



Sledding while towed behind motorized vehicles associates with more severe and lethal injuries^{☆☆}



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ABSTRACT

Introduction: Our institution has recently experienced an increase in sledding-related injuries, particularly when towed behind motorized vehicles. The purpose of this study was to characterize injury severity and clinical outcomes between pediatric patients who sustain injuries owing to motorized sledding accidents to aid in injury prevention messaging.

Methods: This retrospective study queried all patients who presented with a sledding-related injury to a single ACS-verified Level 1 Pediatric Trauma Center located in the Southeastern United States between 01/2015 and 01/2022. Demographics, injury details, and clinical outcomes were compared between two groups: patients towed behind a motorized vehicle (MOTOR) and those who were not (GRAVITY).

Results: Of the 67 patients included in our analysis, 15 (22%) were in the MOTOR group. Patients in the MOTOR group presented with significantly higher injury severity (ISS) and lower Glasgow coma scale (GCS) scores. Additionally, patients in this MOTOR group more often received a blood transfusion and intubation, had longer intensive care and overall hospital lengths of stay, and incurred higher hospital costs. In a multivariate analysis, the use of a motorized vehicle to sled was independently associated with increased ISS (OR: 9.7, 95% CI 1.9–17.5; $p = 0.02$). Two deaths occurred after sledding while being towed behind a motorized vehicle.

Conclusion: Children experiencing sledding accidents while being towed by motorized vehicles sustain significantly more severe injuries and require more intensive treatments that together lead to increased hospital costs. These findings provide the framework for community educational initiatives and injury prevention measures to mitigate risk among children engaged in sledding.

Level of evidence: IV retrospective cohort study.

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1. Introduction

Sledding is a common recreational activity among children and adolescents during the winter season owing to its relatively low cost and accessibility [1]. Sledding-related injuries can be serious with hospitalization rates among patients presenting to the emergency department ranging from 10 to 25% [2,3]. A nationwide study in 2009 using the National Electronic Injury Surveillance System estimated that almost 230,000 children were treated in emergency departments for sledding-related injuries in the United

States between 1997 and 2007, with an average yearly rate of 26 cases per 100,000 individuals younger than 19 years [4].

We recently noticed a substantial increase in sledding-related injury severity that appeared associated with more frequent towing behind a motorized vehicle, such as all-terrain vehicle (ATV) or truck. No previously published study has examined the impact of sledding while being towed behind a motorized vehicle on pediatric injury severity or injury pattern. Moreover, no formal recommendation or injury prevention guidelines exist to discourage the use of motorized vehicles while sledding. In an effort to provide foundational data that aid injury prevention measures and outreach initiatives, we aimed to characterize injury patterns, severity, and clinical outcomes among patients who sustained sledding-related injuries while being pulled behind a motorized vehicle.

2. Methods

We performed a retrospective review of all pediatric patients (ages 0–18) who were admitted to our American College of Sur-

Abbreviations: ATV, all-terrain vehicle; ACS, American College of Surgeons; ISS, injury severity score; GCS, Glasgow coma scale; ICU, intensive care unit; TBI, traumatic brain injury.

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geons (ACS)-verified Level 1 Pediatric Trauma Center between 01/2015 and 01/2022. After Institutional Review Board Approval (IRB #21007), our institutional trauma database was queried for keywords, including “sled” and “sledding” to identify patients who sustained sledding-related injuries. Patients were then divided into two groups: MOTOR and GRAVITY. The MOTOR group consisted of patients whose sled was pulled behind a motorized vehicle, which was determined after review of the patient’s electronic health record. The GRAVITY group consisted of patients whose sled was not pulled by a motorized vehicle. We utilized our electronic health record-based institutional trauma database to gather demographic information, injury details such as location, setting, and mechanism, pre hospital data, lowest Glasgow coma scale score (GCS), injury severity score (ISS), discharge disposition, and hospital cost. The electronic health record was reviewed to collect details surrounding the patient’s clinical course, including injuries, surgeries, need for intensive care unit (ICU) admission, blood transfusions, and need for intubation. The GCS score used for analysis reflects the lowest GCS score on arrival or prior to presentation. Blood transfusions and intubations were recorded if they were required prior to presentation or upon arrival. Hospital cost was defined as the total dollar amount that the care for each patient cost to the hospital. Injury types, including traumatic brain injury (TBI), cranial fractures, spinal fractures, extremity fractures, hemopneumothoraces, and abdominal solid organ injury (liver, spleen, and kidney) were based on radiographic findings at the time of presentation.

To determine if sledding while being towed behind a motorized vehicle was independently associated with increased ISS, hospital length of stay, and increased hospital cost, we performed a Cox Multivariate regression analysis of factors associated with increased ISS, including use of motorized vehicle, gender, and level 1 trauma activation. Criteria for level 1 trauma activation at our institution include an adaptation of the American College of Surgeons – Committee on Trauma six minimum criteria to include at least one of the following: intubated patient, unstable airway, respiratory distress, age specific hypotension, cardiac arrest, blood transfusion in route, penetrating injury, limb threatening injuries, amputation, degloving injury, pulseless extremity, GCS <9, decreasing GCS, paralysis, or ED physician discretion. Categorical variables are recorded as percentages compared using Chi-squared test, and continuous variables are recorded as means and compared using Kruskal-Wallis test. All analyses were performed using IBM Statistical Product and Service Solutions for Mac, Version 27 (IBM Corp., Armonk, N.Y., USA) software package and statistical significance was set at $p < 0.05$.

3. Results

We identified 67 pediatric patients who presented to our pediatric trauma center between 01/2015 and 1/2022 and treated for injuries sustained while sledding, 22% ($n = 15$) of whom were in the MOTOR group while 78% ($n = 52$) were in the GRAVITY group. The mean age of the entire cohort was 11.1 years, and males comprised 67% ($n = 45$) of patients. No significant demographic differences between patients in the MOTOR and GRAVITY groups were detected. While no difference in the chronology of patient presentation between the two groups emerged, the majority of sledding-related injuries in both groups occurred between 2020 and 2022. Collision with a stationary object was the most common injury mechanism (72%, $n = 48$) and 54% ($n = 36$) of patients were transferred from an outside hospital. Demographic and injury characteristics are detailed in [Table 1](#). Of note, no patients were recorded as wearing any protective equipment, including a helmet or joint padding.

Patients in the MOTOR group were more likely to present to our institution as a level 1 trauma activation (33% vs 5.6%, $p = 0.01$), which was indicative of more severe or life-threatening trauma. Of note, 87% ($n = 13$) of patients in the MOTOR group were pulled behind an ATV at the time of their accident, while 13% ($n = 2$) were pulled behind a pickup truck. Additionally, patients in the MOTOR group showed significantly higher mean ISS (21.3 vs 10.2, $p = 0.02$) and lower mean GCS scores (10.2 vs 14.6, $p = 0.008$). Patients in the MOTOR group were significantly more likely than their GRAVITY counterparts to require intubation (20% vs 0%, $p = 0.01$), a blood transfusion (3.33% vs 5.8%, $p = 0.009$), and a tube thoracostomy (20% vs 0%, $p = 0.01$). While patients in each group were equally likely to be admitted to the hospital owing to their injuries, patients in the MOTOR group were more often admitted to the ICU than the floor (53.3% vs 26.6%), whereas the GRAVITY group was more likely to be admitted to the floor rather than the ICU (75% vs 5.8%; ICU admission: MOTOR 53.3% vs GRAVITY 5.8%, $p < 0.001$). Patients in the MOTOR group had a 3-fold increase in their ICU length of stay (8.4 vs 2.8 days, $p = 0.04$) and greater than 2-fold increase in their hospital length of stay compared to the GRAVITY group (6.1 vs 2.1 days, $p = 0.009$). Most patients in either group did not require surgery (73.4% vs 65.4%, $p = 0.76$). Nonetheless, overall hospital cost was significantly higher in the MOTOR group (\$126,392 vs \$41,259, $p = 0.01$). Of note, both deaths ($n = 2$) in the entire cohort occurred in the MOTOR group (13.4% vs 0%, $p = 0.04$). One patient died in the trauma bay owing to hemorrhagic shock in the setting of blunt force trauma (unknown ISS) while the other mortality was a result of devastating neurologic injury that progressed to brain death in the ICU in the context of a cervical spine fracture, multiple rib fractures, bilateral hemopneumothoraces, splenic and kidney lacerations, and pelvic fractures, resulting in an ISS of 43. Injury details and clinical outcomes are presented in [Table 2](#).

Not only did patients in the MOTOR group have significantly more severe and lethal injuries, but also their injury patterns were different than patients in the GRAVITY group ([Table 3](#)). 67% of patients in the MOTOR group sustained multiple injuries compared to 34.6% in the GRAVITY group ($p = 0.04$). MOTOR patients had significantly increased rate of cervical spinal fractures (20% vs 1.9%; $p = 0.01$), liver lacerations (20% vs 1.9%; $p = 0.009$), spleen lacerations (33.3% vs 5.8%; $p = 0.02$), and kidney lacerations (26.7% vs 3.8%; $p = 0.02$) than their GRAVITY counterparts. Patients in both groups underwent similar rates of orthopedic, otolaryngological, and neurosurgical procedures. A total of three patients in the MOTOR group and one patient in the GRAVITY group required an exploratory laparotomy (20% vs 1.9%; $p = 0.01$). All but one patient required exploratory laparotomy for solid organ injury with hemodynamic instability. One patient sustained an abdominal impalement with a large tree branch requiring exploratory laparotomy with repair of duodenal and gastric injuries [5].

In a Cox multivariate regression analysis controlling for male gender and level 1 trauma activation, sledding while being towed behind a motorized vehicle was independently associated with increased ISS (HR 2.3, 95% CI: 1.84–2.96, $p = 0.02$; [Table 4](#)), increased hospital length of stay (HR 3.0, 95% CI 2.3–3.3, $p = 0.03$; [Table 4](#)), and increased hospital cost (HR 3.7, 95% CI 3.0–4.1, $p = 0.01$; [Table 4](#)).

4. Discussion

In this study, we showed that sledding while being towed behind motorized vehicles was independently associated with increased injury severity, hospital length of stay, and hospital cost. This study is the first to characterize the danger of sledding while being towed behind a motorized vehicle in comparison to traditional gravity sledding. Despite having similar demographics and

Table 1
Demographic and injury characteristics.

Variable	MOTOR% (n)	GRAVITY% (n)	p-value
Total	22% (15)	78% (52)	–
Gender 0.10			
Male	86.7% (13)	61.5% (32)	
Female	13.3% (2)	38.5% (20)	
Age (mean ± std)	11.7 ± 3.3 years	10.8 ± 4.5 years	0.17
Ethnicity 0.88			
Caucasian	80% (12)	88.5% (46)	
African American	6.7% (1)	5.8% (3)	
Hispanic	6.7% (1)	3.8% (2)	
Other	6.7% (1)	1.9% (1)	
Year of Injury			0.16
2015	6.7% (1)	25% (13)	
2016	6.7% (1)	7.6% (4)	
2017	0% (0)	1.9% (1)	
2018	20% (3)	3.8% (2)	
2019	0% (0)	1.9% (1)	
2020	0% (0)	1.9% (1)	
2021	53.3% (8)	46.3% (24)	
2022	13.3% (2)	11.6% (6)	
Injury Location 0.98			
Public Property	53.3% (8)	53.7% (28)	
Private Property	46.7% (7)	46.3% (24)	
Injury Mechanism 0.71			
Collision with stationary object	80% (12)	69.2% (36)	
Collision with moving object	6.7% (1)	17.3% (9)	
Fall off sled	13.3% (2)	13.5% (7)	
Transfer from Outside Hospital	66.7% (10)	50% (26)	0.43

Table 2
Injury details and clinical outcomes.

Variable	MOTOR (n = 15)	GRAVITY (n = 52)	p-value
Level 1 Trauma Activation*	33% (5)	5.6% (3)	0.01
ISS (mean ± std)	21.3 ± 14.7	10.2 ± 6.2	0.02
Lowest GCS (mean ± std)	10.2 ± 5.6	14.6 ± 1.4	0.008
Intubation	20% (3)	0% (0)	0.01
Blood Transfusion	33.3% (5)	5.8% (3)	0.009
Laceration Repair	6.7% (1)	3.8% (2)	0.91
Tube Thoracostomy	20% (3)	0% (0)	0.01
ED Disposition			
Home	13.4% (2)	19.2% (10)	0.72
Floor	26.6% (4)	75% (39)	0.002
ICU	53.3% (8)	5.8% (3)	<0.001
Death	6.7% (1)	0% (0)	0.06
Number of Surgeries			0.76
0	73.4% (11)	65.4% (34)	
1	13.3% (2)	32.7% (17)	
2	13.3% (2)	1.9% (1)	
ICU LOS (mean ± std)	8.4 ± 6.3 days	2.8 ± 2.6 days	0.04
Hospital LOS (mean ± std)	6.1 ± 2.4 days	2.1 ± 1.6 days	0.009
Hospital cost US \$ (mean ± std)	\$126,392 ± 12,651	\$41,259 ± 36,105	0.01
Death	13.4% (2)	0% (0)	0.04

* Level 1 Trauma Activation Criteria include at least one of the following: intubated patient, unstable airway, respiratory distress, age specific hypotension, cardiac arrest, blood transfusion en route, penetrating injury, limb threatening injuries, amputation, degloving injury, pulseless extremity, GCS <9, decreasing GCS, paralysis, or ED physician discretion.

injury mechanisms, patients in the MOTOR group fared worse than their GRAVITY counterparts in almost every clinically meaningful parameter evaluated in this study, including ISS, GCS score, need for intubation, and admission to the ICU. Most strikingly, the average ISS for patients in the MOTOR group was 21.3, which was significantly higher than GRAVITY patients but also well above the threshold of what is considered major or severe trauma or requiring full trauma team activation [6,7]. Our findings echo a previous report of increased ISS and hospital LOS among pediatric patients sustaining aquatic-related injuries while being towed behind a boat compared to other mechanisms [8].

Not only did patients in the MOTOR group sustain more severe injuries compared to the GRAVITY group, but they also displayed a different pattern of injuries. These patients were increasingly likely to sustain cervical spinal fractures and solid abdominal organ injuries. The increase in spinal fractures was likely owing to potential whiplash effect of a sudden collision with a stationary object, while the increase in blunt thoracic and abdominal trauma was due perhaps to increased momentum from the motorized vehicle. Additionally, patients in the MOTOR group required tube thoracostomies at a significantly higher rate than GRAVITY patients, while being diagnosed with a hemopneumothorax, a pneumothorax, or a hemothorax at similar rates. Such findings indicate that a con-

Table 3
Distribution of injury and surgery types.

Variable	MOTOR (n = 15)	GRAVITY (n = 52)	p-value
Multiple Injuries	67% (10)	34.6% (18)	0.04
Injury Type			
Traumatic Brain Injury	33.3% (5)	26.9% (14)	0.63
Cranial Fracture	26.7% (4)	26.9% (14)	0.99
Cervical Spine Fracture	20% (3)	1.9% (1)	0.01
Thoracic Spine Fracture	6.7% (1)	1.9% (1)	0.72
Upper Extremity Fracture	13.3% (2)	11.5% (6)	0.93
Lower Extremity Fracture	20% (3)	23% (12)	0.80
Hemopneumothorax	13.3% (2)	1.9% (1)	0.06
Pneumothorax	6.7% (1)	1.9% (1)	0.22
Hemothorax	6.7% (1)	0% (0)	0.54
Liver Laceration	20% (3)	1.9% (1)	0.01
Spleen Laceration	33.3% (5)	5.8% (4)	0.02
Kidney Laceration	26.7% (4)	3.8% (2)	0.02
Hollow Viscous Injury	6.7% (1)	0% (0)	0.54
Surgery Type			
ORIF (orthopedic)	13.3% (2)	26.9% (14)	0.71
ORIF (ENT/plastic)	6.7% (1)	5.7% (3)	0.97
Craniectomy/Craniotomy (NSGY)	6.7% (1)	1.9% (1)	0.72
Exploratory Laparotomy	20% (3)	1.9% (1)	0.01

Table 4
Cox multivariate regression analysis.

Injury Severity Score Variables	HR	95% CI	P Value
Sledding Behind a Motorized Vehicle	2.3	1.84–2.96	0.02
Male Gender	0.92	0.84–1.11	0.30
Level 1 Trauma Activation	0.14	0.19–3.82	0.85
Hospital Length of Stay Variables	HR	95% CI	P Value
Sledding Behind a Motorized Vehicle	3.0	2.3–3.3	0.03
Male Gender	1.5	0.7–1.9	0.09
Level 1 Trauma Activation	1.8	0.8–2.9	0.11
Hospital Cost Variables	HR	95% CI	P Value
Sledding Behind a Motorized Vehicle	3.7	3.0–4.1	0.01
Male Gender	1.3	0.6–2.2	0.10
Level 1 Trauma Activation	1.6	0.8–2.1	0.09

tributing factor for injury severity in this cohort was sled velocity at the time of injury.

Although patients in the MOTOR group had injuries of higher severity than the GRAVITY group, rates of surgery and admission to the hospital were relatively similar between the two cohorts. The severe injuries sustained by patients in the MOTOR group were not necessarily more operative than injuries sustained in the GRAVITY group but required clinical monitoring that led to increased ICU admission, and ICU length of stay, which likely was responsible for the increased hospital cost observed in this study. Such findings underscore the severity of injury and consequent healthcare burden that can occur in patients who sled while being pulled behind motorized vehicles.

Several interesting trends emerged from this study. Snowstorms are not as common in the Southeastern United States, where this study was performed, as they are in other parts of the United States. However, when relatively large snowstorms occur and cause school closures, a significant increase in sledding-related injuries can be observed. In particular, greater than 60% of patients in the MOTOR group sustained injuries in the last two major snowstorms in our geographic region. Such a trend, coupled with a high rate of ATV ownership in rural counties, indicates that a significant unexpected snowfall may be inciting factors for sledding while being towed behind a motorized vehicle.

This study has several limitations to acknowledge. First, this analysis is a relatively small, retrospective study from a single institution in the Southeastern United States and may not be representative of findings at other institutions nationally. Additionally, since snowstorms are not as common in the Southeastern United States, our data may reflect a disproportionately high incidence of sledding accidents, particularly while being towed behind motorized vehicles. Owing to the opportunistic nature of this recreational activity, children are likely to take advantage of the rare snowstorm to engage in sledding activities, which may lead to overestimation of the popularity of this activity and severity of injuries. Regardless, this study is the first to report on the alarming dangers of sledding while being towed behind a motorized vehicle. Second, it is unclear if the practice of sledding while being towed behind a motorized vehicle is a strictly a regional phenomenon. The authors surmise that this message for safe sledding will be applicable to all states that experience snowfall. Third, since this study only included patients who presented to our high-volume, ACS-verified level 1 pediatric trauma center in middle Tennessee, significant selection bias based on patient acuity is probable and may not be reflective of all sledding injuries that may have presented to local hospitals. Importantly, 82% of patients in this study ($n = 55$) were admitted to the hospital after presentation to our institution. Additionally, 54% of patients in this cohort ($n = 36$) were transferred from another hospital owing to injury severity and patient acuity. Thus, our findings may overestimate the severity of injuries in both patient groups as patients who are likely to present or be transferred to our institution have severe injuries that are best managed at a comprehensive level 1 pediatric trauma center. Despite such a selection bias, we were able to observe significant differences in injury severity and clinical outcomes between the two patient groups when a higher level of care was warranted.

Currently, no professional societies and organizations currently advocate against the dangers of sledding while being towed behind motorized vehicles through public health initiatives or outreach measures. The study findings herein provide alarming and foundational data that support community risk mitigation measures. The authors believe that severe injuries associated with sledding while being towed behind motorized vehicles can be avoided by periodic public service announcements during the winter season discouraging this form of recreational activity. Additionally, the prevalence of such injuries can be limited with legislation that prohibits the use of ATVs in sledding activities. Furthermore, wearing protective

equipment, such as helmets, while sledding should be encouraged - regardless of the use of motor vehicles.

5. Conclusion

Sledding-related injuries are common among children during winter. To date, no evidence-based guidelines or recommendations regarding the dangers of sledding while being towed behind motorized vehicles are published. This seminal study is the first to report that sledding while being pulled behind a motorized vehicle is independently associated with more severe injuries, longer hospital length of stay, and higher hospital costs. Thus, injury prevention measures should be considered to lower the injury severity and healthcare burden of sledding-related injuries.

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Declaration of Competing Interest

The authors have no conflicts of interests to disclose.

Supplementary materials

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References

- [1] Shorter NA, Mooney DP, Harmon BJ. Childhood sledding injuries. *Am J Emerg Med* 1999;17(1):32–4. doi:[10.1016/s0735-6757\(99\)90010-4](https://doi.org/10.1016/s0735-6757(99)90010-4).
- [2] Dershewitz R, Gallagher SS, Donahoe P. Sledding-related injuries in children. *Am J Dis Child* 1990;144(10):1071–3. doi:[10.1542/peds.2009-1499](https://doi.org/10.1542/peds.2009-1499).
- [3] Landsman IS, Knapp JF, Medina F, Sharma V, Wasserman GS, Walsh I. Injuries associated with downhill sledding. *Pediatr Emerg Care* 1987;3(4):277–80. doi:[10.1097/00006565-198712000-00015](https://doi.org/10.1097/00006565-198712000-00015).
- [4] Howell CA, Nelson NG, McKenzie LB. Pediatric and adolescent sledding-related injuries treated in US emergency departments in 1997–2007. *Pediatrics* 2010;126(3):517–24. doi:[10.1542/peds.2009-1499](https://doi.org/10.1542/peds.2009-1499).
- [5] Godfrey CM, Lovvorn HN, Greeno A, Huang E. Situational awareness in the management of pediatric abdominal impalement. *J Pediatr Surg Case Rep* 2022;76. doi:[10.1016/j.epsc.2021.102130](https://doi.org/10.1016/j.epsc.2021.102130).
- [6] Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974;14(3):187–96 PMID: 4814394.
- [7] Copes WS, Champion HR, Sacco WJ, Lawnick MM, Keast SL, Bain LW. The injury severity score revisited. *J Trauma* 1988;28(1):69–77. doi:[10.1097/00005373-198801000-00010](https://doi.org/10.1097/00005373-198801000-00010).
- [8] Keijzer R, Smith GF, Georgeson KE, Muensterer OJ. Watercraft and watersport injuries in children: trauma mechanisms and proposed prevention strategies. *J Pediatr Surg* 2013;48(8):1757–61. doi:[10.1016/j.jpedsurg.2013.03.055](https://doi.org/10.1016/j.jpedsurg.2013.03.055).