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Research

Readiness of emergency departments for pediatric patients and pediatric mortality: a systematic review

Jessica A. Harper MD, Amanda C. Coyle MPH, Clara Tam MESc, Megan Skakum MPAS, Mirna Ragheb MD, Lucy Wilson MD MScPH, Mê-Linh Lê MA MLIS, Terry P. Klassen MD MSc, Alex Aregbesola MD PhD

Abstract

Background: Most children who need emergency care visit general emergency departments and urgent care centres; the weighted pediatric readiness score (WPRS) is currently used to evaluate emergency departments' readiness for pediatric patients. The aim of this study was to determine whether a higher WPRS was associated with decreased mortality and improved health care outcomes and utilization.

Methods: We conducted a systematic review of cohort and cross-sectional studies on emergency departments that care for children (age ≤ 21 yr). We searched MEDLINE (Ovid), Embase (Ovid), the Cochrane Library (Wiley), CINAHL (EBSCO), Global Health (Ovid) and Scopus from inception until July 29, 2022. Articles identified were screened for inclusion by 2 independent reviewers. The primary outcome was mortality, and the secondary outcomes were health care outcomes and utilization. We used the Newcastle–Ottawa Scale to assess for quality and bias of the included studies. The I^2 statistic was calculated to quantify study heterogeneity.

Results: We identified 1789 articles. Eight articles were included in the final analysis. Three studies showed an inverse association between highest WPRS quartile and pediatric mortality (pooled odds ratio [OR] 0.45, 95% confidence interval [CI] 0.26 to 0.78; I^2 = 89%, low certainty of evidence) in random-effects meta-analysis. Likewise, 1 study not included in the meta-analysis also reported an inverse association with a 1-point increase in WPRS (OR 0.93, 95% CI 0.88 to 0.98). One study reported that the highest WPRS quartile was associated with shorter length of stay in hospital (β –0.36 days, 95% CI –0.61 to –0.10). Three studies concluded that the highest WPRS quartile was associated with fewer interfacility transfers. The certainty of evidence is low for mortality and moderate for the studied health care outcomes and utilization.

Interpretation: The data suggest a potential inverse association between the WPRS of emergency departments and mortality risk in children. More studies are needed to refute or confirm these findings. **Protocol registration:** PROSPERO-CRD42020191149.

Children account for approximately 20% of the total emergency department visits in Canada[1] and the United States[2] each year. A portion of these visits are to specialized pediatric emergency departments; however, the majority of the visits are to general emergency departments or urgent care centres, which have a wide range of experience with pediatric patient care.[3] In the US, approximately 90% of pediatric visits are to general emergency departments,[4] and in Canada, approximately 85% of pediatric visits are to general emergency departments.[5] Therefore, it is important to ensure that all emergency departments are optimizing pediatric patient outcomes and safety independent of their pediatric patient volumes, location or presentations.

There is a growing literature evaluating emergency department readiness to provide optimal medical care to acutely ill and injured pediatric patients. The weighted pediatric readiness score (WPRS) was developed as part of the National Pediatric Readiness Project[6] to assess the level of readiness of emergency departments to care for pediatric patients. The 100-point scale includes weighted items in the categories of pediatric-specific infrastructure, administration and coordination, personnel, pediatric-specific policies, equipment and resources.[7] The goal of the WPRS is to identify areas of improvement for emergency departments to maximize readiness to care for pediatric patients.[3,6–8] The National Pediatric Readiness Project assessment of emergency departments across the US in 2013 identified that the median WPRS was 68.9, suggesting that many emergency departments are missing key components of pediatric readiness.[7]

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Correspondence to: Jessica Harper, jharper6@manitoba-physicians.ca

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Recent literature also suggests that higher pediatric readiness scores are associated with better pediatric patient outcomes, including a recent study by Ames and colleagues, which found that high pediatric readiness scores are associated with a fourfold decreased risk of mortality.[9] Mortality is a key measure of quality of emergency department care, as well as an important measure of outcomes of critically ill children presenting to the emergency department. Therefore, the primary objective of this study was to conduct a systematic review and meta-analysis to determine whether a higher pediatric readiness score results in a decreased mortality rate for children presenting to emergency departments and urgent care centres. The secondary objective was to determine whether higher pediatric readiness scores result in improved health care outcomes and health care utilization.

Methods

The systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement,[10] and the protocol was registered with International Prospective Register of Systematic Reviews (PROSPERO) in June 2020 (registration no. CRD42020191149). The primary objective of the study was to determine whether higher WPRS is associated with lower rates of mortality in children presenting to emergency departments and urgent care centres, by synthesizing current research and conducting meta-analysis where possible. The secondary objective of this review was to determine whether there is a difference in health care utilization between centres with high and low pediatric readiness scores.

Study selection and search strategy

We included studies if they met all the population, intervention, comparison, outcomes and study (PICOS) design criteria: population — conducted in an acute care facility that cares for children, including emergency departments or urgent care centres; intervention — used the pediatric readiness score or WPRS; comparator — compared low versus high or use versus nonuse of WPRS; outcome — the primary outcome was mortality, and secondary outcomes were health care outcomes (length of stay in an emergency department, revisits or readmissions to the emergency department), health care utilization (proximity to an emergency department, e.g., access to an emergency department within a 30-min drive); study — observational studies, including cohort and cross-sectional studies, or controlled-clinical study. We included studies published in the English language.

Studies were excluded if the outcome was not relevant, if the study did not include pediatric patients (defined as age ≤ 21 yr)[11] or if the setting was outside of an acute care facility.

An experienced health sciences librarian (M.-L.L.) designed and executed the search strategy, using a combination of subject terms and keywords that were later translated for each database. A slightly modified version of a validated filter was used to focus the search on a pediatric population.[12] Searches were performed in MEDLINE (Ovid), Embase (Ovid), the Cochrane Library (Wiley), CINAHL (EBSCO), Global Health (Ovid), and Scopus from inception until May 25, 2020, and then an updated search was performed on June 16, 2021, and July 29, 2022. The MEDLINE search was peer reviewed by an independent health sciences librarian as per the Peer Review of Electronic Search Strategies guidelines.[13] Our search strategy is available in Appendix 1, available at www.cmajopen.ca/content/11/5/E956/suppl/DC1. Identified studies were deduplicated in EndNote (version X9).

The articles identified in the literature search were first screened by title and abstracts for inclusion in the systematic review by independent reviewers (J.A.H., A.C., C.T., M.S., M.R. and L.W.). The independent reviewers (J.A.H., A.C., C.T., M.S., M.R. and L.W.) then reviewed the full text for inclusion in the final analysis. Disagreements during screening were resolved by discussion between reviewers or in consultation with a third reviewer (A.A.).

Data extraction

The data from the included studies were extracted by independent reviewers (J.A.H., C.T. and L.W.). Reviewers used a customized data extraction tool to identify key characteristics of the articles, including information on study design, objectives, population, intervention, outcomes and conclusion details. The tool was used to pilot-test 5 studies, after which it was adopted for the entire included studies. Two reviewers independently completed the screening and data extraction in duplicate. A third reviewer (A.A.) examined the data to ensure accuracy and identify any errors. We contacted Balmaks and colleagues for more information to rescale their data on mortality.

Risk-of-bias assessment

Independent reviewers (J.A.H., C.T. and L.W.) assessed the included articles for quality and bias using the Newcastle–Ottawa Scale (NOS),[14] a validated critical appraisal checklists for nonrandomized observational studies. A modified version of the NOS for cohort studies was used to assess the cross-sectional studies. We replaced the word “cohort” with “sample” in the selection domain. We omitted questions 2 and 3 regarding follow-up and added a question assessing the statistical tests performed in the outcome domain. The NOS rates articles on a star system to evaluate the selection of study groups, comparability of groups, and ascertainment of exposure or outcome of interest.[14] Two reviewers independently completed the risk-of-bias assessment, and disagreements were resolved by a third reviewer.

GRADE assessment

We used the GRADEPro software[15] to assess the certainty of evidence for the included studies.

Data analysis and synthesis

Data were collected and managed using Excel and Covidence. Individual article characteristics were summarized and presented in tabular form. We used Review Manager 5.4. to perform the statistical analysis to generate the forest plot that showed the point estimates with 95% confidence intervals (CIs) of the studies included in the meta-analysis.

The association between WPRS and mortality was examined in random-effects models, estimated using the DerSimonian and Laird method,[16] with the fixed-effects model included for sensitivity analysis. The pooled estimate of odds ratios (ORs) with 95% CIs was computed and demonstrated graphically with a diamond in the forest plot. The I^2 statistic was calculated to quantify study heterogeneity. We performed a sensitivity analysis to adjust for the risk of possible overlapping studies on the pooled estimate. We narratively synthesized the secondary outcomes, according to the synthesis without meta-analysis (SWiM) guidelines,[17] where the measures of effects were different.

Ethics approval

We did not require ethics approval for this systematic review, because publicly available data were used.

Results

The search and study screening were conducted initially in May 2020, with an update performed in June 2021 and July 2022 (Figure 1). The initial systematic search of the databases identified 1263 articles, and the updated searches identified 186 articles in June 2021 and 340 articles in July 2022. After duplicate articles were excluded, titles and abstracts reviewed, and full-text articles screened, 8 studies were included in the final analysis. See Appendix 2 (available at www.cmajopen.ca/content/11/5/E956/suppl/DC1) for a list of full-text articles screened and reasons for exclusion.

Characteristics of included studies

Characteristics of studies included in the analysis are presented in Table 1. Of the 8 included studies, 7 were conducted in the US[9,18–23] and 1 in Latvia.[24] All 8 studies were completed in emergency departments.

Outcomes

Primary outcome: mortality

Four studies included the primary outcome of interest, pediatric mortality.[9,19,22,24] Table 2 describes the study outcomes, including the adjusted ORs that were used for analysis. The study by Ames and colleagues[9] compared the odds of mortality between emergency departments in the highest (fourth) versus lowest (first) WPRS quartiles. The study demonstrated that critically ill children have a significantly lower risk of mortality if they present to an emergency department with a high WPRS (OR 0.25, 95% CI 0.18 to 0.37).[9] Secondary analysis showed no significant association between emergency department pediatric readiness scores and mortality for children with cardiac arrest (OR 0.23, 95% CI

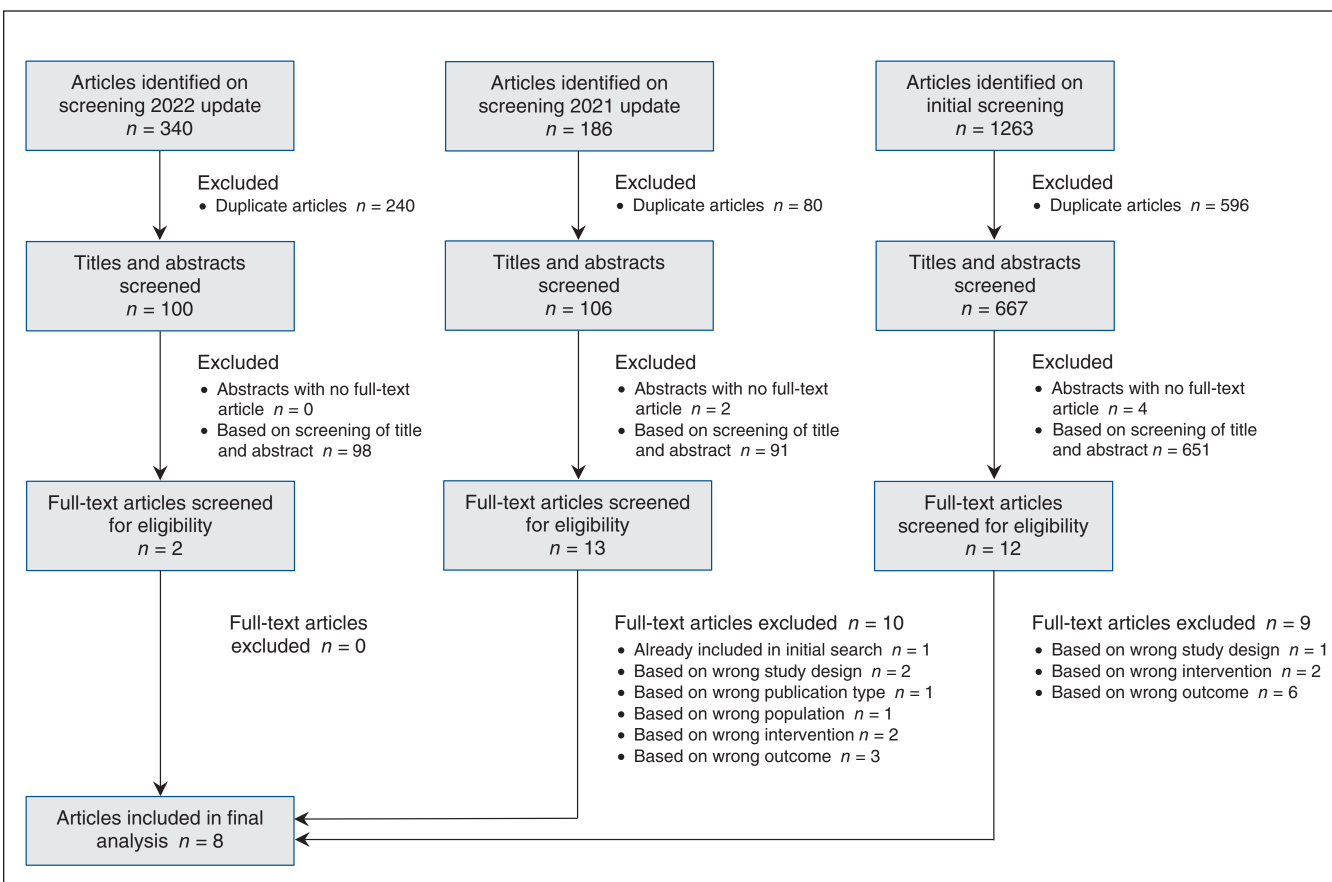

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagrams of articles identified on initial screening, updated in June 2021 and July 2022 and included in the final analysis.

Table 1 (part 1 of 2): Study characteristics

Publication, country	Study design	Study period	Type of centre, *N*	Study objective	Volume of ED	No. of participants	Mean age (range), yr
Ames et al.,[9] 2019, United States	Retrospective cohort	Data collection: Jan. 1 to Aug. 31, 2013	ED, 426	To determine the proportion of patients presenting to EDs with various levels of pediatric readiness and to evaluate if ED pediatric readiness is associated with mortality	No. of ED centres, annual pediatric ED volume *n* = 153, Low (< 1800) visits *n* = 113, Medium (1800–4999) visits *n* = 69, Medium-to-high (5000–9999) visits *n* = 91, High (> 10 000) visits	20 483	Mean = 8 (0–18)
Ray et al.,[18] 2018, United States	Cross-sectional	Data collection: Jan. 1 to Aug. 23, 2013	ED, 4090	To determine the geographic accessibility of EDs with high pediatric readiness by assessing the percentage of US children living within a 30-minute drive time of an ED with high pediatric readiness	No. of ED centres, ED volume *n* = 739, Low (< 4999) visits *n* = 490, Medium (5000–9999) visits *n* = 2861, High (> 10 000) visits	NA	Mean = NA (0–17)
Newgard et al.,[19] 2021, United States	Retrospective cohort	Data collection: Jan. 1, 2012, to Dec. 31, 2017	ED, 832	To evaluate the association between ED pediatric readiness, in-hospital mortality, and in-hospital complications among injured children presenting to US trauma centres	No. of ED centres, annual pediatric ED volume *n* = 160, Low (1–4900) visits *n* = 86, Medium (4900–8400) visits *n* = 105, Medium-to-high (8400–13 800) visits *n* = 186, High (> 13 800) visits *n* = 295, Unknown visits	372 004	Mean = NA Median = 10 (4–15)
Lieng et al.,[20] 2021a, United States	Cross-sectional	Data collection: Jan. 1, 2011, to Dec. 31, 2013	ED, 283	To determine the association between potentially avoidable transfers (PATs) and ED pediatric readiness scores and the score's associated components	No. of ED centres, ED volume: median (IQR) *n* = 275, 6820 (3148–11 042) *n* = 269, 6876 (3167–11 046)	25 601	Mean = NA (0–18)
Lieng et al.,[21] 2021b, United States	Cross-sectional	Data collection: 2011 to 2012	ED, 54	To determine the association of pediatric readiness scores with the odds of interfacility transfer among a cohort of noninjured children (< 18 yr) presenting to EDs in small rural hospitals in the state of California	No. of ED centres, ED volume by WPRS: median (IQR) *n* = 44, WPRS (≤ 70): 2194 (1350–4412) visits *n* = 10, WPRS (> 70): 2696 (1618–4694) visits	135 388	Mean = NA (0–18)

Table 1 (part 2 of 2): Study characteristics							
Publication, country	Study design	Study period	Type of centre, *N*	Study objective	Volume of ED	No. of participants	Mean age (range), yr
Newgard et al.,[22] 2022, United States	Retrospective cohort	Data collection: Jan. 1, 2012, to Dec. 31, 2017, with follow-up to December 2018	ED, 146	To evaluate the association between ED pediatric readiness and 1-year survival among injured children presenting to 146 trauma centres	No. of ED centres, annual pediatric ED volume *n* = 37, Low (101–5699) visits *n* = 36, Medium (5700–12 199) visits *n* = 36, Medium-to-high (12 200–19 999) visits *n* = 37, High (> 20 000) visits	88 071	Mean = NA Median = 11 (0–17)
Newgard et al.,[23] 2023, United States	Cross-sectional	Data collection: Jan. 1, 2012, to Dec. 31, 2019	ED, 2261	To quantify the number of children transported by 911 emergency medical services to high readiness EDs, additional children within 30 min of a high-readiness ED, and the estimated effect on survival	No. of ED centres, annual ED volume by WPRS: median (IQR) *n* = 583, WPRS (22–57): 11 751 (4399–27 586) visits *n* = 559, WPRS (58–70): 18 937 (7537–36 631) visits *n* = 570, WPRS (71–85): 21 757 (9968–47 400) visits *n* = 549, WPRS (86–100): 45 633 (23 818–77 415) visits	808 536	Mean = NA Median = 10 (0–17)
Balmaks et al.,[24] 2020, Latvia	Prospective cohort	Data collection: June 1, 2017, to May 31, 2018 Recruitment: Sept. 24, 2017, to Apr. 26, 2018	ED, 16	To assess the quality of pediatric acute care and pediatric readiness and determine their association with patient outcomes using a patient registry	No. of ED centres, annual ED volume: median (IQR) *n* = 5, Low (< 1800) visits: 1238 (809–11 916) *n* = 6, Medium (1800–4999) visits: 2746 (1965–3000) *n* = 4, Medium-to-high (5000–9999) visits: 7703 (5572–7160) *n* = 1, High (> 10 000) visits: 63 905	254	Mean = NA Median = 5 (1–13)

Note: ED = emergency department, IQR = interquartile range, NA = not available, WPRS = weighted pediatric readiness score.

0.02 to 2.16) or sepsis (OR 0.59, 95% CI 0.05 to 7.31). However, they did identify a significant decrease in mortality risk for children with traumatic brain injury presenting to emergency departments with high WPRS (OR 0.21, 95% CI 0.06 to 0.78).[9]

The study in Latvia by Balmaks and colleagues[24] demonstrated that higher WPRS was associated with lower 6-month mortality (OR 0.93, 95% CI 0.88 to 0.98).[24] The authors were contacted in order to rescale the OR to be comparable with the other primary outcome studies; however, the authors could not provide us with the necessary data to be included in the meta-analysis.

The 2021 study by Newgard and colleagues[19] evaluated the association between emergency department pediatric readiness and in-hospital mortality among injured children presenting to trauma centres. This study also demonstrated that injured children who were treated in trauma centres with high WPRS had

Table 2 (part 1 of 2): Primary outcome: mortality

Publication	Intervention v. comparator	Primary outcome	Primary outcome effect estimate	Primary outcome results (unadjusted)	Variables used to adjust primary outcome	Primary outcome results (adjusted)	Conclusion
Ames et al.,[9] 2019	High WPRS v. low WPRS	Mortality	OR	NA	Age, chronic complex conditions, and severity of illness	WPRS associated with presenting hospital and in-hospital mortality in quartiles, OR (95% CI), *p* value: Q1 (WPRS 30–59): 1.00 (ref.) Q2 (WPRS 59–75): 0.52 (0.30–0.90), $p = 0.018$ Q3 (WPRS 75–88): 0.36 (0.22–0.58), $p < 0.001$ Q4 (WPRS 88–100): 0.25 (0.18–0.35), $p < 0.001$	This study showed that critically ill children presenting to hospitals with a high pediatric readiness score is associated with decreased mortality. Efforts to increase ED readiness for pediatric emergencies may improve patient outcomes.
Newgard et al.,[19] 2021	High WPRS v. low WPRS	Mortality	OR	ED pediatric readiness score association with in-hospital mortality, OR (95% CI), *p* value: Non-transfer patients (*n* = 317 005) Q1 (least ready): ref., $p = 0.077$ Q2: 1.34 (0.97–1.86) Q3: 1.01 (0.74–1.36) Q4 (most ready): 0.69 (0.51–0.92) Transferred patients (*n* = 54 999) Q1 (least ready): ref., $p = 0.033$ Q2: 0.99 (0.65–1.49) Q3: 0.84 (0.58–1.22) Q4 (most ready): 0.59 (0.39–0.90)	Demographic characteristics (age, sex, race), comorbidities, initial physiology (age-adjusted hypotension), emergent airway intervention, mechanism of injury, ISS, transfer status, blood transfusion, nonorthopedic surgery, orthopedic surgery, and geographic region	WPRS associated with in-hospital mortality, OR (95% CI): Q1 (WPRS 32–69): 1.00 (ref.) Q2 (WPRS 70–87): 1.16 (0.87–1.54) Q3 (WPRS 88–94): 0.90 (0.70–1.17) Q4 (WPRS 95–100): 0.58 (0.45–0.75)	In this cohort study, injured children treated in high-readiness EDs had lower mortality compared with similar children in low-readiness EDs, but not fewer complications. These findings support national efforts to increase ED pediatric readiness in US trauma centres that care for children.

lower risk of mortality when comparing the highest and lowest WPRS quartiles (OR 0.58, 95%CI 0.45 to 0.75). The 2022 study by Newgard and colleagues[22] evaluated the association between emergency department pediatric readiness and mortality including in-hospital and 1-year survival among children presenting to trauma centres. This study found that children presenting with injuries to trauma centres with the highest quartile of pediatric readiness had significantly lower risk of death in hospital (adjusted OR 0.61, 95% CI 0.42 to 0.89) and by 1 year (adjusted OR 0.60, 95% CI 0.44 to 0.81).[22]

Random-effects meta-analysis was conducted to examine the association between WPRS and mortality including the studies by Ames and colleagues,[9] Newgard and colleagues,[19] and Newgard and colleagues[22] (Figure 2). The pooled estimate of OR of the 3 included studies[9,19,22] was 0.45 (95% CI 0.26 to 0.78; I^2 = 89%, low certainty of evidence), indicating high heterogeneity between the 3 studies. We performed a sensitivity analysis with either of the Newgard and colleagues studies[19,22] and found pooled estimates OR of 0.39 (95% CI 0.16 to 0.93) and OR of 0.38 (95% CI 0.17 to 0.87), respectively.

Table 2 (part 2 of 2): Primary outcome: mortality

Publication	Intervention v. comparator	Primary outcome	Primary outcome effect estimate	Primary outcome results (unadjusted)	Variables used to adjust primary outcome	Primary outcome results (adjusted)	Conclusion
Newgard et al.,[22] 2022	High WPRS v. low WPRS	Mortality	OR	NA	Demographic characteristics (age, sex, race), comorbidities, age-adjusted hypotension, emergent airway intervention, blood transfusion, mechanism, ISS, interhospital transfer, and year of visit	WPRS associated with in-hospital mortality comparing the highest v. lowest quartiles of ED pediatric readiness, OR (95% CI): Q1 (WPRS 32–69): 1.00 (ref.) Q2 (WPRS 70–87): NA Q3 (WPRS 88–94): NA Q4 (WPRS 95–100): 0.61 (0.42–0.89)	This study showed that children treated in high-readiness trauma centre EDs after injury had a lower risk of death that persisted to 1 year. These findings further support the importance of ED pediatric readiness and the imperative for US trauma centres to meet the high level of ED readiness required to reduce pediatric mortality after injury.
Balmaks et al.,[24] 2020	High WPRS v. low WPRS	Mortality	OR	NA	Nesting of patients in each ED, and patient demographics	1-point increase in WPRS is associated with 6-mo mortality, OR (95% CI), *p* value: OR = 0.93 (0.88–0.98), *p* = 0.011 (re-scaled into OR of 0.93^17 = 0.29 for an increase of 1 interquartile range, which equals 0.87 at the highest quartile)	This study nationally assessed that pediatric readiness in EDs, in Latvia was associated with shorter ICU length of stay, shorter hospital length of stay and lower 6-mo mortality.

Note: CI = confidence interval, ED = emergency department, ISS = Injury Severity Score, NA = not available, OR = odds ratio, Q = quartile, Ref. = reference, SD = standard deviation, WPRS = weighted pediatric readiness score.

Study or subgroup	Log (OR)	SE	Weight, %	OR IV, random 95% CI
Ames et al.,[9] 2019	−1.3863	0.1676	33.2	0.25 (0.18–0.35)
Newgard et al.,[19] 2021	−0.5447	0.1295	34.8	0.58 (0.45–0.75)
Newgard et al.,[22] 2022	−0.4943	0.1904	32.1	0.61 (0.42–0.89)
Total (95% CI)			**100.0**	**0.45 (0.26–0.78)**

Heterogeneity $\tau^2 = 0.22$; $\chi^2 = 18.64$, $df = 2$ ($p < 0.0001$); $I^2 = 89\%$
Test for overall effect Z = 2.84 ($p = 0.004$)

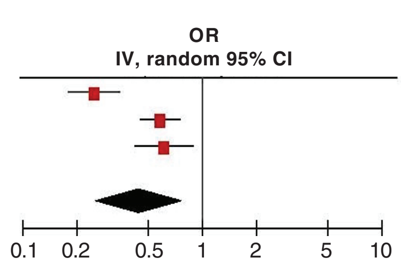

Figure 2: Random-effects meta-analysis of the association between in-hospital mortality and weighted pediatric readiness score. Note: CI = confidence interval, IV = inverse variance, SE = standard error.

Table 3 (part 1 of 2): Secondary outcome: health care outcomes and utilization

Publication	Intervention v. comparator	Secondary outcome	Secondary outcome effect estimate	Secondary outcome results (unadjusted)	Variables used to adjust secondary outcome	Secondary outcome results (adjusted)	Conclusion
Ray et al.,[18] 2018	High WPRS v. no WPRS	Access to EDs within a 30-min drive	Percentage	NA	ED characteristics (pediatric ED, trauma centre level, total volume, triage system) Hospital characteristics (bed size, inpatient pediatric ward, pediatric ICU, neonatal ICU, pediatric cardiology, CT scanner, MRI) Accreditations (The Joint Commission, Accreditation Council for Graduate Medical Education) Geographic characteristics (rural/urban status, state)	National proportion of pediatric population (%) within 30-min drive to ED with: WPRS ≥ 83.6 (at 75th percentile) = 70.20 WPRS ≥ 94.3 (at 90th percentile) = 55.30 WPRS 100 = 33.70 No WPRS specified threshold = 93.70	This study nationally quantified geographic access to EDs, in the US, with high pediatric readiness for children, and indicated major gaps in access are due to the lack of an ED with high pediatric readiness. One in 3 children can reach an ED with a max WPRS score. 90.9% of children lived closer to at least 1 alternative ED with a WPRS below the maximum.
Lieng et al.,[20] 2021a	High WPRS v. low WPRS	Potentially avoidable transfers (PATs)	OR	10-point increase in WPRS associated with PATs, OR (95% CI): Injured children PATs: OR 0.93 (0.90–0.96) Noninjured children PATs: OR 0.90 (0.88–0.93)	Patient demographics, injury/illness severity, complex chronic condition, pediatric volume, trauma centre designation, pediatric admitting capability	10-point increase in WPRS associated with PATs, OR (95% CI): Injured children PATs: OR 0.92 (0.86–0.98) Noninjured children PATs: OR 0.94 (0.88–1.00)	Hospital ED pediatric readiness is associated with lower odds of a PAT. Having a nurse pediatric emergency care coordinator and a quality improvement plan are modifiable risk factors that EDs may target to reduce PATs.
Lieng et al.,[21] 2021b	High WPRS v. low WPRS	Interfacility transfer	OR	High pediatric readiness score > 70 associated with inter-facility transfers, OR (95% CI), *p* value: OR 0.64 (0.55 to 0.74), $p < 0.01$	Patient demographics, insurance, severity of illness, complex chronic condition, pediatric inpatient capabilities, pediatric volume, proportion Medicaid, index hospital-level	High pediatric readiness score > 70 associated with interfacility transfers, OR (95% CI), *p* value: OR 0.55 (0.33–0.93), $p < 0.05$	Pediatric patients presenting to EDs at small rural hospitals with high pediatric readiness scores may be less likely to be transferred.

Secondary outcome: health care outcomes and utilization

Five studies included the secondary outcome of interest[18,20,21,23,24] (Table 3). The study by Balmaks and colleagues[24] showed that a 1-point increase in WPRS was associated with shorter ICU length of stay (β –0.06 days, 95% CI –0.10 to –0.01) and shorter hospital length of stay (β –0.36 days, 95% CI –0.61 to –0.10).

The studies by Ray and colleagues[18] and Newgard and colleagues[23] quantified children's geographic access to emergency departments in the US with high WPRS. Ray and colleagues[18] identified that 93.7% of children have access to an emergency department within a 30-minute drive.[18] They found that 33.7% of children in the US have access to an emergency department with WPRS of

Table 3 (part 2 of 2): Secondary outcome: health care outcomes and utilization							
Publication	Intervention v. comparator	Secondary outcome	Secondary outcome effect estimate	Secondary outcome results (unadjusted)	Variables used to adjust secondary outcome	Secondary outcome results (adjusted)	Conclusion
Newgard et al.,[23] 2023	High WPRS v. low WPRS	Proportion of high-risk children transported by ambulances to EDs within a 30-min drive	Percentage	NA	Day, time, and traffic	High-risk children transported to EDs, *n* (%), by WPRS: Q1 (WPRS 22–57): 26 757 (10.55) Q2 (WPRS 58–70): 39 908 (15.74) Q3 (WPRS 71–85): 50 336 (19.85) Q4 (WPRS 86–100): 136 540 (53.85) High-risk children transported to lower WPRS EDs but within 30-min to high WPRS EDs, *n* (%): 58 981 (23.26)	Approximately half of children transported by emergency medical services were taken to high-readiness EDs and an additional one quarter could have been transported to such an ED, with a measurable effect on survival.
Balmaks et al.,[24] 2020	High WPRS v. Low WPRS	Patient length of stay	Regression (β) coefficient	WPRS associated with PICU length of stay and hospital length of stay, β (95% CI), *p* value: PICU length of stay (d): β –0.01 (–0.02 to 0.01), *p* = 0.41 Hospital length of stay (d): β –0.03 (–0.15 to 0.09), *p* = 0.61	Nesting of patients in each ED, and patient demographics	WPRS associated with PICU length of stay, hospital length of stay, β (95% CI), *p* value: PICU length of stay (days): β –0.06 (–0.10 to –0.01), *p* = 0.02 Hospital length of stay (days): β –0.36 (–0.61 to –0.10), *p* = 0.01	This study nationally assessed that pediatric readiness in the ED was associated with shorter ICU length of stay, shorter hospital length of stay, and lower 6-mo mortality.

Note: CI = confidence interval, CT = computed tomography, ED = emergency department, ICU = intensive care unit, MRI = magnetic resonance imaging, NA = not available, OR = odds ratio, PAT = potentially avoidable transfers, PICU = pediatric intensive care unit, Q = quartile, SD = standard deviation, WPRS = weighted pediatric readiness score.

100, and 55.3% have access to an emergency department with a WPRS score in the 90th percentile or greater (WPRS score ≥ 94.3).[18] Newgard and colleagues[23] examined how often children were transported by emergency medical serves to emergency departments with high pediatric readiness, and number of children within 30 minutes of an emergency department with high fourth quartile WPRS score. Newgard and colleagues[23] found that 50.85% of high-risk children were transported to a WPRS with highest quartile score. However, 23.26% of high-risk children were transferred to emergency departments with lower WPRS but were within 30 minutes of an emergency department with high WPRS, which they hypothesize would have had a measurable effect on patient survival.

Both studies by Lieng and colleagues[20,21] investigated the association between WPRS and transfers between facilities. Lieng and colleagues[20] found that a 10-point increase in WPRS is associated with lower odds of potentially avoidable transfers in injured (OR 0.92, 95% CI 0.86 to 0.98) and noninjured (OR 0.94, 95% CI 0.88 to 1.00) children. Additionally, Lieng and colleagues[21] concluded that children presenting to small rural hospital emergency departments with higher WPRS (score > 70) are less likely to be transferred to another facility (OR 0.55, 95% CI 0.33 to 0.93).

The findings of our assessment on the certainty of evidence for the included studies are presented in Table 4 and Table 5. There is low certainty of evidence for mortality and moderate certainty of evidence for the studied health care outcomes and utilization.

Table 4: Summary of findings, high WPRS compared with low WPRS in mortality

Patient or population: Mortality
Setting: Emergency departments
Intervention: High WPRS
Comparison: Low WPRS

	Anticipated absolute effect* (95% CI)				
Outcome	Risk with low WPRS	Risk with high WPRS	Relative effect (95% CI)	No. of participants	Certainty of the evidence (GRADE)†
Mortality	1000 per 1000	450 per 1000 (260–780)	RR 0.45 (0.26–0.78)	480 558	⊕⊕∅∅‡ Low§,¶,**,††

Note: CI = confidence interval; GRADE = Grading of Recommendations Assessment, Development and Evaluation; RR = risk ratio; WPRS = weighted pediatric readiness score.
*The risk in the intervention group (and its 95% CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).
†GRADE Working Group grades of evidence. High certainty: we are very confident that the true effect lies close to that of the estimate of the effect. Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.
‡Commonly used symbols to describe certainty in evidence in evidence profiles: high certainty ⊕⊕⊕⊕, moderate certainty ⊕⊕⊕∅, low certainty ⊕⊕∅∅ and very low certainty ⊕∅∅∅.
§We downgraded by 1 level for risk of bias. The contributing studies were all high.
¶We downgraded by 1 level for inconsistency. There was considerable heterogeneity (I^2 = 89%) and variation in point estimates.
**We upgraded by 1 level for large effect. The pooled odds ratio was less than 0.5.
††We upgraded by 1 level for dose response gradient. We observed a change in odds ratio for every increase in WPRS.

Table 5: Summary of findings, high WPRS compared with low WPRS in health care outcomes and utilization

Patient or population: Health care outcomes and utilization
Setting: Emergency departments
Intervention: High WPRS
Comparison: Low WPRS

Outcome	Impact	No. of participants	Certainty of the evidence (GRADE)*
Length of stay assessed with: days	Pediatric readiness in the ED was associated with shorter ICU length of stay, shorter hospital length of stay, and lower 6-month mortality.	254	⊕⊕∅∅† Low‡,§,¶
Access to an ED within a 30-min drive	1 in 3 children can reach an ED with a WPRS score of 100. 90.9% of children lived closer to at least 1 alternative ED with a WPRS below the maximum.	NA	⊕⊕∅∅† Low‡,§,¶
Proportion of high-risk children transported by ambulances to EDs within a 30-min drive	Approximately 50% of children transported by emergency medical services were taken to high WPRS EDs and an additional 25% could have been transported to such an ED, with a measurable effect on survival.	808 536	⊕⊕∅∅† Low‡,§,¶
Interfacility transfer	Pediatric patients presenting to EDs at small rural hospitals with high WPRS may be less likely to be transferred.	135 388	⊕⊕∅∅† Low‡,§,¶
Potentially avoidable transfers	High WPRS of EDs is associated with lower odds of a potentially avoidable transfers.	25 601	⊕⊕∅∅† Low‡,§,¶

Note: ED = emergency department; GRADE = Grading of Recommendations Assessment, Development and Evaluation; ICU = intensive care unit; NA = not applicable.
*GRADE Working Group grades of evidence. High certainty: we are very confident that the true effect lies close to that of the estimate of the effect. Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.
†Commonly used symbols to describe certainty in evidence in evidence profiles: high certainty ⊕⊕⊕⊕, moderate certainty ⊕⊕⊕∅, low certainty ⊕⊕∅∅ and very low certainty ⊕∅∅∅.
‡We downgraded by 1 level for risk of bias. The contributing study was high.
§We upgraded by 1 level for plausible confounding. There are residual confounders in the estimate.
¶We upgraded by 1 level for dose response gradient. We observed a change in the point estimate for every increase in WPRS.

Table 6: Risk of bias: Newcastle–Ottawa Scale quality-assessment summary

Publication	Study design	Selection*				Comparability†	Assessment‡	Follow-up§		Statistical¶
		1	2	3	4	5	6	7	8	9
Ames et al.,[9] 2019	Retrospective cohort	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk	NA
Ray et al.,[18] 2018	Cross-sectional	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	NA	NA	Low risk
Newgard et al.,[19] 2021	Retrospective cohort	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk	NA
Lieng et al.,[20] 2021a	Cross-sectional	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	NA	NA	Low risk
Lieng et al., 2021b[21]	Cross-sectional	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	NA	NA	Low risk
Newgard et al.,[22] 2022a	Retrospective cohort	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk	NA
Newgard et al.,[23] 2023	Cross-sectional	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	NA	NA	Low risk
Balmaks et al.,[24] 2020	Prospective cohort	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk	NA

Note: NA = not applicable.
*Selection: 1. Representativeness of the exposed sample (selection bias); 2. Selection of the non-exposed sample (selection bias); 3. Ascertainment of exposure (selection bias); 4. Demonstration that outcome of interest was not present at start of study (selection bias).
†Comparability: 5. Comparability of samples on the basis of the design or analysis (comparability bias).
‡Assessment: 6. Assessment of outcome (assessment bias).
§Follow-up: 7. Was follow-up long enough for outcomes to occur (follow-up bias); 8. Adequacy of follow-up of cohorts (follow-up bias).
¶Statistical: 9. Statistical test (statistical bias).

Risk of bias across studies

The NOS[14] was used to evaluate the included studies. The results of the assessment are presented in Table 6. All 8 studies were rated as having a low risk of bias in the areas of representativeness of exposed sample, selection of the nonexposed sample, ascertainment of exposure, comparability, and follow-up and statistical tests (where applicable). All articles were classified as high risk for selection bias as they could not demonstration that the outcome of interest was not present at the start of the study.

Interpretation

The results of our systematic review highlight that a critically ill or injured child who presents to an emergency department with a high pediatric readiness score has a lower risk of mortality than a child presenting to an emergency department with low pediatric readiness score. Our study also identified that higher pediatric readiness scores as assessed by WPRS are associated with shorter length of stay in hospital and lower rates of interfacility transfer, which can have an impact on patient outcomes.

The 4 articles included in the systematic review that assessed pediatric mortality in relation to WPRS each found that higher WPRS significantly lowers the risk of mortality.[9,19,22,24] All studies evaluated a diverse range of centres and pediatric volumes, suggesting that these findings are relevant for a wide range of emergency departments. When 3 of 4 studies[9,19,22] were combined in the random-effects meta-analysis, a higher WPRS was significantly associated with lower risk of mortality. These findings have important implications for pediatric emergency medicine, as they support all hospitals advocating for improved access to pediatric-specific resuscitation equipment, medication dosing, interfacility transfer guidelines, emergency department policies and care coordinators.[6] As higher WPRS and readiness to care for critically ill and injured children has a direct impact on risk of mortality, emphasis should be placed on preparing all emergency departments for children.

The systematic review also highlighted several important health care utilization outcomes associated with pediatric readiness. Length of stay in the intensive care unit and hospital is a common quality indicator for patient care, as well as an important factor when considering hospital resource allocation.[25] Length of stay is a multifactorial measure; however, if by increasing WPRS, hospital length of stay decreases, this has positive impact on the patient, patient outcomes, and hospital costs and resource use.

Ray and colleagues[18] identified that 93.7% of children in the US live within a 30-minute drive of any emergency department; however, only 33.7% of children live within a

30-minute drive of an emergency department with a WPRS of 100. Additionally, Newgard and colleagues[23] identified that approximately 50% of high-risk children were transported to emergency departments with the highest level of pediatric readiness, and that 23% of children were transported to emergency departments with lower WPRS but were within 30 minutes of an emergency department with high WPRS. Improving emergency department readiness to care for children in all types of centres could lead to improved mortality rates for children.[26–28] Furthermore, if children are presenting to hospitals with low readiness scores, they are more likely to require interfacility transportation, as concluded by Leing and colleagues.[20,21] Although sometimes necessary, interfacility patient transfers can involve increased risk of psychological distress, delay in accessing care, repetition of care, communication issues, increased mortality and increased costs.[7,29]

Future research is needed to continue to explore the association between pediatric readiness scores and mortality, as well as the role of WPRS in emergency departments in rural or remote communities, and whether location affects WPRS and mortality. To advocate for implementation of WPRS and pediatric readiness in all emergency departments, barriers to implementation and strategies for improvement should be explored. More rigorous studies of WPRS, such as randomized control trials, would be beneficial to identify evidence-based strategies to improve WPRS and pediatric mortality.

Limitations

There were relatively few studies identified during the systematic review, and mortality is a relatively rare pediatric outcome, which limits the strength of the evidence or the robustness of the findings. We also acknowledge that the studies included in the meta-analysis are observational studies with possible residual confounding. Residual confounding cannot be completely eliminated in studies, especially in observational studies. Although plausible confounders have been adjusted for in the included studies, improper categorization, or misclassification of variables such as emergency department characteristics, patient demographics and severity of illness could distort the estimate reported in the included studies. Although all studies included children presenting to emergency departments, there is a slight variation in the characteristics of the emergency departments, patients admitted, severity of injury and the time frame used in estimating the mortality. Some studies included all critically ill children and others included injured children only, which may affect mortality rates and contribute to the relatively high heterogeneity of the model. These studies, however, presented considerably adjusted point estimates. We were also unable to conduct a meta-analysis for the secondary outcomes due to the wide range of outcomes in the included studies. However, the secondary outcomes consistently supported the improvement of WPRS in emergency departments. The WPRS is a relatively new score,[6,7] which may explain why there is limited published data on readiness scores and pediatric outcomes. Although we performed a comprehensive literature search and had 2 individuals screening articles, there is a possibility that relevant studies could have been missed. As well, the study included articles published in English only, which could have limited the results. Another limitation was that 7 of the 8 included studies were from the US, which has a relatively different health care system from other countries.

Conclusion

The data suggest a potential inverse association between the WPRS of the emergency departments and mortality risk in children. More studies are needed to refute or confirm these findings.

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Affiliations: Department of Pediatrics and Child Health (Harper, Klassen, Aregbesola), University of Manitoba; Children's Hospital Research Institute of Manitoba (Coyle, Tam, Skakum, Ragheb, Wilson, Klassen, Aregbesola), University of Manitoba, Winnipeg, Man.; Faculty of Medicine and Dentistry (Coyle), University of Alberta, Edmonton, Alta.; Max Rady College of Medicine (Skakum, Ragheb, Wilson); Neil John Maclean Health Sciences Library (Lê); Centre for Healthcare Innovation (Klassen), University of Manitoba, Winnipeg, Man.

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