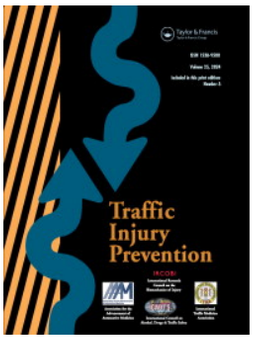

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# Pediatric vehicular heatstroke: An analysis of 296 cases from the National Fatality Review Case Reporting System

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**ABSTRACT**

**Objectives:** To explore the National Fatality Review Case Reporting System (NFR-CRS) as a new data source to (1) characterize pediatric vehicular heatstroke (PVH) deaths among children <15 years of age reviewed by Child Death Review teams, and (2) identify factors independently associated with common PVH scenarios and incident locations.

**Methods:** Data for 2005–2019 were used to characterize 296 PVH deaths. Frequencies and percentages were calculated to describe child, supervisor, and incident characteristics. Multiple logistic regression with and without imputation were carried out to identify factors associated with the two outcomes of interest: PVH scenario (left in vehicle vs. gained access) and incident place (supervisor workplace vs. other locations). Odds ratios and 95% confidence intervals (OR, 95% CI) were calculated.

**Results:** Most children had been left unattended in vehicles ($N=225$, 76.0%) and 13.5% ($N=40$) had gained access independently. Children were most often male ($N=168$, 56.8%), non-Hispanic White ($N=131$, 44.3%), and <2 years of age ($N=172$, 58.1%). Disability or chronic illness was noted for 4.7% ($N=14$), 13.9% ($N=41$) had a history of maltreatment, and 6.1% ($N=18$) an open CPS case at the time of incident. Children left unattended were more likely to be <2 years of age (adjusted imputed OR 26.7, CI 7.3–97.2) and less likely to have an open CPS case (0.2, 0.0–0.4) and for the incident to occur at home (0.2, 0.1–0.9) compared to children who gained access. PVH deaths occurring at the supervisor's workplace were more likely to be <2 years of age (6.2, 2.4–15.8), to have occurred on a weekday (5.9, 1.7–20.9), and to have been supervised by their parent at the incident time (2.7, 1.1–6.7) compared to other locations.

**Conclusions:** The results align with previous PVH findings and added new information on child race/ethnicity, CPS action, disability/chronic illness, and maltreatment. With the exception of parents being more likely to be the supervisor in incidents occurring at home, which was expected, neither supervisor characteristics nor child race/ethnicity or sex were independently significant in multiple regression, suggesting that PVH is pervasive and that education campaigns should be similarly broad.

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Pediatric vehicular heatstroke; heatstroke; hyperthermia; non-crash; non-traffic

## Introduction

Pediatric vehicular heatstroke (PVH) is a tragic and preventable event whereby a child's body temperature rises to dangerous levels (≥104 °F) while unattended in a hot vehicle (Bouchama and Knochel 2002; Rudd et al. 2015). This typically occurs when a child either is left unattended in a vehicle (usually by a supervising parent or caregiver) or gains access to a vehicle independently and becomes trapped. PVH can be fatal without prompt emergency treatment, and those who survive may suffer long-term neurologic damage (Bouchama and Knochel 2002; Koul et al. 2010). Scientific research on the topic is limited despite PVH deaths being frequently reported by the media. One of the major limitations has been the availability of reliable data sources due to the lack of standard reporting for PVH. No specific codes exist in the *International Classification of Diseases* to identify vehicular heat-related deaths (Guard and Gallagher 2005; Zonfrillo et al. 2018; Hammett et al. 2021). The National Highway Traffic Safety Administration (NHTSA) collects data on PVH deaths through non-traffic incident surveillance, but only from a small number of states reporting inconsistent levels of detail (Guard and Gallagher 2005; Zonfrillo et al. 2018; Hammett et al. 2021).

In the absence of standard reporting, the most complete data available to study PVH events are collected through surveillance by KidsAndCars.org (KAC) and NoHeatStroke.org (NHS). Both organizations use media reports as the primary means of case identification and data extraction. According to KAC, 38 children die of PVH in the U.S. each

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year on average, and at least 1,054 PVH deaths occurred between 1990 and 2022 (KidsAndCars.org 2023a). Most of these children had been unknowingly left in a vehicle (55%), while smaller proportions were knowingly left (15%) or had gained access independently to the vehicle (25%). NHS reports similar scenario proportions for 937 deaths identified between 1998 and 2022, and that PVH deaths most frequently occurred at the child's home (52%) and at a workplace (22%) (NoHeatStroke.org 2023). Although both systems provide key information regarding PVH scenarios, they include limited data on socioeconomic and child history characteristics that could be useful for targeted prevention.

A data source that has yet to be explored in the PVH literature is the National Fatality Review Case Reporting System (NFR-CRS), which was developed to facilitate consistent reporting of Child Death Review (CDR) data. Multidisciplinary CDR teams meet to review the circumstances of child deaths and compile data from each participating agency. Data sources, including death certificates, autopsy reports, child protective services (CPS) records, law enforcement records, and medical records can be available to CDR teams. This allows CDR teams to create a more comprehensive picture of factors contributing to death and formulate recommendations for prevention. Data compiled from each review are then entered into the NFR-CRS. This study sought to use the NFR-CRS data to (1) describe the characteristics of PVH deaths among children <15 years of age reviewed by CDR teams, and (2) identify factors independently associated with PVH scenarios and incident locations.

## Methods

### Study sample

The NFR-CRS is a web-based standardized reporting tool used by CDR teams to systematically record and analyze information discussed during the fatality review. The system was initially piloted in 2005 and is currently used by CDR programs in 47 states. CDR teams currently operate at the state- or local-level in all 50 states and the District of Columbia. The NFR-CRS collects information about the demographic and social characteristics of the child, family and supervisor; incident characteristics; investigative actions; and risk and protective factors by cause of death. Further details regarding the purpose, strengths, and limitations of the NFR-CRS have been described elsewhere (Covington 2011).

The current study utilizes national de-identified data obtained from the NFR-CRS and was ruled exempt by the Children's National Hospital Institutional Review Board. Eligible deaths included children <15 years of age documented in the NFR-CRS as having died of hyperthermia in an enclosed vehicle between 2005 and 2019. Until 2018, NFR-CRS included an Exposure section where users could indicate a circumstance of "left in a car" and a condition of "hyperthermia." One hundred sixty-five deaths occurring between 2005 and 2017 were identified in this way. The Exposure section was retired in the NFR-CRS beginning in 2018. A search of key text fields in the NFR-CRS for the terms "left in car," "hyperthermia," "heat stroke," "hot car," and "heat exhaustion" identified 73 deaths between 2018 and 2019 and an additional 58 deaths not previous captured under the Exposure section between 2005 and 2017. This yielded a total of 296 PVH deaths occurring in 35 states between 2005 and 2019.

### Data categorization

Using information in key text fields, the 296 PVH deaths were divided into two PVH scenario categories: children who were left unattended in vehicles by a supervisor ("left unattended" deaths) and children who had gained access independently to vehicles ("gained access" deaths). Deaths with insufficient scenario detail were classified as unspecified or unknown; these are reported in the results but excluded from further analysis. Left in vehicle deaths were further divided into knowingly left and unknowingly left for descriptive analysis purposes where sufficient detail was available. Child age was categorized as <2 years and 2 years or older based on findings by KAC that 54% of children who died of PVH between 1990 and 2022 were under 2 years of age (KidsAndCars.org 2023a). Supervisor age was categorized to compare young through early adulthood supervisors (18–34 years) to older supervisors (35 years or older). Incident place was categorized as child's home, supervisor workplace, other residence, day care center, business/retail, and other for descriptive analysis and further collapsed into the supervisor's workplace and other when used as an outcome in regression. The supervisor at the time of the incident's relation to child was categorized as parent, grandparent, childcare worker/babysitter, aunt/uncle, other relative, and other when for descriptive analysis and further collapsed to parent and other when used as a covariate in regression.

### Outcomes of interest

Two outcomes of interest were examined for this study: (1) the scenario – whether the child was left unattended in the vehicle or gained access to the vehicle, and (2) the incident place – whether the vehicle was located at the caregiver's workplace or elsewhere.

### Covariates

Variables within the NFR-CRS were reviewed and considered for inclusion if percent missing was no more than 40%. Child characteristics selected as covariates included age, sex, race and ethnicity; and whether the child had a disability or chronic illness, a history of maltreatment, or an open CPS case at the time of the incident. Supervisor characteristics selected as covariates included age, sex, and relation to the child. Incident characteristics included incident place, geographic area type, and day of week. Variables with category frequencies below the NFR-CRS reporting threshold of 6+ cases were collapsed to avoid small cell sizes when appropriate. Supervisor's relation to child was collapsed to parent (including mother, father, and parents with unknown sex)

and other. Incident place was collapsed to child's home and other when used as a covariate. Incident day of week was collapsed into weekday (Monday-Friday) and weekend (Saturday and Sunday).

### Statistical analysis

Some covariates of interest had relatively high proportion of missing values ranging from 3.7% to 34.8% missing. Because multiple imputation may produce less biased regression estimates when large proportions of data are missing, we also conducted a multiple imputation analysis to estimate missing values. For this study we presented the results using both non-imputed and imputed datasets.

Frequencies and percentages were calculated for covariates of interest. Differences in child, supervisor, and incident characteristics were compared for each of the outcomes of interest (scenario and incident place). Univariate logistic regression was performed to determine the strength of association between each of the covariates and each outcome. Odds ratios (OR) and 95% confidence intervals (CI) were calculated. Multiple logistic regression (MLR) analysis was performed for the two outcome variables to identify the strength of association of covariates that were statistically significant in the univariate models while controlling for the effect of the others. MLR models also controlled for year of death and state to account for variability within the NFR-CRS database. Data were analyzed using SPSS version 26 and Stata 17.0 statistical software.

## Results

### Characteristics

Most of the 296 children who died of PVH had been left unattended by the supervisor in a vehicle ($N=225$, 76.0%) and 13.5% ($N=40$) had gained access to a vehicle independently (Figure 1). Scenario could not be determined for 10.5% ($N=31$) of deaths due to insufficient detail in key text fields. Children who were unknowingly left unattended in vehicles ($N=143$) accounted for 63.6% of left in vehicle deaths and 48.3% of deaths overall.

Tables 1–3 present additional incident, child, and supervisor characteristics for the overall sample. The distribution of these characteristics by scenario and incident place can be found in Appendix Tables A1 and A2. PVH most frequently occurred in urban (35.1%) or suburban (37.5%) areas and on a weekday (72.3%). The child's home was the most frequent incident place for both left in vehicle deaths (30.7%) and gained access deaths (71.0%). Incident place was known for 91.0% (130 of 143) of children unknowingly left unattended in vehicles, and of these deaths, 40.8% occurred at the child's home, 28.5% occurred at the supervisor's workplace, and 30.8% occurred at other locations.

Overall, children who died of PVH were most often male (56.8%), non-Hispanic White (44.3%), and <2 years of age (58.1%; range 0–13 years) (Table 2). Children <1 year of age accounted for a higher number of deaths than any other single year of age (Figure 2) and had a median age of 6.1 months (range <1 month–11 months, data not shown). Age and sex differences were even more pronounced when examined by scenario, with children <2 accounting for 68.4% of left unattended deaths and males accounting for 75.0% of gained access deaths (Appendix Table A). At the time of death, 4.7% of children overall had a disability or chronic illness, 13.9% had a history of maltreatment, and 6.1% had an open CPS case. CPS action was substantiated following the incident in 36.8% of deaths overall, 37.8% of left in vehicle deaths, and 35.0% of gained access deaths (data not shown). The manner of death obtained from death certificates for most deaths was accident (80.4%), while 11.8% were classified as homicide, and 6.1% were undetermined (pending, natural, and unknown cause categories were suppressed). An autopsy was performed on 93.9% of the children included in the analysis.

Supervisors responsible for the child at the time of the incident were most often between 18 and 34 years of age (41.6%; range 19–79 years), and the child's parent (71.6%) (Table 3). Supervisors also included grandparents (9.1%), childcare workers/babysitters (5.7%), aunt/uncles (3.0%), and other relatives (2.0%). Of the 212 deaths where a parent was the supervisor, 45.3% were the mother only, 41.5% were the father only, and 11.3% were both; none were reported to be stepparents (data not shown). In eight deaths the parent supervisor was a foster parent. Of the 27 grandparent supervisors, 63.0% were grandmothers and 37.0% were grandfathers. Of the 17 childcare workers/babysitters, most (60.0%) were female and 40.0% were male.

### Regression analysis

The results using non-imputed and imputed datasets were essentially the same; only imputed results are displayed in

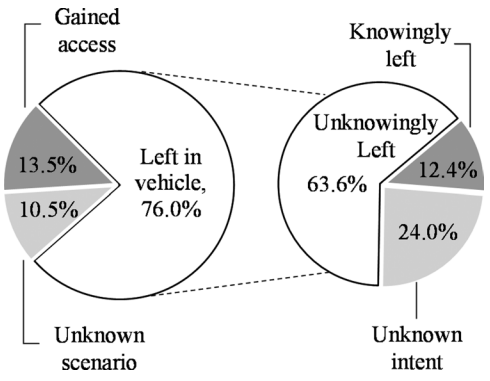


Figure 1. Incident scenario for PVH deaths ($N=296$) and supervisor intent among children left in vehicles ($N=225$).

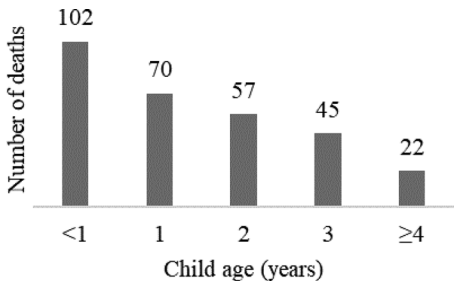


Figure 2. Age of children who died of PVH ($N=296$).

**Table 1.** Other incident characteristics ($N = 296$).

| Characteristic | N (%) | Characteristic | N (%) | Characteristic | N (%) |
|---|---|---|---|---|---|
| **Geographic area type** | | **Place** | | **Day of week** | |
| Urban | 104 (35.1) | Child's home | 110 (37.2) | Weekday | 214 (72.3) |
| Suburban | 111 (37.5) | Workplace | 50 (16.9) | Weekend | 71 (24.0) |
| Rural | 39 (13.2) | Other residence | 37 (12.5) | Missing/unknown | 11 (3.7) |
| Missing/unknown | 42 (14.2) | Day care center | 16 (5.4) | | |
| | | Business/retail | 7 (2.4) | | |
| | | Other | 17 (5.7) | | |
| | | Missing/unknown | 59 (19.9) | | |

**Table 2.** Child characteristics ($N = 296$).

| Characteristics | **N (%)**[a] | Characteristics | **N (%)**[a] | Characteristics[a] | **N (%)**[a] |
|---|---|---|---|---|---|
| **Race/ethnicity** | | **Sex** | | **Had history of maltreatment** | |
| White, non-Hispanic | 131 (44.3) | Male | 168 (56.8) | Yes | 41 (13.9) |
| Black, non-Hispanic | 61 (20.6) | Female | 128 (43.2) | No | 152 (51.4) |
| Hispanic | 51 (17.2) | | | Missing/unknown | 103 (34.8) |
| Other, non-Hispanic | 27 (9.1) | **Had disability/chronic illness** | | | |
| Missing/unknown | 26 (8.8) | Yes | 14 (4.7) | **Had open CPS case at death** | |
| | | No | 210 (70.9) | Yes | 18 (6.1) |
| **Age** | | Missing/unknown | 72 (24.3) | No | 216 (73.0) |
| <2 years | 172 (58.1) | | | Missing/unknown | 62 (20.9) |
| 2 years or older | 124 (41.9) | | | | |

[a]Percentages may not total 100.0 due to rounding.

**Table 3.** Supervisor characteristics ($N = 296$).

| Characteristic | ***N* (%)**[a] | Characteristic | ***N* (%)**[a] | Characteristic | ***N* (%)**[a] |
|---|---|---|---|---|---|
| **Supervisor relation to child** | | **Supervisor age** | | **Supervisor sex** | |
| Parent | 212 (71.6) | 18–34 years | 123 (41.6) | Male | 118 (39.9) |
| Grandparent | 27 (9.1) | 35 years or older | 81 (27.4) | Female | 155 (52.4) |
| Childcare worker/babysitter | 17 (5.7) | Missing/unknown | 92 (31.1) | Missing/unknown | 23 (7.8) |
| Aunt/uncle | 9 (3.0) | | | | |
| Other relative | 6 (2.0) | | | | |
| Other | 9 (3.0) | | | | |
| Missing/unknown | 16 (5.4) | | | | |

[a]Percentages may not total 100.0 due to rounding.

**Table 4.** Multiple logistic regression models for factors associated with PVH death due to a child being left unattended in a vehicle vs. having gained access independently, controlling for year of death and state.

| | Full models | | Reduced models | |
|---|---|---|---|---|
| **Characteristics**[a] | **Non-imputed OR (95% CI)**[b] | **Imputed OR (95% CI)**[b] | **Non-imputed OR (95% CI)**[b] | **Imputed OR (95% CI)**[b] |
| **Child age** | | | | |
| <2 years | **29.4 (5.5–157.7)** | **25.2 (6.9–92.3)** | **32.4 (6.0–175.2)** | **26.7 (7.3–97.2)** |
| **Child sex** | | | | |
| Male | 0.4 (0.1–1.2) | 0.4 (0.2–1.1) | 0.4 (0.1–1.3) | 0.4 (0.2–1.1) |
| **Child had open CPS case** | | | | |
| Yes | **0.1 (0.0–0.4)** | **0.2 (0.1–0.9)** | **0.0 (0.0–0.4)** | **0.2 (0.0–0.4)** |
| **Incident place**[c] | | | | |
| Child's home | **0.2 (0.0–0.6)** | **0.2 (0.1–0.6)** | **0.1 (0.0–0.6)** | **0.2 (0.1–0.9)** |
| **Incident day of week** | | | | |
| Weekday | 1.8 (0.5–6.0) | 1.3 (0.5–3.4) | – | – |

[a]Reference categories were 2 years or older (child age), female (child sex), no (child open CPS case), other (incident place), and weekend (incident day of week).
[b]Adjusted odds ratios; odds ratios excluding 1 bolded.
[c]Incident place categories collapsed to home and other to avoid cell suppression.

the text. Factors associated with children having been left unattended in vehicles (compared to having gained access) during univariate logistic regression were related to child age, child sex, open CPS case at death, incident day of week, and incident place (see Appendix Table A1). When controlling for year of death and state in multiple regression, only child age, open CPS case, and incident place remained significant (Table 4, full models). Upon examination of the results, a second model was constructed that excluded incident day of the week without significantly effecting the model (Table 4, reduced models). The imputed model shows that children who died of PVH after being left unattended were more likely to be <2 years of age (adjusted imputed odds ratio [$OR_{ai}$], 26.7; 95% confidence interval [95% CI], 7.3–97.2) and less likely to have an open CPS case at the time of the incident ($OR_{ai}$ 0.2, 95% CI 0.0–0.4) and for the incident to occur at home ($OR_{ai}$ 0.2, 95% CI 0.1–0.9) compared to children who gained access.

Table 5. Multiple logistic regression models for factors associated with PVH death incidents occurring at the supervisor's workplace vs. other locations, controlling for year of death and state.

| Characteristics[a] | Non-imputed OR (95% CI)[b] | Imputed OR (95% CI)[b] |
|---|---|---|
| **Child age** | | |
| <2 years | **5.3 (2.0–13.4)** | **6.2 (2.4–15.8)** |
| **Supervisor relation to child**[c] | | |
| Parent | 2.1 (0.8–5.4) | **2.7 (1.1–6.7)** |
| **Incident day of week** | | |
| Weekday | **5.2 (1.5–18.7)** | **5.9 (1.7–20.9)** |
| **Incident geographic area type** | | |
| Suburban | 1.0 (0.5–2.2) | 1.0 (0.5–2.2) |
| Rural | 0.2 (0.0–1.1) | 0.2 (0.1–1.1) |

[a]Reference categories were 2 years or older (child age), other (supervisor relation to child), weekend (incident day of week), and urban (incident geographic area type).
[b]Adjusted odds ratios; odds ratios excluding 1 bolded.
[c]Supervisor categories collapsed to parent and other to avoid cell suppression.

Factors associated with PVH incidents occurring at the supervisor's workplace (compared to other locations) during univariate logistic regression were related to child age, supervisor relation to child, geographic area type, and incident day of week (see Appendix Table A2). Child age and incident day of week remained significant in both the non-imputed and imputed MLR models, while supervisor relation to child was significant in the imputed model only (Table 5). The imputed MLR models show that children who suffered PVH at the supervisor's workplace were more likely to be <2 years of age ($OR_{ai}$ 6.2, 95% CI 2.4–15.8), for the incident to have occurred on a weekday ($OR_{ai}$ 5.9, 95% CI 1.7–20.9), and to have been supervised by their parent at the time ($OR_{ai}$ 2.7, 95% CI 1.1–6.7) compared to children who suffered PVH at other locations. A second model was constructed that excluded geographic area type, but this significantly affected the non-imputed model so that model was not used.

### Team assessment

CDR teams indicated *yes/probable* for the question *Did child abuse, neglect, poor or absent supervision or exposure to hazards cause or contribute to the child's death?* for 83.4% of deaths. Teams are asked to indicate the primary cause or contributor as a follow-up question. Of the 247 deaths marked *yes/probable*, poor or absent supervisor was most often indicated (50.6%), followed by child neglect (39.3%), exposure to hazards (7.7%), and child abuse (2.4%) (data not shown). Teams concluded that 260 (88%) of the deaths could have been prevented and submitted prevention recommendations for 36.5% (108 of 296) of deaths. These included PVH public service campaigns (42.6% of recommendations), education to parents and caregivers (23.1%), prevention recommendations for parents/caregivers (20.4%), and the need for preventive vehicle technology (13.9%).

## Discussion

This study adds to a limited body of scientific research characterizing PVH incidents. Guard and Gallagher (2005) examined a cohort of 233 PVH deaths among children ≤5 years of age for between 1995 and 2002 using online news reports. A subsequent study by Booth et al. (2010) examined 231 PVH deaths among children ≤14 years of age between 1999 and 2007 using data from online searches, the Centers for Disease Control and Prevention's Compressed Mortality File, and the Golden Gate Weather Service. Hammett et al. (2021), focusing solely on children ≤14 years of age left in vehicles, analyzed 541 PVH deaths between 1990 and 2016 using data from KAC. These studies primarily relied on information obtained from media reports, whereas the current study is the first to use data from the NFR-CRS.

Our review identified 296 eligible PVH deaths among children <15 years of age from 35 states between 2005 and 2019. This is roughly half the number of deaths identified by KAC ($N=604$) and NHS ($N=597$) during the same period (KidsAndCars.org 2023a; NoHeatStroke.org 2023). This was not surprising as states only started participating in the NFR-CRS in 2005 when 8 states entering data reported a PVH death. The number of states using the NFR-CRS has increased gradually since then, with 17 of 35 states reporting a PVH death in 2019. Additionally, not every state reviews every child death as the laws and policies governing which deaths are reviewed vary by state (Covington 2011; Quinton 2017). The extent of agreement of PVH deaths identified in the NFR-CRS and by KAC/NHS is unknown.

The descriptive results of our study align with and expand upon what has been previously reported. Most children died after being left unattended in a vehicle (76.0%), similar to the leading scenario reported by KAC (70%) and NHS (73%) and previous study findings by Guard and Gallagher (73%) and Booth et al. (83%) (Guard and Gallagher 2005; Booth et al. 2010; KidsAndCars.org 2023a; NoHeatStroke.org 2023). Overall, children in the present study were most often male (56.8%) and <2 years of age (58.1%). Male children accounted for 75.0% of gained access deaths and children <2 years of age accounted for 68.4% of left in vehicle deaths; similarly, KAC (2023a) report these proportions as 68% and 70%, respectively. To the authors' knowledge, this is the first study to report on the race and ethnicity of children who died of PVH death. Non-Hispanic Black children made up 15% of children < 15 years of age nationally between 2005 and 2019 yet accounted for 20.6% of the overall study sample and 23.6% of children left unattended (CDC National Center for Health Statistics 2022). Neither non-Hispanic White nor Hispanic children represented a higher proportion in the study sample relative to their population proportions. Additionally, the use of NFR-CRS data allowed us to identify that 6% of children who died of PVH had an open CPS case at death; 13.9% had a history of child maltreatment; and 4.7% had a disability or chronic illness. It was also identified that 94% of children who died in our study were autopsied. For comparison, 76% of all deaths due to an external cause in the NFR-CRS were autopsied (2023 June 15 personal email communication, NCFRP).

That the authors are aware, this is the first study to identify factors commonly associated with PVH scenarios and

incident locations using regression analysis. The results were mostly consistent with what is currently known about PVH deaths. The variables uniquely available in the NFR-CRS showed little to no significant difference in regression. The odds of being left unattended in a vehicle were higher for children <2 years compared to older children and lower for incidents occurring at the child's home compared to other locations. This is likely explained, at least in part, by the fact that infants are more likely to be sleeping or otherwise quiet throughout the course of a drive and that the comparison group, gained access, is more likely for older children accessing vehicles at home. That children with an open CPS case had lower odds of being left unattended may again in part be explained by the choice of the comparison group in that children who gain access to a vehicle independently may have a history with CPS due to inadequate supervision. Still, this suggests a potential target group for preventive education. The increased odds of PVH incidents occurring at the supervisor's workplace on weekdays is also not unexpected given the typical Monday-Friday work week. Of note, neither scenario nor incident place were associated with child race/ethnicity, supervisor age or sex, or geographic area type. A recent national survey by Sartin et al. (2023) similarly found no differences by race/ethnicity, sex, and state of residence when asking parents how often they leave children alone in vehicles. The survey did find differences by education and income, but these variables were highly missing in our dataset and thus not included for analysis.

Children who were unknowingly left in vehicles represented the most common scenario in our study (48.3% of all deaths). This is also the most common scenario reported by KAC (55%) and NHS (53%) (KidsAndCars.org 2023a; NoHeatStroke.org 2023). One PVH researcher, a neuroscientist, has hypothesized that this tragic loss of awareness results from competition between the brain's habit memory system (responsible for routine acts carried out automatically, or in 'autopilot'), and prospective memory system (responsible for planning and executing a future task) (Diamond 2019). Despite having every intention to stop at a daycare on their daily drive to work, a parent's habit memory system can prevail, causing them to forget to stop and proceed throughout the day believing they had done so. Common factors in PVH death scenarios that increase the likelihood of a prospective memory system failure include a change in routine, stress, distraction, and lack of sleep (Diamond 2019).

PVH is a complex issue with no single solution. Recognizing this, Guard and Gallagher were the first researchers to call for a multi-layered approach to its prevention through legislation, parent education, and technology; similar to the recommendations made by CDR teams in our study (Guard and Gallagher 2005; Williams and Grundstein 2018). Twenty-one states currently have laws making it illegal to leave children unattended in vehicles and 25 states have Good Samaritan laws related to rescuing children in hot cars (KidsAndCars.org 2023b, 2023c). A number of public health campaigns addressing the prevention of PVH have been mounted since 2005 (National Highway Traffic Safety Administration 2022; National Safety Council 2023; Safe Kids Worldwide 2023). However, these campaigns need further evaluation to assess their reach and effectiveness. In their national survey of caregivers, Sartin et al. found that 47% were unaware of such campaigns, although 95% agreed it was important that caregivers receive education about not leaving children in vehicles (Sartin et al. 2023). Technology-based countermeasures have also emerged to address PVH, ranging from simple visual rear seat reminders to complex occupant detection systems to alert drivers/bystanders if a child is left behind. The Infrastructure Investment and Jobs Act (IIJA), passed by Congress in 2021, includes a provision for NHTSA to require audio and visual reminder systems be installed on all new vehicles (117th Congress 2021). Advocates for technological enhancements to prevent PVH recommend occupant detection systems over reminder systems (KidsAndCars.org 2023d; Null 2023). Regardless of approach, new requirements only apply to new vehicles. Given the average age of vehicles in the U.S. is 12.2 years, and that low-income populations are more likely to be driving older vehicles, the need for education and public awareness campaigns will continue for some time to come (Glenn et al. 2021; U.S. Department of Transportation 2023).

### Limitations

The NFR-CRS itself poses some potential limitations. Because not all states participate and not all states review all child deaths, the data are not population based. Further, the fact that participation in the system has grown over time precludes assessing temporality of this phenomenon in the NFR-CRS. While analyses of NFR-CRS data are therefore typically descriptive in nature, the data contain important detail not available in other data systems, so are quite useful for detailed description and hypothesis generating analyses. Further, our results are not inconsistent with results from analyses using data considered to be population-based. This despite the fact that the variable allowing specification of PVH death ceased to be collected in 2018.

The high proportion of missing data for select variables is another limitation of the current study. PVH scenario could not be determined for 10.5% of deaths due to missing narrative data. Similarly, whether the child was knowingly or unknowingly left could not be determined for 24.0% of left in vehicle deaths. Covariates in our analysis with high degrees of missing values included child disability/chronic illness at death (24.3% missing), open CPS case at death (20.9% missing), and history of maltreatment (34.8% missing); although these covariates were complete enough to allow imputation, others were not. Parent income and other indicators of socioeconomic status such as education level and health insurance coverage were largely missing and therefore not suitable for imputation. The role of poverty or socioeconomic status on PVH deaths therefore could not be assessed. The utility of the NFR-CRS for examining PVH death characteristics could be enhanced by improving the completeness of data submitted by CDR teams. A final limitation relates to the selection of comparison groups. We chose to compare scenario and incident place within the subset of PVH deaths; had we

compared PVH deaths to non-PVH deaths available in the NFR-CRS, the results may have differed.

## Conclusion

This study was the first to use NFR-CRS data to characterize PVH deaths. The descriptive findings are consistent with what has previously been reported and adds new information to what is known in terms of the child's race/ethnicity, history of CPS action, disability/chronic illness, and history of maltreatment. The fact that children with a history of CPS action were more likely to have gained access to a vehicle suggests a possible new target group for preventive education. With the exception of parents being more likely to be the responsible supervisor in PVH deaths occurring at home, which was expected, neither supervisor characteristics nor child race/ethnicity or sex were significant in the models presented, suggesting that PVH is pervasive and education campaigns should be similarly broad.

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