Paediatric frequent use of emergency medical services: A systematic review

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Abstract

Background
Frequent use of emergency medical services (EMS) is recognised to be a global phenomenon, although paediatric frequent use is poorly understood. This systematic review aimed to understand how paediatric frequent use of EMS is currently defined, identify factors associated with paediatric frequent use of EMS and determine effectiveness of interventions for paediatric patients who frequently use EMS.

Methods
Four electronic databases (Medline, CINAHL, Web of Science and PsycINFO) were searched to September 2022 for primary, peer-reviewed research studies published in English from January 2000. Studies were included that examined frequent use (>1 contact during study period) of EMS or other services with arrival via EMS. Paediatric patients were defined as <18 years of age or otherwise defined by study authors as paediatric/adolescent/children. Data were extracted using a structured proforma, and quality was assessed using the Standard Quality Assessment Criteria for Quantitative Studies but did not influence inclusion decisions. Data were presented using narrative synthesis.

Results
The search resulted in 4,172 unique references, with 12 papers included in the review from seven countries. Four were EMS studies, and eight Emergency Department (ED) with arrival via EMS. All studies used retrospective designs, with no interventional studies identified. Paediatric frequent EMS users were more likely to use services for medical reasons rather than trauma, including respiratory complaints, mental health, and seizures, but data on gender and ethnicity were inconclusive and silent on socio-economic status. There was no consistency in definitions of either a paediatric patient or of frequent use.

Conclusion
The broad range of reasons for frequent use suggests that a single intervention is unlikely to be effective at addressing the causes of frequent use. There is a need for further research to better identify the underlying reasons for frequent EMS use amongst paediatric patients and to develop interventions in this population.

Keywords
Paediatrics, emergency medical services, frequent use

What is already known on this subject

- Previous systematic reviews have examined paediatric frequent use of emergency departments, and evidence suggests that interventions in the emergency department setting can result in positive outcomes.
- Little is known about paediatric patients who frequently use emergency medical services, with no previous systematic review conducted on this topic.

What this study adds

- In this systematic review, we identified that paediatric frequent use was associated with respiratory problems, mental health and seizures, with no two studies using either the same definition of frequent use, or the same definition of a paediatric patient

How this study might affect research, practice or policy

- Lack of literature and homogeneity across studies highlight a clear need for more comparative research to understand the epidemiology of paediatric frequent use of emergency medical services, as well as a need within emergency medical services to develop standardised definitions of paediatric frequent use.
- Further research is also needed to understand the pre-hospital care pathway for paediatric frequent users to inform intervention development.

INTRODUCTION

Frequent use of emergency medical services (EMS) is recognised to be a worldwide phenomenon, and definitions of frequent use remain inconsistent internationally.[1] Disproportionate use may be explained by frequent users having unmet health or social care needs and being unable to access appropriate services due to their own circumstances or availability.[2-4] Studies of frequent EMS use have focused largely on adult populations, where a combination of physical health, mental health and social problems including isolation and loneliness contribute to frequent use.[5 6] There are now efforts to proactively identify and manage adult frequent EMS users to better meet their needs,[7-9] however, there are significantly different challenges associated with managing paediatric patients in the EMS setting.[10] Evidence from the Emergency Department (ED) setting, where one in 11 children who use the service do so frequently,[11] suggests that management of paediatric patients who use services frequently can result in positive outcomes.[12]

Epidemiological studies identify that paediatric patients make up a minority of overall service use, constituting around 5%[13] to 10% of EMS responses,[14] though little data are available for cross-country comparisons. This relatively low usage has implications for individual and service readiness,[15] with services in England historically reporting little support for managing paediatric patients.[16] Trauma is often the main cause of paediatric EMS use, but this is age-specific and more common in older paediatric patients, whereas younger patients are more likely to have respiratory disorders and seizures[17] Paediatric mental health is an increasingly prominent reason for EMS usage, with a US-based study identifying that this category had the largest absolute increase across a ten year period.[18]

Systematic reviews have examined the evidence on frequent ED presentations by paediatric patients[19] and paediatric presentations for mental health,[20] but no review has examined paediatric frequent use of EMS. Furthermore there appears to be no standard definition of paediatric frequent use in the literature in any emergency care setting; a recent systematic review of paediatric frequent use of the ED used author-defined thresholds, with 20% (n=3) of their sample consisting of two or more ED uses in a 12 month period.[19] This systematic review therefore aimed to identify what is known about paediatric frequent users of EMS, including how paediatric frequent use is defined, and to make recommendations for future research.

Methods

This systematic review was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards,[21] with the PRISMA checklist included as Supplementary Material 1. We sought to answer the following research questions:

- What is currently known about paediatric frequent use of EMS?
- How is paediatric frequent use of EMS currently defined?
- What factors are associated with paediatric frequent use of EMS?
- How effective are interventions for paediatric frequent use of EMS?

Eligibility criteria and definitions

There were no restrictions for inclusion based on study design. We applied a wide definition of what ‘frequent use’ means, with studies included where patients used a service on more than one occasion for different reasons. We took this approach as there is no consistent policy definition of paediatric frequent use of EMS nor were we able to identify a relevant definition within the literature other than a review which used authors’ own definitions.[19] Studies selected for review were required to meet the following inclusion criteria:

- Frequent (>1 contact within study period) service use (face-to-face or telephone contact) of:
    - Emergency Medical Services (EMS), or
    - Other services where arrival was via EMS
- Paediatric patients, <18 years of age or otherwise defined by study authors as paediatric/adolescent/children
- Ability to extract paediatric data on frequent service use separately where reported alongside adult data.
- Primary, peer-reviewed research published in English from January 2000.

Search strategy
Four electronic databases (Medline, CINAHL, Web of Science and PsycINFO) were searched up to September 2022 using a modified search strategy based on a previous systematic review of frequent EMS users.[1] The search strategy combined the terms 'paediatric', 'EMS', 'patient' and 'frequent'. More specifically, this was based on the Population, Interest, Context (PICo) framework, with Population being paediatric patients, Interest being frequent use and Context being emergency medical services. The search strategy is reported in full in Supplementary Material 2.

Searches were conducted by AK, with title and abstract sifting conducted by JSc. All full texts were then independently reviewed by two reviewers; JSc reviewed all texts, with AK, AP, HS and JSt each reviewing approximately 25%. Disagreements were discussed until consensus was reached.

Data extraction
A data extraction sheet was developed based on a previous review of frequent EMS use.[1] The data fields were discussed with the wider team and revised during extraction. Data were then extracted directly into Microsoft Excel, which included headings related to study characteristics, methods and results. (Supplementary Material 2)

Data analysis
Due to the heterogeneity of included studies, it was not possible to pool data for a meta-analysis. Following data extraction, we analysed the data using narrative synthesis. A table of study characteristics was created and populated. For each of the two settings (EMS and ED) tables were then formed that incorporated data deemed relevant to the research questions; specifically, the number of frequent users, comparisons with non-frequent users (where applicable) and characteristics associated with frequent use. The data were then organised and reported based on study characteristics, patterns of frequent EMS use, and predictors of frequent EMS use, with a focus on identifying key similarities and differences in the included studies.

Quality assessment
The Standard Quality Assessment Criteria for Quantitative Studies[22] was used to assess study quality. Two reviewers (JSc and AS) independently scored studies and converted the total score into a percentage, with a mean total score reported. Where scores differed by >10% the two authors discussed the papers until agreement was reached. Percentage scores are reported as the denominator may differ depending on applicability of quality assessment items. Study quality was not categorised as high or low as there are no recognised thresholds for this quality assessment tool. A higher percent score equates to a higher quality study. As

this study was exploratory and not attempting to pool data, all studies were included regardless of quality.

Patient and public involvement

There was no patient and public involvement in the design or planning of the study.

RESULTS

A total of 5939 articles were identified from the search (figure 1), of which 1767 were duplicates leaving 4172 articles. Following review of title and abstract, 208 full text articles were reviewed, with 12 meeting the inclusion criteria. There was an initial 91% agreement in the independent double review of full texts, which reached 100% following discussion.

[Figure 1 around here]

Study characteristics and Definitions

Study design

Four studies [23-26] were conducted in EMS settings, of which three[24-26] used all EMS contacts via telephone and one[23] examined ED conveyance. Eight studies [27-34] were conducted using ED data with arrivals via EMS or ambulance as inclusion criterion. All twelve studies were conducted retrospectively and none followed an interventional design. All four EMS studies [23-26] were conducted in single EMSs. Four ED studies[30 31 33 34] were conducted in a single site, and the other four ED studies [27-29 32] ranged from three sites[29] to 22 sites,[27] with one conducted in an unreported number of sites across two Canadian provinces.[32] Table 1 summarises the study characteristics of all twelve included studies.

Study quality

Most studies were of reasonably high quality with a mean quality score of 85% (range=68% to 98%), with particular strengths in reporting the research question or objective, describing methods, reporting outcomes, using appropriate sample sizes and reporting the results in detail with conclusions supported by results. There were areas for improvement in reporting characteristics of comparison groups, reporting estimates of variance and controlling for confounding variables. Table 1 gives quality scores; the full quality assessment scores are provided in Supplementary Material 3.

Table 1: Study characteristics for all included studies

Author(s)	Year of publication	Country	Study design	Primary study setting (inclusion criterion)	Number of study sites	Sample size	Definition of frequent	Definition of paediatric (categories used, years)	Quality score
Alpern et al.[27]	2014	United States	Retrospective cohort study	ED (conveyance to ED)	22	695,188 patients	≥1 return within 12 months of index visit	<18 years (Infant, 1-4, 5-9, 10-14, 15-17)	95%
Broxterman et al.[23]	2000	United States	Retrospective observational study	EMS (conveyance to ED)	1	15,168 patients	>1 transport over study period (4 years) or >6 transports over study period	<21 years (<1, 1 - 5.9, 6 - 10.9, 11-16.9, 17-20.9)	80%
Gibson et al.[28]	2010	Australia	Retrospective population study	ED (conveyance to ED)	9	229,883 patients	Frequent (5-9 and 10-19) and extremely frequent (20-29, 30-39, 40+) attendances in a single year	<15 years (Neonates, 0-4, 5-9, 10-14)	73%
Kim et al.[29]	2018	Republic of Korea	Retrospective observational study	ED (conveyance to ED)	3	33,765 patients	>1 use over study period (12 months)	<16 years (Infant, 1-4, 5-9, 10-14, 15)	89%
Knowlton et al.[24]	2013	United States	Retrospective observational study	EMS (all EMS contacts)	1	135,122 patients	6 or more EMS incidents during study period (23 months)	Not defined (0-14, 15-24)	91%
Knowlton et al.[25]	2016	United States	Retrospective observational study	EMS (all EMS contacts)	1	24,760 patients	>1 use over study period (23 months)	<21 years (0-4, 5-9, 10-14, 15-17, 18-20)	86%
Markham et al.[30]	2013	Australia	Retrospective case-control study	ED (conveyance to ED)	1	34,392 patients*	>7 attendances in 12-month period	<19 years (no categorisation)	73%

Marr et al.[31]	2021	United States	Retrospective observational study	Psychiatric ED (conveyance to ED)	1	885 patients	≥1 return within 180 days of index visit	<19 years (2-5, 6-11, 12-15, 16-18)	95%
Rosychuk et al.[32]	2022	Canada	Retrospective cohort study	ED (conveyance to ED)	2 provinces †	743,042 patients	Complex high system users ‡ during study period (12 months)	<18 years (no categorisation)	98%
Tarnqvist et al.[26]	2017	Sweden	Retrospective observational study	EMS (all EMS contacts)	1	339 patients	>3 uses over study period (12 months)	Not defined (<10, 10-19)	68%
Vitello et al.[33]	2021	Italy	Retrospective observational study	ED (conveyance to ED)	1	2,064 patients	≥1 return within 72 hours of index visit, or return visit during study period (2 months)	<18 years (<1, 1-5, 6-11, 12,17)	82%
Vrijlandt et al.[34]	2022	The Netherlands	Retrospective observational study	ED (conveyance to ED)	1	10,209 patients	>3 visits within 12 months	<19 years (<1, 1-2, 2-5, 5-12, ≥12) §	95%

ED=emergency department. EMS=emergency medical service
* Authors arbitrarily excluded patients with six or seven attendances.
† Total number of EDs represented in the data are not reported.
‡ Dynamic definition incorporating highest acute care cost, highest length of stay, most frequent hospitalisations, and most frequent ED visits.
§ Overlapping years are not explained by authors.

Definition of paediatric patients
Definitions of a paediatric patient varied across studies. Two studies, both of which included EMS callers of any age across the full sample, provided no definition of paediatric patients.[24 26] The most common definitions, both used in three studies, were <18 years [27 32 33] and <19 years.[30 31 34] The lowest age definition of paediatric users was <15 years.[28] Ten studies reported age categories,[23-29 31 33 34] but again there was no consistency in reporting. Only one study included a specific category for neonates.[28]

Definition of frequent use
As with the definitions of a paediatric patient, the definitions of frequent use also differed across almost all studies regardless of whether studies were predominantly EMS or ED based. The most frequent time period across all studies was usage across either a 12-month period[26 28-30 32 34] or within 12 months of an index visit,[27] though only one of these studies[26] were based in an EMS. Amongst the EMS studies, definitions ranged from more than one usage within the study period of 23 months[24] or 48 months,[23] through to six or more within the study period of 23 months.[25] No single definition of frequent use was used in more than one EMS study.

Country of study
Studies were conducted in seven different countries, the modal country being United States (n=5).[23-25 27 31] No studies were conducted across multiple countries. EMS studies were conducted in the United States (n=3)[23-25] and Sweden (n=1).[26]

Patterns of paediatric frequent use of EMS
Ten studies exclusively included paediatric users,[23 25 27-34] of which only two were specifically based in an EMS setting.[23 25] There was no standard reporting of how many times paediatric frequent users utilised or accessed service(s), reflecting the heterogeneity of study design, sample and definitions of frequent user.

Three EMS-based studies[23-25], all conducted in the United States, reported comparisons in usage between frequent and non-frequent users (table 2). One study[23] identified that in the age group 17-20, 49% of frequent users were transported to ED compared to 39% of non-frequent users. No further data were available for other age groups. This differed from the findings of Knowlton et al.[24] who identified that EMS use was lower amongst frequent users aged 0-14 (1.1%) and 15-24 (6.6%) when compared with non-frequent users of the same age (8.8% and 13.6% respectively). However, this contrasted with a later study by the same authors [25] who identified that EMS use was lower in frequent users under the age of 15 (groups 0-4, 5-9 and 10-14), but higher in frequent users over the age of 14 (groups 15-17, 18-20).

Table 2: Key findings from studies of paediatric frequent EMS use

Author(s)	Data source(s)	Number of paediatric frequent users	Age distribution of frequent use	Paediatric frequent EMS users compared with non-frequent users	Significance level / 95% CI	Predictors of paediatric frequent EMS use (within-group % in frequent users vs non-frequent users)	Significance level
Broxterman et al.[23]	EMS database	>1 transport: 1,691 (11.1% of paediatric users) >6 transports: 55 (0.36% of paediatric users)	Bimodal	Age 17-20: 49.0% of repeat transports compared to 38.0% of single transports. No extractable data were provided for other age groups.	p<0.0001	Female (51.4% vs 48.5%) Medical reasons (46.9% vs 30.5%) Seizure, assault, suicide attempts, abdominal or chest pain, respiratory complaints, pregnancy and mental/behavioural problems (% comparisons not reported) Public insurance (39.0% vs 19.8%)	p=0.0008 p<0.0001 p<0.0001 p<0.0001
Knowlton et al.[24]	EMS database and 911 dispatch records	Ages 0-14: 1.1% of 1,967 patients frequent users † Ages 15-24: 6.6% of 1,967 frequent users †	Data not reported for only paediatric patients	Ages 0-14: Frequent users 1.1% of all frequent users. Non-frequent users 8.8% of non-frequent users (7.7% lower). Ages 15-24: Frequent users 6.6% of all frequent users. Non-frequent users 13.6% of all non-frequent users (7.0% lower).	95%CI = -7.2 to -8.2 95%CI = -5.9 to -8.1	Ages 0-14: Medical/surgical‡ (92.8% vs 73.5%), including: Respiratory (29.6% vs 21.6%) Asthma (23.7% vs 10.9%) Mental problems (8.6% vs 2.5%) Seizures (22.4% vs 6.8%) Ages 15-24: Medical/surgical‡ (95.1% vs 74.7%) including: Respiratory (17.7% vs 7.8%) Asthma (14.6% vs 5.0%) Mental problems (8.2% vs 6.5%) Seizures (7.0% vs 3.6%)	p<0.001 p<0.001
Knowlton et al.[25]	EMS database and 911	1,931 (9.0% of paediatric users)	Bimodal	Ages 0-4: 24.6% frequent, 31.8% non-frequent	p<0.001 (all age groups)	Female in ages 10-14 (50.6% vs 45.0%), 15-17 (63.7% vs 53.6%), and 18-20 (68.6% vs 56.5%).	p<0.001

	dispatch records			Ages 5-9: 7.1% frequent, 11.8% non-frequent Ages 10-14: 9.0% frequent, 12.3% non-frequent Ages 15-17: 17.7% frequent, 15.8% non-frequent Ages 18-20: 41.5% frequent, 28.3% non-frequent		Males in ages 0-4 (61.5% vs 58.6%) and 5-9 (62.8% vs 59.6%). Black/African American § (89.3% vs 81.5%) Medical-related (92.6% vs 71.4%) Asthma (41.2% vs 21.2%) Mental health (18.3% vs 7.7%) Substance use (12.4% vs 7.7%) Seizures (11.6% vs 4.9%) Diabetes (3.1% vs 1.4%) Behavioural health in ages 0-4 (5.8% vs 5.7%), 5-9 (5.5% vs 3.1%) and 10-14 (7.8% vs 5.8%). Obstetric/gynaecological in ages 18-20 (14.4% vs 7.9%) and 15-17 (13.9% vs 6.2%).	p<0.001 p<0.001 p<0.001
Tarnqvist et al.[26]	EMS patient record system	Ages <10: 1 (0.3% of all users) Ages 10-19: 3 (0.9% of all users)	Data not reported for only paediatric patients	Data not reported	N/A	Ages <10: 1 male (100%) Ages 10-19: 3 female (100%)	N/A

CI = confidence interval. EMS = emergency medical service
* sample consisted of ages 15-98 (mean=57.6, SD=21.4).
† Numerator not reported. Denominator reported as 1,967 patients in table, and 1,969 patients in text.
‡ Exact definition of 'medical/surgical' was not reported. Sub-categories selected for reporting were same as those reported by Knowlton et al.[A] Exact numbers were not reported, only percentages.
§ Authors use 'Black' and 'African American' interchangeably.
¶ Sample consisted of ages 13-90 (mean=57.7, SD=15.94)

Three of the eight ED studies [28-30] identified that frequent ED use was associated with an increased usage of EMS. For instance, Gibson et al.,[28] a multi-centre study with nine sites conducted in Australia, identified that amongst those attending the ED 10-19 times per year, arrival was via ambulance in 10.4% of attendances as opposed to 5.6% amongst the non-frequent attenders. This difference was not consistent across the three studies; Markham et al.,[30] a single-centre study also conducted in Australia, identified that EMS arrival in frequent presenters was 49% of arrivals, compared to 11% amongst non-frequent presenters. Two studies identified that frequent use of ED was associated with decreased EMS use; Alpern et al.,[27] a multi-centre study in the United States with 22 sites, found that users without recurrent visits arrived via EMS in 10% of visits, as opposed to 5-6% for recurrent visits. Vrijlandt et al.,[34] a single-centre study in The Netherlands, found that 11.7% of frequent users arrived via ambulance compared to 20.7% of non-frequent attenders, meaning that arrival via ambulance reduced the hazard of returning. Two single-centre studies conducted in United States[31] and Canada[32] found no difference in ambulance use between frequent and non-frequent users. One single-centre study conducted in Italy[33] only reported ambulance use for repeat visits within 72 hours of index visit, of which there were 6 (6.5% of all repeat visits). Table 3 provides an overview of arrival to ED via EMS for paediatric frequent users.

Table 3: Key findings from studies of emergency department paediatric frequent users arriving via EMS

Author(s)	Data source(s)	Number of paediatric frequent users (% of all users)	Number of ED visits (% of all visits)	EMS Usage	Significance level / Odds Ratio (CI 95%)
Alpern et al.[27]	Electronic patient billing and tracking systems	Total: 247,577 (35.6%) 1 recurrent visit: 141,742 (20.4%) 2 recurrent visits: 56,395 (8.1%) 3 recurrent visits: 24,889 (3.6%) >3 recurrent visits: 24,551 (3.5%)	Total: 1,150,776 1 recurrent visit: 283, 484 (24.6%) 2 recurrent visits: 169,185 (14.7%) 3 recurrent visits: 99,556 (8.7%) >3 recurrent visits: 150,940 (13.1%)	0 recurrent visits: 10/100 1 recurrent visit: 6/100 2 or 3 recurrent visits: 5/100 >3 recurrent visits: 6/100	p<0.001
Gibson et al.[28]	ED records linked to morbidity and mortality records	Total: 5,750 (2.5%) representing 6,897 annualised chain of events* *Frequent attenders (5-19 attendances)* 5-9 attendances: 6,405 annualised chain of events 10-19 attendances: 461 annualised chain of events	Total: 551,260, representing 378,068 annualised chain of events* Data not reported on number of attendances by frequent attenders and extremely frequent attenders	Non-frequent attenders: 5.6% † Frequent attenders (5-9/year): 6.4%† Frequent attenders (10-19/year), arrival 10.4%† Extreme frequent attenders "arrived by ambulance four times more often than NFAs". †	- p<0.001 compared to NFAs p<0.001 compared to 5-9FAs. No significance levels reported

		Extremely frequent attenders (>19 attendances) 492 annualised chain of events			
Kim et al.[29]	Medical records	Total: 10,381 (30.7%) 1 recurrent visit: 5,610 (16.6%) 2 recurrent visits: 2,353 (7.0%) 3 recurrent visits: 1,172 (3.5%) >3 recurrent visits: 1,246 (3.7%)	Data not fully reported ‡	Patients with 5 or more ED visits more likely to arrive via EMS (n=84, 6.7%) compared to single visit (n=1,168, 5.21%), two visits (n=299, 5.3%), three visits (n=121, 5.1%) and four visits (n=62, 5.2%).	P<0.01
Markham et al.[30]	Electronic patient records and medical record database	Total: 130 (0.4%)	Total: 46,883 Frequent attenders: 839 (1.7%)	Non-frequent attenders: 11% of arrivals Frequent attenders: 49% of arrivals	Frequent users twice as likely to arrive via EMS OR=2.040 (95%CI=1.7 to 2.4), p<0.0001
Marr et al.[31]	Patient charts	Total: 186 (21.0%)	Data not fully reported ¶	All patients: 253/885 (28.6%) No revisits: 195/699 (28.0%) § Revisits: 58/186 (31.2%) §	P=0.38
Rosychuk et al.[32]	Administrative health databases	Total: 151,497 (not reported) #	617,328 (not reported) # Median=3 IQR=3-4	Control: 32,884 (5.6%) admissions via ground, air or water ambulance Frequent users: 20,444 (13.5%) admissions via ground, air or water ambulance	Univariate model: OR=0.98 (CI=0.98 to 0.99), p<0.05. Multivariate model: OR=0.99 (CI=0.98 to 1.00), p>0.05

Vitello et al.[33]	Clinical health records	Total: 244 (12.8%) Repeat visit within 72 hours of index visit: 97 (4.7%)	Total: data not reported Total visits by patients with a repeat visit within 72 hours of index visit: 197 ‖	Repeat visits within 72 hours of index visit: 6 (6.5%) patients attended via ambulance Data not reported on non-repeat visits	No inferential tests conducted
Vrijlandt et al.[34]	Electronic medical record system	Total: 500 (4.9%)	Total: 16,397 visits Frequent users: 3,481 (21.2%)	Non-frequent users: 2,674 (20.7%) attended via ambulance Frequent users: 406 (11.7%) attended via ambulance	Hazard Ratio: 0.82 (CI=0.76 to 0.90), p<0.01

OR = Odds Ratio. CI=confidence interval. ED=emergency department. EMS=emergency medical service. FA=frequent attender
* annualised chain of events defined as first and subsequent ED visits within a year.
† Exact data not reported. Authors do not report whether this is based on attendances or annualised chain of events.
‡ Recalculated total visits based on available data provides more visits (n=52,581, assumption that >3 recurrent visits always = 4) than the total number of paediatric visits (n=46,237)
¶ Revisits ranged from 1 to 9 (mean=1.61, standard deviation=1.02).
§ overall % recalculated based on data presented as % reported in paper was not calculated consistently between 'no revisits' and 'revisits' groups.
# Control group participants were selected as a proportion of frequent users (4:1) so data on the whole population were not reported and proportions were not possible.
‖ recalculated using numbers provided by authors: 92 patients with single repeat visit (=184 visits), 3 patients with 2 repeat visits (=9 visits) and 1 patient with 2 index visits for unrelated reasons each with single repeat visit (=4 visits).

Predictors of paediatric frequent use of EMS

Trauma vs medical reasons

Three studies examined differences in trauma- and medical-related EMS use,[23-25] all of which identified that paediatric frequent users were more likely to use the service for medical reasons than due to trauma, however the definition of what constituted a medical-related use was often vague. Across all three studies, respiratory problems, mental health and seizures were common medical reasons associated with increased EMS use.

Gender

Two studies[23 25] reported data that gave an indication of gender differences. Broxterman et al.[23] reported that female paediatric patients were significantly more likely to be frequent users, and Knowlton et al.[25] reported that females in the age groups 15-17 and 18-20 were significantly more likely to be frequent users, and those younger than ten were significantly more likely to be male.

Ethnicity

One study,[25] based in the US, reported on ethnicity. The authors identified that paediatric frequent EMS users were significantly more likely to be Black/African American than paediatric non-frequent users.

Effectiveness of interventions for paediatric frequent users of EMS

No studies reported any data on interventions for paediatric frequent users of EMS.

Discussion

The findings of this review suggest that paediatric frequent users of EMS are a poorly understood population, with few studies examining the epidemiology of paediatric frequent use. We identified no single unifying definition of either a paediatric patient or thresholds for paediatric frequent use, though there was a tendency to define paediatric as either <18 years or <19 years. Frequent use was often measured over 12 months, though only one of the four EMS studies used this timeframe. A similar problem of definition heterogeneity was identified in previous reviews of paediatric frequent ED users[19] and all frequent EMS users.[1] UK ambulance services have addressed this for adult populations by standardising the definition.[8] There has been a call for more standard definitions of frequent use without specifying whether this should be paediatric or adult populations,[35] but there is as of yet no common definition of paediatric frequent use. Without further research to better understand paediatric frequent use it is not possible to speculate on what a definition may look like.

Another key finding of our study, albeit one identified via its silence rather than presence in the data, was that no studies specifically examined interventions for paediatric frequent users. The considerable heterogeneity of studies is perhaps exacerbated by the complexity of care delivered across varying healthcare systems. Whilst not within the scope of this study, a previous review of adult ED frequent use[36] compared five types of healthcare systems and identified commonalities that would support international collaboration and knowledge translation. Future studies on paediatric frequent EMS use should consider comparisons across different healthcare systems to better understand how the systems and broader social conditions contribute to frequent use.

Factors that contribute to paediatric frequent EMS use across the literature are not well understood, though a common finding identified in our review was that paediatric frequent users were more likely to use EMS for medical rather than trauma reasons.[23-25] This is

contrary to the epidemiological evidence which suggests that trauma can be a larger contributor to paediatric EMS use.[17 37 38] Whilst categorisation of medical reasons varied and were applied inconsistently, common issues included respiratory and breathing problems, mental health and seizures. As broad and eclectic categories, physical and mental health have also been recognised to be factors in adult frequent EMS use,[1 3] and chronic or complex conditions are factors in both adult and paediatric ED frequent usage.[3 19] However what appeared to be missing amongst paediatric users of the studies included in this review were social issues, including a silence relating to socio-economic status. Community deprivation is associated with increased EMS use by children,[39] and lower socioeconomic status is linked to increased non-emergency use of EMS for paediatric patients.[40] More broadly, deprivation is strongly associated with increased levels of chronic conditions amongst children such as diabetes and asthma.[41 42]. These silences may reflect the limited datasets used in the included studies which typically relied on retrospective routinely collected data, rather than the qualitative approaches that are beginning to examine adult frequent use in greater detail.[3 4 43] There is therefore a clear need to understand whether there is an association between frequent use and markers of inequality such as socio-economic status or deprivation using prospective methods. Quantitative or qualitative research with paediatric frequent users and their primary caregivers is also necessary to understand reasons for frequent user from their perspectives, which will be required to underpin interventions.

Higher prevalence of medical rather than trauma causes for frequent use mirrors that of adult frequent EMS[1] and ED users,[44] suggesting that there are commonalities between population groups. It can be hypothesised that interventions developed for those other populations and have demonstrated some effectiveness[7 45] might be suitable for adaptation for paediatric frequent users. It is however important to recognise that there are important biological and contextual differences, including the greater role of primary caregivers,[46] that suggest the need for further research to fill the evidence gap we have identified.

Finally, we found that where EMS mode of arrival was reported in ED studies, it was unclear whether frequent users were less or more likely to attend via EMS with three studies reporting increased EMS use, two studies reporting decreased EMS use and two studies reporting no difference. We identified eight ED studies that reported mode of arrival, and a recent systematic review of paediatric frequent ED use did not report on mode of arrival at all.[19] This has implications for EDs, specifically that interventions should take into account mode of arrival, and further exploration of this phenomenon is required to determine whether interventions could be delivered within an EMS setting to reduce ED usage. For practice and policy, this points towards a greater need to better integrate the care delivered across EMS and ED providers.

Limitations

It is possible that other studies on frequent use of EMS or frequent use of ED where arrival is via EMS included a small number of participants under 18 years but had not used relevant keywords (paediatric, child, adolescent), and so were not captured by our search strategy. By erring on the side of caution when sifting and reviewing the full texts of 208 papers, we anticipate that if any were missed, they would have a negligible impact on the study findings or conclusions. The heterogeneity of studies and lack of a single definition of either paediatrics or frequent use, whilst primarily a limitation of the evidence base rather than our review, does mean that caution should be used when interpreting the results. Further limitations were that the systematic review was not prospectively registered, one person

performed the initial literature search and one person identified papers at title and abstract sifting.

Conclusion

The evidence base on paediatric frequent callers is limited to a small number of mostly retrospective database reviews. Of the evidence available, paediatric frequent use was associated with respiratory problems, mental health and seizures, rather than trauma. This broad range of complaints suggests that a single intervention is unlikely to be effective at addressing the causes of frequent use, and there is a clear need for further research to better identify the underlying reasons for frequent EMS use amongst paediatric patients. The lack of interventional studies identified in this review suggests a clear need to develop interventions in this population.

Competing interests

The authors have no conflicts of interest relevant to this article to disclose.

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Contributors statement

Dr Jason Scott conceptualised and designed the study, acquired, analysed and interpreted the data, drafted the initial manuscript, and reviewed and revised the final manuscript.
Dr Ashra Khanom acquired, analysed and interpreted the data, and reviewed and revised the final manuscript.
Mrs Joanne Straw conceptualised and designed the study, analysed and interpreted the data, and reviewed and revised the final manuscript.
Mrs Annette Strickland conceptualised and designed the study, analysed and interpreted the data, and reviewed and revised the final manuscript.
Dr Alison Porter analysed and interpreted the data, and reviewed and revised the final manuscript.
Prof Helen Snooks analysed and interpreted the data, and reviewed and revised the final manuscript.

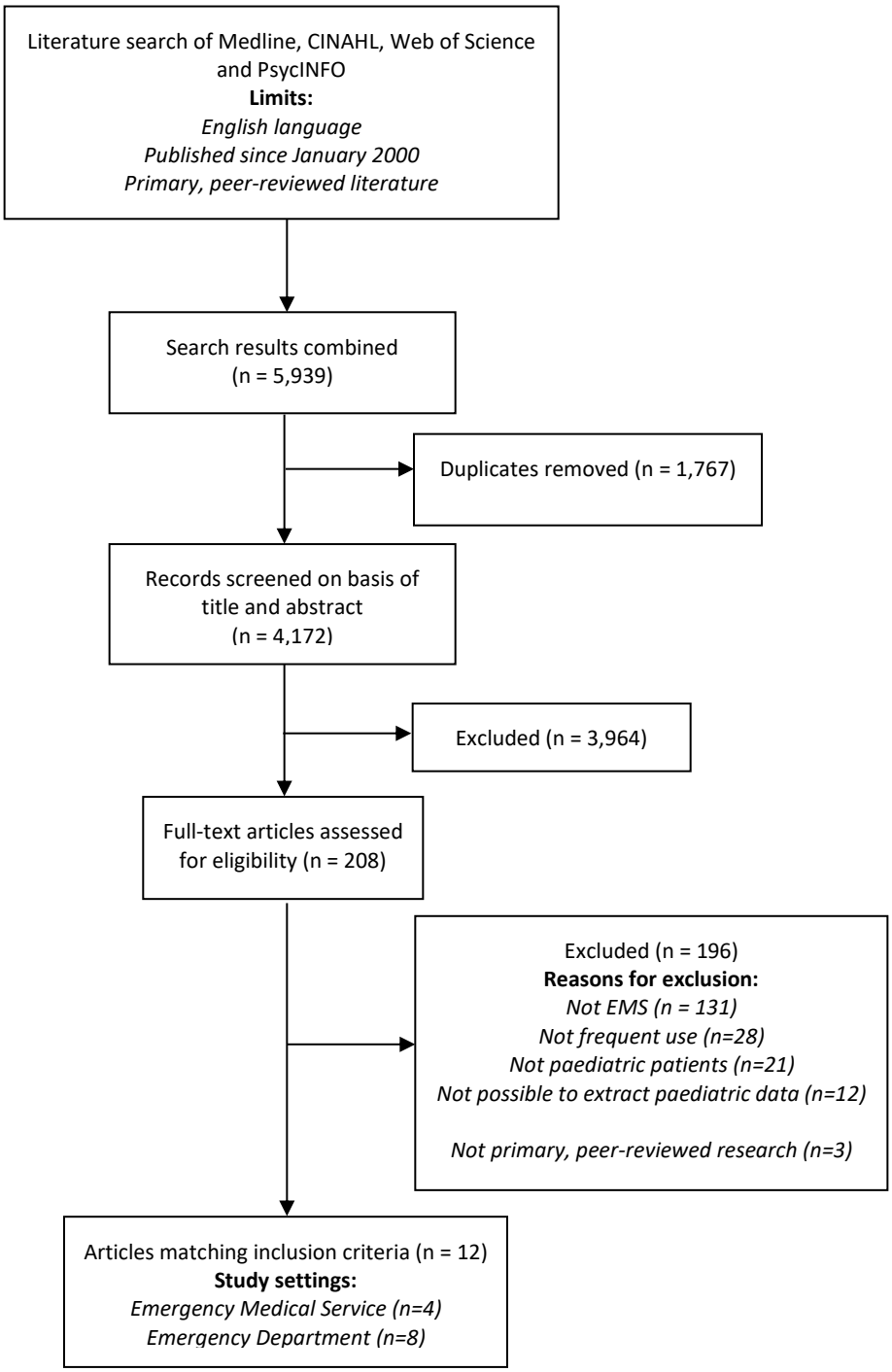
References

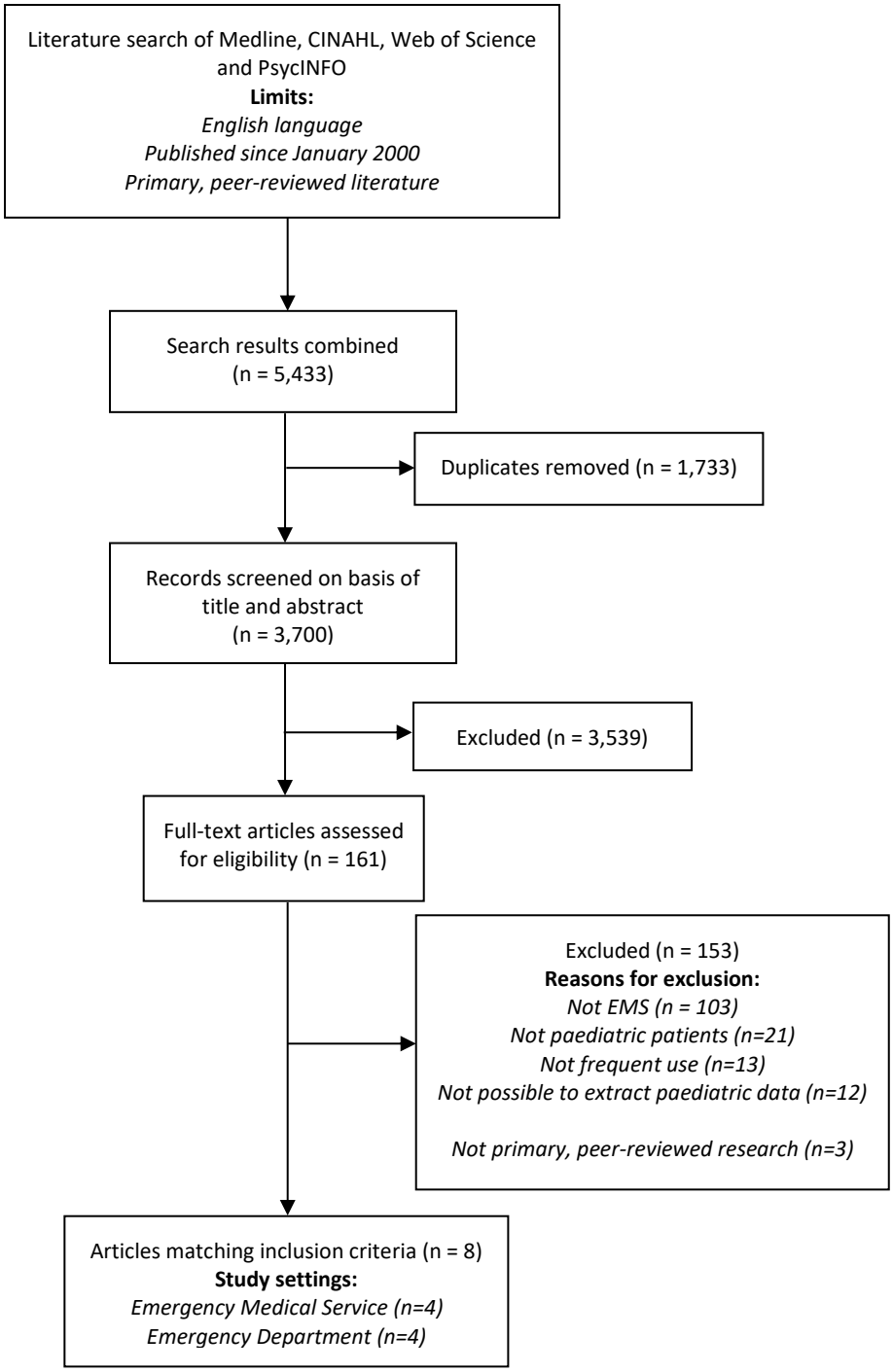
1. Scott J, Strickland AP, Warner K, et al. Frequent callers to and users of emergency medical systems: A systematic review. Emerg Med J 2014;**31**(8):684-91 doi: 10.1136/emermed-2013-202545.
2. Scott J, Strickland AP, Warner K, et al. Describing and Predicting Frequent Callers to an Ambulance Service: Analysis of 1 Year Call Data. Emerg Med J 2014;**31**(5):408-14 doi: 10.1136/emermed-2012-202146.
3. Mahmuda S, Wade-Vallance A, Stosic A, et al. Understanding Why Frequent Users of EMS Call 9-1-1: A Grounded Theory Study. Health Promotion Practice 2018:1524839918799504 doi: 10.1177/1524839918799504.
4. Agarwal G, Lee J, McLeod B, et al. Social factors in frequent callers: a description of isolation, poverty and quality of life in those calling emergency medical services frequently. BMC Public Health 2019;**19**(1):684 doi: 10.1186/s12889-019-6964-1.
5. Kuek BJW, Li H, Yap S, et al. Characteristics of Frequent Users of Emergency Medical Services in Singapore. Prehospital Emergency Care 2019;**23**(2):215-24 doi: 10.1080/10903127.2018.1484969.
6. Norman C, Mello M, Choi B. Identifying Frequent Users of an Urban Emergency Medical Service Using Descriptive Statistics and Regression Analyses. West J Emerg Med 2016;**17**(1):39-45 doi: 10.5811/westjem.2015.10.28508.
7. Edwards MJ, Bassett G, Sinden L, et al. Frequent callers to the ambulance service: patient profiling and impact of case management on patient utilisation of the ambulance service. Emerg Med J 2015;**32**(5):392-96 doi: 10.1136/emermed-2013-203496.
8. Snooks HA, Khanom A, Cole R, et al. What are emergency ambulance services doing to meet the needs of people who call frequently? A national survey of current practice in the United Kingdom. BMC Emergency Medicine 2019;**19**(1):82 doi: 10.1186/s12873-019-0297-3.
9. Rinke ML, Dietrich E, Kodeck T, et al. Operation care: a pilot case management intervention for frequent emergency medical system users. The American Journal of Emergency Medicine 2012;**30**(2):352-57
10. Jeruzal JN, Boland LL, Frazer MS, et al. Emergency Medical Services Provider Perspectives on Pediatric Calls: A Qualitative Study. Prehospital Emergency Care 2019;**23**(4):501-09 doi: 10.1080/10903127.2018.1551450.
11. Greenfield G, Blair M, Aylin PP, et al. Characteristics of frequent paediatric users of emergency departments in England: an observational study using routine national data. Emerg Med J 2021;**38**(2):146-50 doi: 10.1136/emermed-2019-209122.
12. Breen C, Altman L, Ging J, et al. Significant reductions in tertiary hospital encounters and less travel for families after implementation of Paediatric Care Coordination in Australia. BMC Health Serv Res 2018;**18**(1):751 doi: 10.1186/s12913-018-3553-4.
13. Harve H, Salmi H, Rahiala E, et al. Out-of-hospital paediatric emergencies: a prospective, population-based study. Acta Anaesthesiologica Scandinavica 2016;**60**(3):360-69 doi: https://doi.org/10.1111/aas.12648.
14. Drayna PC, Browne LR, Guse CE, et al. Prehospital Pediatric Care: Opportunities for Training, Treatment, and Research. Prehospital Emergency Care 2015;**19**(3):441-47 doi: 10.3109/10903127.2014.995850.
15. Owusu-Ansah S, Moore B, Shah MI, et al. Pediatric Readiness in Emergency Medical Services Systems. Pediatrics 2020;**145**(1):e20193308 doi: 10.1542/peds.2019-3308.
16. Houston R, Pearson GA. Ambulance provision for children: a UK national survey. Emerg Med J 2010;**27**(8):631-36 doi: 10.1136/emj.2009.088880.
17. Eich C, Russo SG, Heuer JF, et al. Characteristics of out-of-hospital paediatric emergencies attended by ambulance- and helicopter-based emergency physicians.

Resuscitation 2009;**80**(8):888-92 doi: https://doi.org/10.1016/j.resuscitation.2009.05.008.
18. Oliveira J. e Silva L, Anderson JL, Bellolio MF, et al. Pediatric emergency medical services in privately insured patients: A 10-year national claims analysis. The American Journal of Emergency Medicine 2019;**37**(8):1409-15 doi: https://doi.org/10.1016/j.ajem.2018.10.029.
19. Giannouchos TV, Washburn DJ, Gary JC, et al. Frequent emergency department use in the paediatric population: A systematic literature review. Journal of Evaluation in Clinical Practice 2021;**27**(1):193-203 doi: https://doi.org/10.1111/jep.13382.
20. Leon SL, Cloutier P, Polihronis C, et al. Child and Adolescent Mental Health Repeat Visits to the Emergency Department: A Systematic Review. Hospital Pediatrics 2017;**7**(3):177 doi: 10.1542/hpeds.2016-0120.
21. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009;**339** doi: 10.1136/bmj.b2535.
22. Kmet LM, Lee RC, Cook LS. *Standard quality assessment criteria for evaluating primary research papers from a variety of fields*. Alberta, Canada: Alberta Heritage Foundation for Medical Research, 2004.
23. Broxterman K, Sapien R, Fullerton L, et al. Repeat ambulance use by pediatric patients. Academic Emergency Medicine: Official Journal Of The Society For Academic Emergency Medicine 2000;**7**(1):36-41
24. Knowlton A, Weir BW, Hughes BS, et al. Patient Demographic and Health Factors Associated With Frequent Use of Emergency Medical Services in a Midsized City Factores Sanitarios y Demográficos del Paciente Asociados con el Uso Frecuente de los Servicios Médicos de Emergencias en una Ciudad de Tamaño Medio. Academic Emergency Medicine 2013;**20**(11):1101-11 doi: 10.1111/acem.12253.
25. Knowlton AR, Weir B, Fields J, et al. Pediatric use of emergency medical services: the role of chronic illnesses and behavioral health problems. Prehospital Emergency Care 2016;**20**(3):362-68
26. Tärnqvist J, Dahlén E, Norberg G, et al. On-Scene and Final Assessments and Their Interrelationship Among Patients Who Use the EMS on Multiple Occasions. Prehospital and Disaster Medicine 2017:1-8 doi: 10.1017/S1049023X17006458.
27. Alpern ER, Clark AE, Alessandrini EA, et al. Recurrent and high-frequency use of the emergency department by pediatric patients. Academic Emergency Medicine 2014;**21**(4):365-73
28. Gibson NP, Jelinek GA, Jiwa M, et al. Paediatric frequent attenders at emergency departments: A linked-data population study. Journal of Paediatrics and Child Health 2010;**46**(12):723-28 doi: 10.1111/j.1440-1754.2010.01829.x.
29. Kim B-S, Kim J-Y, Choi S-H, et al. Understanding the characteristics of recurrent visits to the emergency department by paediatric patients: a retrospective observational study conducted at three tertiary hospitals in Korea. BMJ open 2018;**8**(2):e018208
30. Markham D, Graudins A. Characteristics of paediatric frequent presenters to an A ustralian emergency medicine network. Journal of Paediatrics and Child Health 2013;**49**(11):950-54
31. Marr M, Horwitz SM, Gerson R, et al. Friendly Faces: Characteristics of Children and Adolescents With Repeat Visits to a Specialized Child Psychiatric Emergency Program. Pediatric Emergency Care 2021;**37**(1)
32. Rosychuk RJ, Chen A, McRae A, et al. Characteristics of Pediatric Frequent Users of Emergency Departments in Alberta and Ontario. Pediatric Emergency Care 2022;**38**(3)

33. Vitello AS, Clavenna A, Cartabia M, et al. Evaluation of the Pattern of Use of a Pediatric Emergency Department in Italy. Pediatric Emergency Care 2021;**37**(12)
34. Vrijlandt SEW, Nieboer D, Zachariasse JM, et al. Characteristics of pediatric emergency department frequent visitors and their risk of a return visit: A large observational study using electronic health record data. PLOS ONE 2022;**17**(1):e0262432 doi: 10.1371/journal.pone.0262432.
35. Brown JF, Raven MC, Tangherlini NL, et al. Frequent Users of 9-1-1 Emergency Medical Services: Sign of Success or Symptom of Impending Failure? Prehospital Emergency Care 2019;**23**(1):94-96 doi: 10.1080/10903127.2018.1475531.
36. Soril LJ, Leggett LE, Lorenzetti DL, et al. Characteristics of frequent users of the emergency department in the general adult population: a systematic review of international healthcare systems. Health policy 2016;**120**(5):452-61
37. Lee SU, Suh D, Kim HB, et al. Epidemiology of prehospital emergency medical service use in Korean children. Clin Exp Emerg Med 2017;**4**(2):102-08 doi: 10.15441/ceem.14.024.
38. Shah MN, Cushman JT, Davis CO, et al. The Epidemiology of Emergency Medical Services Use by Children: An Analysis of the National Hospital Ambulatory Medical Care Survey. Prehospital Emergency Care 2008;**12**(3):269-76 doi: 10.1080/10903120802100167.
39. Riney LC, Brokamp C, Beck AF, et al. Emergency Medical Services Utilization Is Associated With Community Deprivation in Children. Prehospital Emergency Care 2019;**23**(2):225-32 doi: 10.1080/10903127.2018.1501124.
40. Proctor A, Baxter H, Booker MJ. What factors are associated with ambulance use for non-emergency problems in children? A systematic mapping review and qualitative synthesis. BMJ Open 2021;**11**(9):e049443 doi: 10.1136/bmjopen-2021-049443.
41. Lee AR, Kingdon CC, Davie M, et al. Child poverty and health inequalities in the UK: a guide for paediatricians. Archives of Disease in Childhood 2022 doi: 10.1136/archdischild-2021-323671.
42. Spencer NJ, Blackburn CM, Read JM. Disabling chronic conditions in childhood and socioeconomic disadvantage: a systematic review and meta-analyses of observational studies. BMJ Open 2015;**5**(9):e007062 doi: 10.1136/bmjopen-2014-007062.
43. Brodeur M, Margo-Dermer E, Chouinard M-C, et al. Experience of being a frequent user of primary care and emergency department services: a qualitative systematic review and thematic synthesis. BMJ Open 2020;**10**(9):e033351 doi: 10.1136/bmjopen-2019-033351.
44. Rivas García A, Manrique Martín G, Butragueño Laiseca L, et al. Frequent users in paediatric emergency departments. Who are they? Why do they consult? Anales de Pediatría (English Edition) 2017;**86**(2):67-75 doi: https://doi.org/10.1016/j.anpede.2016.03.010.
45. Moe J, Kirkland SW, Rawe E, et al. Effectiveness of Interventions to Decrease Emergency Department Visits by Adult Frequent Users: A Systematic Review. Academic Emergency Medicine 2017;**24**(1):40-52 doi: https://doi.org/10.1111/acem.13060.
46. Nicholson E, McDonnell T, De Brún A, et al. Factors that influence family and parental preferences and decision making for unscheduled paediatric healthcare – systematic review. BMC Health Serv Res 2020;**20**(1):663 doi: 10.1186/s12913-020-05527-5.

Figure 1:


Literature search of Medline, CINAHL, Web of Science and PsycINFO
Limits:
English language
Published since January 2000
Primary, peer-reviewed literature
Search results combined (n = 5,939)
Duplicates removed (n = 1,767)
Records screened on basis of title and abstract (n = 4,172)
Excluded (n = 3,964)
Full-text articles assessed for eligibility (n = 208)
Excluded (n = 196)
Reasons for exclusion:
Not EMS (n = 131)
Not frequent use (n=28)
Not paediatric patients (n=21)
Not possible to extract paediatric data (n=12)
Not primary, peer-reviewed research (n=3)
Articles matching inclusion criteria (n = 12)
Study settings:
Emergency Medical Service (n=4)
Emergency Department (n=8)


Literature search of Medline, CINAHL, Web of Science and PsycINFO
Limits:
English language
Published since January 2000
Primary, peer-reviewed literature
Search results combined (n = 5,433)
Duplicates removed (n = 1,733)
Records screened on basis of title and abstract (n = 3,700)
Excluded (n = 3,539)
Full-text articles assessed for eligibility (n = 161)
Excluded (n = 153)
Reasons for exclusion:
Not EMS (n = 103)
Not paediatric patients (n=21)
Not frequent use (n=13)
Not possible to extract paediatric data (n=12)
Not primary, peer-reviewed research (n=3)
Articles matching inclusion criteria (n = 8)
Study settings:
Emergency Medical Service (n=4)
Emergency Department (n=4)

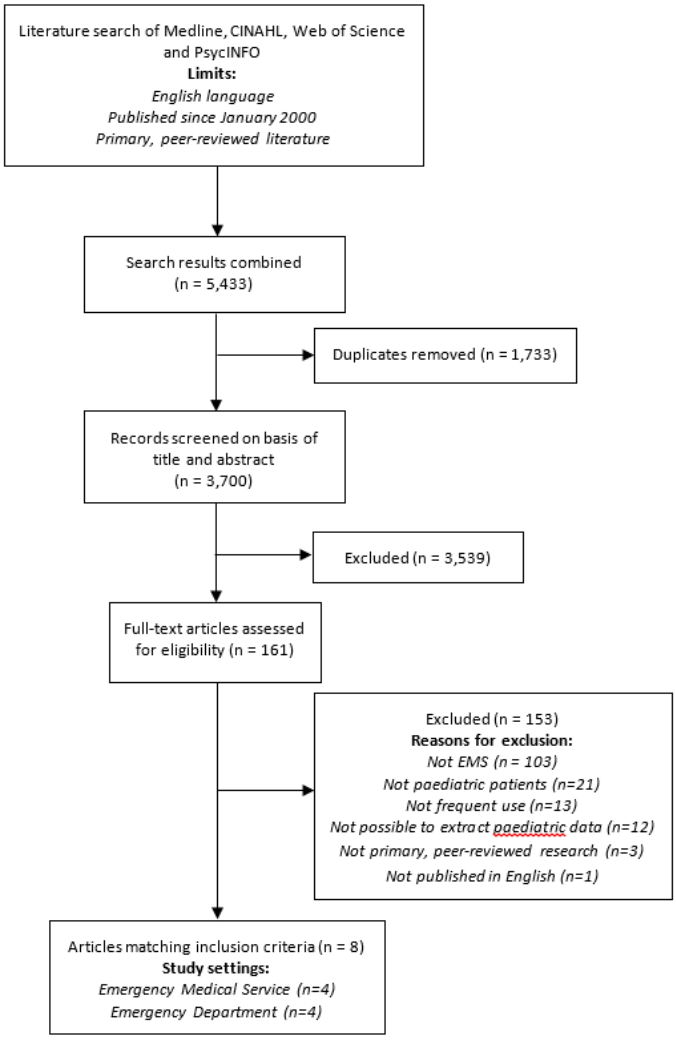

Literature search of Medline, CINAHL, Web of Science and PsycINFO
Limits:
English language
Published since January 2000
Primary, peer-reviewed literature
Search results combined (n = 5,433)
Duplicates removed (n = 1,733)
Records screened on basis of title and abstract (n = 3,700)
Excluded (n = 3,539)
Full-text articles assessed for eligibility (n = 161)
Excluded (n = 153)
Reasons for exclusion:
Not EMS (n = 103)
Not paediatric patients (n=21)
Not frequent use (n=13)
Not possible to extract paediatric data (n=12)
Not primary, peer-reviewed research (n=3)
Not published in English (n=1)
Articles matching inclusion criteria (n = 8)
Study settings:
Emergency Medical Service (n=4)
Emergency Department (n=4)

Table 1: Quality assessment criteria, available at: https://www.ihe.ca/advanced-search/standard-quality-assessment-criteria-for-evaluating-primary-research-papers-from-a-variety-of-fields

Question number	Question*
Q1	Question / objective sufficiently described?
Q2	Study design evident and appropriate?
Q3	Method of subject/comparison group selection or source of information/input variables described and appropriate?
Q4	Subject (and comparison group, if applicable) characteristics sufficiently described?
Q5	If interventional and random allocation was possible, was it described?
Q6	If interventional and blinding of investigators was possible, was it reported?
Q7	If interventional and blinding of subjects was possible, was it reported?
Q8	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? Means of assessment reported?
Q9	Sample size appropriate?

Q10	Analytic methods described/justified and appropriate?
Q11	Some estimate of variance is reported for the main results?
Q12	Controlled for confounding?
Q13	Results reported in sufficient detail?
Q14	Conclusions supported by the results?
Q15	Question / objective sufficiently described?

***** Questions are answered with yes, partial, no or not applicable.
Yes = 2 points
Partial = 1 point
No = 0 points
Not applicable = exclude question from calculations

Table 2: Reviewer 1 quality assessment scores (JSc)

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Total (%*)
Alpern et al. [27]	2	2	2	N/A	N/A	N/A	N/A	2	2	2	2	1	2	2	19 (95)
Broxterman et al. [23]	2	1	2	2	N/A	N/A	N/A	2	2	2	0	1	1	2	17 (77)
Gibson et al. [28]	1	1	2	2	N/A	N/A	N/A	2	2	1	0	1	1	2	15 (68)
Kim et al. [29]	2	1	2	2	N/A	N/A	N/A	2	2	2	2	1	2	2	20 (91)
Knowlton et al. [24]	2	1	2	1	N/A	N/A	N/A	2	2	2	2	2	2	2	20 (91)
Knowlton et al. [25]	1	1	2	2	N/A	N/A	N/A	2	2	1	0	1	2	2	16 (73) **
Markham et al. [30]	2	2	2	1	N/A	N/A	N/A	1	2	0	1	0	1	1	13 (59) **

Marr et al. [31]	2	2	2	2	N/A	N/A	N/A	2	2	2	2	1	2	2	21 (95)
Rosychuk et al. [32]	2	2	2	2	N/A	N/A	N/A	2	2	2	2	1	2	2	21 (95)
Tarnqvist et al. [26]	2	2	2	2	N/A	N/A	N/A	2	2	1	0	0	1	1	15 (68)
Vitello et al. [33]	2	1	1	1	N/A	N/A	N/A	2	2	2	2	1	2	2	18 (82)
Vrijnaldt et al. [34]	2	2	2	2	N/A	N/A	N/A	2	2	2	2	1	2	2	21 (95)

N/A = not applicable
* % is calculated following exclusion of N/A questions
** Difference in score of >10% between the two reviewers, see table 4 for joint assessment

Table 3: Reviewer 2 quality assessment scores (AS)

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Total (%*)
Alpern et al. [27]	2	2	2	N/A	N/A	N/A	N/A	2	2	2	2	1	2	2	19 (95)
Broxterman et al. [23]	2	2	1	1	N/A	N/A	N/A	1	2	2	2	1	2	2	18 (82)
Gibson et al. [28]	2	2	1	1	N/A	N/A	N/A	2	2	1	2	1	1	2	17 (77)
Kim et al. [29]	2	2	1	1	N/A	N/A	N/A	2	2	2	2	1	2	2	19 (86)
Knowlton et al. [24]	2	2	2	1	N/A	N/A	N/A	1	2	2	2	2	2	2	20 (91)
Knowlton et al. [25]	2	2	2	1	N/A	N/A	N/A	2	2	2	2	1	2	2	20 (91) **
Markham et al. [30]	2	2	2	1	N/A	N/A	N/A	2	1	1	2	0	2	2	17 (77) **

Marr et al. [31]	2	2	2	2	N/A	N/A	N/A	1	2	2	2	2	2	2	21 (95)
Rosychuk et al. [32]	2	2	2	2	N/A	N/A	N/A	2	2	2	2	2	2	2	22 (100)
Tarnqvist et al. [26]	2	1	1	1	N/A	N/A	N/A	1	2	2	1	1	2	1	15 (68)
Vitello et al. [33]	2	2	1	1	N/A	N/A	N/A	2	2	2	1	1	2	2	18 (82)
Vrijnaldt et al. [34]	2	2	2	2	N/A	N/A	N/A	2	2	2	2	1	2	2	21 (95)

N/A = not applicable
* % is calculated following exclusion of N/A questions
** Difference in score of >10% between the two reviewers, see table 4 for joint assessment

Table 4: Joint quality assessment scores where original scores differed by >10%

Study	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Total (%*)**
Knowlton et al. [25]	2	2	2	2	N/A	N/A	N/A	2	2	2	0	1	2	2	19 (86)

Markham et al. [30]	2	2	2	1	N/A	N/A	N/A	2	2	1	2	0	1	1	16 (73)

N/A = not applicable
* % is calculated following exclusion of N/A questions