

Occupational fatal injuries associated with mobile hand-fed wood chippers

Julia Zhu MS  | Kitty Gelberg PhD, MPH

Bureau of Occupational Health and Injury Prevention, New York State Department of Health, Albany, New York

Correspondence

Julia Zhu, MS, Bureau of Occupational Health and Injury Prevention, New York State Department of Health, Corning Tower, Room 1336, Empire State Plaza, 12237 Albany, NY. Email: julia.zhu@health.ny.gov

Funding information

Centers for Disease Control and Prevention, Grant number: U60 OH008474-14

Background: Workers are killed every year in wood chipper-related incidents despite the repeated hazard warnings. In-depth, comprehensive, and up-to-date studies are needed to identify causal, risk, and contributing factors and assess the current control measures so that an effective and proactive prevention approach can be developed.

Methods: Cases were identified from four online databases and manually reviewed to characterize and categorize the fatal events.

Results: The study identified 113 wood chipper-related worker deaths (1982-2016). The victims were killed in struck-by (57), caught-in (41), motor vehicle (7), electrical (4), fall (2), and heat stroke (2) incidents while performing chipper-related tasks.

Conclusions: Chipper-related worker deaths are preventable. Young and inexperienced workers may be at higher risk for caught-in deaths. The current feed wheel control devices are not effective for workers to self-rescue. Fully automatic feed wheel stop devices are needed to prevent caught-in incidents.

KEYWORDS

caught-in, entanglement, fatal injuries, struck-by, wood-chippers

1 | INTRODUCTION

Mobile hand-fed wood chippers are widely used for tree care, landscaping, and land clearing. Workers feed tree materials into the chipper's infeed hopper; its hydraulic feed wheels rotate and pull the materials into the disc or drum cutter (chipping unit) at a speed of 1.5-2 feet per second (ft/s). The chipping unit, rotating between 1000 and 2000 rpm, cuts and shreds the woody materials and propels the chips through a discharge chute into a chipper truck. The housing of the chipping unit has a removable cover (aka "chipper hood") allowing access to the unit during maintenance. Some chippers have a winch for pulling large tree trunks and most have a hitch for attachment to a towing vehicle.¹⁻³

All wood chippers have a mechanical feed control bar that is required by the American National Standards Institute (ANSI) to stop and reverse the feed wheels.⁴ A worker can activate the feed control bar to stop or reverse the materials that are being pulled into the

machine. Other available emergency feed stopping devices include "panic bar,"⁵ bottom feed stop bar, and "last chance cables."⁶ The "last chance cables" are located inside the infeed hopper and pulling them can reverse the feed wheels. To protect workers from being struck by the chipper hood, interlocks are installed to prevent workers from opening a chipper hood before the chipping unit stops completely.⁶

Workers are killed in chipper-related incidents every year in the United States.^{7,8} Both the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have issued repeated hazard warnings, yet worker deaths continued to happen.⁹⁻¹² In order to develop an effective and proactive prevention approach, comprehensive, in-depth, and up-to-date studies are needed to identify causal and risk factors and assess the effectiveness of the current prevention measures including the wood chipper safety features.

This study examines worker deaths associated with all chipper-related tasks, identifies causal, risk, and contributing factors, assesses the effectiveness of the current feed control devices, and discusses the prevention measures. The findings of this study, can be utilized to raise

awareness of the wood chipper hazards, develop a comprehensive prevention approach, promote more effective wood chipper safety features, and generate policies for better protection of at-risk working populations.

2 | METHODS

A case was selected if the death occurred prior to 2017 and was caused directly by a chipper regardless of the victim's job at the time of the incident; or if the victim was killed while performing a chipper-related task regardless of what caused the injury. A chipper-related task is defined as a task that was associated with transporting, setting up, feeding, operating, troubleshooting, maintaining, or repairing a chipper.

Cases were identified from four online databases: OSHA Fatality and Catastrophe Investigation Summaries,¹³ OSHA Reports of Fatalities and Catastrophes—Archive,¹⁴ NIOSH and State Fatality Assessment and Control Evaluation (FACE) Investigation Reports,¹⁵ and Tree Care Industry Association (TCIA) Accident Briefs.¹⁶

OSHA investigates all work-related fatalities excluding the ones involving non-employees such as company owners and self-employed individuals.^{17,18} The OSHA databases contain inspection records dating back to 1984. The following keywords and phrases were used for case identification from the OSHA databases: blade, brush chipper, chipper, entangled, rotary knife, winch, wood chips, and wire rope.

NIOSH and collaborating states investigate occupational fatalities through the FACE program by collecting case information, identifying causes and contributing factors, and proposing prevention

measures.¹⁹ The FACE database currently contains over 2600 reports with the earliest investigation conducted in 1982.

TCIA, a trade association representing tree care firms and affiliated companies, compiles, and posts information on tree-work related incidents. The TCIA database contains approximately 650 incidents including both fatal and non-fatal and work-related and non-work-related cases with the earliest case recorded in 2010.

Google searches with phrases such as “wood chipper accidents,” and “wood chipper worker death” yielded additional cases and case information. Google Maps²⁰ was used to identify the geographic locations of the incidents. United States Business Database²¹ and Manta²² were used to identify employer business information.

Cases that met the inclusion criterion were selected and each of the source files was manually reviewed to eliminate duplicates and ensure the accuracy of the information. A spreadsheet was created using Excel (Version 2016) to store and categorize the case information. SAS statistical software (Version 9.4) was used to generate data summaries. *T*-tests applied as part of linear regression were used to determine if trends over time were statistically significant. The associations between worker age and risks for chipper-related fatal injuries were assessed using Chi-square tests.

3 | RESULTS

The study identified 113 wood chipper-related worker deaths between 1982 and 2016. These cases occurred in 32 states (Figure 1) and approximately a quarter of the cases occurred in Florida (15) and California (14). Table 1 summarizes the total number of cases by 5-year

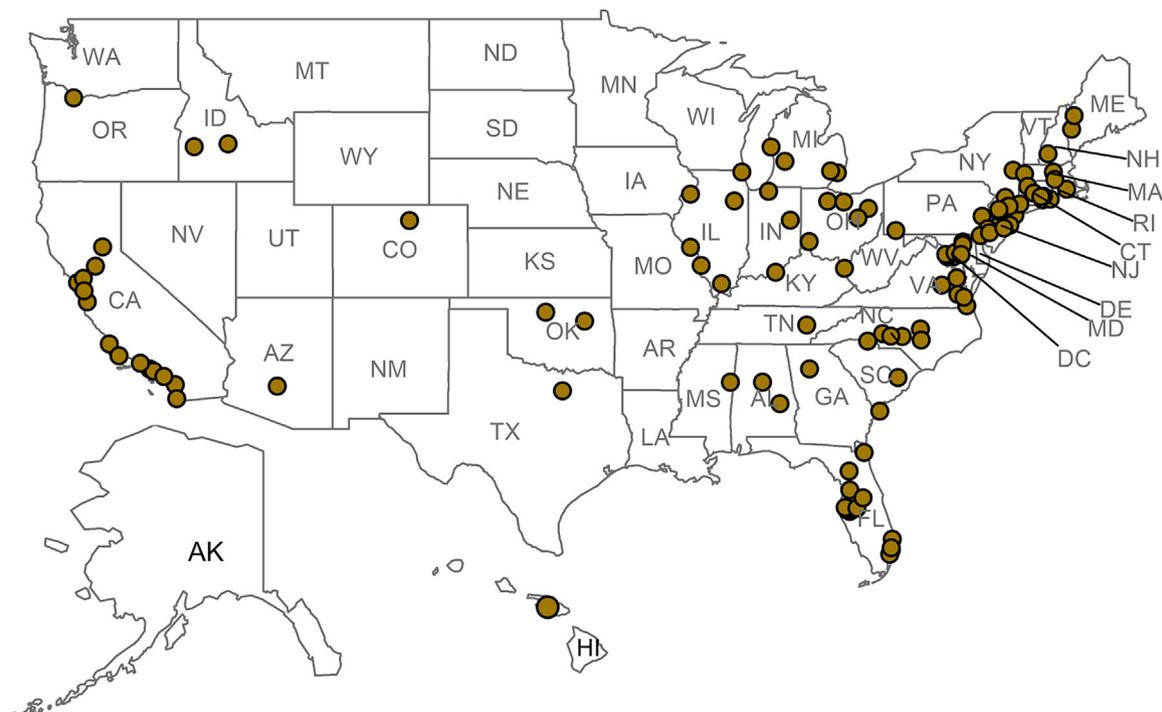


FIGURE 1 Locations of wood chipper-related fatalities, 1982-2016 [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Number of six types chipper-related deaths by five-year period, 1982-2016

5-Year period	Struck-by	Caught-in	Transportation	Electrocution	Fall	Heat stroke	Total
1982-1986	1	0	0	0	0	1	2
1987-1991	2	1	1	0	0	0	4
1992-1996	8	2	1	0	2	0	13
1997-2001	9	8	0	1	0	0	18
2002-2006	12	8	0	1	0	0	21
2007-2011	13	12	2	1	0	1	29
2012-2016	12	10	3	1	0	0	26
Total	57	41	7	4	2	2	113

period. Chipper-related worker deaths have been increasing steadily over the years (P for trend = 0.0004) and peaked between 2007 and 2011 with 29 cases. The victims died from struck-by (57), caught-in (41), transportation (7), electrocution (4), fall (2), and heat stroke (2) incidents.

3.1 | Victim demographic and occupational information

Most victims (94.7%) were male with ages ranging from 6 to 72 years old with a mean age of 38.2, although a considerable number of victims (46%) had no age information (Table 2). While race and ethnicity were missing in most cases (85%), victims included Hispanic and black individuals. Most victims (75.2%) were ground workers. At the time of the incidents, the victims were performing tree trimming or landscaping, right-of-way maintenance, construction, post-storm cleanup, and farm work. The employers were primarily in tree care and landscaping business, privately-owned, and non-union. Total employment ranged from 0 to 7000 and most companies had 10 or fewer employees.

3.2 | Characteristics of fatal-struck by incidents

The 57 struck-by victims had ages ranging from 21 to 60 years old (Table 2). Workers who were 45 years old and older had statistically significant higher risk for fatal struck-by injuries than the younger workers (age <45 years) ($P = 0.04$). The victims were struck by tree limbs, projectiles, chippers or chipper trucks, rope or winch cables caught in chippers, or unsecured chippers or chipper parts while feeding, trouble shooting, transporting, setting up, and repairing chippers, and trimming trees (Table 3).

Of the 25 workers who were struck by tree limbs, 21 (84.0%) were struck by tree limbs fallen or cut by co-workers. Workers were also struck by a "hazard" tree limb broken from a tree, and tree pieces being pulled by a chipper winch or falling off an excavator or aerial bucket.

Among the 15 workers who were struck by projectiles, 14 were troubleshooting and 1 was clearing a jam without turning off the chipper. Workers were struck by the hoods that struck the rotating chipper knives. Some chipper hoods were not installed properly with bolts missing or hinges bent or broken. The rotating chipper knives contacted the hoods sending them flying. One worker was holding the

hood that weighed approximately 80 lbs. The hood slipped and bounced off the rotating knives, striking him. Another victim was using a pry bar to unjam a piece of wood while the chipper knives were still rotating and he was struck by the pry bar.

3.3 | Characteristics of fatal-caught in incidents

Of the 41 caught-in victims, 37 were caught and entangled in branches and pulled into chippers and 4 were caught by ropes or winch cables that were fed into chippers inadvertently (Table 3). Other contributing factors included missing or broken feed controls, feeding small twigs without using a push paddle, and hand-feeding a chipper that was designed to be machine-fed.

Workers became entangled in branches after they slipped or fell, or their clothing was caught by branches. Some victims were wearing gloves with flared and extended cuffs and their gloves were caught. Seven workers were feeding chippers with their feet: they were standing on top of the feed tray kicking the materials into the chippers when they either fell or their shoe laces were caught by the branches. Other victims were feeding the chipper standing right in front of the infeed hopper and they were pushed into the chipper from behind by the branches moving into the chipper.

Even though most caught-in victims (73%) had coworkers present at the time of the incidents, only 30% of these incidents had witnesses. Coworkers were nearby and able to reverse the feed wheels in seven cases, but the victims had already sustained fatal injuries when they were released from the chippers.

Thirteen of the 17 young victims (age <25 years) died in caught-in incidents. Among them, a 19-year-old and a 23-year-old were killed on their first day on the job and a 20-year-old died on the second on the job. Young workers were statistically more likely to be pulled into chippers than workers who were older than 24 years ($P = 0.006$).

Six of the nine victims who were confirmed of Hispanic origin died in caught-in incidents and two of the three were confirmed as having language barriers (unable to understand English) were pulled into chippers. The risk of caught-in incidents for Hispanic workers could not be statistically assessed due to inadequate data. All of the young and known Hispanic caught-in victims were feeding chippers at the time of the incidents.

TABLE 2 Demographics of victims, occupation, company size, and industry by type of injury, 1982-2016

	Struck by victims <i>n</i> (%), <i>N</i> = 57	Caught-in victims <i>n</i> (%), <i>N</i> = 41	Other* injury victims <i>n</i> (%), <i>N</i> = 15	Total <i>n</i> (%), <i>N</i> = 113
Sex				
Male	55 (96.5)	39 (95.1)	13 (86.7)	107 (94.7)
Female	0	1 (2.4)	0	1 (0.9)
Unknown	2 (3.5)	1 (2.4)	2 (13.3)	5 (4.4)
Age (years)				
< = 24	1 (1.8)	13 (31.7)	3 (20.0)	17 (15.0)
25-34	6 (10.5)	4 (9.8)	1 (6.7)	11 (9.7)
35-44	2 (3.5)	5 (12.2)	0	7 (6.2)
45-54	9 (15.8)	7 (17.0)	1 (6.7)	17 (15.0)
55-64	5 (8.8)	2 (4.9)	1 (6.7)	8 (7.1)
65+	0	1 (2.4)	0	1 (0.9)
Unknown	34 (59.6)	9 (22.0)	9 (60.0)	52 (46.0)
Race				
White	4 (7.0)	3 (7.3)	0	7 (6.2)
Black	1 (1.8)	0	0	1 (0.9)
Hispanic	3 (5.3)	6 (14.6)	0	9 (8.0)
Unknown	49 (86.0)	32 (78.0)	15 (100)	96 (85.0)
Occupation				
Ground worker	42 (73.7)	30 (73.1)	13 (86.7)	85 (75.2)
Construction laborer	5 (8.8)	2 (4.9)	0	7 (6.2)
Tree trimmer	3 (5.3)	0	2 (13.3)	5 (4.4)
Mechanic	2 (3.5)	0	0	2 (1.8)
Machine operator	2 (3.5)	0	0	2 (1.8)
Farm worker	0	2 (4.9)	0	2 (1.8)
Owner	3 (5.3)	4 (9.8)	0	7 (6.2)
Son of owner or crew	0	2 (4.9)	0	2 (1.8)
Unknown	0	1 (2.4)	0	1 (0.9)
Company size				
<=10	11 (19.3)	13 (31.7)	2 (13.3)	26 (23)
11-25	1 (1.8)	2 (4.9)	1 (6.7)	4 (3.5)
26-50	2 (3.5)	0	1 (6.7)	3 (2.7)
51-100	2 (3.5)	0	0	2 (1.8)
101-500	0	0	0	0
>500	4 (7.0)	3 (7.3)	5 (33.3)	12 (10.6)
Unknown	37 (64.9)	23 (56.1)	6 (40.0)	66 (58.4)
Industry				
Tree care/landscaping	49 (86.0)	34 (82.9)	14 (93.3)	97 (85.8)
Construction	5 (8.8)	2 (4.9)	0	7 (6.2)
Farming	0	2 (4.9)	0	2 (1.8)
Local government	0	2 (4.9)	0	2 (1.8)
Utility	0	0	1 (6.7)	1 (0.9)
Waste management	1 (1.8)	0	0	1 (0.9)
Warehouse	1 (1.8)	0	0	1 (0.9)
Unknown	1 (1.8)	1 (2.4)	0	2 (1.8)

*Includes transportation, electrocution, fall, and heat stroke victims.

TABLE 3 Number of struck-by, caught-in, and fall deaths, by direct cause, victim task, and coworker availability, 1982-2016

	Struck-by <i>n</i> (%), <i>N</i> = 57	Caught-in <i>n</i> (%), <i>N</i> = 41	Fall <i>n</i> (%), <i>N</i> = 2	Total <i>n</i> (%) <i>N</i> = 100
Direct cause				
Tree limbs	25 (43.9)	0	0	25 (25.0)
Projectiles	15 (26.3)	0	0	15 (15.0)
Chipper or chipper truck	9 (15.8)	0	0	9 (9.0)
Unsecured chipper (part)	4 (7.0)	0	0	4 (4.0)
Rope or winch in chipper	4 (7.0)	4 (9.8)	1 (50.0)	9 (9.0)
Feed wheels	0	37 (90.2)	0	37 (37.0)
Falling off chipper	0	0	1 (50.0)	1 (1.0)
Victim task				
Feeding chipper	30 (52.6)	40 (97.6)	0	70 (70.0)
Troubleshooting	15 (26.3)	0	1 (50.0)	16 (16.0)
Transporting chipper	7 (12.3)	0	0	7 (7.0)
Repairing chipper	2 (3.5)	0	0	2 (1.0)
Setting up chipper	1 (1.8)	0	0	1 (2.0)
Trimming trees	1 (1.8)	0	1 (50.0)	2 (2.0)
Unknown	1 (1.8)	1 (2.4)	0	2 (2.0)
Coworker availability				
Coworker present	40 (70.2)	30 (73.2)	2 (100.0)	72 (72.0)
Incident witnessed	20 (50.0)	9 (30.0)	0	29 (40.3)
Incident not witnessed	5 (12.5)	14 (46.7)	0	19 (26.4)
Unknown witness	15 (37.5)	7 (23.3)	2 (100.0)	24 (33.3)
Coworker not present	2 (3.5)	2 (4.9)	0	4 (4.0)
Unknown	15 (26.3)	9 (22.0)	0	24 (24.0)

3.4 | Fatal injuries caused by ropes or cables in chippers

Nine workers' deaths were directly caused by rope materials that were mixed in with tree trimmings and fed into chippers inadvertently (Table 3). Eight of the victims were grounds workers who were feeding chippers and one was a tree climber. The earliest case occurred in 1984 and the latest in 2014.

Two workers were caught by the ropes that decapitated them and two other workers were pulled into the chippers by the ropes. Winch cables and a pruning tool fatally struck three workers. Another worker was dragged by a rope being pulled by the chipper; he was thrown onto the feed table striking his head. A tree climber was pulled off a tree by a climbing rope that was fed into the chipper. He fell 50 feet and died from fall injuries.

4 | DISCUSSION

At a typical tree-work site, wood chippers are often run simultaneously alongside tree trimming operations exposing workers to additional hazards. Falling tree limbs can strike ground workers. Ropes or cables can be inadvertently fed into chippers, creating struck-by or entanglement hazards. Cranes and aerial lifts can contact powerlines

causing electrocutions. Workers are exposed to traffic hazards while transporting, setting up, and feeding chippers. Mechanics can suffer crushing injuries during maintenance if chippers and parts are not properly secured. Hot weather and high humidity can cause fatal heat stroke among unaccustomed workers.

Wood chipper-related worker deaths increased steadily over the years with statistical significance. Some researchers speculated that the hydraulic feed mechanism that was introduced in early 80's might have contributed to the increasing trend.²³ More studies are needed to determine the cause of this increase.

4.1 | Fatal struck-by incidents and prevention

Ground workers are in great danger of being struck by tree limbs if a chipper is placed too close to the drop zone, or if a worker has to walk through the drop zone to retrieve trimmings or tools. Chippers should be set up in a safe location outside the drop zone. A standard communication procedure should be established between the ground crew and the tree trimmers. Ground workers should never enter a drop zone until they receive a positive confirmation from the tree trimmer that it is safe to enter. A tree trimmer should never drop cuttings unless he receives a clear response from the ground crew that it is safe to drop.

More than a quarter of the struck-by deaths were caused by projectiles. The chipping unit does not stop immediately after the power is turned off due to its kinetic energy. The magnitude of the kinetic energy depends on the unit's mass, radius, and rotational velocity. The heavier and the larger the unit and the faster it rotates, the longer the time it needs to decelerate to a motionless state.²⁴ A chipping unit rotating at normal speed may take several minutes to reach the state of rest.²⁵

To prevent struck-by injuries, chipper hoods should be maintained to prevent damaged or missing hinges, latches, or pins. Employers should ensure that the chipper hood interlocks are functioning properly. Before opening the hood, a worker should always check either the bearings or the drive belts of the chipping unit to make sure that the rotation has stopped.⁸⁻¹⁰

4.2 | Fatal caught-in incidents and prevention

Among the varied jobs at a tree work site, feeding a chipper seems simple and straightforward and requires no special skill compared with troubleshooting a chipper or operating a chainsaw. Some employers failed to recognize the hazards associated with feeding a chipper. Often young and inexperienced workers are assigned to feed a chipper with minimal training while older and more experienced workers take on jobs requiring more skills. That may have contributed to the higher caught-in risk associated with the younger workers and the higher struck-by risk associated with older workers. The lack of experience and training also makes young workers more susceptible to fatal caught-in incidents.

The most dangerous part of a wood chipper is the feed wheels. While the automatic feed system has provided modern chippers with highly desired power and efficiency, it has also contributed to many worker injuries and deaths. The machine can pull branches at approximately 2 ft/s. If an infeed hopper is 36 inches deep and a feed tray is 40 inches long, it would take approximately 3 s for the machine to pull a worker who is standing by the end of the feed tray (76 inches away from the feed wheels) into the chipper.

Since caught-in incidents can happen in seconds, supervision only or having co-workers nearby is not a reliable control measure. Employers should implement an integrated prevention approach. All workers should receive training on safe feeding techniques and wear proper personal protective equipment including safe clothing, gloves, and footwear. The area surrounding the chipper should be kept free of tripping hazards. All safety devices and controls should be maintained to function properly.⁹

4.3 | Fatal incidents caused by ropes and prevention

Rope materials, such as climbing or rigging ropes and pruning tool cords, or chipper winch cables, can be mixed in tree trimmings and fed into chippers inadvertently, endangering both ground workers and tree trimmers. Workers should always inspect the materials before feeding. If feasible, employers should separate the tree cutting and chipper operations so that the work of tree trimmers does not

endanger the ground workers' safety, and vice versa.⁹ Chipping only when the tree cutting is completed at the same site or trimming trees at one site and running a chipper at another site are options.

4.4 | Assessment of current feed control safety devices

When a victim is entangled or caught by branches and starts moving into the machine, the window of opportunity for a successful intervention is only a few seconds. To stop the feed wheels during the emergency, a coworker must be right there by the machine. Feeding a chipper is mobile work; workers move between the cutting pile and the chipper. The task is fast-paced and demands a worker's attention. That may be the reason why many caught-in incidents had no witnesses even though most victims did not work alone. With the few cases that coworkers responded, the intervention efforts were not timely enough to save the victims.

Current chipper feed control devices are all mechanical, requiring a worker's action to reverse the feed wheels. The "last chance cables" are 18 inches from the feed wheels in one model.²⁶ With the feed speed of 2 f/s, a trapped victim would have 0.75 s to pull the cable. When a worker is being rapidly pulled into a chipper, in addition to the physical constraints, human factors such as fear, confusion, and panic, can further impede a worker's ability to self-rescue.²⁷

Since a caught-in incident happens in seconds, coworkers are not likely to be available to intervene, and the victim's ability to self-rescue is severely impaired; automatic feed control devices are imperative to save entangled workers.

Patents of fully automatic feed control devices are available and some of the technologies were patented more than 20 years ago. These include a metal detector that can reverse the feed wheels upon detecting the presence of a metal chip worn by an entangled worker.²⁸ An electrical sensing system or radio frequency identification technology can also be used to shut down a chipper.^{29,30} Manufacturers should utilize these technologies to develop more effective self-rescue devices.

4.5 | Populations at high-risk for fatal wood chipper-related incidents

The study found that young workers (age <25 years) had higher risk for caught-in incidents and older workers (age >45 years) were at higher risk for fatal struck-by injuries; both were statistically significant. Immigrant or foreign-born workers may also be at higher risk for chipper-related injuries, although this study was not able to assess the risk due to inadequate data. Most victims were employed by businesses with ten or fewer employees that represent the majority of the tree service industry.³¹⁻³³ These businesses have limited resources and are less likely to hire in-house safety experts, seek free consultations from OSHA, or join trade associations to receive membership training and education benefits.³⁴ Effectively reaching, educating, and changing the mindset of this population remains a tough challenge for the injury prevention community.

4.6 | Limitations of the study

The findings of this study are subject to the following limitations:

1. The OSHA summary database does not include all work-related deaths associated with mobile wood chippers. OSHA does not investigate fatal incidents that occurred among business owners and self-employed individuals and the cases in which an employee-employer relationship cannot be established.
2. Most cases identified from the OSHA summary database did not have victim age and race.
3. Some of the case information were obtained from sources and the accuracy of the information could not be verified.
4. Missing or inadequate data limited the study's ability to accurately assess the impacts of certain variables on worker risks for wood chipper-related fatal injuries.

5 | CONCLUSIONS

Chipper-related worker deaths are preventable. Young and inexperienced workers may be at higher risk for fatal caught-in injuries. Better data are needed for accurately assessing chipper-related fatal injury risks for young, inexperienced, or foreign-born workers, workers employed by small businesses, and self-employed individuals. Employers should develop and implement a comprehensive and proactive chipper safety program and provide adequate employee training. The current feed wheel control devices are not effective for workers to self-rescue. Wood chipper manufacturers should develop and install fully automatic feed control devices. More research should be conducted and resources allocated to help the small tree and landscaping firms and self-employed individuals to achieve better worker protection.

AUTHORS' CONTRIBUTIONS

JZ participated in the conception and design of the research project, the acquisition, analysis, and interpretation of the data, drafting the work, and revising it for final publication. KG contributed to the original concept and design of the research project, interpretation of the data, statistical analysis, as well as draft development and revision. Both authors reviewed the data to ensure the accuracy and completeness of the data.

ACKNOWLEDGMENTS

The authors would like to acknowledge Alicia Fletcher for her assistance with the data analysis and Sanjaya Kuma for developing the chipper fatality map.

FUNDING

This publication was supported by the Cooperative Agreement Number, 5 U60 OH008474-14-00 formerly five U60 OH008474-14, funded by the Centers for Disease Control and Prevention.

ETHICS APPROVAL AND INFORMED CONSENT

The project was conducted under the FACE program which was exempted from review by the New York State Department of Health Institution Review Board, as posing no more than minimal risk to human subjects.

DISCLOSURE (AUTHORS)

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Rodney Ehrlich declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

The contents of the article are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention or the Department of Health and Human Services.

ORCID

Julia Zhu  <http://orcid.org/0000-0001-5017-1201>

REFERENCES

1. Vermeer. Equipment. Vermeer brush chippers. Available at: https://www.vermeer.com/NA/en/N/equipment/brush_chippers. Accessed April 11, 2018.
2. Bandit Industries, Inc. Menu. Hand-fed chippers. Available at: http://www.banditchippers.com/bandit_equipment/product_line/7/. Accessed April 11, 2018.
3. Carlton Professional Tree Equipment. Wood chippers. Available at: <https://www.stumpcutters.com/wood-chippers/>. Accessed April 11, 2018.
4. American National Standards Institute (ANSI). Pruning, repairing, maintaining, and removing trees, and cutting brush-safety requirements. ANSI Z133.1-2000.
5. Altec. Altec Chippers. Available at: <https://www.altec.com/products/chippers/> Accessed April 6, 2018.
6. Bandit Industries, Inc. A commitment to Safety. Available at: <http://www.banditchippers.com/support/safety/> Accessed April 6, 2018.
7. United States Department of Labor (US DOL). Bureau of Labor Statistics (BLS). Injuries, Illnesses, and Fatalities. Census of fatal occupational injuries (CFOI)-current and revised data. Available at: <https://www.bls.gov/iif/oshcfoi1.htm> Accessed April 6, 2018.
8. Centers for Disease Control and Prevention (CDC). Fatal and nonfatal occupational injuries involving wood chippers—United States, 1992-2002. 2004. MMWR Morb Mortal Wkly Rep. 2004;53:1130-1131.
9. National Institute for Occupational Safety and Health (NIOSH). Injury associated with working near or operating wood chippers. Hazard ID. August 1999. Available at: <https://www.cdc.gov/niosh/docs/99-145/pdfs/99-145.pdf> Accessed April 6, 2018.
10. Occupational Safety and Health Administration (OSHA). Hazards of wood chippers. Safety and Health Information Bulletin SHIB 04-16-2008. Available at: <https://www.osha.gov/dts/shib/shib041608.html> Accessed April 6, 2018.

11. Occupational Safety and Health Administration (OSHA). Chipper Machine Safety Tips. Available at: https://www.osha.gov/Publications/chipper_machine.html Accessed July 10, 2018.
12. National Institute for Occupational Safety and Health (NIOSH). NIOSH Science Blog. Preventing Wood Chipper Fatalities. Available at: <https://blogs.cdc.gov/niosh-science-blog/2015/12/17/wood-chippers/>. Accessed July 10, 2018.
13. Occupational Safety and Health Administration (OSHA). Fatality and catastrophe investigation summaries. Available at: <https://www.osha.gov/pls/imis/accidentsearch.html> Accessed April 6, 2018.
14. Occupational Safety and Health Administration (OSHA). Reports of fatalities and catastrophes-Archive. Available at: https://www.osha.gov/dep/fatcat/dep_fatcat_archive.html Accessed April 6, 2018.
15. National Institute for Occupational Safety and Health (NIOSH). Fatality Assessment and Control Evaluation (FACE) Program. Fatality investigation reports indexed by program. Available at: <https://www.cdc.gov/niosh/face/default.html> Accessed April 6, 2008.
16. Tree Care Industry Association (TCIA). Accident briefs. Available at: https://tcia.org/TCIA/PUBLICATIONS/TCI_Magazine/Accident_Briefs/TCIA/Publications/TCI_Magazine/Accident_Briefs.aspx?hkey=475b3c3f-8934-4045-9cba-f4512ad77252 Accessed April 6, 2008.
17. Occupational Safety and Health Administration (OSHA). All About OSHA. Available at: <https://www.osha.gov/Publications/about-osha/3302-06N-2006-English.html> Accessed April 24, 2018.
18. Occupational Safety and Health Administration (OSHA). Standard Interpretations. Standard Number: 1975;3:1910.120. Available at: <https://www.osha.gov/laws-regs/standardinterpretations/1992-02-12> Accessed April 24, 2018.
19. Higgins DN, Casini VJ, Bost P, Johnson W, Rautiainen R. The Fatality Assessment and Control Evaluation program's role in the prevention of occupational fatalities. *Inj Prev*. 2001;7:i27-i33.
20. Google. Google Maps. Available at: <https://www.google.com/maps> Accessed April 6, 2018.
21. United States (USA) Business Database. Available at: <http://www.usbizs.com/> Accessed April 6, 2018.
22. Manta. Rediscover America's Small Business. Available at: <https://www.manta.com/business> Accessed April 6, 2018.
23. John Ball, Donald F. Chipper accidents are more common than reported. 2009. Tree Care Industry. Available at: <https://www.tcia.org/TCI-publications/tci-magazine/pdfs/03-2009-TCI-Mag.pdf>. Accessed August 22, 2018.
24. The Physics Classroom. Kinetic energy. Available at: <http://www.physicsclassroom.com/class/energy/Lesson-1/Kinetic-Energy> Accessed April 10, 2018.
25. Occupational Safety and Health Administration (OSHA). Inspection detail. Inspection:119960789. Available at: https://www.osha.gov/pls/imis/establishment.inspection_detail?id=119960789. Accessed April 11, 2018.
26. Bandit Industries, Inc. Bandit Brush Chipper Model 250 Operating & Parts Manual. October 2002, Remus, MI, USA.
27. Heist AM, Ziernicki RM, Railsback BT. Analysis of the hazards of wood chipper accidents. Proceedings of the ASME 2011 International Mechanical Engineering Congress & Exposition. November 11-17, 2011, Denver, CO, USA.
28. Mooring JE. Patents. US5667152 A. Safety system for a wood chipper. 1997. Available at: <https://patents.google.com/patent/US5667152A/en>. Accessed April 11, 2018.
29. Mather GA, Gust MW. Patents. US6418004B1. Safety system utilizing a passive sensor to detect the presence of a hand of a worker and provide a signal to interrupt the operation of a machine. 1998. Available at: <https://patents.google.com/patent/US6418004>. Accessed April 11, 2018.
30. Mather GA, Gust MW. Patents. US7365955B2. Material processing machine. 1998. Available at: <https://patents.google.com/patent/US7365955B2/en?q=us+patent+7365955b2>. Accessed April 11, 2018.
31. Centers for Disease Control and Prevention (CDC). Work-related fatalities associated with tree care operations—United States, 1992–2007. 2009. *MMWR Morb Mortal Wkly Rep*. 2009;58:389–393.
32. Centers for Disease Control and Prevention (CDC). Fatal injuries among grounds maintenance workers—United States, 2003–2008. *MMWR Morb Mortal Wkly Rep*. 2011;60:542–546.
33. Buckley JP, 1, Sestito JP, Hunting KL. Fatalities in the landscape and horticultural services industry, 1992–2001. *Am J Ind Med*. 2008;51:701–713.
34. Mendeloff J, Nelson C, Ko K, Haviland A. Small Businesses and Workplace Fatality Risk, An Exploratory Analysis. 2006. Rand Corporation. Available at: https://www.rand.org/content/dam/rand/pubs/technical_reports/2006/RAND_TR371.pdf Accessed April 11, 2018.

How to cite this article: Zhu J, Gelberg K. Occupational fatal injuries associated with mobile hand-fed wood chippers. *Am J Ind Med*. 2018;61:978–985. <https://doi.org/10.1002/ajim.22913>