (ED) visits and hospital admissions[21,22] of young people. As previous studies of the impact of asthma on academic performance have been inconclusive, this study aims to compare scholastic performance and high school completion of young people hospitalized with asthma compared to matched peers not hospitalized with asthma.

2 | METHOD

This is a retrospective population-level case-comparison cohort study of young people hospitalized with asthma aged ≤ 18 years in New South Wales (NSW), Australia, using linked birth, health, education and mortality data collections from 1 January 2005 to 31 December 2018.[23] Ethical approval and a waiver of consent was obtained from the NSW Population and Health Services Research Ethics Committee (2018HRE0904).

2.1 | Data sources

Information on health service use was obtained from emergency department (ED) visit and hospital admission data collections. ED visits to public hospitals included data on arrival and departure times, visit

Key messages

- Academic performance is worse for young people hospitalized with asthma compared to matched peers.
- Young males hospitalized with asthma had a higher risk of not achieving numeracy and reading minimum standards compared to peers.
- Young females hospitalized with asthma had a higher risk of not completing high school compared to peers.

type and provisional diagnosis. Hospital admissions were to public or private hospitals, and contained information on demographics, diagnoses, separation type (eg hospital transfer, death) and clinical procedures. Mortality data were obtained from the NSW Registry of Births, Deaths and Marriages and young people who died during the study period were excluded from analyses (Figure S1).

School performance and parental demographic information were obtained from National Assessment Plan for Literacy and Numeracy (NAPLAN) assessments conducted annually in May from 2008 to 2018 for government, Catholic and independent schools. Assessments were conducted in primary school grades 3 (7–9 years of age) and 5 (9–11 years of age), and secondary school grades 7 (11–13 years of age) and 9 (13–15 years of age), and included assessments in numeracy and reading. Each score is translated into proficiency bands that indicate whether performance was above, at, or below the national minimum standard (NMS). Inability to achieve the NMS indicates that a young person will have difficulty making progress in school without assistance.[24] Within each assessment, scores represent the same level of achievement over time.[25]

A young person's attendance, absence, withdrawal (eg philosophical objections to testing or religious beliefs) or exemption due to significant disability for the assessments was obtained (Table S1). Young people exempt from sitting an assessment due to severe disability or language difficulties were rated as scoring below the NMS as per technical guidelines.[26]

A young person was classified as having a language background other than English (LBOTE) if either they or their parents/guardians spoke a language other than English at home.[25] Where there were multiple records of the parents' level of education and occupation, the highest level of education and occupation of either parent was identified. For each young person, information on high school completion at years 10 (15–16 years of age), 11 (17–18 years of age) and 12 (17–18 years of age) were obtained through the Record of School Achievement and the Higher School Certificate.

The Centre for Health Record Linkage (CHeReL) identified the population comparison group and linked the birth, health, education and mortality records using probabilistic record linkage. Upper and lower probability cut-offs for a link were 0.75 and 0.25 and record groups with probabilities between the cut-offs were clerically reviewed.

2.2 | Case inclusion criteria

Young people with a year of birth ≥ 1997 who were aged ≤ 18 years at index hospitalization who had a principal or additional diagnosis of asthma in up to 50 additional diagnosis classifications (International Classification of Diseases, 10th Revision, Australian Modification (ICD-10-AM: J45) during 1 January 2005 to 31 December 2018). Cases were included if the young person completed both the numerical and reading NAPLAN assessments in a school grade.

2.3 | Population-comparison group criteria

A population-based comparison group not hospitalized with asthma from 1 July 2001 to 31 December 2018 was randomly selected from NSW birth records matched 1:1 on age, gender and residential postcode to their counterpart. The selection timeframe for comparisons included a 3.5-year wash-out period prior to the case selection timeframe to avoid the potential selection of comparisons who may have been hospitalized with asthma prior to the case criteria timeframe.

2.4 | Geographical location and socioeconomic status

The Australian Statistical Geographical Standard (ASGS)[27] is based on distance to service centres and was used to classify the postcode of residence of the young person as either urban (ie major cities) or rural (ie inner and outer regional, remote, and very remote). The remoteness area of the school was obtained from NAPLAN records and was categorized as major city, inner regional, outer regional or remote.[27] The young person's postcode of residence was used to partition socioeconomic disadvantage into quintiles from most (ie 1) to least (ie 5) disadvantaged.[28]

2.5 | Identification of chronic health conditions

Common chronic health conditions for young people were identified from prior studies of paediatric comorbidities[29–31] and were conditions reasonably expected to last 12 months or need ongoing healthcare.[29] For this study, a chronic health condition was identified using a three-year look-back period (to 1 January 2002) and diagnosis classifications from ICD-10-AM (Table S2). Whether the young person with asthma was also diagnosed with status asthmaticus (ICD-10-AM: J46) was also identified.

2.6 | Data organization and analysis

Data analysis was conducted using SAS 9.4 (SAS Institute, Cary NC). All hospital episodes of care related to the same event were linked

to form a period of care. Chi-square tests of independence and Wilcoxon's Mann-Whitney tests were used to examine characteristics of young people hospitalized with asthma and their matched peer. The number of ED visits, hospital admissions and hospital length of stay (LOS) before and during, and after, the index admission were identified for cases and their matched counterpart. The calculation of hospital LOS was cumulative and included transfers between hospitals.

To examine the school performance generalized linear regression using PROC GENMOD assessed the difference in proportions of performance below the NMS for each assessment at each school grade (ie 3, 5, 7 and 9) for young people hospitalized with asthma and their matched peers (Table S3). Adjusted relative risks (ARR) were calculated with 95% confidence intervals (CIs). For each assessment, models were fitted using generalized estimating equations (GEE) with binomial distribution and a log link function. Forward selection was used to sequentially add covariates to the model[23] and significance was assessed using *p*-values ($p < .05$) to examine the overall effect in the model. The final models included asthma status, gender, socioeconomic status, highest level of education for any parent/guardian (ie $\leq$ Year 12; certificate I-IV, trade or diploma; bachelor or higher degree; or other), highest level of any parent/guardian occupation (ie senior manager/qualified professional; business manager/associate professional; trades/clerks/skilled office/sales and service; machine operators/ hospitality/ assistants /labourers; or not in paid work in last 12 months), and a logarithm of hospital LOS. As comparison group members could have nil hospital LOS, a constant value was added to LOS before transformation.[32]

Generalized linear mixed modelling (GLMM) was conducted to perform multi-level modelling of school performance below the NMS for each assessment for cases and their counterpart who had completed multiple grades of schooling. For each domain, PROC GLIMMIX was used with a binary distribution, log link function, and Kenward and Roger denominator degrees of freedom. The residual option of the random statement was used to model R-side covariance and data were analysed to account for within student correlation in the longitudinal data and repeated measurements using an autoregressive covariance structure. ARRs and 95% CIs were generated. The final models included: asthma status, NAPLAN grade (ie 3, 5, 7, 9), gender, comorbidity status (Y/N), LBOTE, socioeconomic status, highest level of education and occupation for any parent/guardian, logarithm of hospital LOS, and a school sector (ie government, Catholic, independent).

Factors associated with high school completion at either year 10, 11 or 12 for cases compared to their peers were examined using generalized linear regression using PROC GENMOD. For each grade, models were fitted using GEE with binomial distribution and a log link function. ARR and 95% CIs were calculated. The final models included as follows: asthma status, gender, comorbidity status (Y/N), LBOTE, socioeconomic status, highest level of education and occupation for any parent/guardian, and geographic location of residence.

3 | RESULTS

There were 28,114 young people hospitalized with asthma where a matched peer could be identified and who completed the NAPLAN assessments in Grade 3; 21,192 in Grade 5; 14,161 in Grade 7; and 8083 in Grade 9 during 2015–2018. There were 11,388 young people hospitalized with asthma with a matched counterpart who could have completed year 10; 9537 year 11; and 7114 year 12 of high school.

Across school grades 3 to 9, there was a higher proportion of young males (~61%) compared to females (~39%), and a higher proportion of young people in urban (~75%) compared to rural (~25%) locations hospitalized with asthma. Most young people (≥71%) were from English-speaking households and very few (~2%) had another chronic health condition identified. Young people hospitalized with asthma had a slightly lower proportion of parents with a university degree or who were not in paid employment in the last 12 months than their matched peers for each grade. Young people hospitalized for asthma had higher mean ED visits, hospital admissions and hospital LOS than their matched peers in each grade. Of the young people hospitalized with asthma, 614 (2.1%) were also diagnosed with status asthmaticus, and 71.8% were hospitalized once and 28.2% had ≥2 hospitalizations (Table 1).

Most young people predominantly attended government schools (~71%) in major cities (~74%), with the type of school attended and its geographic location differing for young people hospitalized with asthma compared to matched counterparts at each school grade. Almost double the proportion of young people hospitalized with asthma did not achieve the NMS for their numeracy or reading school assessments across grades 3 to 9 compared to matched peers (Table 2).

Young males hospitalized with asthma had a 13% higher risk of not achieving the NMS on school assessments for numeracy (ARR: 1.13; 95%CI 1.04–1.22) and a 15% higher risk of not achieving the NMS for reading (ARR: 1.15; 95%CI 1.07–1.23) compared to matched counterparts. After adjustment for covariates, young females hospitalized with asthma did not have an increased risk of not achieving the NMS for numeracy or reading compared to matched peers (Table 3).

Young males hospitalized with asthma had a 51% (ARR 1.51; 95%CI 1.22–1.86) higher risk of not completing year 10, and around a 20% higher risk of not completing year 11 (ARR: 1.25; 95%CI 1.15–1.36) or year 12 (ARR: 1.27; 95%CI 1.17–1.39) compared to matched peers. Young females hospitalized with asthma showed no difference in year 10, had a 21% higher risk of not completing year 11 (ARR: 1.21; 95%CI 1.09–1.36) and a 33% higher risk of not completing year 12 (ARR: 1.33; 95%CI 1.19–1.49) compared to matched counterparts (Table 4).

4 | DISCUSSION

This study found an association between young males hospitalized with asthma and a higher risk of not achieving minimum standards

for numeracy and reading in national school-based assessments compared to matched peers. It also found both young males and females hospitalized with asthma had a higher risk of not completing high school compared to matched peers.

Previous studies have identified that young people with inadequately controlled asthma have lower school performance in grades 7, 8 and 9 compared to young people without asthma,[15] a lower performance in grade 9 compared to young people with controlled asthma,[9] and a lower performance in grade 9 compared to siblings with no asthma.[15] In addition, Rujisbroek et al.[10] found that young people with persistent asthma across their first 11 years had worse performance on standardized school assessments compared to young people who experienced asthmatic symptoms only in their early years ie age ≤5 years.

Whilst some studies found no significant difference in academic performance for young people with asthma compared to those with no asthma,[6,13] it appears that an association between asthma and academic performance is probable,[4] particularly for young people with inadequately controlled asthma.[6] Some of the differences in findings of the impact of asthma on school performance are likely due to differences in method of identification (eg self- or parental-reported, physician-diagnosed, or medication-prescribed), list of symptoms (eg wheeze episodes, night-time waking), classification of asthma (eg mild, moderate, severe asthma, ever asthma, or controlled versus uncontrolled), school performance measures used (eg teacher- or parent-reported performance versus assessment tests), school grade examined, age of the young person, and differences in school systems across countries.[5,9,10,13,17,33]

The current study identified that males hospitalized with asthma had worse performance on both numeracy and reading assessments than their matched peers. Similarly, other studies also identified that young students with asthma had lower scores on mathematical assessments compared to students without asthma.[7,34] Furthermore, students with inadequately controlled asthma had lower mathematics scores compared to students with controlled asthma.[5] Likewise, students with moderate or severe asthma had between a 1.6 to 1.4 times higher likelihood, respectively, of having worse scores on mathematical assessments than young people with no chronic health conditions.[35] Possible reasons for poor performance on mathematical assessments for students with asthma could result from teaching strategies. Mathematical curricula are usually taught in a sequential fashion, resulting in some students, who may have been absent due to their asthma, missing critical instructive lessons.[34]

In terms of reading assessments, previous research identified that young students with moderate asthma had a 1.6 times higher likelihood of having worse reading assessment scores compared to students with no chronic conditions.[35] Students with asthma in both primary and middle schools were identified as having lower reading scores than students without asthma.[7] Furthermore, students with persistent asthma at age 6 in their first year of school were identified as being 13 months behind their expected reading ability compared to their peers whose asthma management had improved from age ≤5 years.[36]

(Continues)

Characteristics	Grade 3 ^a						Grade 5 ^b						Grade 7 ^c						Grade 9 ^d					
	Case (n = 28,114)			Comparison (n = 28,114)			Case (n = 21,192)			Comparison (n = 21,192)			Case (n = 14,161)			Comparison (n = 14,161)			Case (n = 8083)			Comparison (n = 8083)		
	n	%		n	%		n	%		n	%		n	%		n	%		n	%		n	%	
Gender																								
Male	17,519	62.3		17,519	62.3		13,155	62.1		13,155	62.1		8,658	61.1		8,658	61.1		4,955	61.3		4,955	61.3	
Female	10,595	37.7		10,595	37.7		8,037	37.9		8,037	37.9		5,503	38.9		5,503	38.9		3,128	38.7		3,128	38.7	
Location of residence ^e																								
Urban	20,972	74.6		20,972	74.6		15,669	73.9		15,669	73.9		10,517	74.3		10,517	74.3		6,110	75.6		6,110	75.6	
Rural	7,119	25.3		7,119	25.3		5,506	26.0		5,506	26.0		3,628	25.6		3,628	25.6		1,961	24.3		1,961	24.3	
Socioeconomic status ^e																								
Most disadvantaged	6,976	24.8		6,976	24.8		5,266	24.9		5,266	24.9		3,501	24.7		3,501	24.7		1,978	24.5		1,978	24.5	
2	6,551	23.3		6,551	23.3		5,041	23.8		5,041	23.8		3,347	23.6		3,347	23.6		1,926	23.8		1,926	23.8	
3	6,049	21.5		6,049	21.5		4,573	21.6		4,573	21.6		3,038	21.5		3,038	21.5		1,713	21.2		1,713	21.2	
4	5,710	20.3		5,710	20.3		2,101	9.9		2,101	9.9		1,408	9.9		1,408	9.9		791	9.8		791	9.8	
Least disadvantaged	5,710	20.3		5,710	20.3		4,194	19.8		4,194	19.8		2,851	20.1		2,851	20.1		1,663	20.6		1,663	20.6	
LBOTE ^f																								
Non-LBOTE	19,937	70.9		20,860	74.2		15,417	72.8		16,030	75.6		10,470	73.9		10,878	76.8		5,953	73.7		6,138	75.9	
LBOTE	8,067	28.7		7,125	25.3		5,738	27.1		5,117	24.2		3,671	25.9		3,266	23.1		2,120	26.2		1,936	24.0	
Not known	110	0.4		129	0.5		37	0.2		45	0.2		20	0.1		17	0.1		10	0.1		9	0.1	
Health condition																								
0	27,562	98.0		27,855	99.1		20,728	97.8		20,969	99.0		13,801	97.5		14,004	98.9		7,834	96.9		7,978	98.7	
≥1	552	2.0		259	0.9		552	2.0		259	0.9		360	2.5		157	1.1		249	3.1		105	1.3	
Parent highest level of education																								
Year 11 or equivalent	2,315	8.2		1,914	6.8		2,087	9.9		1,747	8.2		1,316	9.3		1,144	8.1		711	8.8		648	8.0	
Year 12 or equivalent	1,258	4.5		1,244	4.4		1,139	5.4		1,143	5.4		762	5.4		740	5.2		448	5.5		446	5.5	
Certificate I-IV or trade	8,341	29.7		8,442	30.0		6,461	30.5		6,442	30.4		4,365	30.8		4,356	30.8		2,512	31.1		2,496	30.9	
Advanced diploma/ diploma	4,675	16.6		4,805	17.1		3,655	17.3		3,832	18.1		2,557	18.1		2,673	18.9		1,480	18.3		1,535	19.0	
Bachelor degree or higher	10,225	36.4		10,487	37.3		7,559	35.7		7,770	36.7		4,978	35.2		5,129	36.2		2,816	34.8		2,879	35.6	
Not stated/not known	1,300	4.6		1,222	4.4		291	1.4		258	1.2		183	1.3		119	0.8		116	1.4		79	1.0	
Parent highest occupation																								

TABLE 1 (Continued)

Characteristics	Grade 3 ^a				Grade 5 ^b				Grade 7 ^c				Grade 9 ^d			
	Case (n = 28,114)		Comparison (n = 28,114)		Case (n = 21,192)		Comparison (n = 21,192)		Case (n = 14,161)		Comparison (n = 14,161)		Case (n = 8083)		Comparison (n = 8083)	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Senior manager/ qualified professional	7874	28.0	8283	29.5	6087	28.7	6408	30.2	4202	29.7	4435	31.3	2415	29.9	2531	31.3
Business management/ associate professional	6604	23.5	7207	25.6	5099	24.1	5618	26.5	3519	24.9	3892	27.5	2040	25.2	2250	27.8
Trades, clerks, skilled office, sales and service	6207	22.1	6297	22.4	4748	22.4	4812	22.7	3177	22.4	3179	22.5	1820	22.5	1838	22.7
Machine operators, hospitality, assistants, labourers	4093	14.6	3739	13.3	3069	14.5	2740	12.9	1985	14.0	1726	12.2	1086	13.4	996	12.3
Not in paid work in last 12 months	2430	8.6	1835	6.5	1666	7.9	1202	5.7	947	6.7	687	4.9	492	6.1	316	3.9
Not known	906	3.2	753	2.7	523	2.5	412	1.9	331	2.3	242	1.7	230	2.9	152	1.9

Health care use	Mean		SD		Mean		SD		Mean		SD		Mean		SD	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ED visits	7.8	8.1	3.1	4.3	8.2	8.2	3.2	4.3	8.1	8.0	3.0	4.2	7.5	7.5	2.5	3.9
Hospital admissions	3.4	5.3	1.0	2.0	3.5	5.7	1.0	2.2	3.5	6.2	0.9	1.8	3.2	6.8	0.7	1.4
Hospital length of stay	8.3	22.0	3.1	8.9	8.2	20.6	3.1	8.5	7.3	18.1	2.8	10.7	6.2	15.5	2.1	5.9

^aGrade 3 chi-square test: LBOTE $p < .0001$; Health conditions $p < .0001$; Parent highest level of education $p < .0001$; Parent highest occupation $p < .0001$; and Wilcoxon Mann-Whitney tests: ED visits $p < .0001$; Hospital admissions $p < .0001$; Hospital length of stay $p < .0001$.

^bGrade 5 chi-square test: LBOTE $p < .0001$; Health conditions $p < .0001$; Parent highest level of education $p < .0001$; Parent highest occupation $p < .0001$ and Wilcoxon Mann-Whitney tests: ED visits $p < .0001$; Hospital admissions $p < .0001$; Hospital length of stay $p < .0001$.

^cGrade 7 chi-square test: LBOTE $p < .0001$; Health conditions $p < .0001$; Parent highest level of education $p < .0001$; Parent highest occupation $p < .0001$; and Wilcoxon Mann-Whitney tests: ED visits $p < .0001$; Hospital admissions $p < .0001$; Hospital length of stay $p < .0001$.

^dGrade 9 chi-square test: LBOTE $p < .0001$; Parent highest level of education $p < .04$; Parent highest occupation $p < .0001$; and Wilcoxon Mann-Whitney tests: ED visits

$p < .0001$; Hospital admissions $p < .0001$; Hospital length of stay $p < .0001$.

^eExcludes not known location of residence and socioeconomic status for 23 comparisons in grade 9.

^fLanguage background other than English.

NAT LAY, National Assessment Plan for Literacy and Numeracy, NIMJ, National Millennium Standards.

TABLE 3 Multilevel model of asthma associated with a below NMS NAPLAN assessment for young people with an index hospitalization for during 2005–2018 compared to a matched comparison, linked health and school performance data NSW

	Numeracy				Reading			
	RR ^a	95%CI	ARR ^b	95%CI	RR ^a	95%CI	ARR ^b	95%CI
All persons ^c	1.47*	1.40–1.54	1.10***	1.03–1.17	1.36*	1.30–1.42	1.12**	1.06–1.19
Male ^c	1.47*	1.39–1.56	1.13****	1.04–1.22	1.33*	1.27–1.40	1.15*	1.07–1.23
Female ^d	1.47*	1.36–1.60	1.02	0.91–1.15	1.44*	1.33–1.57	1.03	0.91–1.15

* $p < .0001$; ** $p < .0002$; *** $p < .006$; **** $p < .003$.

^aUnadjusted relative risk.

^bAdjusted for asthma status, gender, LBOTE, socioeconomic status, comorbidity status, NAPLAN grade, parental education, parental occupation, school sector, and hospital LOS. Excludes 68 (0.1%) cases with missing socioeconomic status, 177 (0.3%) with missing LBOTE and 23 (0.03%) who were home-schooled.

^cAdjusted relative risk for reading excludes comorbidity status.

^dAdjusted relative risk for numeracy excludes LBOTE and reading excludes comorbidity status and LBOTE.

TABLE 4 Analysis of characteristics associated with not completing high school for young people with an index hospitalizations with asthma compared to a matched comparison by grade, linked health and school performance data NSW, 2005–2018

	Year 10 <i>n</i> = 11,388 in each cohort			Year 11 <i>n</i> = 9537 in each cohort			Year 12 <i>n</i> = 7114 in each cohort		
	<i>n</i>	% ^a		<i>n</i>	% ^a		<i>n</i>	% ^a	
No school completion									
Case	347	3.1		1980	20.8		1954	27.5	
Comparison	228	2.0		1552	16.3		1463	20.6	
Gender	<i>n</i> ^b	ARR ^c	95%CI	<i>n</i> ^b	ARR ^d	95%CI	<i>n</i> ^b	ARR ^e	95%CI
All persons	347	1.43*	1.21–1.69	1980	1.24*	1.16–1.32	1954	1.29*	1.21–1.38
Male	228	1.51*	1.22–1.86	1268	1.25*	1.15–1.36	1231	1.27*	1.17–1.39
Female	119	1.31	0.99–1.72	712	1.21**	1.09–1.36	723	1.33*	1.19–1.49

* $p < .0001$; ** $p < .0006$.

^aPer cent calculated for young people in case and comparison cohorts not completing the school grade.

^bNumber of students hospitalized with asthma not completed the year.

^cYear 10 all person adjusted relative risk for asthma status, gender, LBOTE, socioeconomic status (excluding 14 cases with missing socioeconomic status), residential geographic location, and parental education and occupation. Both males and females adjusted for asthma status, LBOTE, residential geographic location, and parental occupation.

^dYear 11 all person and females adjusted relative risk for asthma status, gender, comorbidity status, LBOTE, socioeconomic status (excluding 11 cases with missing socioeconomic status), residential geographic location, and parental education and occupation. Males adjusted for asthma status, LBOTE, socioeconomic status, and parental education and occupation.

^eYear 12 all person adjusted relative risk for asthma status, gender, comorbidity status, LBOTE, socioeconomic status (excluding 9 cases with missing socioeconomic status), residential geographic location, and parental education and occupation. Males adjusted for asthma status, LBOTE, socioeconomic status, residential geographic location, and parental education and occupation. Females adjusted for asthma status, comorbidity status, LBOTE, socioeconomic status, and parental education and occupation.

Gender-based performance differences for young people with asthma have been little studied. The current study found no difference in performance for young females hospitalized with asthma compared to matched peers. Similarly, young females aged 7–9 years with asthma had better teacher-reported academic performance than young males with asthma.[33] Differences in school performance may stem from males being more likely to experience inadequately controlled asthma than females.[37]

The current study found that young people hospitalized with asthma had a higher risk of not completing high school than their matched peers. Other studies have also found that a higher

proportion of young people with asthma did not complete high school. In Scotland, 33% of young people with asthma left school at 16 years compared to 28% of those with no asthma.[11] In the United States, young people with asthma had a 1.6 times higher likelihood of not completing high school compared to young people with no chronic health conditions.[18]

Possible explanations for reduced academic performance for young people hospitalized with asthma include cognitive deficits commonly associated with academic achievement (eg attention, language, learning, memory) from intermittent cerebral hypoxia[7,38] and frequent absences due to seeking hospital care.[7] Young

people hospitalized with asthma may also experience nocturnal disturbances that may, in turn, have a negative impact on ability to concentrate and learn during school hours.[7,8,39]

The association between common chronic health conditions of young people and their adverse impact on academic performance has previously been demonstrated.[40,41] Yet, it appears that studies of the impact of asthma on school performance that also include less severe asthma (eg seasonal or mild) may underestimate the effect of inadequately controlled asthma on performance.[40] It is also possible that the effect of asthma on school performance may be mediated by school absences.[11] However, after controlling for school absence, Kohn[35] found that worse performance on mathematical assessments was still evident for young people with asthma compared to young people with no chronic health conditions.

Inadequate control of asthma in young people has several implications for their academic life, such as missing school.[5] It can also adversely affect social relationships with peers and participation in physical activities.[5] A comprehensive multimodal asthma management pathway that includes active care co-ordination between acute and primary care settings and community based services, asthma self-management education and active home-based follow-up visits to assess home environmental triggers can reduce asthma hospital presentations by 80%.[42] More intensive asthma management, such as through intensive clinical or case management services,[43] and better asthma symptom control[7] instigated by health professionals, such as through medication to manage symptoms[13] and the development of an asthma management plan,[13,20] could enhance academic performance for young people[7] via reducing the impact of comorbidities on educational outcomes. Raising caregiver awareness of the benefits of adherence to treatment and asthma management strategies[20,44] and further consideration of school-based interventions to that could raise awareness with teaching staff and students of the importance of adherence to medication management of asthma (eg inhaler)[1,5,7,20] could also assist in improving performance at school. Identification of young people with inadequately controlled asthma who may benefit from additional learning support services should be undertaken[36,38] and strategies to assist young people to manage their asthma symptoms as they move into adulthood is also likely to improve overall health outcomes.[4] Within NSW, a state-wide programme has been established, *Aiming for Asthma Improvement in Children*, coordinated by Clinical Nurse Consultants, that includes self-paced training for school staff on asthma first aid management, along with resources for managing asthma in a school setting.[45] Future research could consider longitudinal studies of the impact of asthma on tertiary academic performance and examine long-term healthcare use as young people with asthma transition to adulthood.

A strength of this study was that it was a large population-based study linking health and educational records over a 13-year period that was able to control for parental education and socioeconomic status. However, there were some limitations. The study only included young people with asthma who had been hospitalized, so did not include young people presenting solely to primary care or other health professionals

for treatment. Although, hospitalized young people are likely to be the most seriously affected. There was no information on the severity of asthma symptoms, use of asthma management plans or medication, or potential moderating factors, such as smoking status of household members, sleep disturbance or school absences, of the young person. Only comorbidities relevant to a hospitalization are indicated in diagnosis classifications, and it is possible that some comorbid conditions were not identified. This is particularly likely for the comparison cohort, where 49.6% had not been hospitalized, leaving no opportunity to identify comorbid conditions, despite the three-year look-back period.

A small number of residential postcodes were not provided to the authors and socio-economic status for these was not able to be identified. The recency of residential postcode may vary between datasets, which may affect estimates of socioeconomic status. No assessment of data validity was able to be conducted and it is possible that there could be some misclassification of data. Visits to private hospital EDs were not able to be accessed for this study. A higher proportion of young people with asthma were absent for NAPLAN assessments compared to their matched counterparts and the current study was not able to take into account school clustering. No information was available regarding any tutoring or additional education services that a young person may have received.

5 | CONCLUSION

Educational attainment is worse for young people hospitalized with asthma compared to their peers with no asthma-related hospitalizations. Early intervention and strategies for better management of asthma symptoms, such as adherence to medication regimens and development of asthma management plans, may enhance academic performance for students with asthma.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

RM, CC, AM: Involved in study concept and design. RM: Acquired and organized the data, conducted the analysis and wrote the first draft of the manuscript. TB-P: Provided statistical assistance for the GLMM analysis. All authors (RM, CC, NH, RPL, AM and TB-P) were involved in interpretation of data and critical revision of the manuscript.

ETHICAL APPROVAL

Ethical approval was obtained from the NSW Population and Health Services Research Ethics Committee (2018HRE0904). A waiver of consent was granted by the ethics committee.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from NSW Ministry of Health, NSW Department of Education, and NSW Education Standards Authority. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the author(s) with the permission of NSW Ministry of Health, NSW Department of Education, and NSW Education Standards Authority and HREC approval.

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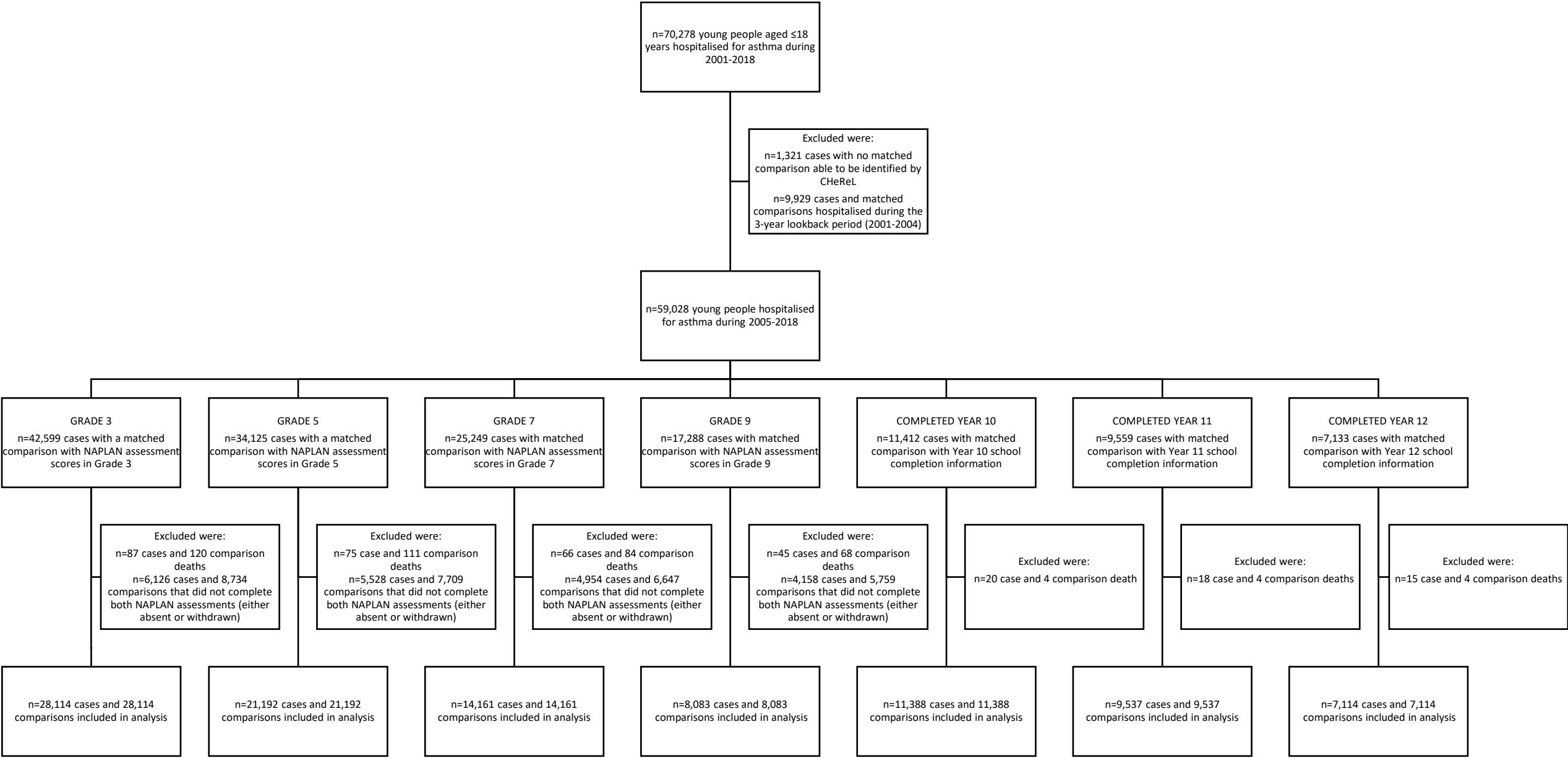
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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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Supplementary Table 1: Number of young people absent or withdrawn from a NAPLAN assessment by grade, linked health and school performance data NSW, 2005-2018

	Grade 3				Grade 5				Grade 7				Grade 9			
	Asthma case		Comparison		Asthma case		Comparison		Asthma case		Comparison		Asthma case		Comparison	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Absent for NAPLAN test																
Numeracy	1,030	2.7	655	1.9	831	2.8	524	1.9	975	4.5	590	3.0	1,132	7.7	643	5.2
Reading	839	2.2	548	1.6	661	2.2	426	1.6	781	3.6	451	2.3	942	6.4	548	4.4
Withdrawn from NAPLAN test																
Numeracy	416	1.1	342	1.0	250	0.8	187	0.7	163	0.8	111	0.6	184	1.3	100	0.8
Reading	433	1.1	356	1.0	256	0.9	193	0.7	165	0.8	112	0.6	174	1.2	101	0.8

¹ Percent calculated for young people in case and comparison cohorts available to take each NAPLAN assessment.

Supplementary Table 2: Health conditions and ICD-10-AM classifications

Health condition	ICD-10-AM classifications
Circulatory system	
Hypertension	I10-I15
Digestive system and allergies	
Celiac disease and other serious allergies	K52.2, K90.0, T78.0, T78.2, T78.4
Endocrine, nutritional and metabolic conditions	
Diabetes	E09-E14
Obesity	E66
Cystic fibrosis	E84
Immune system conditions and coagulation defects	
Anaemia	D50-D53 and D55-D64
Coagulation defects (e.g. haemophilia)	D65-C68
Mental disorders	
Autism spectrum disorders	F84
Conduct disorders: behavioural and emotional disorders of childhood	F90-F98
Cognitive and behavioural delay	F80-F83 and F88-F89
Eating disorders	F50
Hyperkinetic disorder	F90
Mental retardation	F70-F79
Mood affective disorders	F30-F39
Neurotic, stress-related and somatoform disorders	F40-F48
Personality disorders	F60-F69
Schizophrenia, schizotypal and delusions disorders	F20-F29
Neoplasms	
All malignancies	C00-D48
<i>Acute lymphoblastic leukaemia and acute myeloid leukaemia</i>	C91.0, C92.0
<i>Brain cancer</i>	C71
Nervous system conditions	
Cerebral palsy	G80
Epilepsy	G40
Renal conditions	I12.0, I13.1, NO3, NO5, N18-N19, N25.0, Z49, Z94.0, Z99.2

Supplementary Table 3: Adjusted relative risk of a below NMS NAPLAN assessment for young people hospitalised with asthma compared to a matched comparison by grade, linked health and school performance data NSW, 2005-2018

		Numeracy				Reading			
	n ¹	RR	95%CI	ARR	95%CI	RR	95%CI	ARR	95%CI
School grade 3²									
Grade 3	27,980	1.39*	1.29-1.49	1.24*	1.14-1.34	1.40*	1.31-1.50	1.26*	1.17-1.35
Grade 5	21,138	1.50*	1.39-1.63	1.31*	1.20-1.42	1.28*	1.20-1.37	1.16*	1.08-1.25
Grade 7	14,124	1.55*	1.39-1.74	1.32*	1.17-1.49	1.39*	1.27-1.53	1.18**	1.07-1.30
Grade 9 ³	8,060	1.84*	1.55-2.18	1.69*	1.43-2.01	1.46*	1.31-1.62	1.37*	1.23-1.52

*Type 3 GEE analysis: *p<0.0001; **p<0.001.

¹ n=number with hospitalised asthma and excludes young people with missing values for socioeconomic status and LBOTE and home schooled.

² Adjusted for asthma status, sex, LBOTE, socioeconomic status, parental education, parental occupation, and hospital LOS, with reference groups of no asthma hospitalisation, male, English-speaking, least disadvantaged, bachelor or higher degree, and senior manager/qualified professional, respectively.

³Excludes hospital LOS.

Supplementary Figure 1: Flow chart of study population